COYNE ELECTRICAL TROUBLE SHOOTING MANUAL

With

600 WIRING DIAGRAMS

COYNE ELECTRICAL

INDUSTRIAL ELECTRONICS

TROUBLE SHOOTING MANUAL

1964 PRINTING

Lithographed in United States of America

COYNE ELECTRICAL INDUSTRIAL ELECTRONICS TROUBLE SHOOTING MANUAL

600 Wiring Diagrams

- ELECTRICITY
- INDUSTRIAL ELECTRONICS

Prepared and published by the Coyne School Publications, Inc., 1455 West Congress Pkwy., Chicago, Ill. All data in this manual including actual wiring diagrams has been field tested in thousands of industrial concerns throughout the country.

ACKNOWLEDGMENTS

Through our close association with the Electrical industry for over 50 years we have received invaluable assistance in preparing this manual. We wish therefore to acknowledge our sincere appreciation to the following companies for their help in supplying data, illustrations, and actual wiring diagrams for this book.

General Electric Co.
Westinghouse Elec. & Mfg. Co.
Allis Chalmers Mfg. Co.
Louis Allis Co.
Janette Mfg. Co.
Bodine Electric Mfg. Co.
Emerson Electric Co.
Delta Star Mfg. Co.
Nela Park Laboratories
Square D Mfg. Co.
Sangamo Electric Company
Western Electric Co.
Branson Instruments Inc.
Machine-O-Matic Inc.
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Philco Corp.
Electronics Industries
Deep Freeze Motor Products Corp.
RCA Electronics Div.
Bradley Laboratories, Inc.
Kelvinator Corp.
I.T.E. Circuit Breaker Co.
Cutler-Hammer Inc.
Ward Leonard Electric Co.
Howell Electric Motors Co.
Dumore Company
Crosley Corporation
Autotron Co.
Amperex Electronics Corp.
Minneapolis-Honeywell Reg. Co.

FOREWORD

The NEW COYNE ELECTRICAL - INDUSTRIAL ELECTRONICS - TROUBLE SHOOTING MANUAL is a PRACTICAL book for Practical Electrical workers. It is especially valuable to the electrical maintenance man and the electrical or electronics-serviceman.

This book is the ONLY one of its kind. It has over 600 specially selected electrical wiring diagrams. Most of these diagrams are exact duplicates of the original manufacturers blueprints even to showing specific notes and circuit tracing data. These diagrams cover almost every type of electrical equipment in common use and include a great deal of material on: MOTORS, CONTROLLERS, STARTERS, GENERATORS, TRANSFORMERS as well as hundreds of other types of industrial and home electrical apparatus. In addition, the book also covers THE NEW FIELD OF INDUSTRIAL ELECTRONICS.

Of practical time saving value to the maintenance man or serviceman is the special material on NEW methods of trouble shooting. Hundreds of short cuts, and FAST trouble finding information is included. Much of this type of material was taken right out of the electrical courses in the Coyne Electrical School training shops and is backed by 60 years of experience. There are dozens of trouble shooting plan sheets that cannot be purchased anywhere else because they are the sole property of the Coyne Electrical School. You get this valuable material as part of this great book.

PRACTICAL TROUBLE SHOOTING MATERIAL FROM AMERICA'S

LEADING ELECTRICAL AND ELECTRONICS COMPANIES

In compiling this book the publishers had the cooperation of some of America's leading electrical and electronics companies. Any electrical maintenanceman or electrical serviceman has a decided advantage with this book -- here's why. The average maintenance man does not have access to his employers blueprints (if the employer has a file of wiring diagrams). In the case of companies that have a file of prints they are usually the ONLY copies available. It is understandable that they would be careful of the only set of diagrams and would release them only when absolutely needed.

In many electrical plants the only wiring diagrams on the equipment were those that originally came when the equipment was installed. In most cases these loose sheets were put into a desk drawer and have become lost or misplaced. If this is the situation in your plant or service shop then owning the Coyne Trouble Shooting Manual means additional advantages for you.

INCLUDES 600 SPECIALLY SELECTED WIRING DIAGRAMS

THIS BOOK GIVES YOU A PERSONAL FILE OF OVER 600 SPECIALLY SELECTED WIRING DIAGRAMS. MOST OF THESE ARE EXACT DUPLICATES OF THE DIAGRAMS FOR THE EQUIPMENT OF YOUR COMPANY. Owning this manual gives you a chance to read up on the equipment of your company and TO EVEN PRESENT THE NEEDED WIRING DIAGRAM WHENEVER A BREAKDOWN OCCURS.

If you work at electrical service work this book should be worth its weight in gold. It has a great deal of information that deals with motors, switches, controls etc., on HOUSEHOLD APPLIANCES, including house wiring.

The successful electrical maintenance or service and appliance repairman knows the value of a collection of commercial wiring diagrams. He realizes that the fellow who gets ahead is generally the one who has these diagrams and also up to date trouble shooting data. This book provides the material that gives a man the confidence to step into all types of electrical trouble shooting emergency problems.

Prior to the publishing of this book it has been almost impossible for the average electrical worker to gather a worthwhile collection of electrical wiring diagrams. There have been companies that offered certain diagrams for individual purchase but the cost of compiling a collection of diagrams this way was prohibitive. Another way to get diagrams was to write to the manufacturers. Unless a man is in a supervisory position (Chief Electrician, General Manager, Chief Engineer etc.) he may not get the diagrams direct from the manufacturer at any cost.

Because COYNE has been training men for 50 years and has been cooperating with the electrical industry we have secured the diagrams you need. Bringing you over 600 in this book means that you get these valuable diagrams for about 1¢ each. You get, in addition, some of the most helpful trouble shooting hints and plans ever made available to the man on the job.

INDUSTRIAL ELECTRONICS INCLUDED

Today, in thousands of plants, and homes INDUSTRIAL ELECTRONICS devices are being added. They are being installed to step up production, increase safety or improve efficiency. The electrical worker of "tomorrow" will have to know electronic equipment. This book covers dozens of new industrial electronics circuits and applications - the same kind of installations you may be called upon to work on in your plant before the year is out. This special material on electronics will prepare you to step in and take over when necessary.

NEW METHOD OF QUICK REFERENCE INDEXING

We have incorporated an ENTIRELY NEW method of indexing for quick reference. The entire volume is divided into seven major sections as shown in the "SUBJECT AND APPLICATION GUIDE" to be found on page VII. Referring to the guide you will note that most of these major subjects are broken down into several divisions. Next, each division is broken down into "applications". Here's how this new idea works.

Suppose you are working on a two-step magnetic controller for a D. C. motor. First, you ask yourself with which of the major subjects you are concerned. The answer is "Controls" so you look under the subject of "Controls" in the first column of the "Subject and Application Guide". Then, which division (second column) are you interested? Since your problem is with a D. C. motor you look in the D. C. motors division. In this division are nine kinds of applications (third column). You will note one of these is "Magnetic, multi step" for which all diagrams and data are covered on pages 474-480. Glance through those pages and you will either find a diagram that will fit your problem exactly or several that are so close in approximation that they will give you all the information that you will need.

To locate the pages on which all diagrams are to be found takes but a fraction of the time it has taken you to read this explanation of how to do it. With our new method of indexing we greatly cut down the time needed to find the information. Further, this method gives the electrical worker an idea where All the information on his problem is located; not only the particular unit he is working on but other similar equipment. In this way he gets a thorough picture of the necessary steps to follow.

We have also included a regular complete index which you will find at the back of this book. This index shows you where every individual diagram or trouble shooting plan can be found. We furnish this conventional type of index in addition to the new SUBJECT & APPLICATION GUIDE mentioned above to provide purchasers of this book with the most up-to-date, complete, time saving methods to help in locating the data they want.

THE COYNE ELECTRICAL - INDUSTRIAL ELECTRONICS TROUBLE SHOOTING MANUAL IS A TOOL

This is not a "book" in the ordinary sense of the word. Rather, it is a "tool" or an instrument you learn to use just like you learn to use a voltmeter or some special tool. To learn to use a tool you first look it all over. So, examine this book ("tool") by looking over the "SUBJECT AND APPLICATION GUIDE". Then thumb through the book. Note the headings at the top of the page (they give you the subject, division and application) of the material on that page. Check the data on some problems you might anticipate on the equipment in your plant - problems you might have trouble handling IF THEY HAPPENED TOMORROW. This will give you a good idea of how this book will help you.

In concluding this introductory message we'd like to leave this important thought with you. Although a book of this type can be used most every day on the job, nevertheless, if you used it only occasionally for IMPORTANT electrical or electronics problems it would represent a most worthwhile investment for you. The value of any reference book is not always determined by how often you use it but rather HOW IMPORTANT AND VALUABLE IT IS WHEN YOU NEED IT.

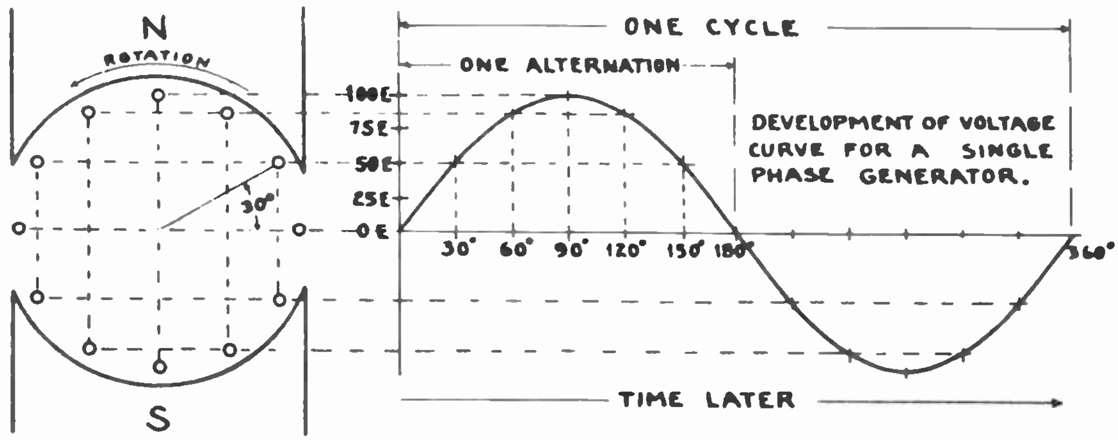
If it pays many types of professional men to spend hundreds of dollars for reference manuals then it follows that an electric worker aspiring toward a better job with more money and responsibility should also have reference material. An investment in this book therefore is an investment in your electrical future.

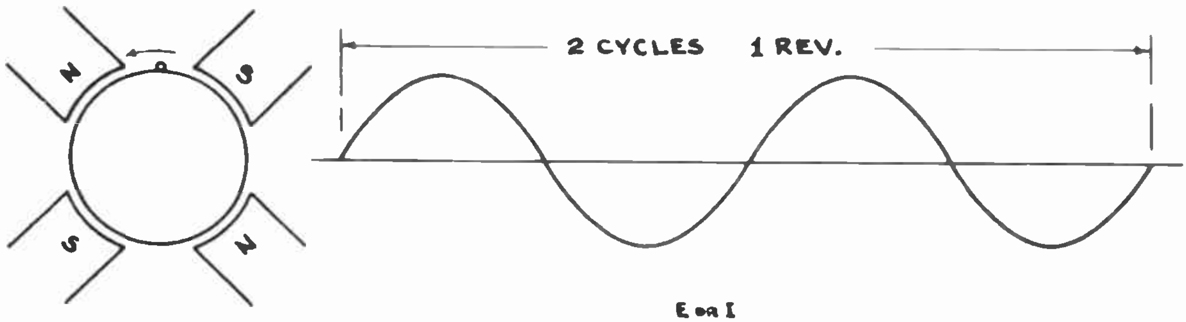
Coyne School Publications, Inc.
Chicago, Illinois

SUBJECT AND APPLICATION GUIDE

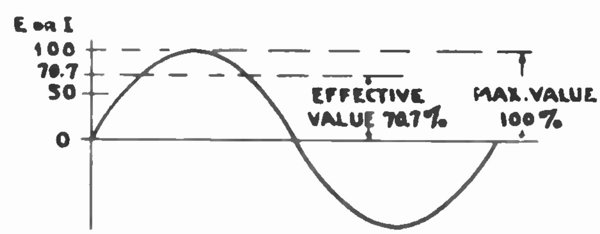
SUBJECT AND APPLICATION GUIDE

FUNDAMENTAL PRINCIPLE OF A.C.





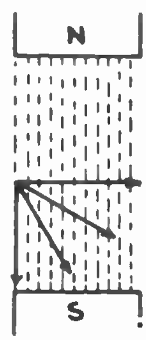
NO. OF POLES	CYCLES PER REV.	REV. PER SEC. FOR 60~	R.P.M. FOR 60~	INDUCTION MOTORS R.P.M. OF MAGNETIC FIELD	INDUCTION MOTORS R.P.M. OF ROTOR
2	1	60	3600	3600	3450
4	2	30	1800	1800	1740
6	3	20	1200	1200	1160
8	4	15	900	900	860
10	5	12	720	720	690
12	6	10	600	600	580



$$\text{POLES} = \frac{120 \times \text{FREQUENCY}}{\text{R.P.M.}}$$

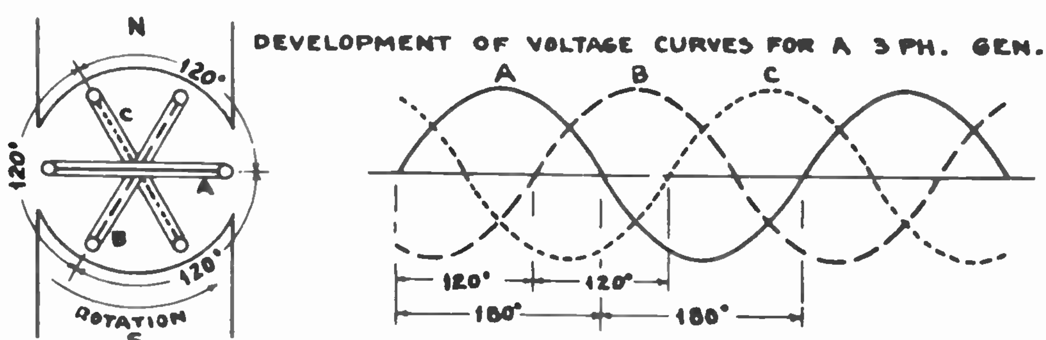
$$\text{R.P.M.} = \frac{120 \times \text{FREQUENCY}}{\text{POLES}}$$

$$\text{FREQUENCY} = \frac{\text{POLES} \times \text{R.P.M.}}{120}$$



THIS SKETCH SHOWS THAT THE NUMBER OF LINES CUT PER SEC. DEPENDS UPON THE FIELD STRENGTH, CONDUCTOR SPEED AND THE ANGLE WHICH THE CONDUCTOR MOVES WITH RESPECT TO THE LINES OF FORCE.

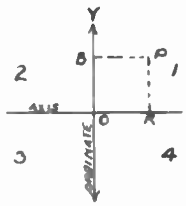
DEVELOPMENT OF VOLTAGE CURVES FOR A 3 PH. GEN.

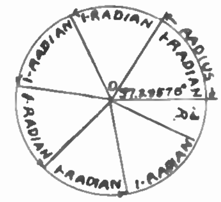


COYNE

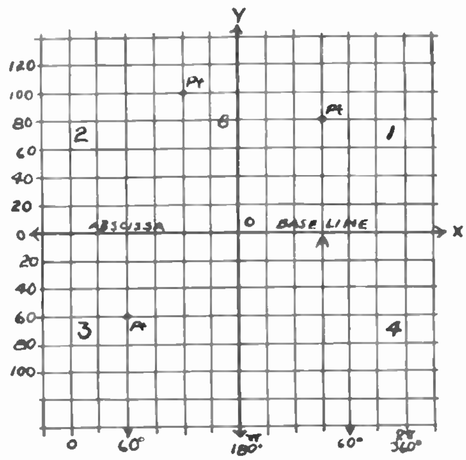
TABLE OF TRIGONOMETRIC FUNCTIONS.

USED FOR SOLVING PROBLEMS INVOLVING RIGHT ANGLE TRIANGLES.

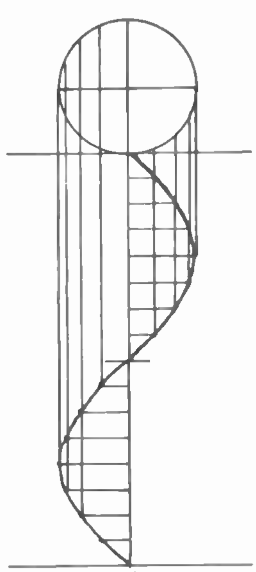


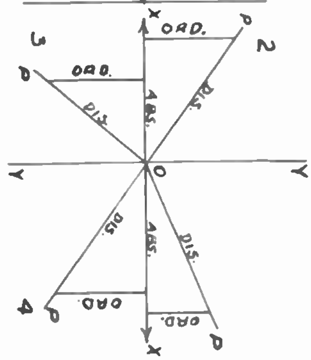


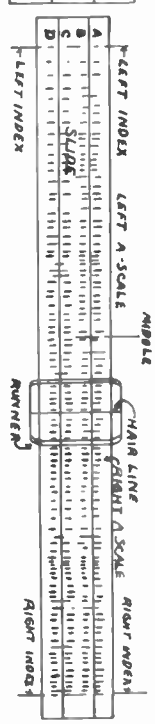
ANGLE DEGREE	SIN.	SEC.	TAN.	COT.	CSC.	COS.	ANGLE DEGREE
0	.000	1.000	.000	∞	∞	1.000	90
1	.017	1.000	.017	57.290	57.299	1.000	89
2	.035	1.001	.035	28.636	28.654	.999	88
3	.052	1.001	.052	19.081	19.107	.999	87
4	.070	1.002	.070	14.301	14.336	.998	86
5	.087	1.004	.087	11.430	11.474	.996	85
6	.105	1.006	.105	9.514	9.567	.995	84
7	.122	1.008	.123	8.144	8.206	.993	83
8	.139	1.010	.141	7.155	7.185	.990	82
9	.156	1.012	.158	6.314	6.392	.988	81
10	.174	1.015	.176	5.671	5.759	.985	80
11	.191	1.019	.194	5.145	5.241	.982	79
12	.208	1.022	.213	4.705	4.810	.978	78
13	.225	1.026	.231	4.331	4.445	.974	77
14	.242	1.031	.249	4.011	4.134	.970	76
15	.259	1.035	.268	3.732	3.864	.966	75
16	.276	1.040	.287	3.487	3.628	.961	74
17	.292	1.046	.306	3.271	3.420	.956	73
18	.309	1.051	.325	3.078	3.236	.951	72
19	.326	1.058	.344	2.904	3.072	.946	71
20	.342	1.064	.364	2.747	2.924	.940	70
21	.358	1.071	.384	2.605	2.790	.934	69
22	.375	1.079	.404	2.475	2.669	.927	68
23	.391	1.086	.424	2.356	2.559	.921	67
24	.407	1.095	.445	2.246	2.459	.914	66
25	.423	1.103	.466	2.145	2.366	.906	65
26	.438	1.113	.488	2.050	2.281	.899	64
27	.454	1.122	.510	1.963	2.203	.891	63
28	.469	1.133	.532	1.881	2.130	.883	62
20	.485	1.143	.554	1.804	2.063	.875	61
30	.500	1.155	.577	1.733	2.000	.866	60
31	.515	1.167	.601	1.664	1.942	.857	59
32	.530	1.179	.625	1.600	1.887	.848	58
33	.545	1.192	.649	1.540	1.836	.839	57
34	.559	1.206	.675	1.483	1.788	.829	56
35	.574	1.221	.700	1.428	1.743	.819	55
36	.588	1.236	.727	1.376	1.701	.809	54
37	.602	1.252	.754	1.327	1.662	.799	53
38	.616	1.269	.781	1.280	1.624	.788	52
39	.629	1.287	.810	1.235	1.589	.777	51
40	.643	1.305	.839	1.192	1.556	.766	50
41	.656	1.325	.869	1.150	1.527	.755	49
42	.669	1.346	.900	1.111	1.494	.743	48
43	.682	1.367	.933	1.072	1.466	.731	47
44	.695	1.390	.966	1.036	1.440	.719	46
45	.707	1.414	1.000	1.000	1.414	.707	45
	COS.	CSC.	COT.	TAN.	SEC.	SIN.	

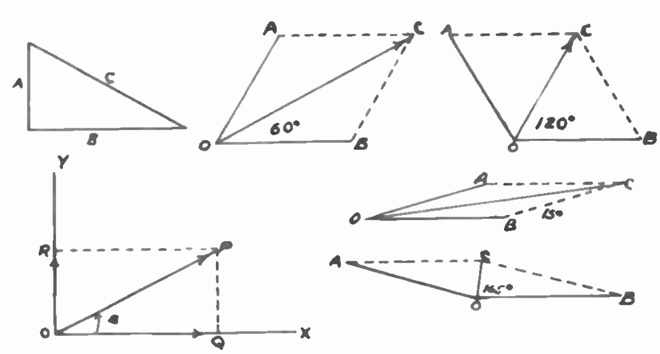


QUADRANT	ABSCISSA	ORDINATE
1	+	+
2	−	+
3	−	−
4	+	−

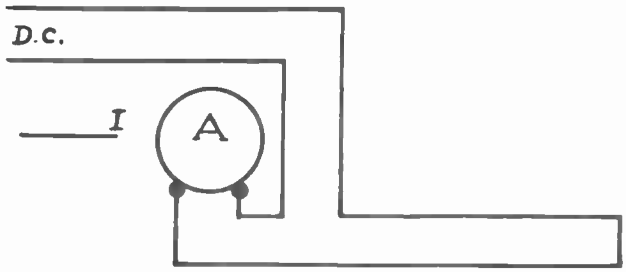


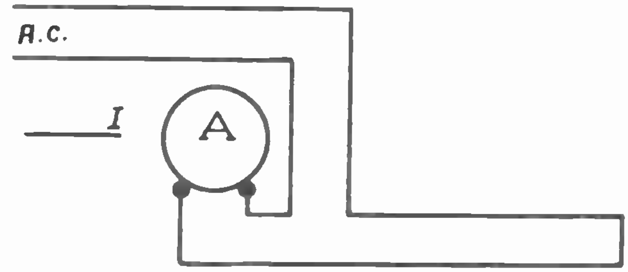






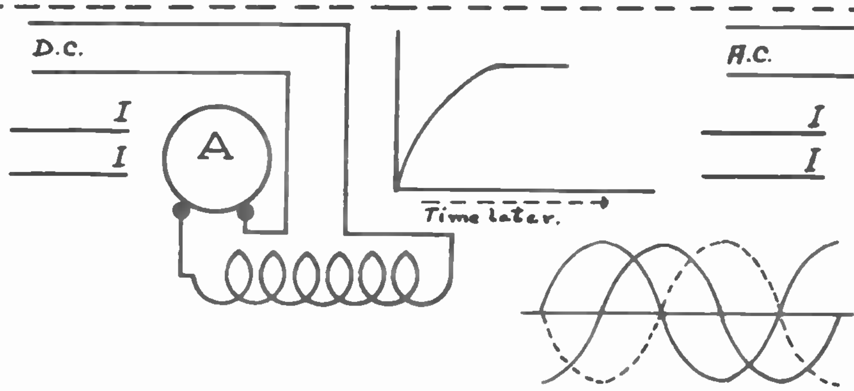
OPPOSITION TO CURRENT IN THE A.C. CIRCUIT. #1.

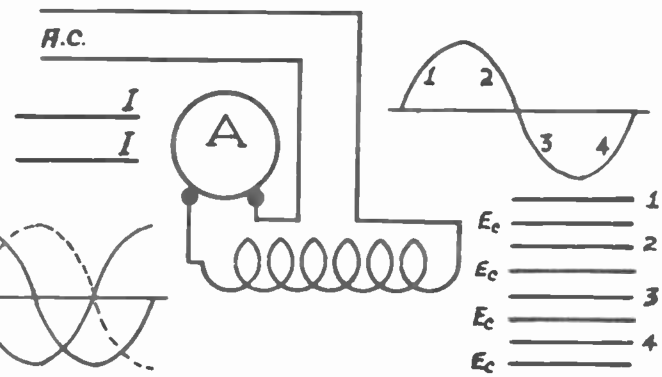




$I = \frac{E}{R} =$ ________ $=$ I $I = \frac{E}{R} =$ ________ $=$ I

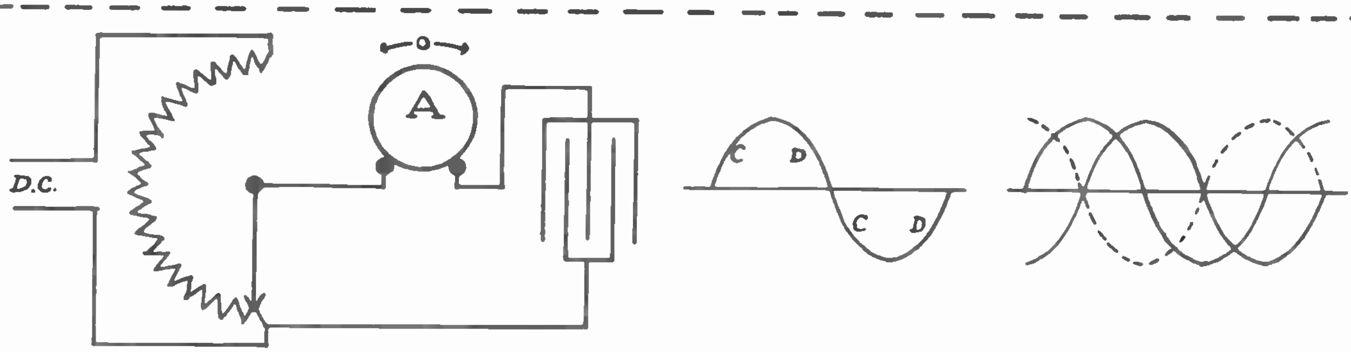
In D.C. circuits resistance is the only opposition encountered by I flow, therefore, the I is proportional to the E applied, or inversely proportional to the resistance of the circuit. OHMS LAW for D.C. also applies to A.C. circuits containing resistance only, and is approximately correct.





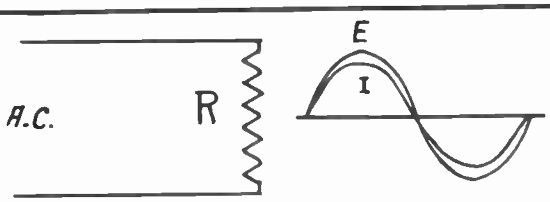
Inductance effects exist in D.C. circuits only during I changes. The I is opposed by a self induced E generated by the expanding magnetic field. This E does not exist when the flux becomes stationary.

INDUCTIVE REACTANCE is a C.E.M.F. generated in the A.C. circuit of inductive nature by the expanding and contracting magnetic field set up by the varying A.C. Its symbol is X_L and its value is measured in ohms. X_L has 2 effects in the A.C. circuit: 1. it opposes I flow. 2. It causes the I to lag the applied E by almost 90°. X_L varies as the frequency. The E applied to apparatus designed for one frequency must be changed in the same proportion when operated on another frequency.



CAPACITY REACTANCE is the opposition offered to the flow of an A.C. by a condenser. Its symbol is Xc, and its value is measured in ohms. Xc has 2 effects in the A.C. circuit: 1. It opposes I flow. 2. It causes the I to lead the applied E by almost 90°. Xc varies inversely as the frequency. When a condenser is to be operated on a higher frequency, frequency is increased.

OPPOSITION TO CURRENT IN THE A.C. CIRCUIT. #2.



In a circuit of resistance only the I will be in phase with the E, since there is no reactance present to cause the I to lag or lead the E applied.

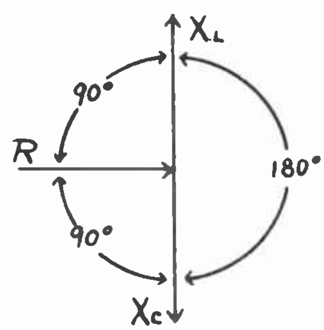
IMPEDANCE is the total opposition offered to the flow of an A.C. Its symbol is Z, and its value is measured in OHMS. Z may consist of R only, X_L only, Xc only, or any combination of these effects.

OHMS LAW for A.C. - The I is proportional to the E applied, and inversely proportional to the IMPEDANCE of the circuit.

$Z = \frac{E}{I}$, $I = \frac{E}{Z}$, $E = I \times Z$.

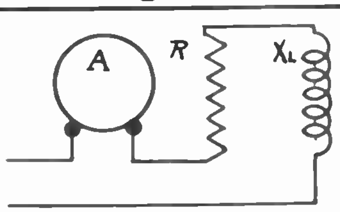
X_L is 90° out of phase with R.
Xc is 90° out of phase with R.
X_L is 180° out of phase with Xc.

A.C. quantities must be added geometrically when out of phase with each other. They may be added by simple arithmetic only when they are in phase with each other.

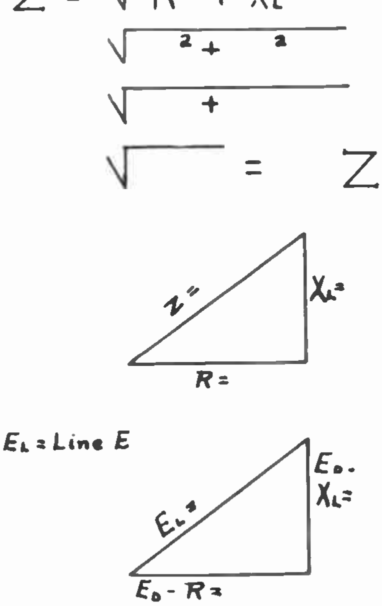


EXAMPLES FOR IMPEDANCE IN A SERIES CIRCUIT.

R and X_L in series.

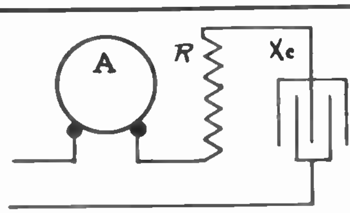


$Z = \sqrt{R^2 + X_L^2}$

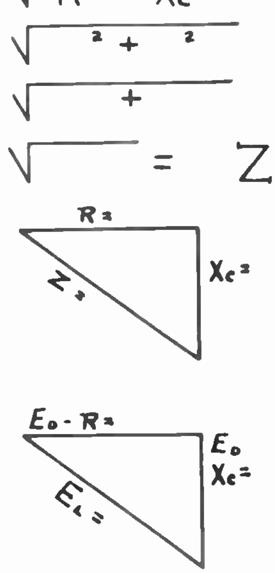


Scale = 1 Unit Per ¼"

R and Xc in series.

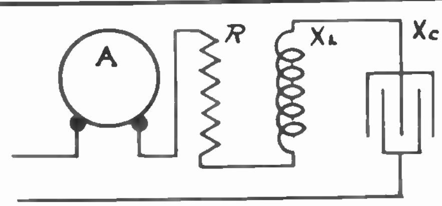


$Z = \sqrt{R^2 + X_C^2}$

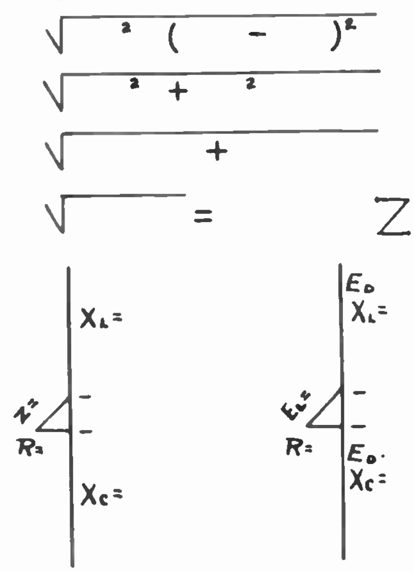


Scale = 1 Unit Per ¼"

R, X_L, and Xc in series.



$Z = \sqrt{R^2 - (X_L - X_C)^2}$



Scale = 10 Units Per 3/16"

What is power-factor?

In an alternating current power system, the voltage and current follow an approximate sine wave. They build up from zero to a maximum in one direction then diminish to zero, build up again to a maximum but in the opposite direction and again diminish to zero; thus completing one cycle or two alternations and 360 electrical degrees.

The power factor is said to be 1.0 or unity, if the voltage and current reach their respective maximum values simultaneously. However in most alternating current systems, the voltage reaches its maximum value in a given direction before the current attains its maximum value, then the current is said to lag behind the voltage. This lag may be measured in degrees.

The lagging of the current is caused by certain inherent characteristics of the system which has a tendency to choke back or oppose any change in direction of the current flow.

Such apparatus as transformers, induction motors, electric welders and electric furnaces are the chief causes of lagging current.

The actual current drawn by apparatus of this class may be considered as having two components, one known as the magnetizing current, or that current which must overcome the choking effect produced by the characteristics of the apparatus, and which lags 90 electrical degrees behind the voltage. The value of this lagging current is zero when the voltage has reached its maximum value. This lagging or magnetizing current is called the reactive current.

The other component is known as the active current, and it is in phase with the voltage. This active current and the voltage reach maximum values simultaneously.

The actual line current is therefore the resultant of the reactive and active currents; furthermore, it is the current that would be registered were an ammeter connection in the circuit. Since there is one component lagging 90 electrical degrees or at right angles to the voltage, the resultant or actual line current, of which this component is a part, must consequently be out of phase with the voltage and lag behind it. The degree or amount that it lags depends upon the magnitude of this reactive current component and is a measure of the power factor.

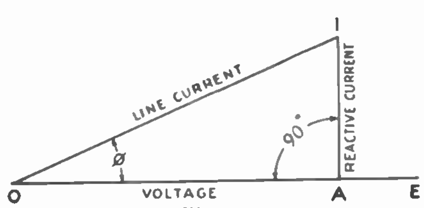


Fig. 30

In Fig. 30 the voltage is represented by the line OE. The line OI represents the actual line current as measured by an ammeter in the circuit, and lags behind the voltage by the angle Ø. The active current component in phase with the voltage is OA and the reactive or magnetizing component is AI, 90 degrees out of phase with the voltage.

The power factor is the ratio of the active current component to the actual current. Therefore:

$$\text{Power factor} = \frac{OA}{OI} \text{ and } \frac{OA}{OI} = \text{cosine } \emptyset$$

If the value of OI is the actual current as read by an ammeter in one phase of a three phase circuit, the

$$\text{K.V.A.} = \frac{\sqrt{3} \times OE \times OI}{1000} \text{ or } \text{K.V.A.} = \frac{\sqrt{3} \times \text{volts} \times \text{amperes}}{1000}$$

and is the apparent power. The actual power is

$$\frac{\sqrt{3} \times \text{volts} \times \text{amperes} \times \text{cosine } \emptyset}{1000} = \text{K.W.}$$

It is, therefore, obvious that K.V.A. and KW are the same and equal at 1.0 or unity power factor, but at power factors below unity, the current for a given KW changes inversely with the power factor, i.e. as the power factor goes below unity, the current increases proportionately.

Power factor is also the ratio of real power to the apparent power, the former measured in KW by a wattmeter and the latter in K.V.A. by voltmeter and ammeter; therefore power factor is also equal to $\frac{\text{KW}}{\text{K.V.A.}}$

How is power measured in two-phase and three-phase circuits?

Wattmeters must be used to measure the power in two- and three-phase circuits. A two-phase circuit can be considered as two single-phase circuits. Each phase is measured separately and the total power equals the sum of the two readings, or sometimes, when the power in both phases is known to be equal, one phase may be measured and the reading doubled.

To read the power in a three-phase circuit a polyphase wattmeter can be used or two single-phase wattmeters connected as shown in Fig. 31. In this diagram it will be noted that the current coil of each wattmeter is connected in one line, and that the potential coil of each wattmeter is connected from the line in which the current coil is connected to the third line. For power-factors above fifty per cent, the power in the three-phase system will be the sum of these two wattmeter readings. At fifty per cent power-factor one wattmeter will read zero. At still lower power-factors this wattmeter will read negatively; its current connections should be reversed and the difference between the readings of the two instruments will then be the true power.

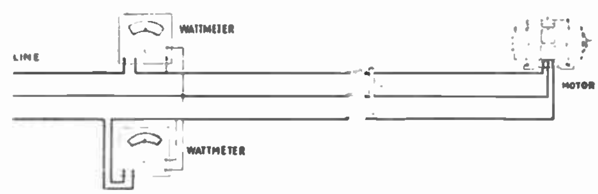


Fig. 31. This diagram shows the method of connecting two wattmeters to read the power in a three-phase circuit. Note that the only connection to one of the conductors is from the potential coils of the two meters

The kv-a. output or input of any machine may be computed as follows:

Single Phase:

$$\text{Apparent Power} = \frac{EI}{1{,}000} = \frac{\text{Volts x Amperes}}{1{,}000} = \text{kv-a.}$$

Two Phase, when both phases have equal currents and equal voltages:

$$\text{Apparent Power} = \frac{2EI}{1{,}000} = \frac{\text{Volts x Amperes x2}}{1{,}000} = \text{kv-a.}$$

Three Phase, when the currents are equal in all three wires and the voltages between any pair of wires are equal:

$$\text{Apparent Power} = \frac{\text{Current in any wire x Voltage between two wires x 3}}{1{,}732}$$

$$= \frac{3EI}{1{,}732} = \frac{\text{Volts x Amperes x 3}}{1{,}732} = \text{kv-a.}$$

$$\text{or, kv-a.} = \frac{\text{Volts x Amperes x 1.73}}{1000}$$

The kilowatt output or input of any machine may be found by multiplying the kv-a. output or input, as the case may be, by the power-factor:

P = kv-a. x Power-factor = Kilowatts.

1800 R.P.M.

MOTOR		CAPACITOR Kv A FOR DESIRED POWER FACTOR	
H.P.	VOLTS	.95	.90
1/2	LOW	1/2	1/2
3/4	LOW	1/2	1/2
1	LOW	1/2	1/2
1 1/2	LOW	3/4	1/2
2	LOW	3/4	1/2
3	LOW	1	3/4
5	LOW	1 1/2	1
7 1/2	LOW	2	1 1/2
10	LOW	2	1 1/2
15	LOW	3	2
20	LOW	4	2
25	LOW	4	3
25	2200	4	3
30	LOW	5	3
30	2200	7 1/2	4
40	LOW	7 1/2	4
40	2200	7 1/2	4
50	LOW	7 1/2	5
50	2200	7 1/2	5
60	LOW	7 1/2	5
60	2200	10	7 1/2
75	LOW	10	7 1/2
75	2200	10	7 1/2

1200 R.P.M.

MOTOR		CAPACITOR Kv-A. FOR DESIRED POWER FACTOR	
H.P.	VOLTS	.95	.90
1/2	LOW	1/2	1/2
3/4	LOW	1/2	1/2
1	LOW	1/2	1/2
1 1/2	LOW	3/4	3/4
2	LOW	1	3/4
3	LOW	1 1/2	1
5	LOW	2	1 1/2
7 1/2	LOW	3	1 1/2
10	LOW	3	2
15	LOW	4	3
20	LOW	5	4
25	LOW	7 1/2	5
25	2200	7 1/2	5
30	LOW	7 1/2	5
30	2200	7 1/2	5
40	LOW	10	7 1/2
40	2200	10	7 1/2
50	LOW	10	7 1/2
50	2200	10	7 1/2
60	LOW	10	7 1/2
60	2200	10	7 1/2
75	LOW	10	7 1/2
75	2200	10	7 1/2

900 R.P.M.

MOTOR		CAPACITOR Kv-A. FOR DESIRED POWER FACTOR	
H.P.	VOLTS	.95	.90
1/2-3/4	LOW	1	1
1	LOW	1	1
1 1/2	LOW	1 1/2	1
2	LOW	1 1/2	1 1/2
3	LOW	2	1 1/2
5	LOW	3	2
7 1/2	LOW	3	3
10	LOW	4	3
20	LOW	5	5
20	2200	10	7 1/2
25	LOW	10	7 1/2
25	2200	10	7 1/2
30	LOW	10	7 1/2
30	2200	10	7 1/2
40	LOW	10	7 1/2
40	2200	10	7 1/2
50	LOW	15	10
50	2200	15	10
60	LOW	15	10
60	2200	15	10
75	LOW	15	10
75	2200	15	10
100	LOW	20	10
100	2200	20	10
125	LOW	25	20
125	2200	25	20
150	LOW	25	20
150	2200	30	20
200	LOW	30	20
200	2200	35	20
15	LOW	5	4

720 R.P.M.

MOTOR		CAPACITOR Kv-A FOR DESIRED POWER FACTOR	
H.P.	VOLTS	.95	.90
5	LOW	2	2
7 1/2	LOW	4	4
10	LOW	4	3
15	LOW	5	4
20	LOW	7 1/2	5
25	LOW	10	5
30	LOW	10	5
30	2200	10	7 1/2
40	LOW	15	10
40	2200	15	10
50	LOW	15	10
50	2200	15	10
60	LOW	20	15
60	2200	20	15
75	LOW	20	15
75	2200	25	20
100	LOW	25	20
100	2200	30	20
125	LOW	30	20
125	2200	30	20
150	LOW	35	25
150	2200	40	35
200	LOW	35	20
200	2200	40	25

600 R.P.M.

MOTOR		CAPACITOR Kv-A. FOR DESIRED POWER FACTOR	
H.P.	VOLTS	.95	.90
5	LOW	4	3
7 1/2	LOW	5	4
10	LOW	5	5
15	LOW	7 1/2	5
20	LOW	10	7 1/2
25	LOW	10	7 1/2
25	2200	20	15
30	LOW	10	7 1/2
30	2200	20	15
40	LOW	15	10
40	2200	20	15
50	LOW	20	15
50	2200	20	15
60	LOW	20	15
60	2200	25	20
75	LOW	25	20
75	2200	40	30
100	LOW	20	15
100	2200	25	20
125	LOW	30	20
125	2200	35	30
150	LOW	50	40
200	LOW	50	35
200	2200	50	40
150	2200	50	50

COYNE.

THE TABLE ABOVE GIVES THE NEAREST STANDARD CAPACITOR Kv-A. RATINGS TO CORRECT POWER FACTOR OF SQUIRREL-CAGE INDUCTION MOTORS TO .95 OR .90. ALTHOUGH THE MAGNETIZING CURRENT REQUIREMENT OF THE INDUCTION MOTOR VARIES SOME WHAT FROM NO LOAD TO FULL LOAD, IF THE MOTOR IS CORRECTED TO THE DESIRED POWER FACTOR AT 1/2 LOAD (VALUES IN THE TABLE ABOVE) IT WILL BE CORRECTED APPROXIMATELY TO THIS POWER FACTOR AT ALL LOADS. ACTUALLY THE POWER FACTOR WILL BE SOME WHAT HIGHER AT NO LOAD AND SLIGHTLY LOWER AT FULL LOAD. NOTE:- LOW VOLTS MEANS 220-440-550.

Power Factor Surveys

Where monthly power bills are affected by power factor as well as the demand, the extent and causes must be known to guide in remedying low power factor conditions.

Portable analyzers are adaptable to make various tests including the power factor of single motors or reasonably heavy feeder loads.

Weston Electrical Instrument Co

Low power factor is one of the reasons why electrical systems as a whole perform below par. Power factor of the load is defined as the ratio between the watts of the load and the product of the volts and amperes measured at the load, or:

$$\text{Power Factor} = \frac{\text{True Power}}{\text{Apparent Power}} = \frac{\text{Watts of the Load}}{\text{Volts x Amperes at the Load}}$$

This is often expressed as a percentage. Whenever this ratio is less than 1, it means that more current is being drawn by the load than would be necessary to perform the work if the ratio were 1. This extra current causes more drop in the feeder circuits, creates more heat losses in feeders and transformers and both must be correspondingly larger to prevent overheating. Of course, some types of load, particularly all inductive loads, must have a power factor of less than unity, but many of them are lower than they should be. Most cases of low power factor can be improved to the advantage of the system and the budget.

SOME CAUSES OF LOW POWER FACTOR

Low power factor conditions commonly are caused by improperly loaded induction motors. Other causes are welding equipment, some types of transformers for mercury vapor lamps and gaseous tube lighting equipment. To overcome this condition tests must be made to determine the actual power factor existing at any one point of load or on any feeder as a whole.

THE BENEFITS OF POWER FACTOR CORRECTION

The benefits derived from the correction of low power factor are realized by relieving the system of the burden of the useless current flow in transformers and other major units of the system. With a higher power factor more use is made of the energy purchased and the demand is kept down to a minimum. Economy is affected in the power bill by the lower rates offered by some power companies to plants having good power factor conditions. In some cases, savings are made by the release of the penalty charges imposed for low power factor. In general, 80 to 90 per cent power factor is considered satisfactory and not subject to rate penalties.

HOW TO MAKE THE SURVEY

To find the causes of low power factor a survey should be made throughout the system. The first thing to do is to check the load and power factor on each motor and other inductive type of equipment. This information may already be available if there is a complete test record of all the motors and equipment in operation.

The next step is to determine in each case how much correction is needed to bring the power factor up to a reasonable value. It is often possible to correct the power factor of the feeder at one point, say at a large motor, to compensate for the low power factor of this motor and several smaller ones on that feeder in the same nearby area.

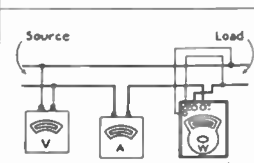
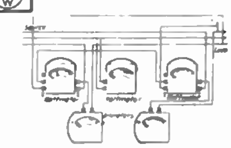
The instruments to use in making the survey and the connection to be made are shown in the accompanying table:

CORRECTING POWER FACTOR

Once the survey is made and the conditions are known it is possible to choose power factor correcting equipment of the proper kva rating to produce the desired power factor. The chart on page 39 can be used as a guide in doing this.

Actual correction is accomplished by adding equipment of low or zero leading power factor, such as capacitors, to compensate for the usual lagging power factor of induction motors and other inductive equipment. In some cases, large induction motors can be replaced by synchronous motors which can be operated at unity or leading power factor.

No loss is too small to be ignored so long as it can be corrected economically. For, assuming 300 work days a year, 8 hours each, a saving of one kilowatt at 2 cents per kilowatt-hour means $48 per year. A saving of 10 kilowatts then amounts to $480 annually.

To Measure	Circuit Tested	Instruments To Use	Diagram of Connections
Single-phase Power Factor	Two-wire	Ammeter Voltmeter Wattmeter or Power Factor Meter	
Three-phase Power Factor	Three-wire	2 Ammeters 1 Voltmeter 2 Single-phase Wattmeters of Analyzer (for 3 phase only) or Power Factor Meter	

TECHNICAL TERMS AND THEIR MEANING

A clear understanding of Electricity can be acquired only if the terms employed to explain it and the units used to measure it are clearly understood. Words used in the technical sense have exact meanings frequently different from those associated with their every day use. Definitions here given refer to the technical meanings only. Some of the most important terms and their units of measurement are:

FORCE - Force is defined as "any agent that produces or tends to produce motion." Force may be mechanical, electrical, magnetic, or thermal in character. Note that force does not always produce motion: a relatively small force may fail to move a large body, but it TENDS to do so. The word "body" refers to any material object: it may be a stone, a building, an automobile, a dust particle, an electron, or anything that has size. Force is usually measured in pounds; therefore the UNIT of FORCE is the POUND.

ENERGY - This word refers to the ability or capacity for doing work. One may speak correctly of the ENERGY in a charged automobile battery, in a raised weight, in a compressed spring, in a tank of compressed air, etc., as work may be done by any one of these devices. Energy may be mechanical, electrical, magnetic, chemical, or thermal type, and the different kinds of energy may be readily converted from one form to another; however, each conversion results in a loss of some of the useful energy, although the total amount of energy remains the same. Since the energy of a device represents the total amount of work that it can do, the units for work and for energy are the same. The UNIT OF ENERGY most frequently used in electrical work is the JOULE. It is equal to approximately 0.74 foot pounds.

WORK - Work is equal to the force applied to an object multiplied by the distance through which the object is moved. If the force applied to a given object is insufficient to move it, no work is done. This definition illustrates the great difference that exists between the technical and the general meaning of the word WORK. The units used for measuring work are the same as those employed for energy. The most frequently used UNITS OF WORK are the FOOT POUND and JOULE.

POWER - Power indicates the rate at which work is done. It is equal to the amount of work done, divided by the time required to do it. This unit does not show how much work has been done, it merely indicates how rapidly, or at what rate, the work is being done. The foundamental UNIT of electrical POWER is the WATT. When the power in an electrical circuit is one watt, this means that work is being done in that circuit at the rate of one joule per second, or 0.74 foot pounds per second. Note that the WATT is not a quantity unit but a RATE unit. Larger power units are the horse-power and the kilowatt. The HORSEPOWER represents a rate of doing work equal to 746 WATTS, or 746 joules per second, or 550 foot pounds per second. Note that TIME, which is not mentioned in the definitions of force or energy, is always a factor in the measurement of POWER.

(a) $$\text{POWER} = \frac{\text{WORK}}{\text{TIME}}$$

(b) $$\text{WORK} = \text{POWER} \times \text{TIME}$$

(c) $$\text{TIME} = \frac{\text{WORK}}{\text{POWER}}$$

With the aid of the above formulas any of the given quantities may be calculated when the other two are given. Thus if work and time are given, the power may be found by (a). If power and time are given, the work may be found by formula (b), and if the work to be done and the rate at which it is to done (power) are specified, the time required to do it may be determined by formula (c).

A little time spent in studying the above definitions and formulas will be well repaid by an increased understanding and clearer conception of the units used.

Coulomb	q or Q	Unit of electrical quantity. The quantity which will deposit .0000116 oz. of copper from one plate to the other in a copper sulphate solution. The quantity of Electricity which must pass a given point in a circuit in one second to produce a current of one ampere.
Ampere	I or A	Unit of current. (Rate of Flow) One coulomb per second.
Milliampere	MI or MA	.001 I (The prefix "milli" means one-thousandth)
Microampere	µI or µA	.000001 I (the prefix "micro" means one-millionth)
Volt	E or V	Unit of pressure. (EMF - Electromotive Force) The pressure required to force current at the rate of one ampere through the resistance of one ohm.
Millivolt	ME or MV	.001 E One-thousandth volt.
Microvolt	µE or µV	.000001 E One-millionth volt.
Kilovolt	KV	1000 E (The prefix "kilo" means one-thousand)
Ohm	R or Ω	Unit of resistance. A measure of the opposition offered to the flow of current. The resistance offered by a column of mercury 106.3 centimeters long and 1 square millimeter in cross sectional area, at a temperature of 32 degrees Fah., or 0 degrees Cent.
Megohm	Meg.	1,000,000 R One-million ohms.
Microhm	µR	.000001 R One-million ohm.
Mho	g	Unit of conductance. A measure of the ease which a conductor will permit current to flow. It is the reciprocal of resistance.
Watt	W	Unit of power. One watt is equal to current at the rate of one ampere under the pressure of one volt. W = I x E.
Horsepower	HP or HP	746 W Thepower required to raise 33,000 pounds, one foot, in one minute.
Milliwatt	MW	.001 W One-thousandth watt.
Kilowatt	KW	1000 W Unit of power.
Watthour	WH	Unit of work. (Power x Time) W x H = WH
Kilowatt-hour	KWH	1000 WH Unit of work.
Farad	C	Unit of capacitance. Capacity of condensers.
Microfared	Mfd. or µF	.00001 C One-millionth farad.
Micro-microfarad	MMF	.000001 mfd. One-millionth microfarad.
Henry	L or H	Unit of inductance.
Millihenry	ML or MH	.001 L One-thousandth henry.

Convenient Formulae and Units for Use in Design Calculations

USEFUL . . . INFORMATION

FORMULAE FOR DETERMINING AMPERES, HORSEPOWER, KILOWATTS AND KILOVOLT-AMPERES

To Find the Value	When Value Below is Known	SYSTEM			
		Direct Current	Single-Phase	Two-Phase Four Wire	Three-Phase
		FORMULAE			
Amperes (I)	Horsepower (hp)	$I = \frac{746\ hp}{E \times eff}$	$I = \frac{746\ hp}{E \times eff \times pf}$	$I = \frac{746\ hp}{2 \times E \times eff \times pf}$	$I = \frac{746\ hp}{1.73 \times E \times eff \times pf}$
Amperes (I)	Kilowatts (kw)	$I = \frac{1000\ kw}{E}$	$= \frac{1000\ kw}{E \times pf}$	$I = \frac{1000\ kw}{2 \times E \times pf}$	$I = \frac{1000\ kw}{1.73 \times E \times pf}$
Amperes (I)	Kilovolt-Amperes (kva)		$I = \frac{1000\ kva}{E}$	$I = \frac{1000\ kva}{2\ E}$	$I = \frac{1000\ kva}{1.73\ E}$
Kilowatts (kw) Input		$kw = \frac{I \times E}{1000}$	$kw = \frac{I \times E \times pf}{1000}$	$kw = \frac{I \times E \times 2 \times pf}{1000}$	$kw = \frac{I \times E \times 1.73 \times pf}{1000}$
Kilovolt-Amperes (kva)			$kva = \frac{I \times E}{1000}$	$kva = \frac{I \times E \times 2}{1000}$	$kva = \frac{I \times E \times 1.73}{1000}$
Horsepower (hp) Output		$hp = \frac{I \times E \times eff}{746}$	$hp = \frac{I \times E \times eff \times pf}{746}$	$hp = \frac{I \times E \times 2 \times eff \times pf}{746}$	$hp = \frac{I \times E \times 1.73 \times eff \times pf}{746}$

I = Amperes.
E = Volts.
eff = Efficiency in decimals.
pf = Power Factor in decimals.

kw = Kilowatts Input.
kva = Kilovolt-Amperes Input.
hp = Horsepower Output.

For two-phase, three wire, balanced circuits the amperes in common conductor = 1.41 × that in either of the other two.

EQUIVALENT VALUES OF ELECTRICAL, MECHANICAL, AND HEAT UNITS

Unit	Equivalent Value in Other Units
1 Kw.-hour =	1,000 watt-hours. 1.341 horsepower-hours. 2,655,200 ft.-lb. 3,600,000 joules. 3,415 heat-units. 367,100 kilogram-meters. 0.234 lb. carbon oxidized with perfect efficiency. 3.52 lb. water evap. from and at 212° F. 22.77 lb. of water raised from 62° to 212° F.
1 Hp.-hour =	0.7457 kw.-hour. 1,980,000 ft.-lb. 2,546.5 heat-units. 273,740 kilogram-meters. 0.174 lb. carbon oxidized with perfect efficiency. 2.62 lb. water evap. from and at 212° F. 17.0 lb. water raised from 62° F. to 212° F.
1 Kilowatt =	1,000 watts. 1.3410 horsepower. 2,655,200 ft.-lb. per hour. 44,254 ft.-lb. per minute. 737.56 ft.-lb. per second. 3,415 heat-units per hour. 56.92 heat-units per minute. 0.9486 heat-units per sec. 0.234 lb. carbon oxidized per hour. 3.52 lb. water evap. per hr. from and at 212° F.
1 Hp. =	745.7 watts. 0.7457 kw. 33,000 ft.-lb. per minute. 550 ft.-lb. per second. 2,546.5 heat-units per hour. 42.44 heat-units per minute. 0.707 heat-units per second. 0.174 lb. carbon oxidized per hour. 2.62 lb. water evap. per hour from and at 212° F.
1 Joule =	1 watt second. 0.000000278 kw.-hour. 0.10197 kilogram-meter. 0.0009486 heat-units. 0.73756 ft.-lb.
1 Ft.-lb. =	1.3558 joules. 0.13826 kilogram-meter. 0.0000003766 kw.-hour. 0.0012861 heat-unit. 0.0000005 hp.-hour.

Unit	Equivalent Value in Other Units
1 Watt =	1 joule per second. 0.001341 hp. 3.415 heat-units per hour. 0.73756 ft.-lb. per second. 0.0035 lb. water evap. per hour. 44.254 ft.-lb. per minute.
1 Watt per Sq. In. =	8.20 heat-units per sq. ft. per minute. 6.373 ft.-lb. per sq. ft. per min. 0.1931 hp. per sq. ft.
1 Heat-Unit =	1,054.2 watt-seconds. 777.54 ft.-lb. 107.5 kilogram-meters. 0.0002928 kw.-hour. 0.0003927 hp.-hour. 0.0000685 lb. carbon oxidized. 0.001030 lb. water evap. from and at 212° F.
1 Heat-unit per Sq. Ft. per Min. =	0.1220 watt per sq. in. 0.01757 kw. per sq. ft. 0.02356 hp. per sq. ft.
1 Kilogram-meter =	7.233 ft.-lb. 0.000003653 hp.-hour. 0.000002724 kw.-hour. 0.009302 heat-unit.
1 lb. Carbon Oxidized with Perfect Efficiency =	14,600 heat-units. 1.11 lb. anthracite coal oxidized. 2.5 lb. dry wood oxidized. 22 cu. ft. illuminating gas. 4.75 kw.-hour. 5.733 hp.-hour. 11,352,000 ft.-lb. 15.05 lb. of water evap. from and at 212° F.
1 Lb. Water Evap. from and at 212° F. =	0.2841 kw.-hour. 0.3811 hp.-hour. 970.4 heat-units. 104,320 kilogram-meter. 1,023,000 joules. 754,525 ft.-lb. 0.066466 lb. carbon oxidized.

WIRE CALCULATIONS

Ohm's Law

Ohm's Law: $I=\frac{E}{R}$, **where I is current; E is voltage; and R is resistance.**

Example: With a voltage of 112 and a resistance of 8 ohms, what current would flow?

$$I=\frac{112}{8} \text{ or 14 amperes.}$$

Example: What resistance is necessary to obtain a current of 14 amperes at 112 volts?

$$R=\frac{E}{I} \text{ or } R=\frac{112}{14} \text{ or 8 ohms.}$$

Example: What voltage would be required to produce a flow of 14 amperes through a resistance of 8 ohms.

$$E=IR \text{ or } E=14 \times 8 \text{ or 112 volts.}$$

Voltage Drop

The resistance of a copper wire one foot long and one circular mil in cross section is approximately 10.8 ohms.

In Ohm's law $I=\frac{E}{R}$, R is equal to: Length of conductor in feet x 10.8 divided by the circular millage of the conductor or,

$$R=\frac{2 \times \text{feet (length of circuit)} \times 10.8}{CM}$$

Using Ohms' law, E = IR,

$$E=\frac{\text{Amps.} \times 2 \times \text{feet} \times 10.8}{CM}$$

where the term "feet" indicates the length of the circuit, the number of feet of wire in the circuit being double the length of the circuit.

Example: What would be the volts loss in a circuit of No. 12 wire carrying 20 amperes a distance of 50 feet?

$$E=\frac{20 \times 2 \times 50 \times 10.8}{6530}$$ or 3.3 volts drop, or 3% on a 110-volt circuit.

Example: What size of conductor would be necessary to give a 3% drop on a 110 volt circuit carrying 20 amperes a distance of 50 feet?

$$CM=\frac{\text{Amps.} \times 2 \times \text{feet} \times 10.8}{E} \text{ or}$$

$$CM=\frac{20 \times 2 \times 50 \times 10.8}{3.3}$$ or 6530 CM or a No. 12 wire.

Example: What current can a No. 12 wire carry on a 50 foot circuit with a voltage drop of 3.3 volts?

$$\text{Amp.}=\frac{CM \times E}{2 \times \text{feet} \times 10.8} \text{ or}$$

$$I=\frac{6530 \times 3.3}{50 \times 2 \times 10.8} \text{ or 20 amperes.}$$

Current Calculations

The formula W = EI, where W = watts; E = voltage and I = current, can be used to determine the watts W = EI; the voltage, $E=\frac{W}{I}$; or the current; $I=\frac{W}{E}$. This formula is applicable where the power-factor is unity. To determine the current:

2-wire, Direct Current: $I=\frac{W}{E}$

3-wire, Direct Current: $I=\frac{W}{2E}$ where E is the voltage between the outside wire and the neutral.

2-wire, Single-phase: $I=\frac{W}{E \times PF}$, where PF represents the power factor of the circuit.

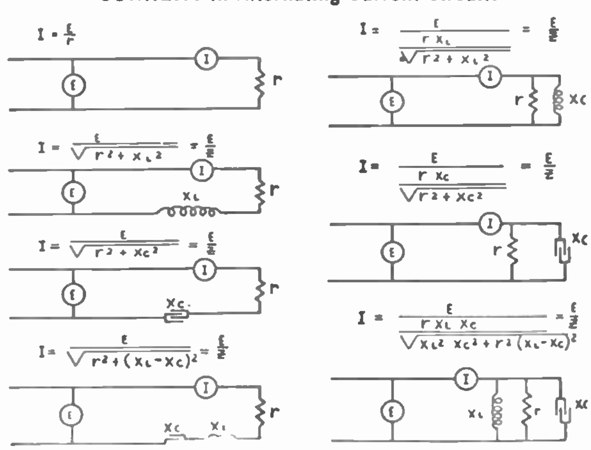
3-wire, Single-phase: $I=\frac{W}{2E \times PF}$ where E is the voltage between the outside wire and the neutral.

3-wire, Three-phase: $I=\frac{W}{1.73E \times PF}$, where E is the voltage between outside wires.

4-wire, Three-phase: $I=\frac{W}{3E \times PF}$, where E is the voltage between one outside wire and the neutral.

(Courtesy of International Association of Inspectors)

FORMULAE FOR DETERMINING ALTERNATING CURRENT in Alternating Current Circuits



r = Resistance in Ohms
X_L = Inductive reactance in Ohms = $2\pi fL$
X_C = Condensive Reactance in Ohms = $\frac{1}{2\pi fc}$
Z = Impedance in Ohms
I = Current in Amperes
E = Pressure in Volts

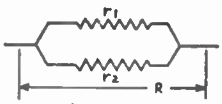
f = frequency in cycles per second
L = ind. in Henrys
c = capacity in Farads

CONVENIENT TABLES AND FORMULAE

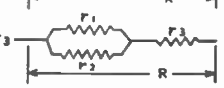
FORMULA FOR COMBINING RESISTANCE AND REACTANCE

$R = r$

$R = \dfrac{1}{\frac{1}{r_1} + \frac{1}{r_2}} = \dfrac{r_1 r_2}{r_1 + r_2}$



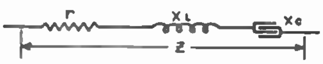
$R = \dfrac{1}{\frac{1}{r_1} + \frac{1}{r_2}} + r_3 = \dfrac{r_1 r_2}{r_1 + r_2} + r_3$



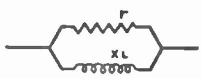
$Z = \sqrt{r^2 + X_L^2}$

$Z = \sqrt{r^2 + X_C^2}$

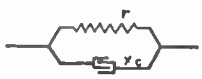
$Z = \sqrt{r^2 + (X_L - X_C)^2}$



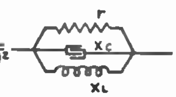
$Z = \dfrac{1}{\sqrt{\left(\frac{1}{r}\right)^2 + \left(\frac{1}{X_L}\right)^2}} = \dfrac{r X_L}{\sqrt{r^2 + X_L^2}}$



$Z = \dfrac{1}{\sqrt{\left(\frac{1}{r}\right)^2 + \left(\frac{1}{X_C}\right)^2}} = \dfrac{r X_C}{\sqrt{r^2 + X_C^2}}$



$Z = \dfrac{1}{\sqrt{\left(\frac{1}{r}\right)^2 + \left(\frac{1}{X_L} - \frac{1}{X_C}\right)^2}} = \dfrac{r X_L X_C}{\sqrt{X_L^2 X_C^2 + r^2 (X_L - X_C)^2}}$



r = Resistance in Ohms
X_L = Inductive reactance in Ohms $= 2\pi f L$
X_C = Condensive Reactance in Ohms $= \dfrac{1}{2\pi f C}$
{ f = frequency, L = ind. in Henrys, C = capacity in Farads }
Z = Impedance in Ohms
I = Current in Amperes
E = Pressure in Volts

DETERMINATION OF TEMPERATURE by Resistance Measurements

Based on a temperature co-efficient for copper wire of .00427 at 0°C, the following relations exist between resistance and temperature:

R = Resistance of winding at T° C (Final Temp.)
r = Resistance of winding at t° C (Initial Temp.)

then $\dfrac{R}{r} = \dfrac{234.5 + T}{234.5 + t}$ or $T = \dfrac{R}{r}(234.5 + t) - 234.5$

HANDY FORMULAS

Power Transmission by Shaft

$\text{Hp.} = \dfrac{\text{Torque (in ft. lb.)} \times \text{Rpm.}}{5250}$

Hydraulics

Hp. of Water Fall = .114 x cu. ft. per sec. x head in ft. x Eff. Assuming 88% eff. of water wheel, then:

100 cu. ft. per sec. with 10 ft. head = 100 Hp.

Power to Drive Pumps

$\text{Hp.} = \dfrac{\text{Gal. per min.} \times \text{Total head (inc. friction)}}{3960 \times \text{Eff. of Pump}}$

Fans and Blowers

$\text{Hp. to drive fans} = \dfrac{K \times \text{cu. ft. min.} \times \text{water gage pressure in in.}}{33000 \times \text{Eff. of fan}}$

Water gage inches = 1.728 oz. per sq. in.
K = 5.2
Eff. = .5 for ordinary fans to .65 for Sirocco type

Rotating Mass Formula

Useful in estimating time to start–stop or change speed of fly-wheels, motors, etc. with certain applied torque =

$\text{Time (Sec.)} = \dfrac{WR^2 \times \text{change in Rpm.}}{322 \times \text{torque (ft. lb.)}}$

MENSURATION OF SURFACES AND VOLUMES

Area of Rectangle = length x breadth.
Area of Triangle = ½ base x perpendicular height.
Circumference of Circle = diameter x 3.1416.
Area of Circle = square of diameter x .7854.

To Find Diameter of a Circle of Given Area

Divide area by .7854 and extract square root.

To Find Volume of a Cylinder

Area of section in square inches x length in inches = Volume in cubic inches.
Cubic inches ÷ 1728 = Volume in cubic feet.
Surface of a Sphere = Square of diam. x 3.1416.
Volume of a Sphere = Cube of diam. x .5236.
Diameter x .8862 = Side of square of equal area.
Diameter x .7071 = Side of inscribed square.
Circumference = 3.5449 x $\sqrt{\text{area of circle}}$.
Diameter = 1.1284 x $\sqrt{\text{area of circle}}$.

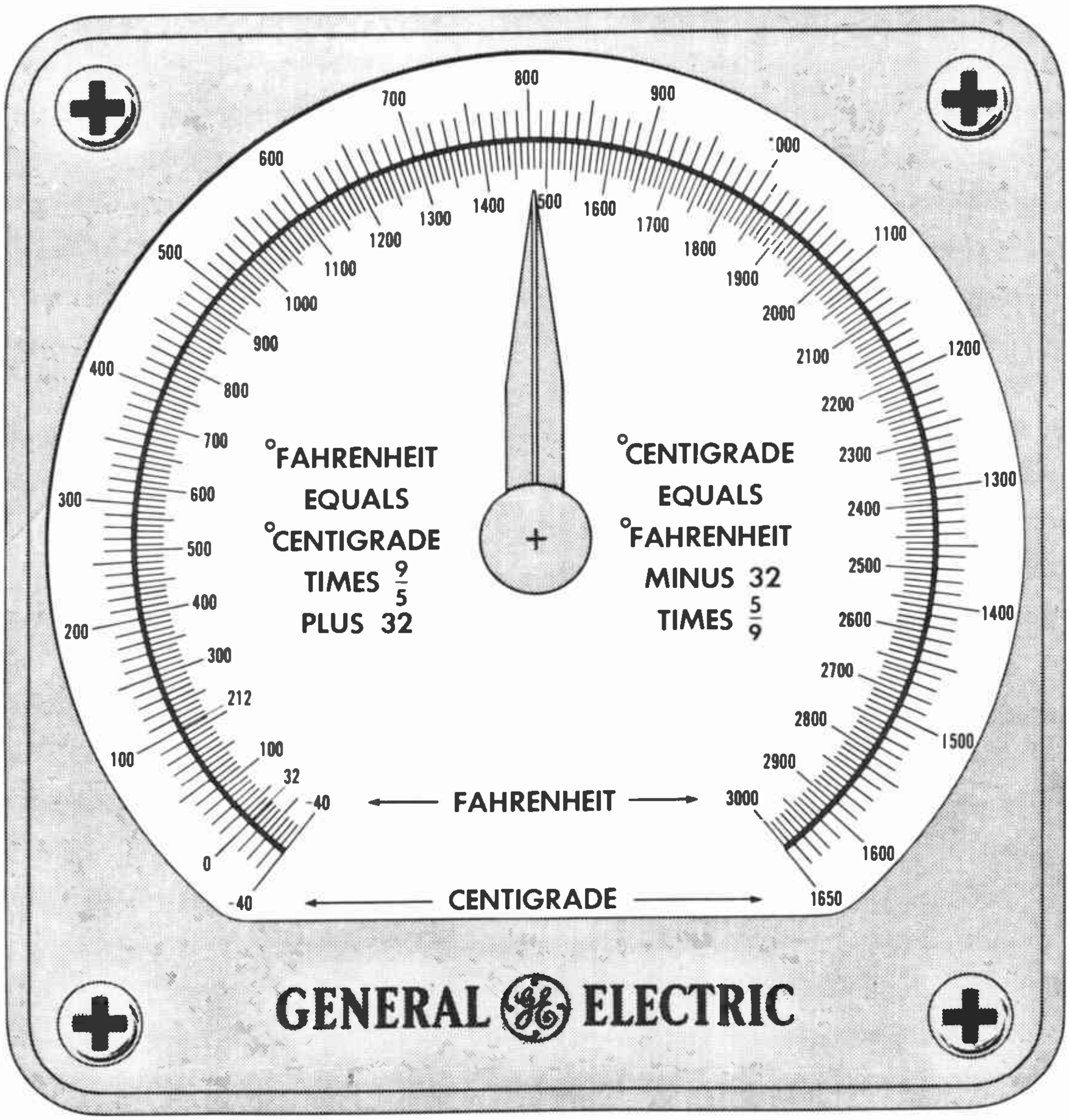
USEFUL ELECTRICAL FORMULAE FOR DETERMINING AMPERES, HORSEPOWER, KILOWATTS, AND Kv-a.

To Find	Direct Current	Alternating Current		
		Single Phase	2 Phase *—Four Wire	Three Phase
Amperes when Horsepower is known	$\dfrac{\text{Hp.} \times 746}{E \times \%\,\text{Eff.}}$	$\dfrac{\text{Hp.} \times 746}{E \times \%\,\text{Eff.} \times \text{P.F.}}$	$\dfrac{\text{Hp.} \times 746}{2 \times E \times \%\,\text{Eff.} \times \text{P.F.}}$	$\dfrac{\text{Hp.} \times 746}{1.73 \times E \times \%\,\text{Eff.} \times \text{P.F.}}$
Amperes when Kilowatts is known	$\dfrac{\text{Kw.} \times 1000}{E}$	$\dfrac{\text{Kw.} \times 1000}{E \times \text{P.F.}}$	$\dfrac{\text{Kw.} \times 1000}{2 \times E \times \text{P.F.}}$	$\dfrac{\text{Kw.} \times 1000}{1.73 \times E \times \text{P.F.}}$
Amperes when Kv-a. is known		$\dfrac{\text{Kv-a.} \times 1000}{E}$	$\dfrac{\text{Kv-a.} \times 1000}{2 \times E}$	$\dfrac{\text{Kv-a.} \times 1000}{1.73 \times E}$
Kilowatts	$\dfrac{I \times E}{1000}$	$\dfrac{I \times E \times \text{P.F.}}{1000}$	$\dfrac{I \times E \times 2 \times \text{P.F.}}{1000}$	$\dfrac{I \times E \times 1.73 \times \text{P.F.}}{1000}$
Kv-a.		$\dfrac{I \times E}{1000}$	$\dfrac{I \times E \times 2}{1000}$	$\dfrac{I \times E \times 1.73}{1000}$
Horsepower—(output)	$\dfrac{I \times E \times \%\,\text{Eff.}}{746}$	$\dfrac{I \times E \times \%\,\text{Eff.} \times \text{P.F.}}{746}$	$\dfrac{I \times E \times 2 \times \%\,\text{Eff.} \times \text{P.F.}}{746}$	$\dfrac{I \times E \times 1.73 \times \%\,\text{Eff.} \times \text{P.F.}}{746}$

I = Amperes; E = Volts; % Eff. = Percent Efficiency; P.F. = Power Factor; Kw. = Kilowatts; Kv-a. = Kilovolt-amperes; Hp. = Horsepower.

* For three-wire, two-phase circuits the current in the common conductor is 1.41 times that in either of the other two conductors.

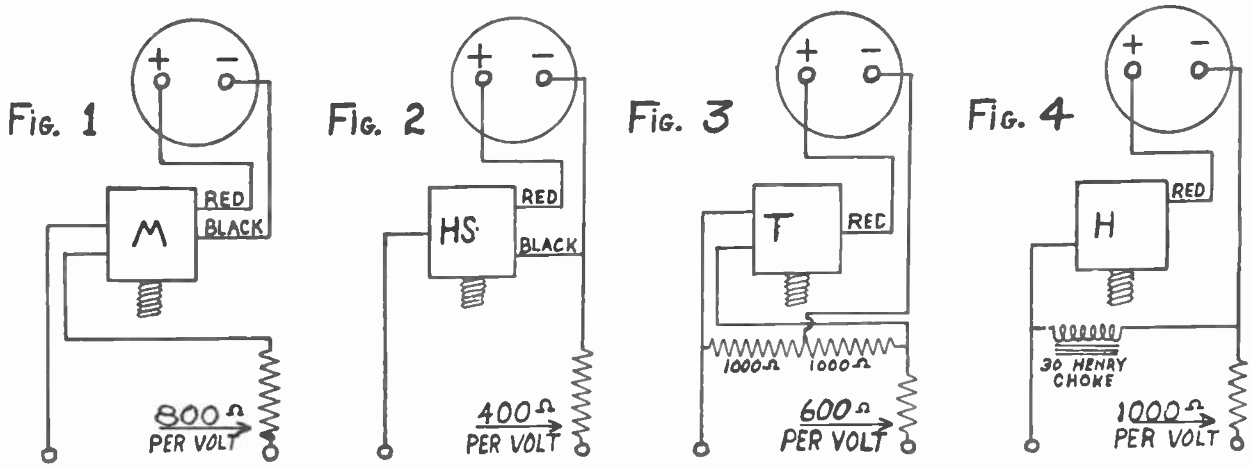
TEMPERATURE-CONVERSION CHART



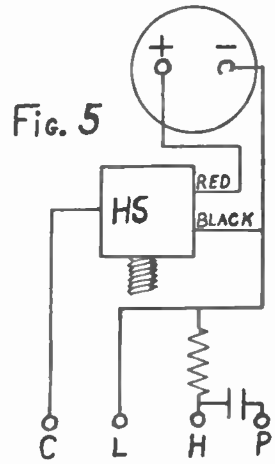
Temperature-conversion chart for easy conversion of readings from one temperature scale to the other. If you wish to remove chart for use as a separate reference, cut along dotted line at left.

METER CIRCUITS FOR CONANT INSTRUMENT RECTIFIERS H, HS, M AND T

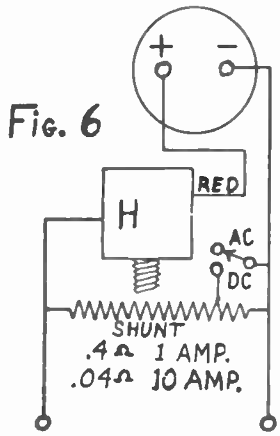
ALTERNATING CURRENT VOLTMETERS



UNIVERSAL OUTPUT METER

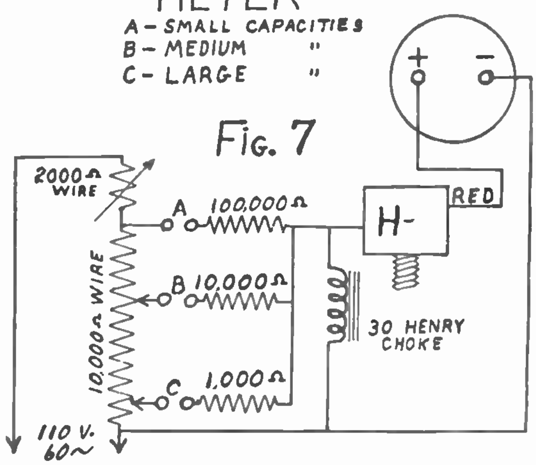


AC-DC AMMETER

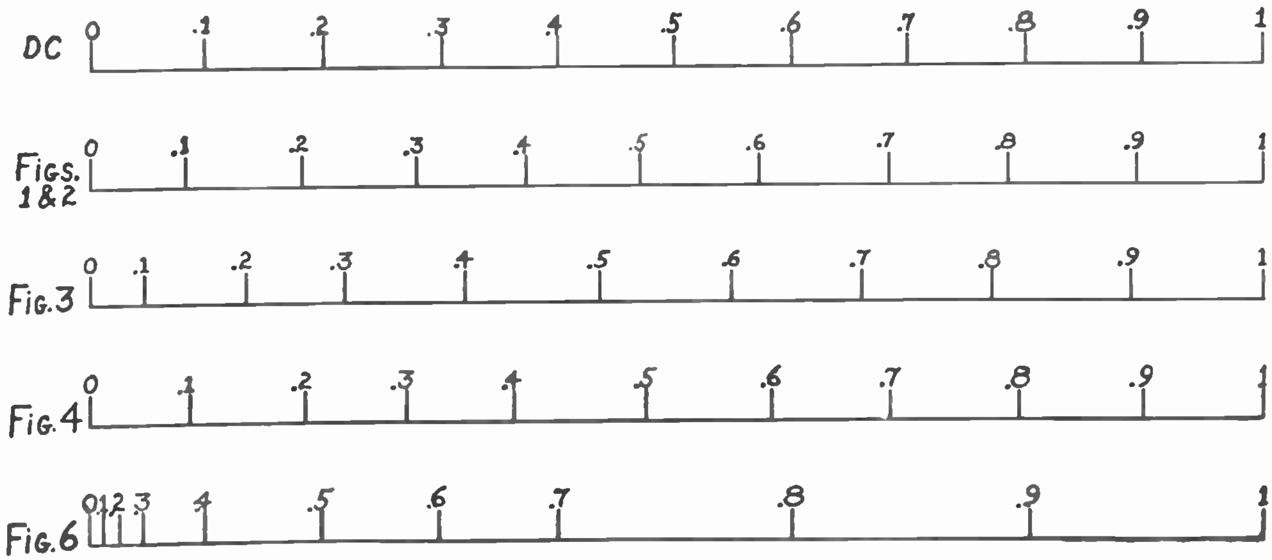


CAPACITY-IMPEDANCE METER

A - SMALL CAPACITIES
B - MEDIUM "
C - LARGE "



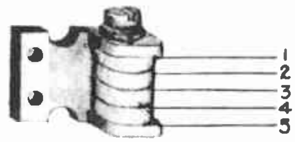
SCALE COMPARISONS



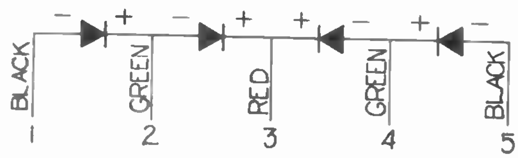
METER CIRCUITS FOR BRADLEY REPLACEMENT TYPE INSTRUMENT RECTIFIERS CX 2E4U

Replacement for all instrument rectifiers and for continuous operation in all circuits in which the AC voltage and the DC current does not exceed rectifier rating.

In replacing any instrument rectifier the calibration of the instrument may be affected. It is recommended that replacement be made by the instrument manufacturer if recalibration is necessary.



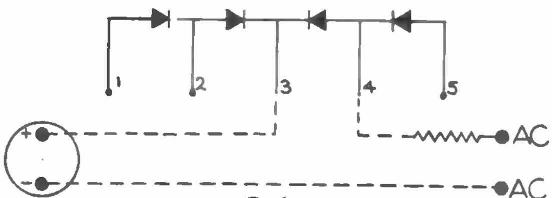
MODEL CX2E4U



Position of Elements and Color Code

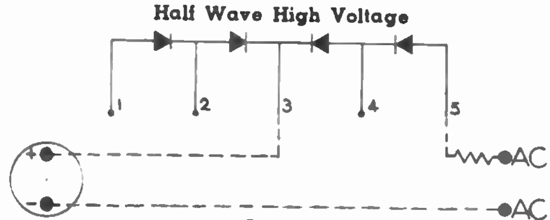
CONNECT RECTIFIER IN CIRCUIT AS SHOWN BY DOTTED LINES. CLIP OFF SURPLUS LEADS **AFTER** CIRCUIT HAS PROVEN SATISFACTORY.

Half Wave



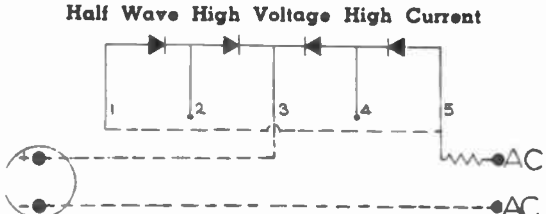
Rating
6 Volts AC — 3 Milliamperes DC

Half Wave High Voltage



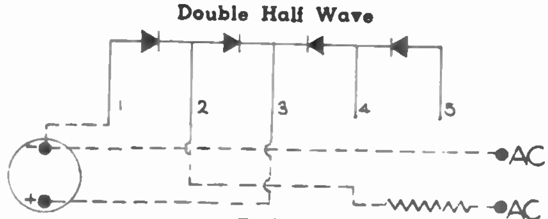
Rating
12 Volts AC — 3 Milliamperes DC

Half Wave High Voltage High Current



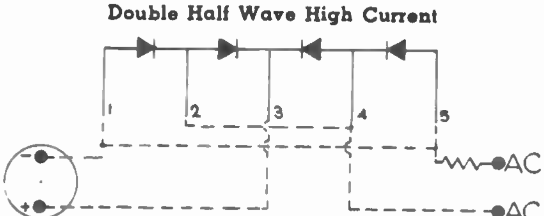
Rating
12 Volts AC — 5 Milliamperes DC

Double Half Wave



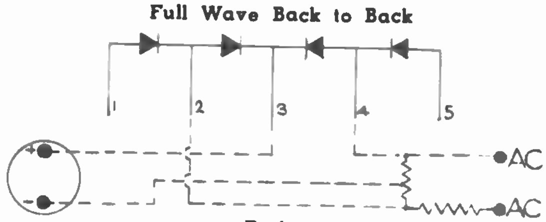
Rating
6 Volts AC — 3 Milliamperes DC

Double Half Wave High Current



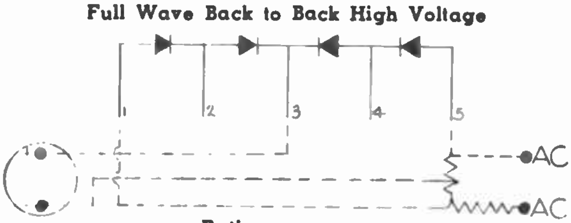
Rating
6 Volts AC — 5 Milliamperes DC

Full Wave Back to Back



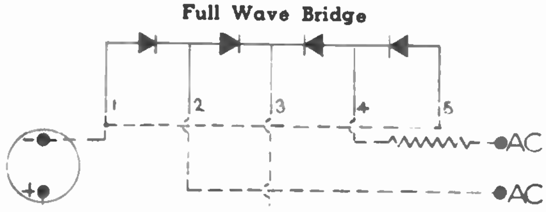
Rating
6 Volts AC — 5 Milliamperes DC

Full Wave Back to Back High Voltage



Rating
12 Volts AC — 5 Milliamperes DC

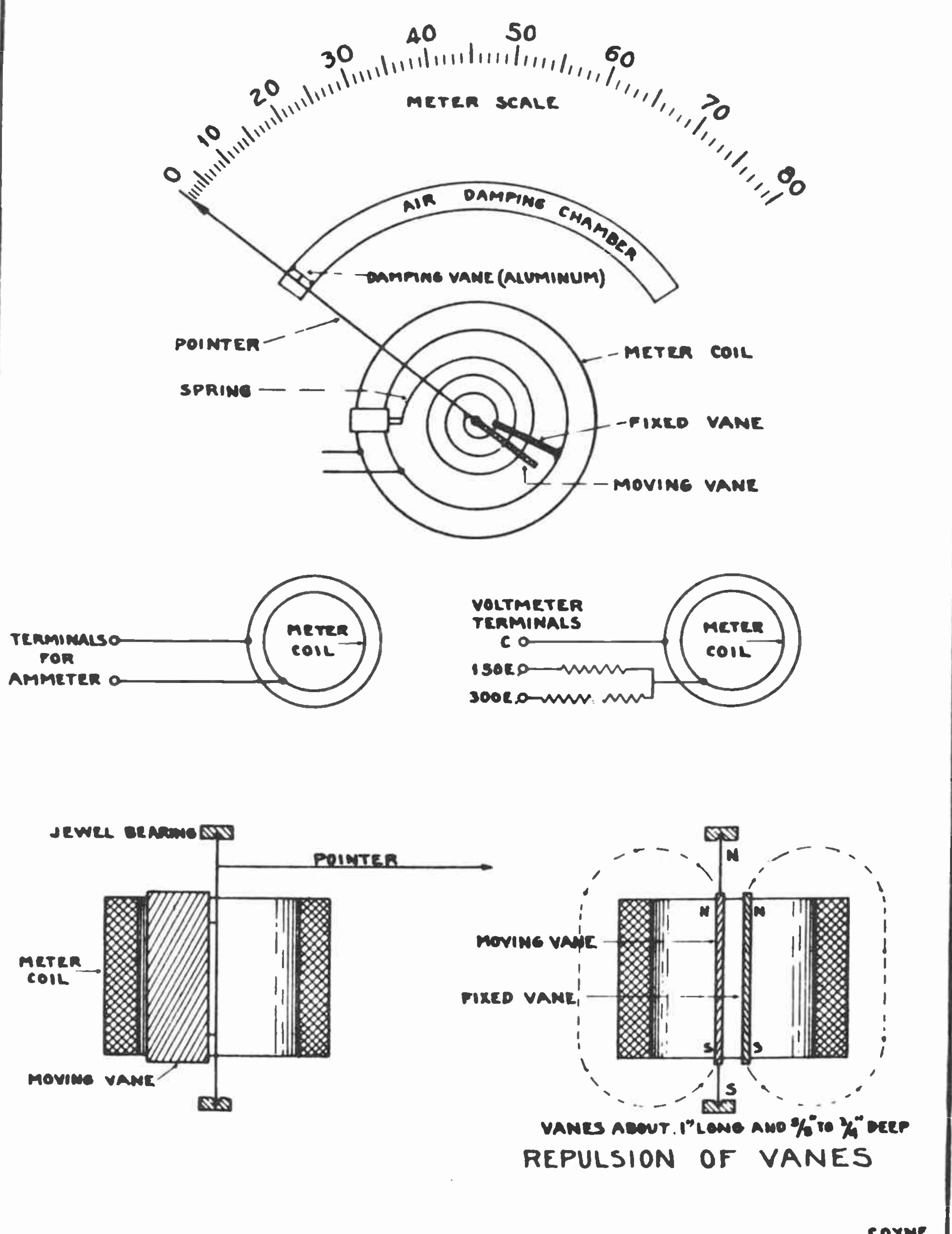
Full Wave Bridge



Rating
6 Volts AC — 5 Milliamperes DC

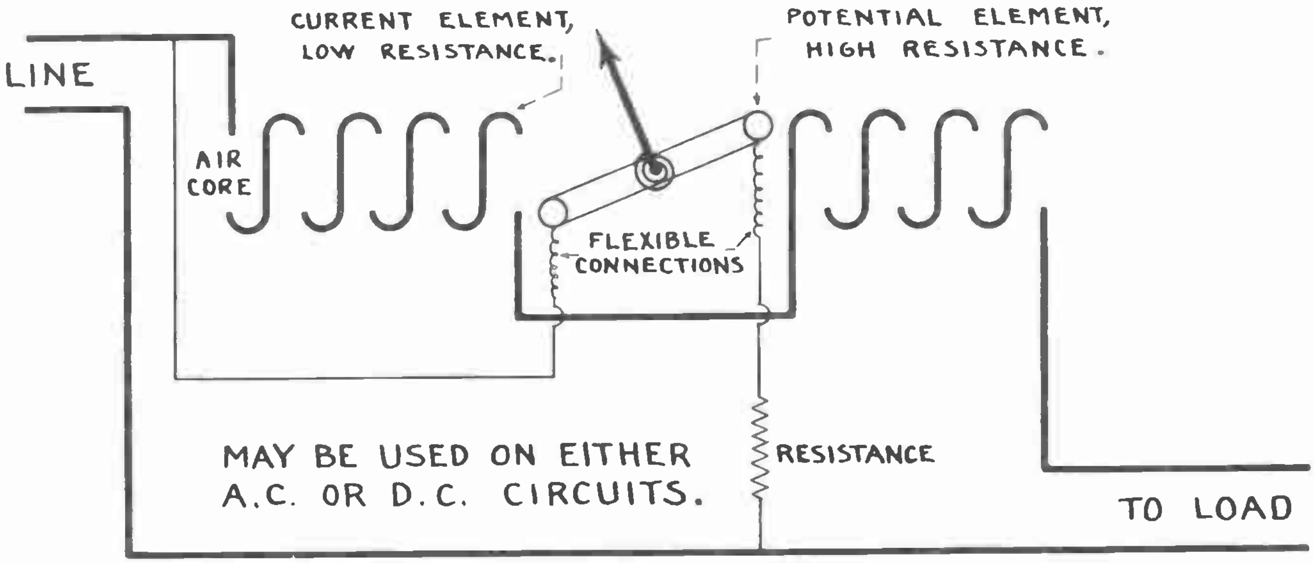
CAUTION: Precision rectifiers should never be operated at greater than rated AC Voltage or DC Current. Bradley rectifiers will withstand several times voltage or current for instantaneous service but must not be operated on continuous service at higher than normal rating. Handle flexible leads with care and do not replace leads if they are too short. Leads are soldered to lugs before assembly to prevent heat of soldering from damaging elements. If lead is too short, solder extension to present lead. Rectifiers must not be disassembled and adjusting screw and nut must not be moved as elements are adjusted and sealed at the factory.

A.C. MOVING IRON TYPE AMMETER & VOLTMETER

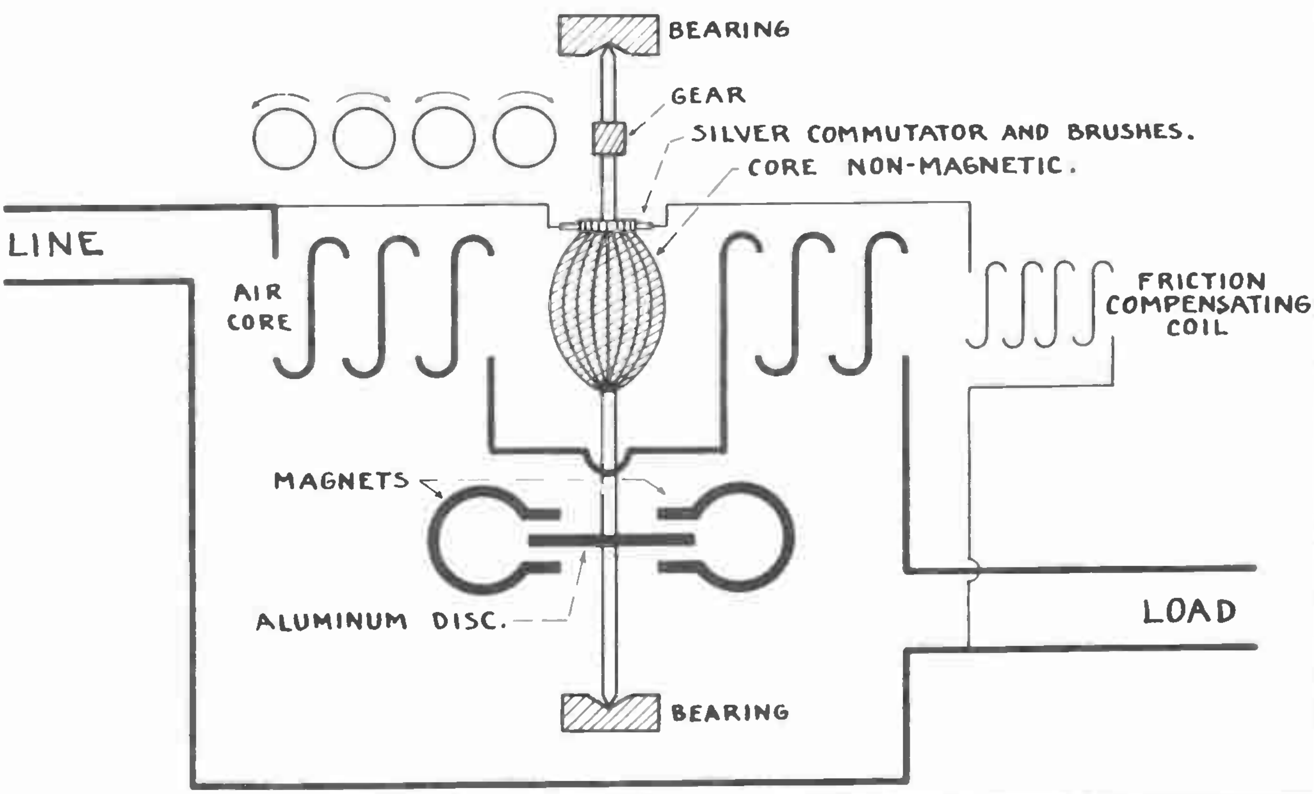


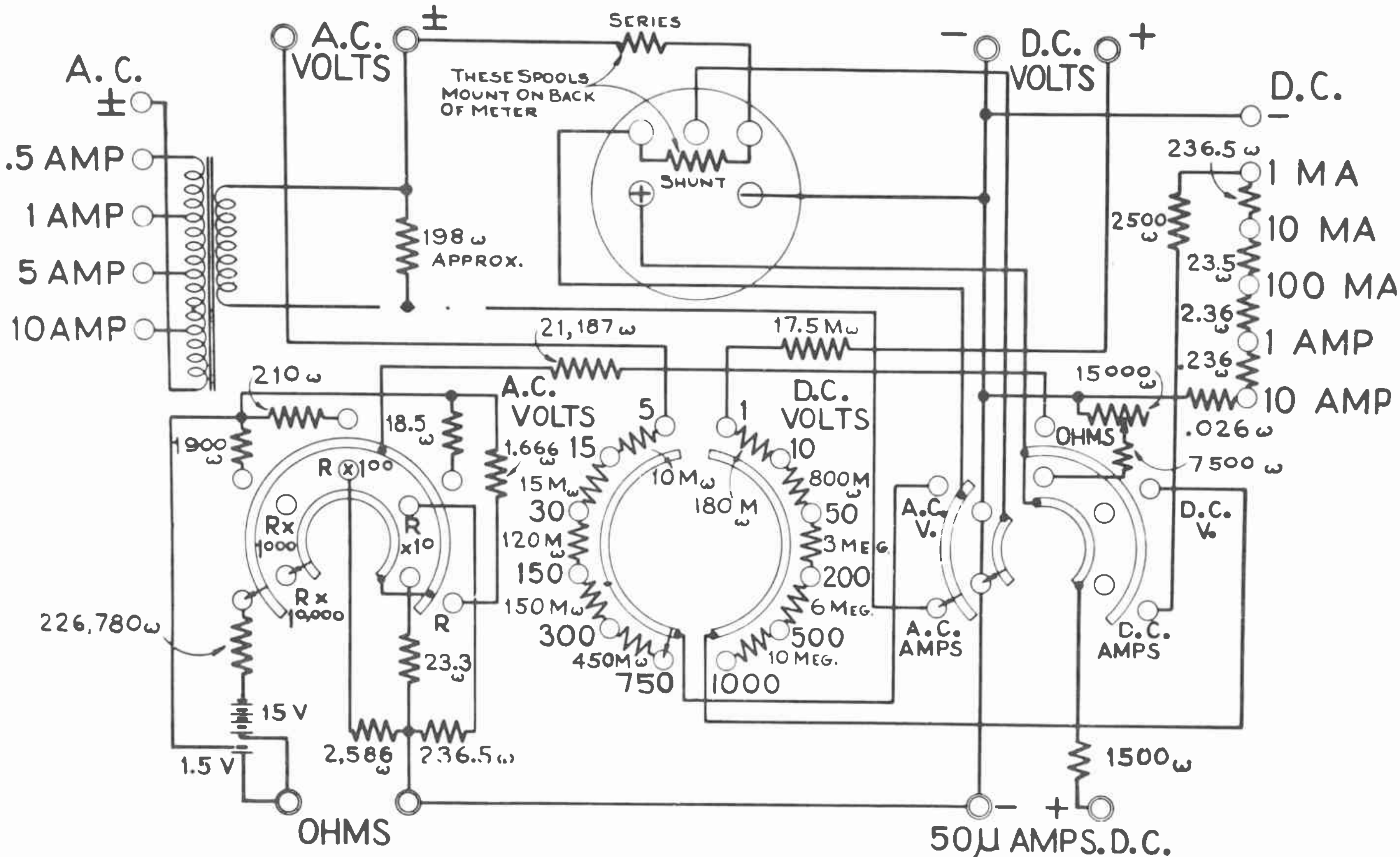
WATTMETER AND WATTHOURMETER DIAGRAMS

INDICATING WATTMETER.



D.C. INTEGRATING WATTMETER.





WESTON INDUSTRIAL CIRCUIT TESTER - MODEL 785
Connections as seen from back of panel.

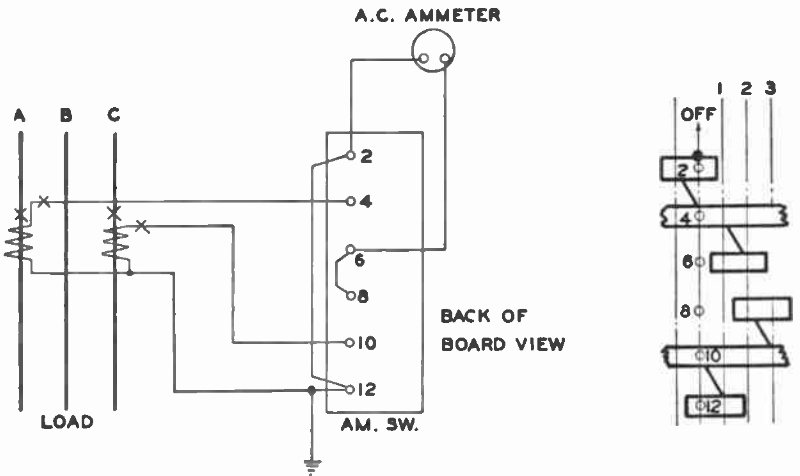
Volts, d-c.	1000	500	200	50	10	1
Volts, a-c.	750	300	150	30	15	5

Current, d-c. 10 amps, 1 amp, 100 ma, 10 ma, 1 ma, 50 microamps.

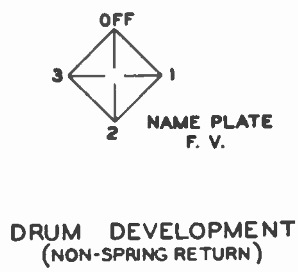
Current, a-c. 10 amps, 5 amps, 1 amp, 0.5 amp.

	Megohms:			Ohms:		
Resistance, full-scale.	30	3		300,000	30,000	3,000
Resistance, center-scale.	0.25	0.025		2,500	250	25

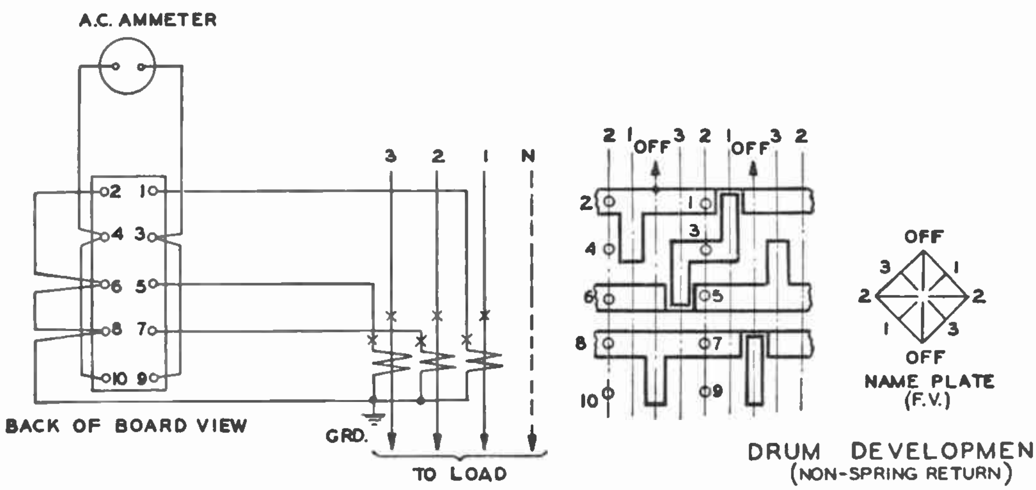
METER SWITCHING CIRCUITS - ALLIS-CHALMERS TYPE 153 ROTARY SWITCHES



CONTACTS	POSITION			
	OFF	1	2	3
2-4	X			X
4-6		X	X	
8-10			X	X
10-12	X	X		

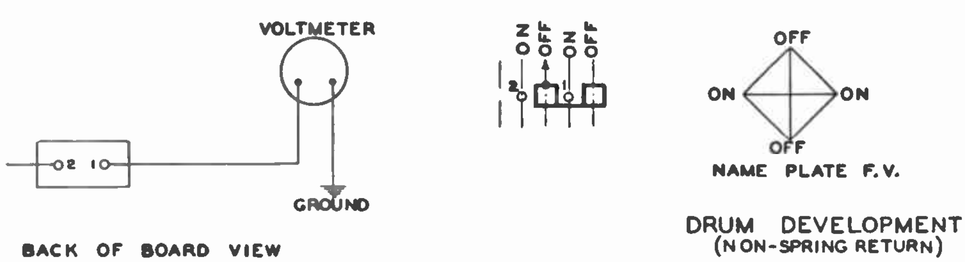


Three-phase Ammeter Switch (Cat. 153-2-39).



CONTACTS	POSITION			
	OFF	1	2	3
1-2	X		X	X
1-3		X		
2-4		X		
3-5				X
4-6				X
5-6	X	X	X	
7-8	X	X		X
7-9			X	
8-10			X	

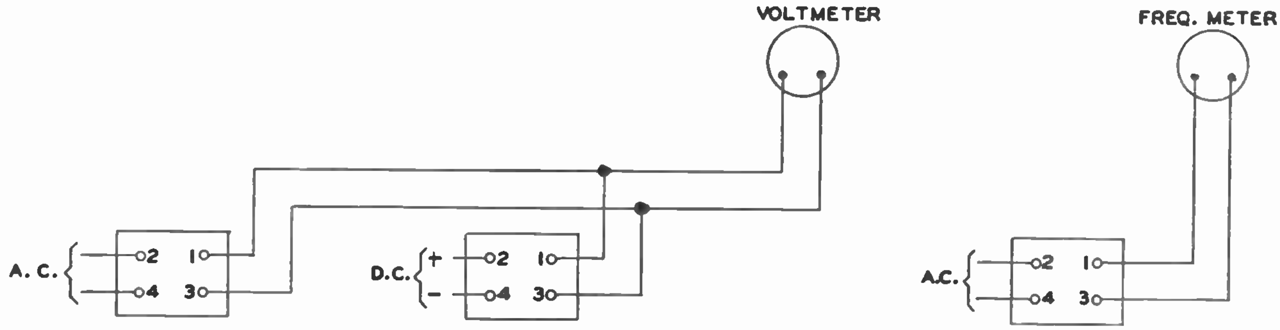
Three independent circuit Ammeter Switch (Cat. 153-2-34).



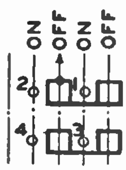
CONTACTS	POSITIONS			
	OFF	ON	OFF	ON
1-2		X		X

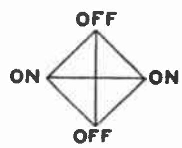
Voltmeter Switch, single pole, a-c or d-c — (Cat. 153-3-4 switch only) (Cat. 153K-3-4 key only)

METER SWITCHING CIRCUITS - ALLIS-CHALMERS TYPE 153 ROTARY SWITCHES



BACK OF BOARD VIEW





NAME PLATE F. V.

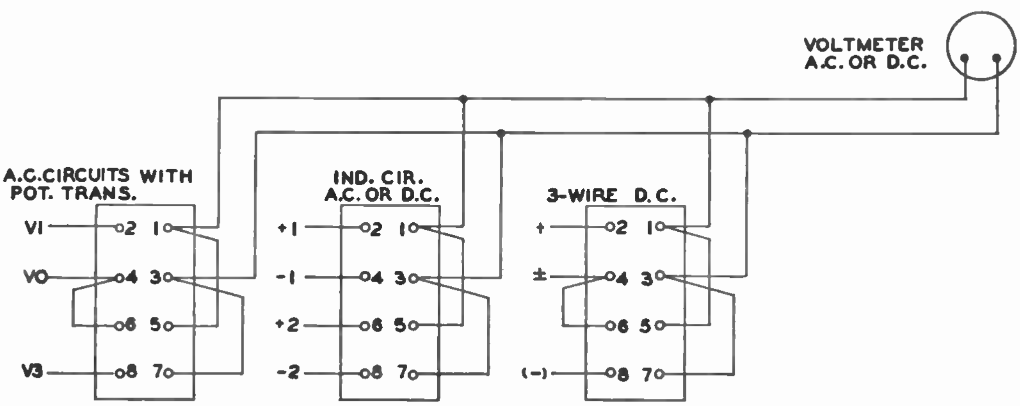
CONTACTS	POSITIONS			
	OFF	ON	OFF	ON
1 - 2		X		X
3 - 4		X		X

CAT. 153-3-3 SWITCH ONLY
CAT. 153K-3-3 KEY ONLY

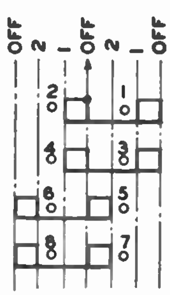
DRUM DEVELOPMENT
(NON-SPRING RETURN)

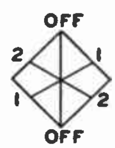
CAT. 153-3-10 SWITCH ONLY
CAT. 153K-3-10 KEY ONLY

Voltmeter Switch, single-phase, or two pole d-c or frequency meter switch.



BACK OF BOARD VIEW





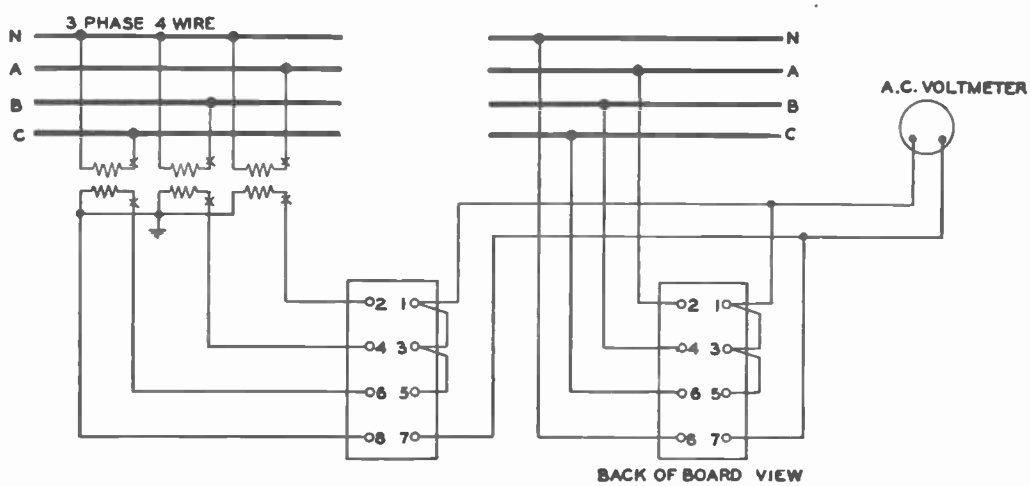
NAME PLATE F.V.

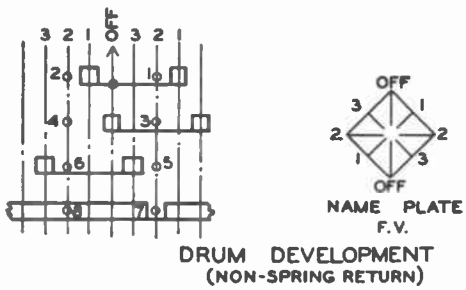
CONTACTS	POSITIONS					
	OFF	1	2	OFF	1	2
1 - 2		X			X	
3 - 4		X			X	
5 - 6			X			X
7 - 8			X			X

DRUM DEVELOPMENTS
(NON-SPRING RETURN)

Voltmeter Switch — 2-phase, 3-wire, or 3-wire d-c, or two independent circuits — (Cat. 153-3-2 switch only) (Cat. 153K-3-2 key only).

METER SWITCHING CIRCUITS - ALLIS-CHALMERS TYPE 153 ROTARY SWITCHES

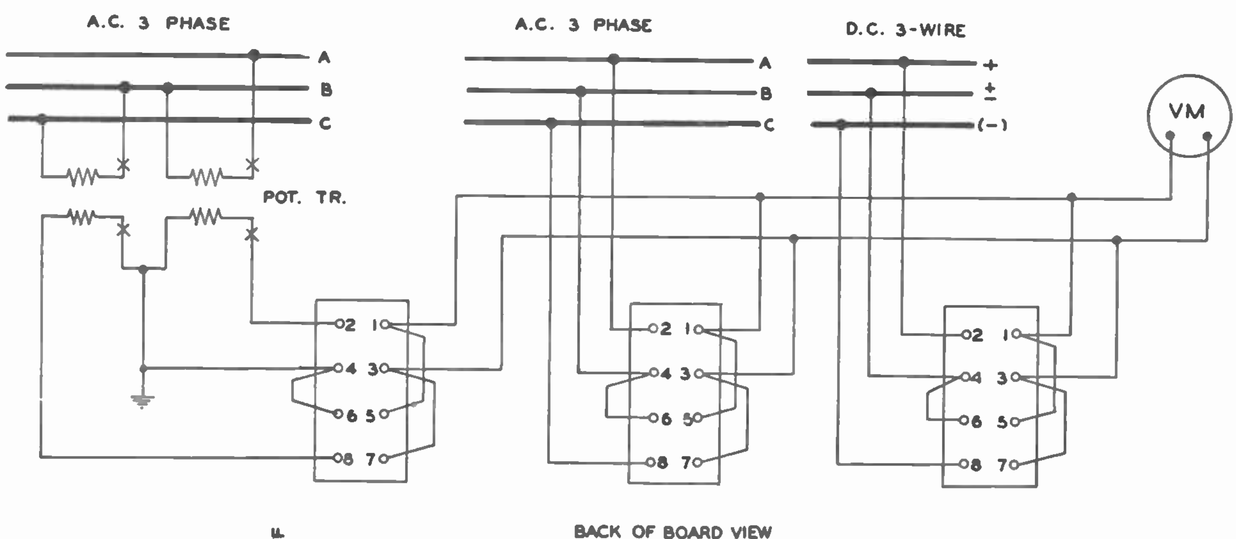


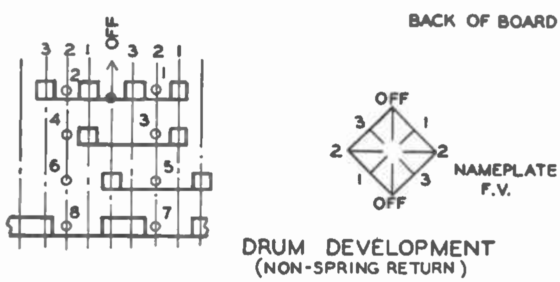


CONTACTS	POSITIONS OFF	1	2	3
1-2		X		
3-4			X	
5-6				X
7-8		X	X	X

CAT. 153-3-5 SWITCH ONLY
CAT. 153K-3-5 KEY ONLY

Voltmeter Switch, three-phase, four-wire.

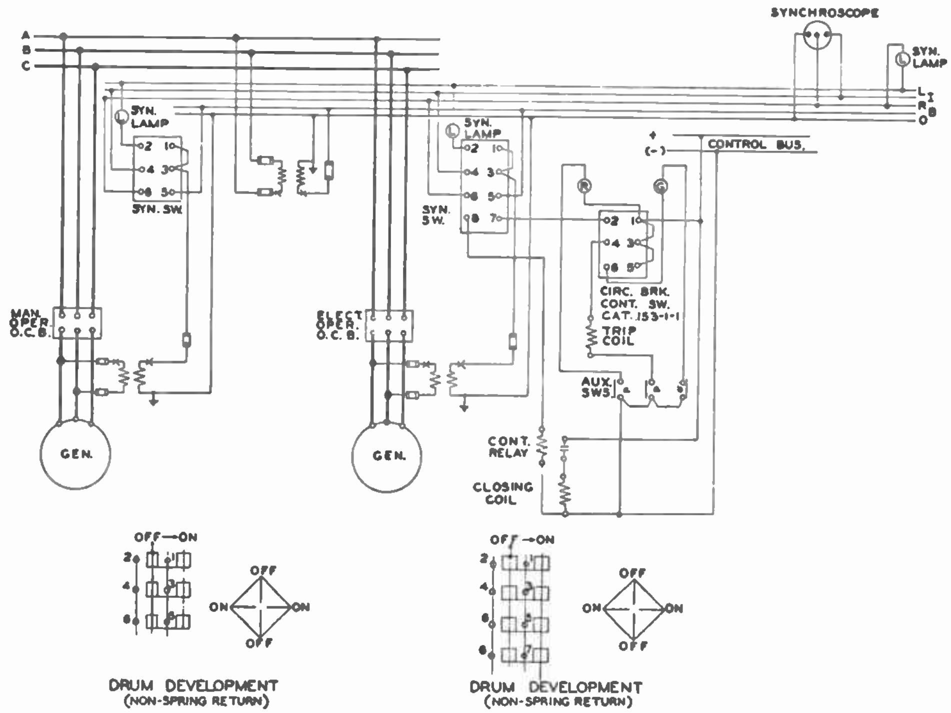




CONTACTS	POSITIONS OFF	1	2	3
1-2		X		X
3-4		X		
5-6			X	
7-8			X	X

Voltmeter Switch for 3-phase, 3-wire — (Cat. 153-3-6 switch only) (Cat. 153K-3-6 key only).

METER SWITCHING CIRCUITS - ALLIS-CHALMERS TYPE 153 ROTARY SWITCHES



CONTACTS	POSITIONS OFF	ON
1 - 2		X
3 - 4		X
5 - 6		X

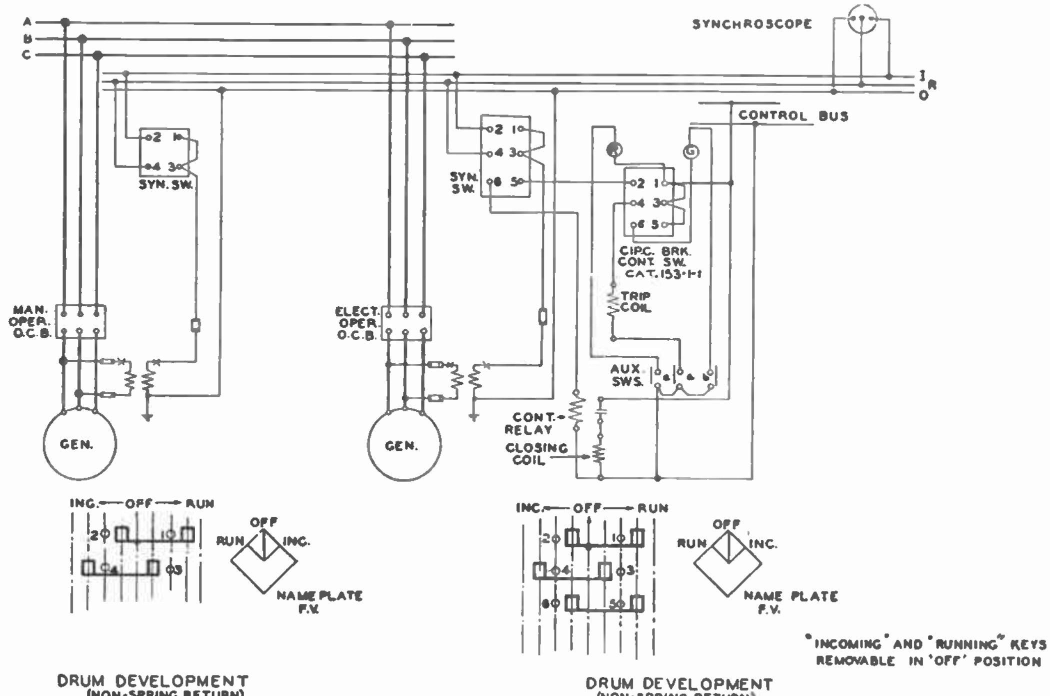
CAT 153-3-8 SWITCH ONLY
CAT. 153K-3-8 KEY ONLY

Synchronizing Switch, between machine and bus, without interlock.

CONTACTS	POSITIONS OFF	ON
1 - 2		X
3 - 4		X
5 - 6		X
7 - 8		X

CAT. 153-3-6 SWITCH ONLY
CAT. 153K-3-6 KEY ONLY

Fig. 12A Synchronizing Switch, between machine and bus, with interlock.



CONTACTS	RUN	OFF	INC.
1 - 2			X
3 - 4	X		

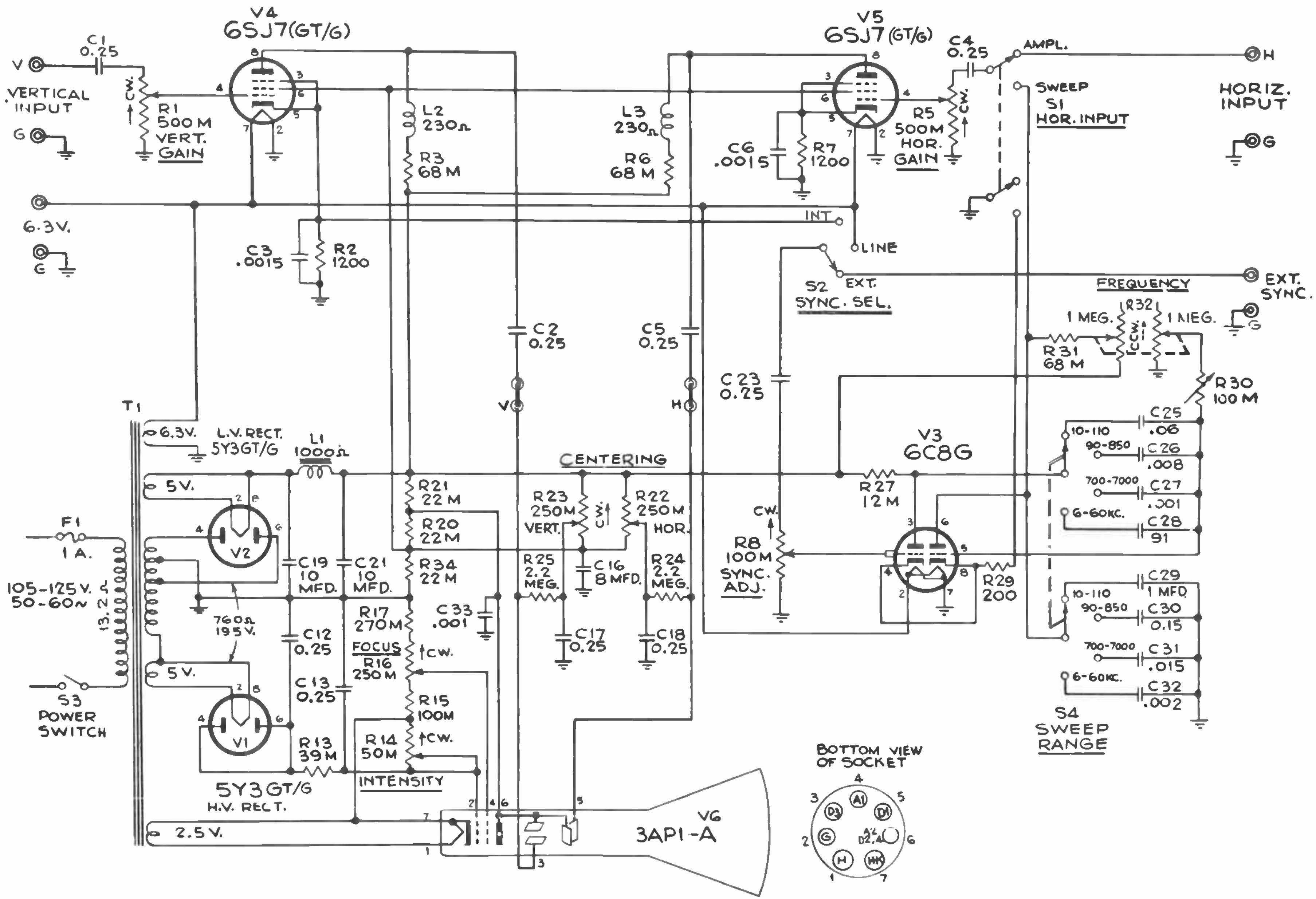
CAT. 153-23-1 SWITCH ONLY
CAT 153K-23-1 'RUN' KEY ONLY
CAT 153K-23-1A 'INC' KEY ONLY

Synchronizing Switch, between machines, without interlock.

CONTACTS	RUN	OFF	INC.
1 - 2			X
3 - 4	X		
6 - 5			X

CAT. 153-23-2 SWITCH ONLY
CAT 153K-23-2 'RUN' KEY ONLY
CAT. 153K-23-2A 'INC' KEY ONLY

Fig. 13A Synchronizing Switch, between machines, with interlock.



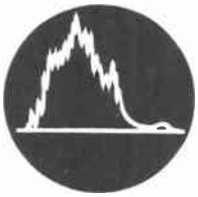
RCA CATHODE-RAY OSCILLOSCOPE - TYPE No. 155C

Frequency range of timing axis oscillator = 10 cycles to 60 kilocycles per second. 6C8G tube.
Deflection sensitivity at 1 kc, gain controls max., 1 volt r-m-s per inch, 2.8 peak-to-peak volts.
Sine wave response: + or - 10% to 40 kc, 20% to 80 kc. Useful range, to 200 kc vert. and hor.

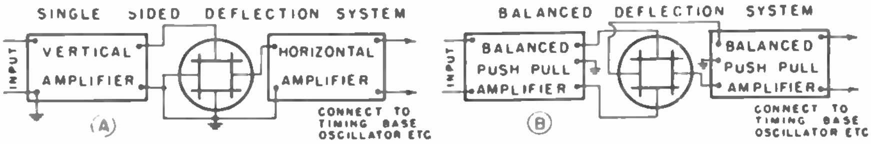
OSCILLOGRAPH RECORDING

TIME BASE METHODS · LINEARIZATION

1—WAVE FORM ANALYSIS, PULSED WAVE



2—FUEL LINE PRESSURE, AUTOMOTIVE TESTS



LINEAR TIME BASE (Single Sweep)

In the usual small general-purpose oscillograph, one of each pair of deflection plates is grounded, as in (A). In larger, precision instruments the deflection plates are isolated from each other and balanced amplifiers are needed, as at (B)

3—PRESSURE WAVE, DETONATION TEST

4—TEST ON FLASH BULBS

In a single sweep system (above) a separate synchronizing pulse is required to start each discharge. If the time base circuit is adjusted so that self oscillations occur, a recurrent form of oscillogram results (shown below). The latter is the most usual form of oscillogram It is useful if the wave under study repeats in a cyclic manner. In either case a similar form of pattern is obtained

Linear Sweep Displacements along the time axis are precisely or approximately proportional to time, depending on the degree of linearization introduced by circuit designer In single frequency sweep circuits, such as is used for television and radar applications precise linearization can be accomplished. In equipments arranged to cover a wide range of frequencies less constancy of the horizontal travel speed usually is found at certain points in the frequency range. Linear sweeps for frequencies higher than a few cycles per second utilize the voltage across a slowly charging capacitor to control the deflection along the time axis. The charging curve is altered from an exponential to a linear curve by providing a constant valued charging current to the capacitor.

5—ELECTROCARDIOGRAM

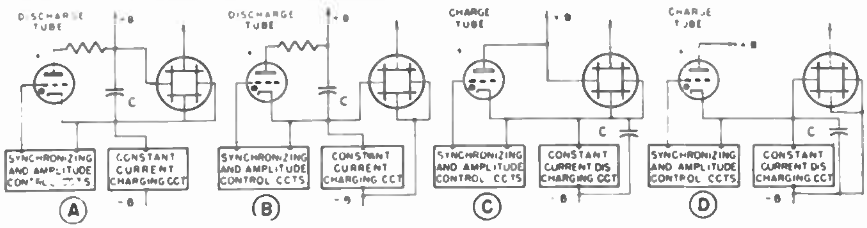
6—PULSED WAVEFORMS FROM MULTIVIBRATOR

LINEAR TIME BASE (Recurrent)

Four methods for connecting the RC timing circuit of a linear sweep to the thyratron control tube. A and B utilize a slowly built up charge and fast discharge, C and D a slow discharge and a fast charge. The over all results are similar.

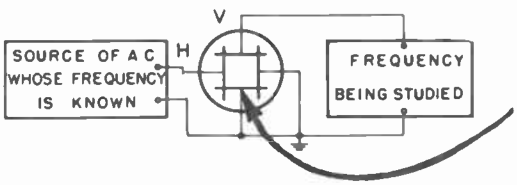
7—CARRIER WAVE PATTERN 100% MODULATION

8—RATE OF CHANGE OF PRESSURE WAVE, DETONATION TEST



9—FREQUENCY RATIO 5:4

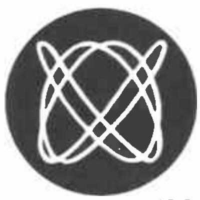
10—MODULATING WAVE AS TIME BASE, TRAPEZOIDAL PATTERN



The symbol for a cathode ray oscillograph showing the connections either to the vertical and horizontal deflection plates or to the amplifiers associated with those plates.

SINUSOIDAL TIME BASE

If a sine wave voltage is applied to a set of deflection plates, and alternating voltage under test to the other plates, the well known Lissajou figures result. The pattern depends on the relative frequencies, their harmonic contents and the phase differences between them Rules for determining the ratio from the pattern f/n is to divide the number of times the trace intersects the horizontal axis (or any line parallel to this axis) by the number of times it intersects the vertical axis, (or a line parallel to it). An inversion of the frequency ratio is equivalent to viewing the diagram turned 90 . This rule is useful if the harmonic content of either of the frequencies is less than say 25% of the fundamental, and is unaffected by phase differences.

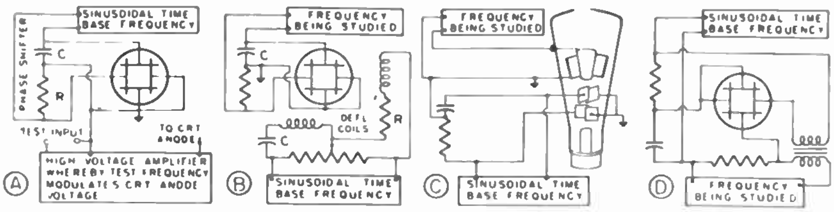


11—FREQUENCY RATIO 3:4

12—1:1 RATIO WITH HARMONICS

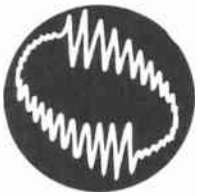
SYSTEMS
SYNCHRONIZATION

A review of the basic equipment arrangements for displaying cathode ray tube patterns. In three parts • PART 1—SINGLE FREQUENCY TIMING

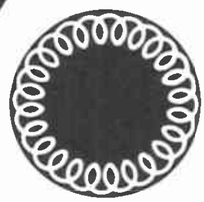


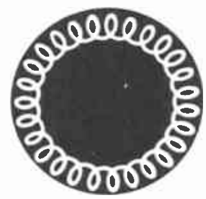
CIRCULAR TIME BASE

This is similar to one with a linear sweep. The spot moves radially to and from the periphery of a circle. The angular advance of the radian containing spot is at a constant speed. Such a sweep is simple, but applying signal to produce the radial excursions is not easy. There are four common arrangements: Use of modulated anode currents, Fig. A, has the disadvantage that intensity of trace decreases with its distance from center of circle. Use of a double deflection system. Magnetic deflection coils connected in quadrature to a sinusoidal time base frequency produce the basic circle. Test voltage is connected through phase splitting circuit to the plates, Fig. B. The third method uses a so-called "polar co-ordinate" cathode ray tube containing an additional pair of concentric truncated cone shaped deflectors to which the signal to be analyzed is placed, Fig. C. These are actually "circular", not polar diagrams. The fourth method uses a double phase-shifting circuit, Fig. D.


13—WAVEFORM APPLIED TO CIRCULAR TIME BASE

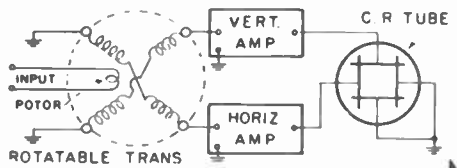

14—780 CYCLE WAVE ON 60 CYCLE BASE


15—TIME BASE ROTATING SAME DIRECTION, 26 1


16—ROTATING OPPOSITE DIRECTIONS 26 1

POLAR OSCILLOGRAMS

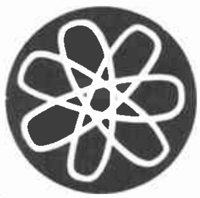
Here the connections from the synchronously driven transformer to the vertical and horizontal deflection system produces a rotating vector whose amplitude (ρ) is proportional to input current and to the speed.



In a polar cure, the radius vector is at all times proportional to the quantity being measured, and the angular movement of this vector either is linear with time, or is proportional to some other factor involved in the problem (such as position). True polar curves are not easy to obtain with a cathode ray tube. In one of the best methods a 2 phase rotatable transformer is turned at constant speed, or at a rate equivalent to the mechanism under test.

This rotatable transformer delivers two 90 voltages, which are proportional to the flux rate-of-change when a steady current is applied to the rotor. These voltages applied to the deflection plates produce a circular trace. A variable current to the rotor turning at constant speed produces a polar curve. With a DC source on the rotor, which is connected to a machine so that it follows the movements of the driving shaft, the diameter of the circle produced is proportional to the speed. Therefore, a "bump" on the circle indicates acceleration.

Another method of indicating speed variations is to apply high frequency pulses to the rotor. A spoked pattern results; the separation of the spokes showing where speed variations occur.


17—POLAR DIAGRAM, SHOWING AN 8 1 RATIO


18—POLAR DIAGRAM OF IRREGULAR WAVE


19—POLAR DIAGRAM, SAWTOOTH WAVE

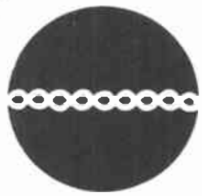

20—POLAR DIAGRAM OF SINE WAVE

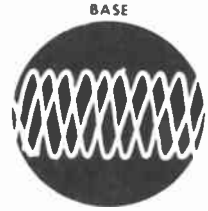
SINUSOIDAL TIME BASE (Extended)

As in the arrangement at the left a sinusoidal voltage of known frequency may be used as a linear time base if its amplitude is increased so that the diagram extends greatly beyond the edges of the cathode ray tube screen. In this case the visible portion is substantially linear. The waveform of any unknown wave applied to the vertical plates will be essentially correct. If the voltage applied is sufficient to give a deflection of, say five times the screen diameter, the greatest deviation from true linearity of the time base will be 2%, assuming no distortion in the deflection. It is usually desirable to blank out the return sweep. A small voltage of the same frequency as that of the time base can be applied to "Z axis" terminals (affecting the modulation grid of the cathode ray tube) to extinguish the pattern during the return interval. This sweep method is simple to apply (60 cycle voltages sometimes being sufficient) and is useful in waveform study. It also serves in determining frequency ratios of a higher order.


21—EXTENDED SINUSOIDAL BASE RETURN SWEEP BLANKED


22—SINE WAVE ON EXTENDED ELLIPTICAL BASE


23—VERTICAL WAVE IS ONE CYCLE OVER AN EVEN MULTIPLE OF BASE


24—WAVE IS 2 CYCLES OVER AN EVEN MULTIPLE OF TIME BASE FREQ

CATHODE RAY OSCILLOGRAPH RECORDING SYSTEMS

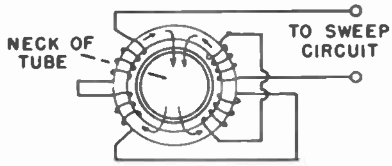
RADAR DISPLAY PATTERNS

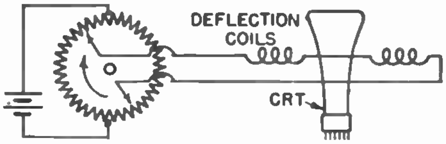
25
TYPE B—RECTANGULAR DISPLAY WITH INTENSITY MODULATED BEAM

26
TYPE C—RECTANGULAR COORDINATE SCAN, MODULATED AS IN TYPE B

27
TYPE RHI, TWO DIRECTIONAL SCAN. Y AXIS REPRESENTS HEIGHT

28
TYPE E, SIMILAR TO (27) BUT Y AXIS SHOWS ELEVATION ANGLE





Left—For a PPI display a Rotatable Magnetic Yoke (driven by motor) surrounds neck of cathode ray tube. Electron beam is perpendicular to paper. *Right*—Circular azimuth position control with 360° continuously rotatable potentiometer. This might be used in a B sweep, etc.

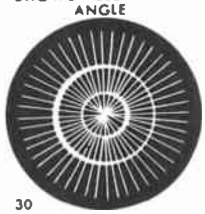
The development of circuits for displaying radar patterns makes great use of doubly timed sweep systems. Many combinations found use in this program, a few being shown here.

The presentation of radar data to the observer may utilize any of the time base systems used in regular oscillography. A modern radar data display system must disclose at least two of the three factors necessary to locate a point in space: direction (azimuth), elevation (or sometimes elevation error), and distance (range). Earliest systems disclosed only range as with Type A display (not shown), as the direction was indicated by means other than the CR tube screen. In some arrangements the three factors are displayed on two tubes, with one factor (such as elevation) common to both.

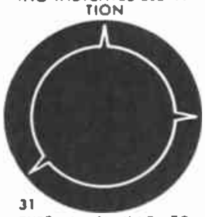
Range data is handled by utilization of travel TIME of a signal too and from the target. Other data is not dependent on TIME but on the simulation of the position of the directive antenna system on the screen. Magnetic deflection arrangements are quite common in radar circuits. To obtain the PPI type of display (oscillogram 31) one design of radar utilizes magnetic deflection coils that rotate about the neck of the cathode ray tube, being driven by a synchronous motor.

RADAR DISPLAY PATTERNS

29
TYPE H (DOUBLE-DOT) DISPLAY. DOT SPACING INDICATES ELEVATION



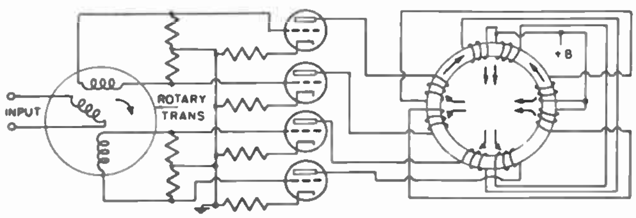
30
TYPE I OR RTB DISPLAY USES RADIAL TIME BASE SWEEP SYSTEM



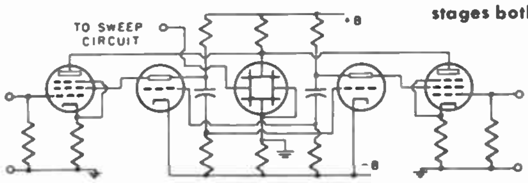
31
TYPE J, SIMILAR TO TYPE A SCAN BUT USES CIRCULAR TIME BASE

32
TYPE PPI DISPLAY. CIRCULAR SCAN = AZIMUTH, RADIAL DISTANCE = RANGE

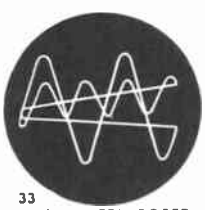
Push-pull stationary deflection yoke for PPI type display. Input signal is distributed to four tubes by a two-phase rotary transformer, whose rotor follows the antenna driver.



SUPERIMPOSED PATTERNS

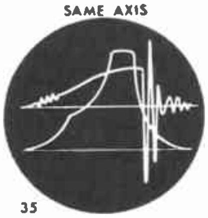


In an electron switch, two pentode amplifier stages both operate into the vertical deflection system. Each amplifier handles one of the two input signals. The stages alternately function and block by the switching potential produced by the triode multivibrator circuit, at a frequency much higher than that of the signals.

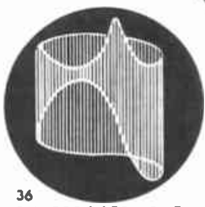


33
TWO SUPERIMPOSED DIAGRAMS USING ELECTRONIC SWITCH. SAME AXIS

34
SAME FORM AS (33) BUT AXES ARE DISPLACED VERTICALLY



35
A WAVE AND ITS RATE-OF-CHANGE VERSION SUPERPOSED



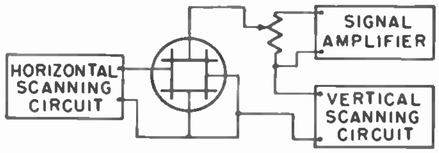
36
SUPERPOSED PATTERNS ON METAL ANALYZER (DUMONT CYCLOGRAPH)

The trace of an oscillogram is produced by a small luminous spot moving around on the screen, usually at a speed fast enough so that it appears as a line. This principle can be extended so that two separate patterns can be superimposed on the screen, by alternately displaying small sections of each pattern. On recurrent diagrams both will appear complete to the eye. A separate amplifier is necessary for each wavefarm displayed. These amplifiers are alternately blocked to the "cut-off' point" by the application of a high frequency blocking potential to the amplifiers, so that alternate half cycles prevent the amplifiers fram passing the signal to the deflection system. This switching frequency is usually hundreds of times higher than the time base frequency. The two traces may have the same base line or they may be offset.

TIME BASE METHODS LINEARIZATION SYNCHRONIZATION

Part II of a three part review of the basic methods and equipment for displaying cathode ray tube patterns. Here the timing base system operates in accordance with the combined effect of TWO DIFFERENT FREQUENCIES.

Two linear time base circuits, having a definite frequency ratio, are applied to the vertical and horizontal deflection systems of a cathode ray tube, in a manner similar to that used in a television system. The wave form or timing pulse is applied in series with the time base having the lower frequency of the two.

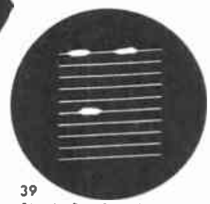


SCANNING SYSTEMS

A trace appearing on the screen, using the regular recurrent type of linear time base, can gradually be offset in a vertical direction so that successive traces are not exactly superimposed. The time base is thus similar to the well known television raster. The vertical shift potential should have a frequency that is a direct submultiple of that of the horizontal time base. This scanning system is useful in measuring precise time intervals, since the length of the time scale effectively is extended by an amount equal to the ratio of the scanning frequencies. The pulses representing the effect under investigation are injected into the amplifier stage that provides the vertical shift effects. For example, if the horizontal sweep is 100,000 cycles and the vertical frequency 1000 cycles, time intervals to the nearest 0.1 microsecond can be measured.

37
TWO TIME BASES WITH 10:1 RATIO GIVE RECTANGULAR RASTER

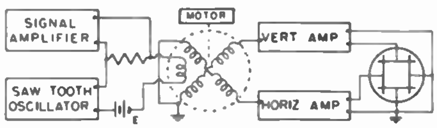
38
SCAN SIMILAR TO (38) SHOWING EXPANSION FOR WAVEFORM STUDIES



39
SIMILAR TO (38) SIGNAL MAKES INTENSITY CHANGES ALONG SCAN LINES

40
SAME METHOD WITH MORE SCAN LINES FORMS BASIC TELEVISION SYSTEM

One method of providing a spiral sweep utilizes a saw tooth voltage input to the rotor of a rotatable transformer, driven by a motor at a speed equivalent to the circular speed desired. The voltage E shown here prevents the spiral from starting at the exact center. The signal is superimposed on the saw tooth potential to give supplementary radial deflections.



SPIRAL TIME BASE

Here the circular time base (mentioned in Part I of this series) is modified so that on successive revolutions, the spot follows an Archimedian spiral, and moves with uniform angular velocity. Pulses (representing the effect being studied) are superimposed on the potential that produces the radial displacement. The method has the same features as the above-mentioned scanning arrangement. To produce the sweep an auxiliary saw-toothed voltage is superimposed on the circular time base frequencies so as to initiote a supplementary radial deflection. If the signal to be displayed is of a recurrent nature it is necessary that the time base frequency that produces the circular trace be a multiple of the recurrent rate. The auxiliary deflection can best be equal to the frequency of the recurring signal.

41
EXTENDED CIRCULAR TIME BASE USING SPIRALLING PRINCIPLE

42
SPIRAL TIME BASE TO SHOW POSSIBLE MISTIMING OF RECURRING EFFECTS

43
2:1 SPIRALLING CAN SHOW TIMING RELATIONS ON TWO-CYCLE ENGINE

44
PHASE ANGLE STUDIES. LOSS INCREASES WITH APPLIED AC VOLTAGE

A closed loop pattern of a complicated nature can be extended linearly in the horizontal direction. In other words, it is doubly displaced along this axis.

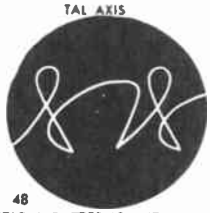
DOUBLE DISPLACED TIMING

With this arrangement the horizontal displacement from a linear time base has a smaller sinusoidal displacement superimposed on it, resulting in an oscillogram that presents analytical advantage in certain problems. For example, the normally narrow ellipse appearing in phase angle measurements in some circuits may be difficult to analyze since the minor axis is too small for precise measurements. In trace (33) this ellipse is drawn out, either by the use of an auxiliary linear sweep superimposed on the horizontal deflection system (as by the use of auxiliary deflection coils in addition to deflection plates) or by photographing the ellipse on a continuously moving film. If the speeds are adjusted so that the intersections of the trace (the necks of the loops) occur on the horizontal axis (the zero point on the ordinate scale) the distance between the horizontal intercepts that the normal ellipse would have had, is equivalent to one-half the distance between the points where the trace intersects at the necks of the loops. This may be measured across several loops for even greater accuracy.

45
ELLIPTICAL PATTERN (SHOWING PHASE ANGLE) EXTENDED HORIZONTALLY

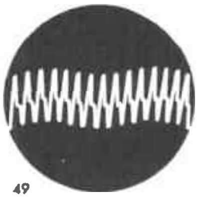
46
SAME AS (45) ADJUSTED SO INTERSECTIONS OCCUR ON HORIZONTAL AXIS

47

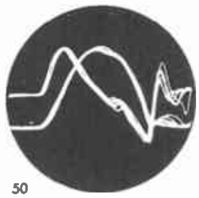


48
COMPLEX FORMS OF ELLIPTICAL PATTERNS WITH EXTENDED SWEEPS. ONE PART OF ELLIPSE IS EXPANDED AND THE OTHER CONTRACTED DURING CYCLE

CATHODE RAY OSCILLOGRAPH RECORDING SYSTEMS PART III



49
CHECK ON "WOW" OF RECORDER

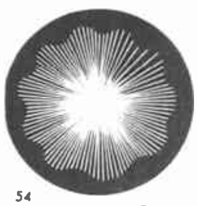


50
LIFT AND VELOCITY CURVES OF COMB. ENGINE

51
HORIZONTAL DEFLECTION REPRESENTS MACHINE SPEED

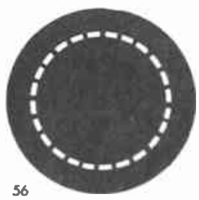
52
INDICATOR CARD STEAM ENGINE, PRESSURE VS POSITION

53
RADIAL PATTERNS OF USING 2 Ø SYNCHRO.



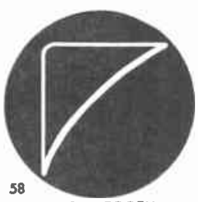
54
ROTATIONAL SPEED DIAGRAM AT LEFT IS MODULATED RADIALLY

55
POLAR OUTPUT PATTERN OF TUNGSTEN LAMP

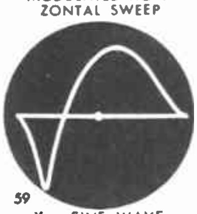


56
CHECK OF SPEED DURING A REVOLUTION. Z-AXIS MODULATED

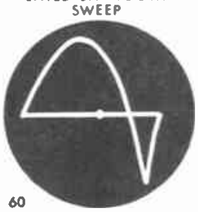
57
WAVEFORM STUDY WITH VELOCITY MODULATED HORIZONTAL SWEEP



58
Y SAWTOOTH. VELOCITY MODULATED SAWTOOTH SWEEP

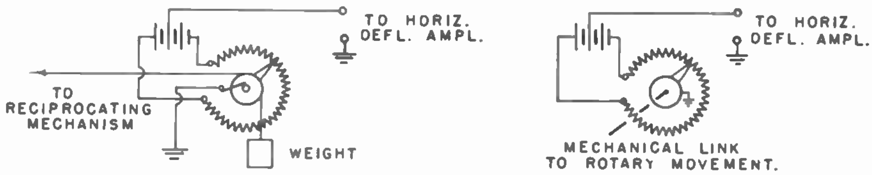


59
Y = SINE WAVE. VELOCITY MODULATED SAWTOOTH SWEEP.



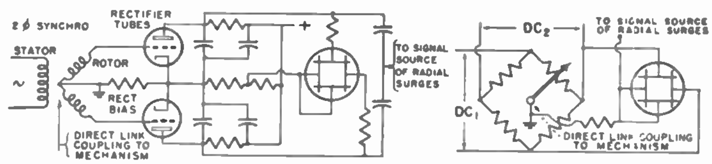
60
Y = SINE WAVE. X = VELOCITY SET BY SINE WAVE

LINEAR DISPLACEMENT SWEEP



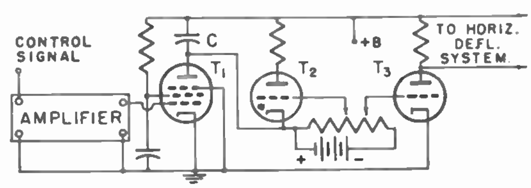
In studies on engines and other mechanisms a delineation of certain positions of parts or effects occurring with respect to the instantaneous position of some master movement is needed. The pattern may have either a linear or a rotary base. For the former to get a position or displacement control of deflection, the simplest arrangement is a cord or belt-driven potentiometer or slide wire rheostat connected as a horizontal position controller in the oscillograph circuit shown above. Either rotary or reciprocating motions can be converted to a linear displacement sweep in this way. These sweeps can be calibrated by stopping the mechanism at various points along its travel and noting the position of the spot at each point. Since only one axis is used to get this for the linear displacement sweep, the auxiliary surges, etc., representing associated effects can be displayed using the other axis on the cathode ray tube screen.

ROTARY DISPLACEMENT SWEEP



For displaying data of rotating mechanisms, the spot may follow a circular path in accordance with the movements of a master. Since the positional correlation must be exact throughout the revolution, it is not sufficient to synchronize the trace once per cycle, with a constant level speed for the rest of the rotation, and so this sweep differs from the circular time base, heretofor described. For slow movements, a four-armed rheostat connected as indicated above, can be rotated continuously by the master mechanism. Using a 360° circular rheostat the spot on the screen describes a square trace instead of a circle, but the square rheostat reduces this discrepancy. For studies of speed variations throughout a revolution, a two phase rotary synchro can be used coupled to the machine, its rotor excited with a high audio frequency, and connected as shown above. Auxiliary excursions in a radial direction represent other phenomena occurring during a revolution, such as valve operation, ignition voltages, etc.

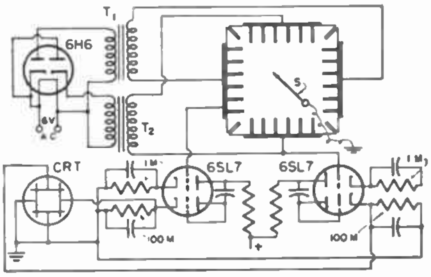
VELOCITY CONTROLLED SWEEPS

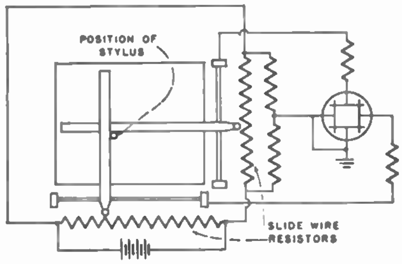


In a velocity-controlled sweep variations of some effect under investigation controls the speed of traverse of the spot in the horizontal direction. The value of such a system might be evident when a rate-of-change effect must be considered in interpreting the patterns. To produce such an effect the charging rate of the capacitor C (circuit above) depends on the anode current in T_1, which varies continually in accordance with the level of the control signal applied to the amplifier. At the end of a desired deflection excursion, the anode voltage to the thyratron T_2 reaches a discharge value set by the bias on its grid, fires and a new sweep starts. The horizontal deflection displacement depends on the instantaneous voltage on C. This sweep is similar to an ordinary linear time base except for the controlled variable charging rate. The characteristics of the tube T_1 must be carefully selected and adjusted.

On these pages, Part III of a series describing typical cathode ray tube patterns, methods for automatically making plots of data, which represent interrelated effects are outlined. In these diagrams A TIME SCALE IS NOT PRESENT as such. In typical applications the position of the spot on the pattern simulates the position of a reference point on an operating mechanism.

X-Y RECORDING





A large variety of oscillographic studies find common use in which characteristic curves of certain equipment are automatically plotted to a convenient scale; graphical diagrams of interrelated effects. A few common examples are:

Characteristics of electron tubes showing relations between i_p, e_g, e_p, i_p, r_p, etc.

Volt-ampere curves with variations in load, resistance, phase, etc.

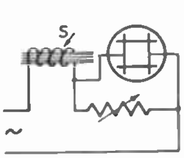
Color characteristics, showing intensities in the visible wavelength range.

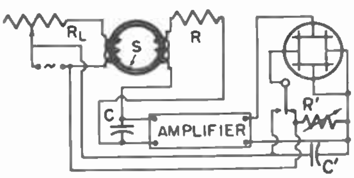
Frequency curves of transformers, amplifiers, microphones, pickups, speakers, etc.

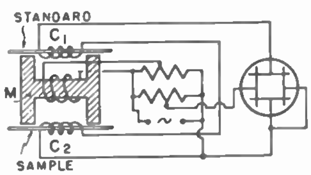
Relationships relating to flow, temperature, pH, concentration, etc. in industrial processes.

Most of these displays are obtained by simply connecting the deflection systems to suitable test circuits. In case the effects under investigation are not represented by variations in electrical quantities, it must first be converted to an electrical quantity. An extension of these methods permits the display of families of characteristic curves, by the introduction of sequential variations of an independent variable. Here either a motor driven commutator systematically applies these variations in synchronism with the horizontal deflection plate, or a self-actuated stepping switch is connected in this role. The horizontal deflection usually represents some factor that is not directly associated with TIME but sometimes it is convenient to vary the factor that produces the horizontal deflection at a linear or a sinusoidal rate. The TIME factor in this case is only incidental. Magnetic tests are used for the study of permeability, coercivity, core loss, etc., to indicate expected operation in electrical equipment, or some different property such as temper, hardness, alloy content, etc., or the existence of concealed flaws. Typical arrangements are shown in the next section below.

MAGNETIC TESTING

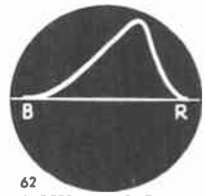




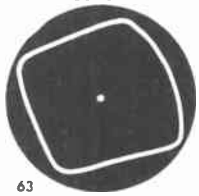


A hysteresis curve (pattern 69) can be delineated either by the direct method, where flux from the sample itself produces a vertical (B axis) deflection (left above) or by voltages induced in a search coil around the magnetic sample (center circuit) produce the B axis deflection. The latter is proportional to the rate-of-change of flux instead of to the actual flux density, so an integrating, correcting network (R and C) is added. Other magnetic inspection methods use comparison principles, where, flux from one sample is compared directly with that of another sample or standard. With equal specimens and equal magnetization a straight diagonal line results. In another method (circuit at right) induced voltages representing the rate-of-change of flux are connected series-opposing to the vertical deflection amplifier. With equivalent samples, the resultant diagram is a horizontal line (pattern 70), or otherwise is as in (71) and (72), etc. These tests are easily set up along production lines, so that either raw stock or fabricated parts can be checked.

61
X — VOLTAGE, Y — CURRENT ON POWER LINE WITH CORONA

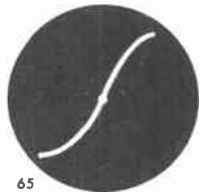


62
SPECTRUM OF TUNGSTEN LAMP 3200°K



63
UHF ANTENNA TURNS IN SYNC. WITH SWEEP

64
AMPLIFIER CURVE, X = AMPLITUDE, Y = FREQ.



65
STATIC CHARACTERISTICS, OUTPUT STAGE TUBE

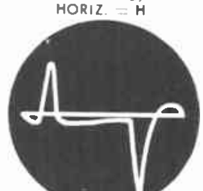
66
DYNAMIC CHARACTERISTICS, OUTPUT STAGE TUBE

67
ELECTROMAGNETIC UNIT, IMPEDANCE/RESISTANCE CURVE

68
MULTIPLE DIAGRAM OF Ep-Ip CHARACTERISTICS

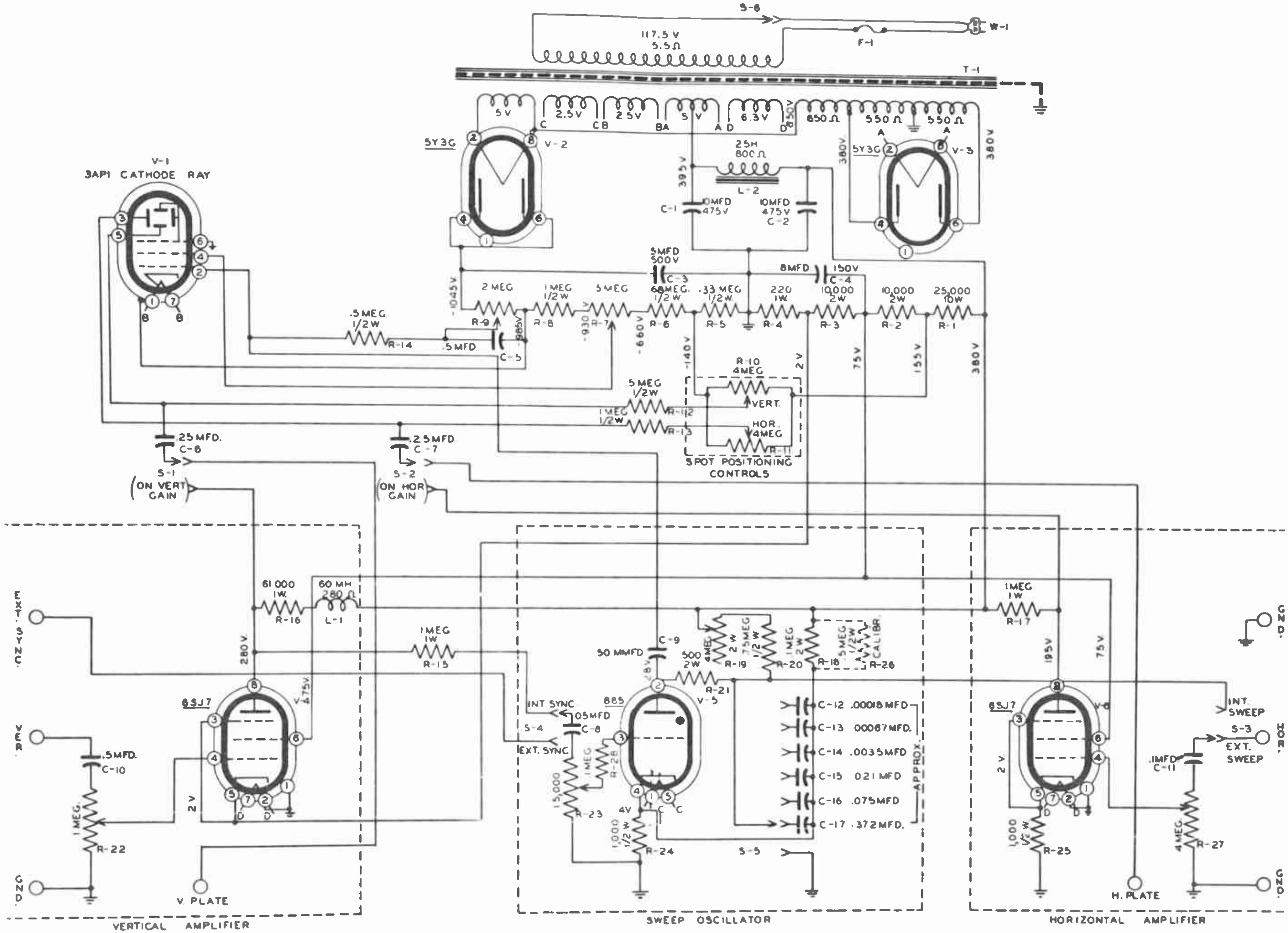
69
HYSTERESIS CURVE, DIRECT METHOD. VERT = B, HORIZ. = H

70
MAGNETIC COMPARISON TESTS, EQUAL SPECIMENS



71
MAGNETIC COMPARISON TEST, UNEQUAL ALLOYS

72
MAGNETIC COMPARISON TEST, UNEQUAL TEMPERS



SUPREME CATHODE-RAY OSCILLOSCOPE - MODEL 546-A

Insulation Resistance

An insulation resistance test is a measure of the resistance in ohms of the insulating material surrounding the conductor. Since all leakage paths to ground are in parallel, insulation resistance will tend to be lower with increased length of the conductor, and higher with shorter lengths. It varies with temperature, humidity and dirt, and therefore is an indicator of moisture, deterioration and neglect. Changes in these local conditions will change the test results from one time to the next.

The trend of insulation resistance values is usually more important than an exact value at a given time. The question is whether the insulation is holding its own or is falling off. Experience gained from a series of tests, together with some knowledge of the type of insulation and conditions under which the conductor is operating, are of more value than any rules for insulation resistance that have so far been devised.

Insulation resistance values are checked to avoid sudden feeder breakdowns because of unknown insulation deterioration or injury. Conductors may have become subjected to excessive moisture or heat, to acids or fumes, severe abrasion or other injuries. Only regular tests will reveal these hidden weak spots in the network of conductors.

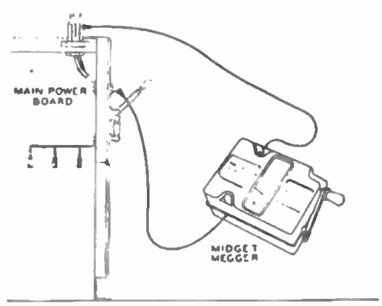
For old insulation a resistance value of 1,000 ohms-per-volt-rating of the conductor insulation is considered to be the minimum, while some authorities advise a minimum value of 1,000,000 ohms (1 megohm). For old 600-volt insulation a value of from 600,000 ohms to 1 megohm is thus considered the lowest safe value. For new installations, these values should be proportionately higher.

INSTRUMENTS TO USE

Megohmmeters are required for obtaining direct measurements of the insulation resistance on distribution systems and insulated electrical apparatus. This type of instrument is available in several ranges of generated voltage, and with various features of construction and application, as a combined hand d-c generator and ohmmeter reading directly in ohms and millions of ohms (megohms). The most popular device is rated at 500 or 1000 volts, and reads up to 100 or 1000 or 2000 megohms. These instruments are simple to use and are as easy to read as a voltmeter.

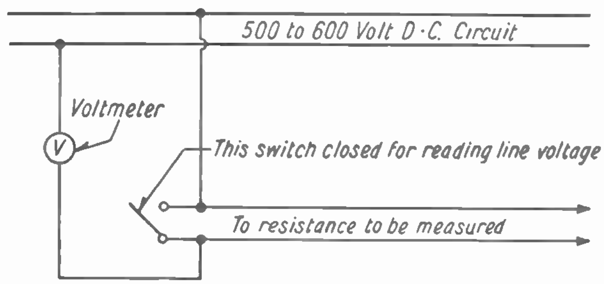
When abnormally low readings are found, steps should be taken at once to locate the weak spot, section or condition. This is most easily done by testing from distribution points or panelboards. If the entire length of a wire or cable is O.K., it follows that each section is all right.

Conductor failures can be avoided by checking insulation resistance values periodically with a portable megohmmeter.



INSULATION TEST

In case a "Megger" is not available, insulation resistance measurements may be easily made using 500-volt direct-current circuit and a 500-volt direct-current voltmeter. The method of measurement is to first read the voltage of the line; then to connect the resistance to be measured in series with the voltmeter and take a second reading.



Connections for Measuring Insulation Resistance

The measured resistance is then calculated by using the following formula:

$$R = \frac{r(V-v)}{v(1,000,000)} \text{ in which}$$

V = voltage on the line.

v = voltage reading with insulation in series with voltmeter.

r = resistance of voltmeters in ohms, (generally marked on label inside the instrument cover.)

R = resistance of insulation in megohms (1 million ohms.)

The method of connecting the apparatus is shown in the diagram.

If a grounded circuit is used in making this measurement, care must be taken to connect the grounded side of the line to the frame of the machine to be measured, and the voltmeter between the windings and the other side of the circuit.

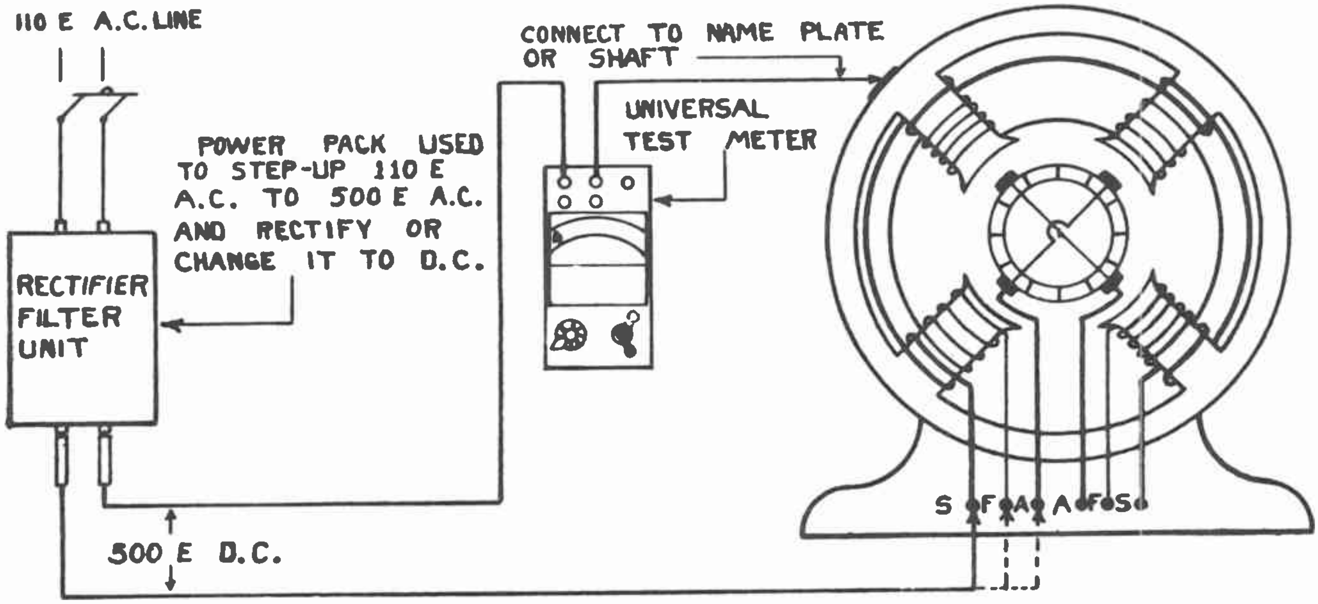
Voltmeters having a resistance of one megohm are now made for this purpose so that, if one of these instruments is used, the calculation is somewhat simplified since r = 1 the formula becomes

$$R = \frac{V}{v} - 1$$

A safe general rule is that insulation resistance should be approximately 1 megohm for each 1000 volts of operating voltage with a minimum of 1 megohm.

No new machine should have an insulation resistance of less than 1 megohm.

INSULATION TESTS



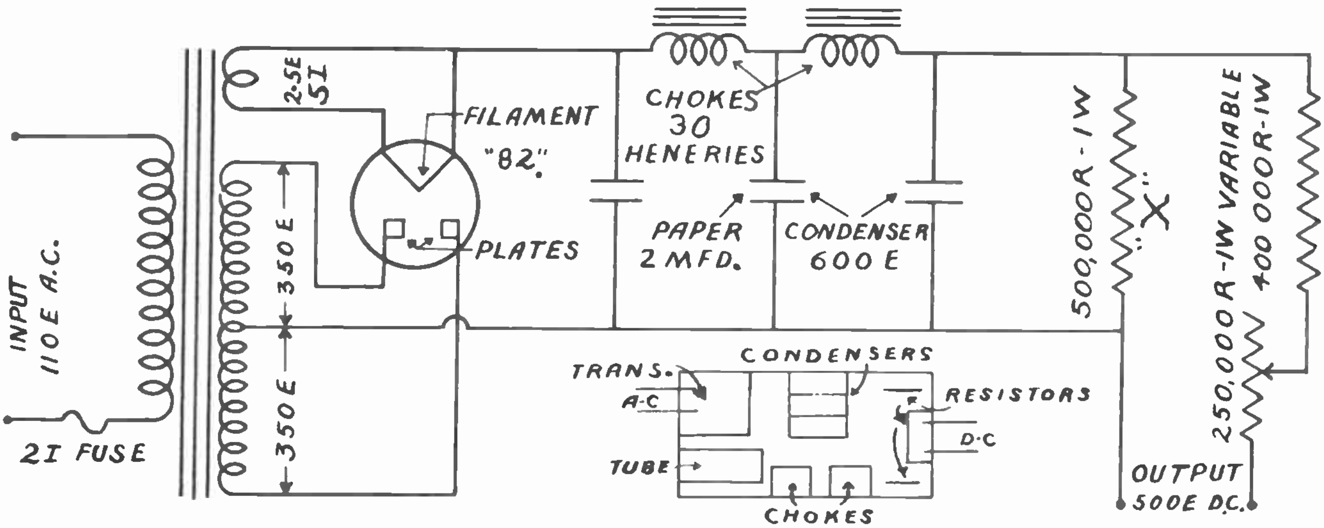
Since the quality of the insulating materials used on any electrical machine deteriorates with age, due to the action of moisture, dirt, oil, acids, etc., it is necessary to periodically test the electrical resistance of the insulation so that weaknesses may be detected and corrected before they result in complete failure.

Insulation resistance tests are usually made up applying 500 volts D.C. between the winding of the machine and the frame; the current which this pressure forces through or over the insulation to the frame is measured by a sensitive instrument, the scale of which is usally calibrated to read in megohms. The 500 volts D.C. may be developed by a hand-operated generator as in the megger, or it may be supplied from an A.C. source by a rectifier-filter combination as shown above.

The readings obtained on any given machine will vary greatly with the temperature of the insulation, a 10 degree Centigrade rise in temperature reducing the insulation resistance as much as 50%. The dampness of the location, and the amount of oil, dust, or dirt on the winding, will also materially affect the readings. Wherever possible, the test should be made when the insulation is at the maximum operating temperature, 167 degrees F., (75 degrees C.) The minimum safe insulation resistance at maximum operating temperature should not be lower than one megohm for equipment having a voltage rating below 1000 volts.

To make the test, connect the rectifier unit to 110 volts A.C., set the control switch on the meter to the one mil position, set switch in D.C. position, make the connections shown above, and read the insulation resistance on the top scale of the dial. Usually a general test is made between one lead of the machine and the frame, and if this proves to be too low, the windings are tested individually. So after the general test, test the armature, shunt field, series field, and brush holders separately. To do this, take the brushes from the holders, disconnect the windings from each other, and test the insulation resistance of each. In this manner, the faulty element can quickly be found. This same procedure is used on A.C. equipment also. If such readings are taken at regular intervals and the values recorded, a close check may be kept on the condition of the insulation resistance of all electrical equipment, and apparatus may be removed from service and reconditioned before breakdown occurs.

POWER PACK FOR INSULATION RESISTANCE TESTER



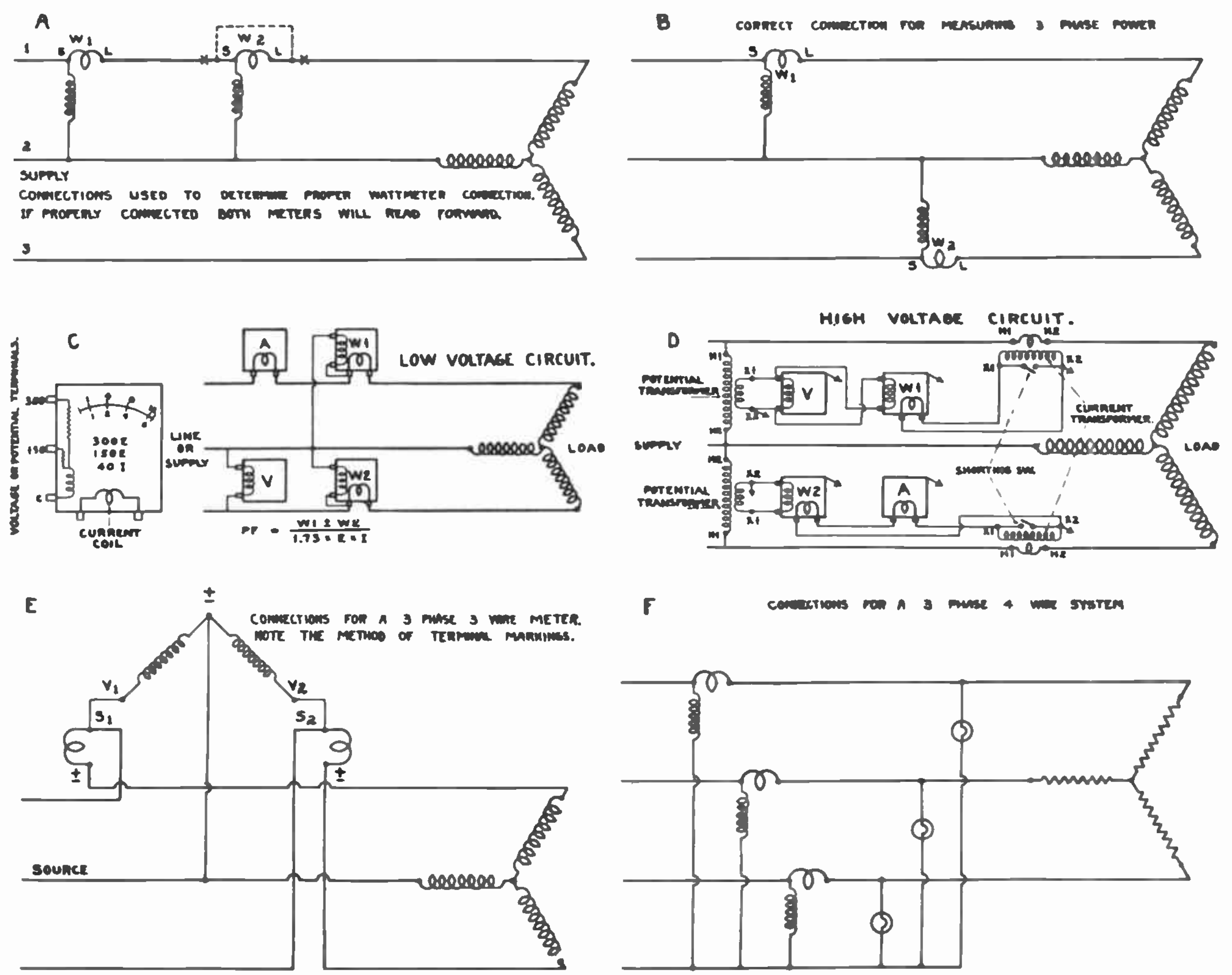
The connecting scheme employed on unit designed to convert 110 volt, 60 cycle A.C. to 500 volt D.C. for insulation resistance testing is shown above. Many of the parts required for this rectifying and filtering device may be obtained from old radio equipment; the remainder may be purchased from any radio supply store. The material needed is listed below.

One power transformer with windings to produce voltages shown.
Three 600 volt, 2 microfarad, paper condensers.
Two 30 henry chokes. 50 milliampere rating.
One 82 tube and socket for same.
One wooden case approximately 5x5x8.
One bakelite cover for wooden case.
One 500,000 ohm 1 watt fixed resistor.
One 400,000 ohm 1 watt fixed resistor.
One 250,000 ohm 1 watt variable resistor.
One control knob for variable resistor.
One instrument fuse base and clips.
One instrument fuse, 2 amperes.
Two tip plugs for leads (one red, one black)
Two pin jacks (one red, one black)

First experiment with parts to find the most suitable arrangement of the different items in the case. Small sketch shows one method that has proved satisfactory. Tube base must be so placed as to permit replacement of defective tube without the removing other parts. All connections must be soldered.

After the unit has been constructed, test the D.C. voltage output with a 0-1 mil voltmeter. If the voltage is too high, use a lower resistance at X. A little experiment and adjustment will probably be necessary before the correct output voltage is obtained. The meter to be used in conjunction with this supply device must not require more than one milliampere to produce full scale deflection. Higher current drain will result in lowering the output voltage of the power supply; this will introduce errors in the readings taken when the unit is being used for insulation resistance tests.

MEASUREMENT OF THREE PHASE POWER



Measurement of power in the 3-phase, 3-wire circuit usually demands the use of at least two single-phase wattmeters, and these meters must be correctly connected to the circuit if accurate indications are to be obtained. Inasmuch as a 3-phase wattmeter is nothing more than two individual single-phase wattmeters in the same case, the same connection scheme will apply.

To correctly connect two single-phase wattmeters to a 3-phase, 3-wire circuit, proceed as follows: (1) Arrange meters as shown in sketch "A" with the individual current coils in series in the same lines. (2) Now check the meters and see if they both read alike; if they do not, one or both of the meters are inaccurate, since they are both measuring the same load. If one meter reads backward, reverse the voltage coil leads. (3) Disconnect wattmeters W2 at X-X and, without disturbing the voltage coil connections, insert the current coil in line 3, taking care not to change the position of the terminals "S" and "L" with respect to the circuit. The "S" terminal should still be attached to the source and the "L" terminal to the load end of the line.

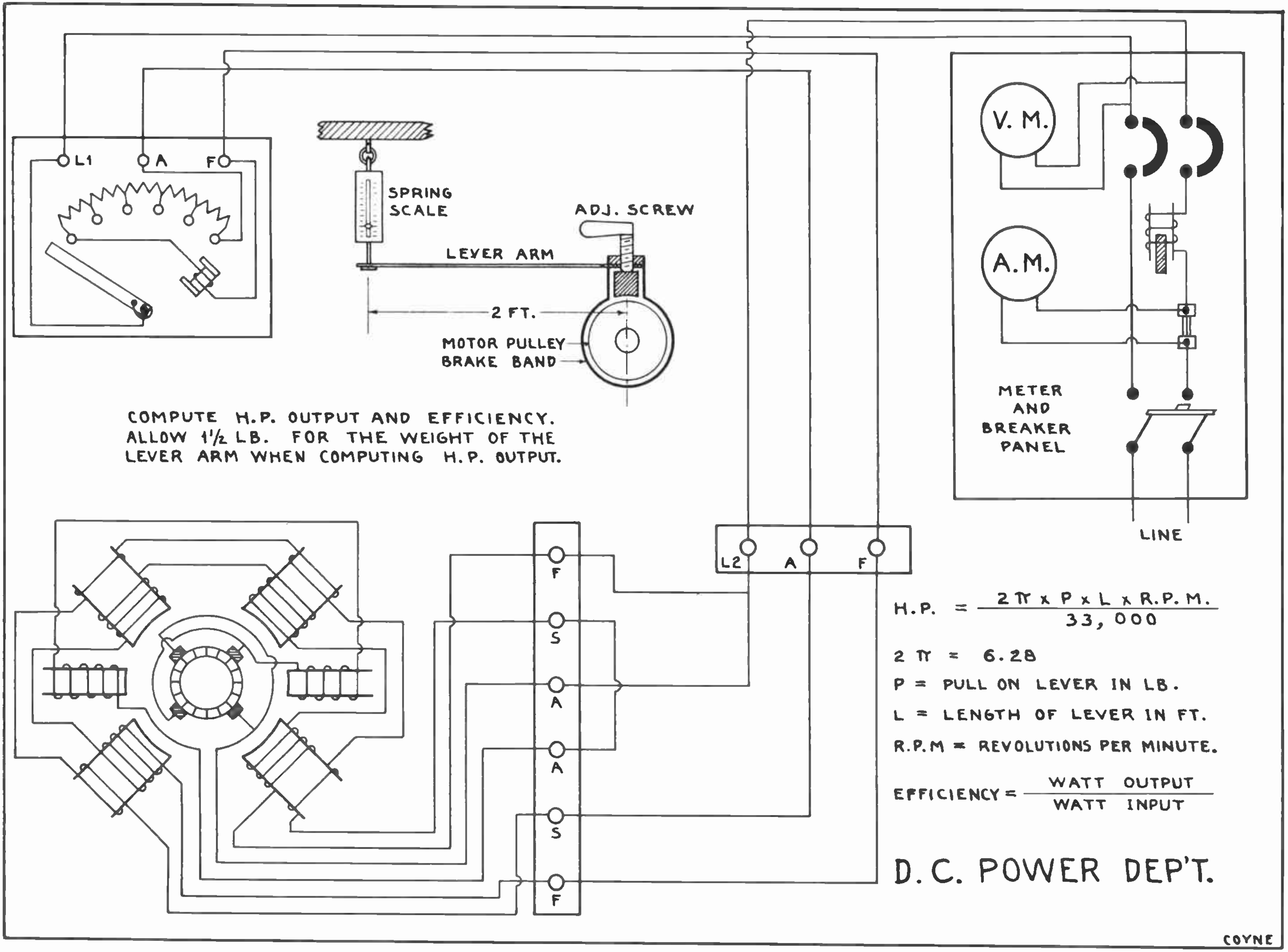
The meters are now correctly connected in the circuit, and the total power taken by the load is equal to the sum of the wattmeter reading. In this regard, it should be observed that the meters will not read alike even upon a perfectly balanced load unless the power factor of the circuit is exactly 100%. As the power factor falls below this value, one meter will indicate a smaller and the other a larger percentage of the total load. At 50% P.F., one meter will indicate the total load and the other will read zero, and as the P.F. falls below this mark, the low meter will start to read backwards. As this reading indicates negative power, it must be subtracted from the reading of the other meter if the true power is to be obtained. Since the backward reading is unintelligible, reverse the voltage coil on the backward reading meter to obtain a forward reading, and then subtract this from the indication on the other unit.

When a 3-phase, 4-wire circuit is to be metered, three wattmeters, connected as shown at "B", are most frequently used. A current coil of each instrument is inserted in series with one line wire and the voltage coils are connected from the separate line wires to neutral as shown. The total power is the sum of the wattmeter readings. A change in power factor will not effect the relative values here as it does in the two-meter arrangement, the meters always reading forward regardless of the power factor value.

The wattmeters show, of course, the true power in watts absorbed by the circuit and, due to the fact the current required to carry a given wattage may be relatively high when the power factor of the circuit is low, there is danger of burning out the current coil of the wattmeter on low power factor loads. To prevent this, it is usual to connect an ammeter in series with the current coil of the meter to make sure that its rating is not exceeded.

If an ammeter and voltmeter are used in conjunction with the wattmeter, the total voltamperes and total watts may be measured, and from these the total power factor of the circuit may be computed by the formula shown. This is true for any circuit, a voltmeter, ammeter, and wattmeter being sufficient to determine the P.F. of any A.C. circuit.

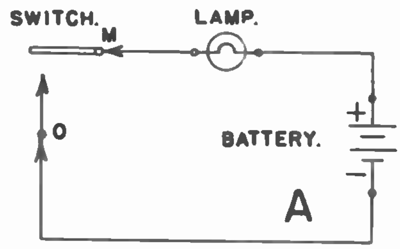
On circuits of high voltage or great power, current and voltage transformers are used to (1) step down the quantities to be measured and (2) isolate the meters from the line. See Fig. D. Such transformers allow the use of smaller and cheaper instruments and at the same time eliminate the hazard associated with the reading and possible handling of meters attached to high voltage circuits. As shunts cannot be used with A.C. ammeters, extension of the meter range is accomplished by a current transformer which sends a small fraction of the line current through the meter. The actual current flowing through such meters never exceeds 5 amperes; however, the meter is calibrated to indicate the actual line current. Due to the peculiar action of the current transformer, its secondary circuit may never be opened while the unit is energized, as voltages of a dangerously high value appear across the secondary when this circuit is broken. The special short-circuiting switch is provided on these units to make possible the insertion and removal of meters without disconnecting the secondary circuit. Note that the cases of all meters are grounded.


L1
A
F
SPRING SCALE
ADJ. SCREW
LEVER ARM
2 FT.
MOTOR PULLEY
BRAKE BAND
V. M.
A. M.
METER AND BREAKER PANEL
LINE
COMPUTE H.P. OUTPUT AND EFFICIENCY. ALLOW 1½ LB. FOR THE WEIGHT OF THE LEVER ARM WHEN COMPUTING H.P. OUTPUT.
F
S
A
A
S
F
L2
A
F
H.P. = 2π x P x L x R.P.M. / 33,000
2π = 6.28
P = PULL ON LEVER IN LB.
L = LENGTH OF LEVER IN FT.
R.P.M = REVOLUTIONS PER MINUTE.
EFFICIENCY = WATT OUTPUT / WATT INPUT
D.C. POWER DEP'T.
COYNE

IDENTIFYING SWITCH TERMINALS

M = MOVING CONTACT.
C = NORMALLY CLOSED CONTACT.
O = " OPEN "

BEFORE WIRING ANY CIRCUIT that involves the use of switches, it is first of all necessary to test the switches themselves to make sure that they are the type required and that they are operating properly.



The test circuit consists of a source of power, a test lamp, and a couple of leads. When the test leads are touched together, the lamp should light. If the lamp does not light, there is something the matter with the test circuit.

Diagram A shows how to test a switch. Note that the leads from the test circuit are placed on the switch terminals. As this switch is normally open the light will not light until the switch button is pressed. If the switch lights the lamp when the button is pressed, two things are shown:

1. The switch is in operating condition
2. The switch is an open circuit type

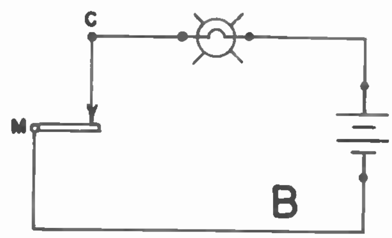


Diagram B shows the test result on a switch that is normally closed. If the test lamp lights when the leads are placed on the switch terminals but goes out when the button is pressed, two things are shown:

1. The switch is in operating condition
2. The switch is a closed circuit type

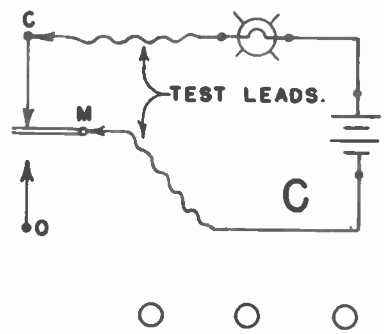
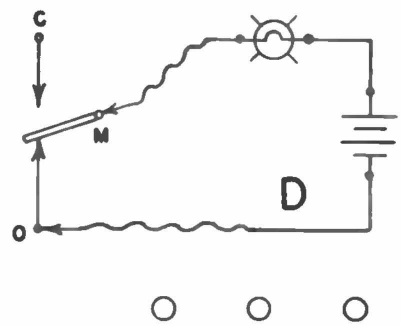
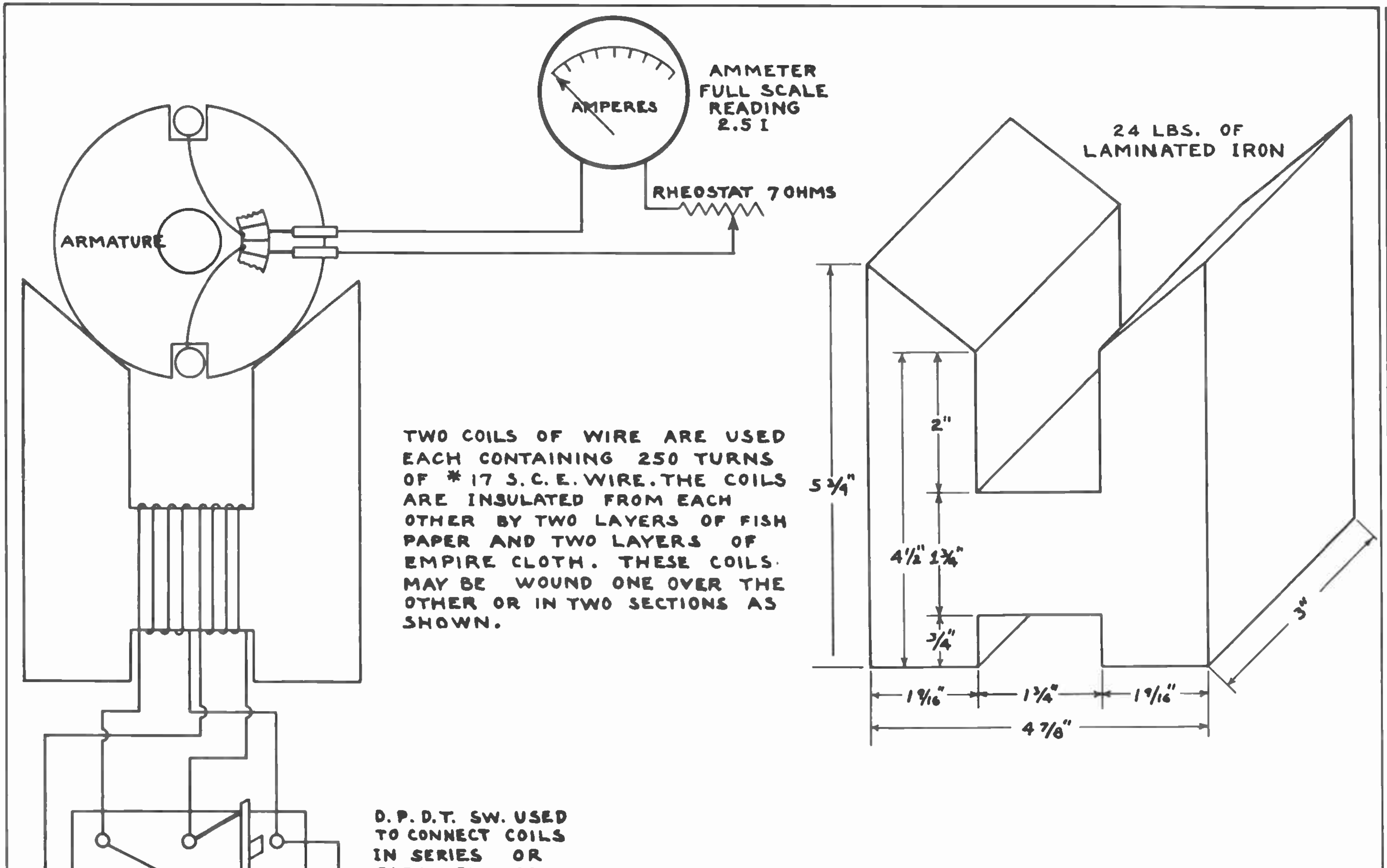


Diagram C shows a double circuit switch. This is really two switches in one, for it is a combination of an open circuit switch and a closed circuit switch. To test this switch and find which terminals connect to the various parts, first find the two terminals that will give a light without pressing the switch. These two terminals must connect to the moving contact of the switch and the closed contact of the switch. The remaining contact must be the open contact. Mark O alongside this terminal.

Next find the pair of contacts that produce a light only when the switch is pressed; these will be the moving and open contact. As the open contact has already been found, the other contact must be the moving contact. Mark this terminal M. The third must be the closed contact. Mark it C. In this way, all of the switch terminals may be identified.

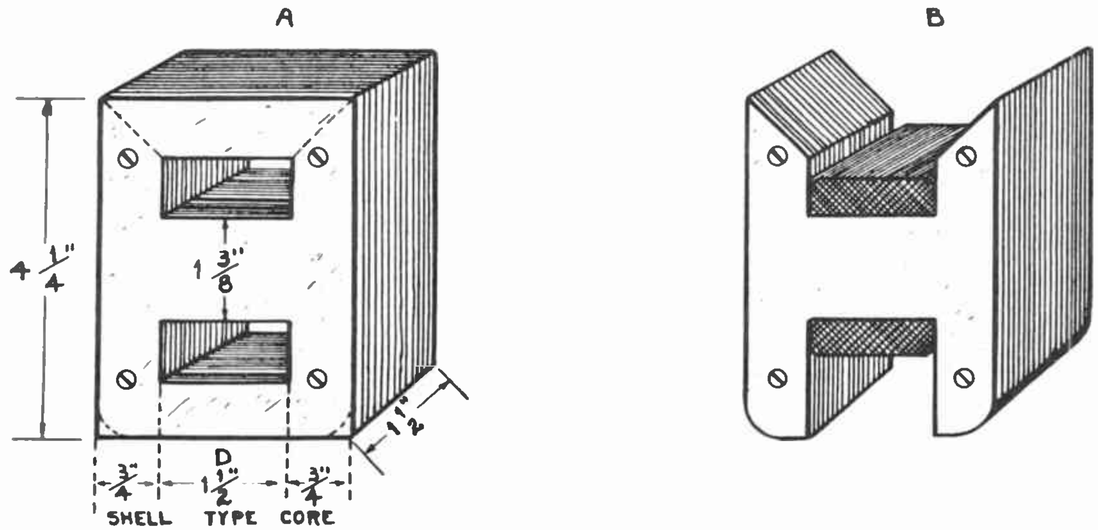


If the above indications cannot be obtained, the switch must be defective. Try another one. Always test switches before wiring them up in a circuit. In this way much time will be saved and, when the connection is properly completed, the circuit will operate.



GROWLER SPECIFICATIONS

CONSTRUCTION DETAILS FOR SIMPLE GROWLER

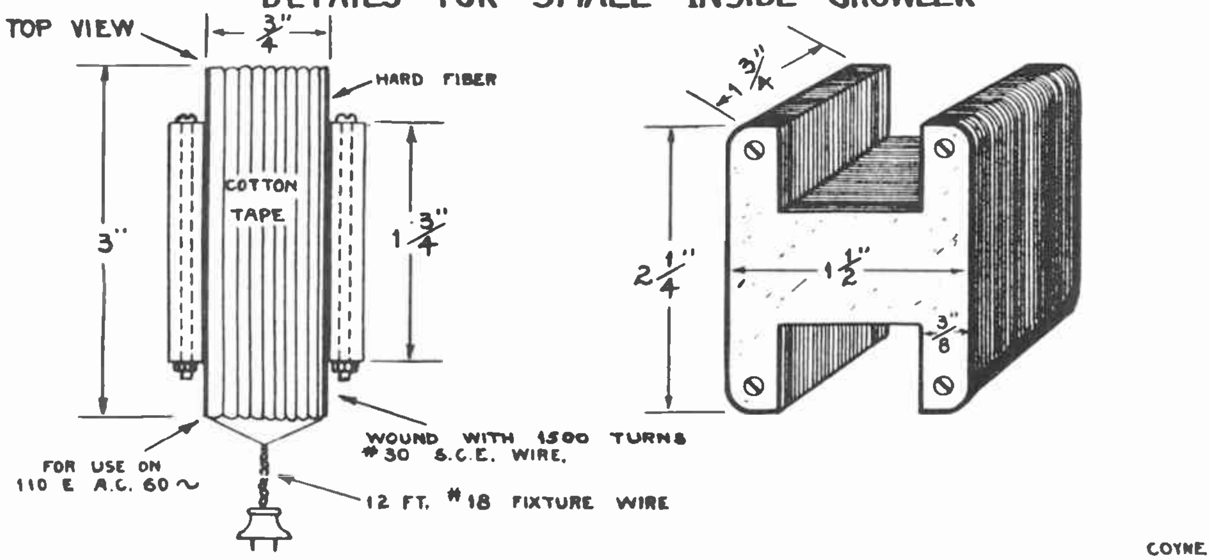


To make the above growler, secure the core of a burned-out, 100 watt radio-power transformer or bell transformer and remove the old winding, preserving the core insulation if possible. Next, trim the laminations along the dotted lines so that, when reassembled, they will have the form shown in "B", and approximate the dimensions given in "A". With some cores, it will be necessary to snip a section from the middle leg of the transformer in order to obtain the proper distance (D) between the sides. After the laminations have been cut, the core is restacked and clamped with the same bolts and brackets that were used in the original assembly; then the cut edges of the laminations are ground or filed to the desired smoothness. The core is then insulated with suitable material (filler board, fiber, fish paper, etc.,) and the winding installed.

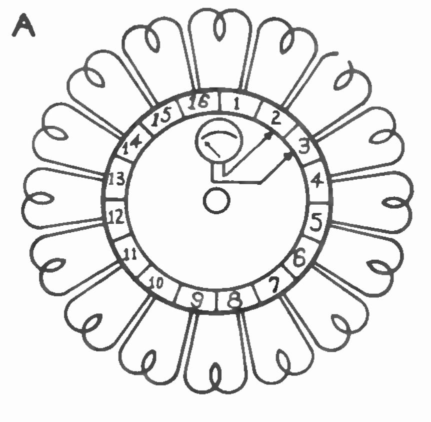
The winding used will depend upon the voltage and frequency employed. Assuming a 60 cycle frequency, the number of turns for the different voltages are as follows: For 32E, 170 turns of #18 SCE; 110E, 500 turns of #22 SCE; 220E, 1000 turns #25 SCE.

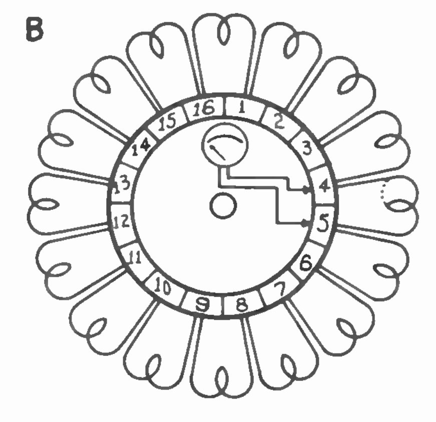
Construction details for an inside growler, suitable for fractional h.p. motors, is given below.

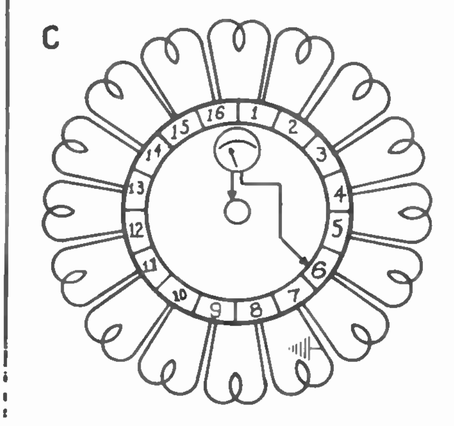
DETAILS FOR SMALL INSIDE GROWLER



ARMATURE GROWLER TESTS



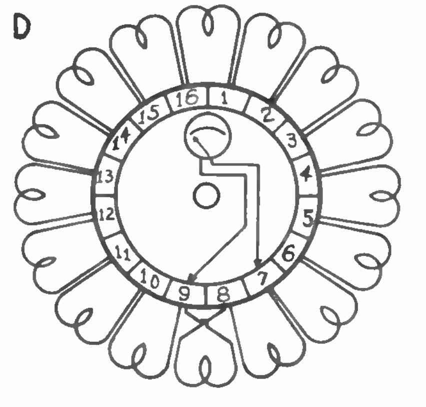


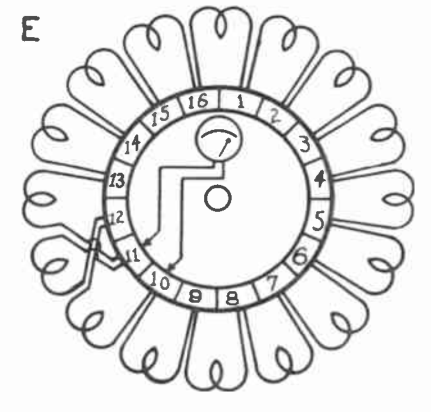


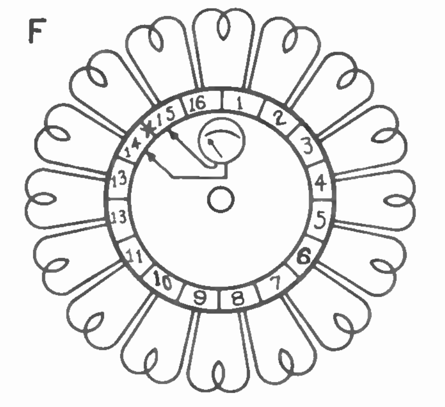
TROUBLE: OPEN COIL
THIS DEFECT SHOWS ITSELF ON THE OPERATING MACHINE BY EXCESSIVE SPARKING AT THE BRUSHES AND BURNING OF THE BARS ATTACHED TO THE COIL. WHEN TESTED ON THE GROWLER, THE METER READING BETWEEN BARS 1 AND 2 WILL BE ZERO. IF THE OPEN IS DUE TO POOR SOLDERING AT THE COMMUTATOR, RESOLDER. IF CAUSED BY AN OPEN IN THE COIL ITSELF, DISCONNECT THE LEADS, INSULATE THE ENDS, AND CONNECT A JUMPER FROM BAR 1 TO BAR 2.

TROUBLE: SHORTED COIL
WHEN THE MACHINE IS IN OPERATION, A SHORTED COIL IS INDICATED BY THE EXCESSIVE HEAT IT GENERATES. WHILE OTHER COILS ON THE ARMATURE MAINTAIN A NORMAL TEMPERATURE, THE SHORTED COIL BECOMES SO HOT THAT IT BURNS THE INSULATION FROM THE WINDING. ON THE GROWLER, THE METER READING BETWEEN BARS 4 AND 5 WILL BE LOW OR ZERO. A HACKSAW BLADE WILL VIBRATE OVER THE SLOTS IN WHICH THE SHORTED COIL LIES.

TROUBLE: GROUNDED COIL
A GROUNDED COIL WILL USUALLY GIVE NO INDICATION DURING OPERATION UNLESS THE FRAME OF THE UNIT BE UNGROUNDED; IN THIS CASE, A SHOCK MAY BE FELT WHEN TOUCHING THE FRAME. TWO GROUNDS ON THE ARMATURE PRODUCE A SHORT-CIRCUIT. ON THE GROWLER, A METER READING IS TAKEN BETWEEN THE COMMUTATOR BARS AND THE SHAFT. THE READING BECOMES LESS AS THE SHORTED BAR IS APPROACHED AND IS MINIMUM WHEN CONTACTED.



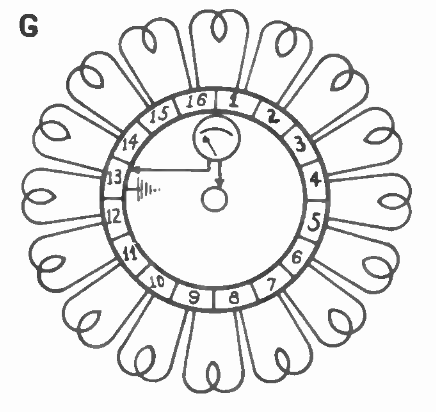


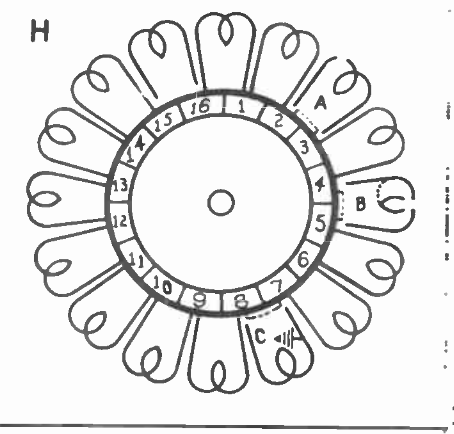


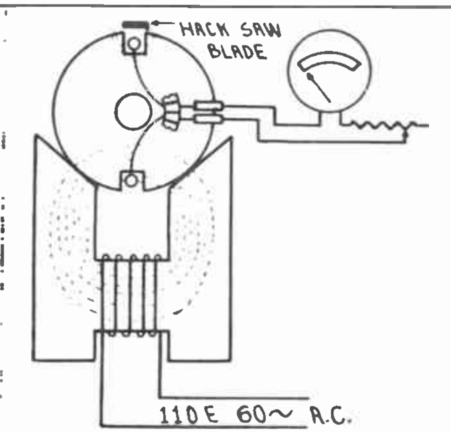
TROUBLE: REVERSED COIL LEADS
IN OPERATION, THIS DEFECT WOULD CREATE UNBALANCE IN THE ARMATURE CIRCUIT WITH THE RESULT THAT CIRCULATING CURRENTS WOULD FLOW AND TEND TO CAUSE OVERHEATING. ON THE GROWLER, MAKE A 1 TO 3 BAR TEST. WHEN TESTING BETWEEN BARS 7 AND 9, THE READING WOULD BE ZERO AND THE SAME READING WOULD BE OBTAINED BETWEEN BARS 8 AND 10. THIS WOULD INDICATE THAT THE LEADS OF THE COIL ATTACHED TO BARS 8 AND 9 ARE REVERSED.

TROUBLE: REVERSED COIL LOOPS
THIS FAULT, WHICH USUALLY OCCURS IN A REWOUND MACHINE, MAY PRODUCE SPARKING AT THE BRUSHES DURING OPERATION. WHEN TESTED ON THE GROWLER, THE METER WILL SHOW A DOUBLE READING BETWEEN BARS 10 AND 11, A NORMAL READING ON 11 AND 12, AND A DOUBLE READING ON 12 AND 13. TO REMEDY, UNSOLDER LOOPS ON 11 AND 12 AND REVERSE THEM. HACKSAW WILL GIVE NO INDICATION OF THIS FAULT.

TROUBLE: SHORTED BARS
INDICATION DURING OPERATION IS OVERHEATING OF COIL ATTACHED TO BARS 14 AND 15 AND POSSIBLE SPARKING AT THE BRUSHES. ON GROWLER HACKSAW BLADE WILL VIBRATE OVER SLOTS CONTAINING COIL CONNECTED TO SHORTED BARS, AND METER READING BETWEEN 14 AND 15 WILL BE ZERO. REMEDY: REMOVE SHORT FROM BARS OR DISCONNECT COIL AND INSTALL A JUMPER FROM 14 TO 15.





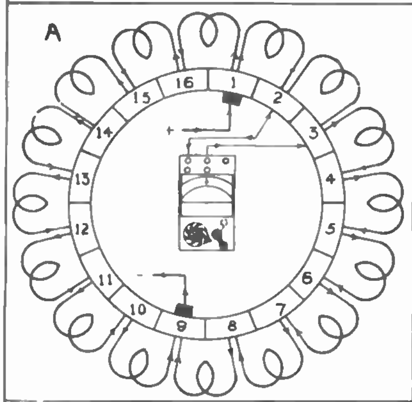


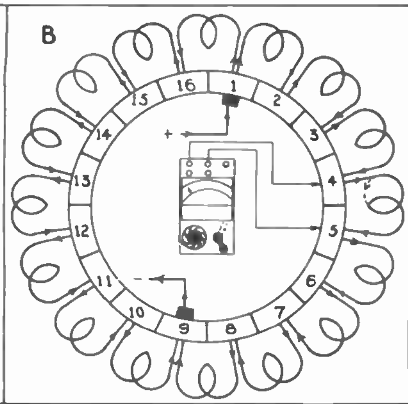
TROUBLE: GROUNDED BARS
IF THERE ARE NO OTHER GROUNDS ON THE MACHINE, THE FAULT WILL NOT AFFECT THE OPERATION OF THE MACHINE AT ALL. IF OTHER GROUNDS ARE PRESENT, SEVERE FLASHING AT THE BRUSHES WILL USUALLY OCCUR. THE TEST PROCEDURE IS THE SAME AS EMPLOYED IN DIAGRAM "C". TO DETERMINE IF GROUND IS COIL OR BAR, DISCONNECT WIRES FROM BAR 13 AND THEN TEST BAR FOR GROUND. REMEDY: REINSULATE BAR.

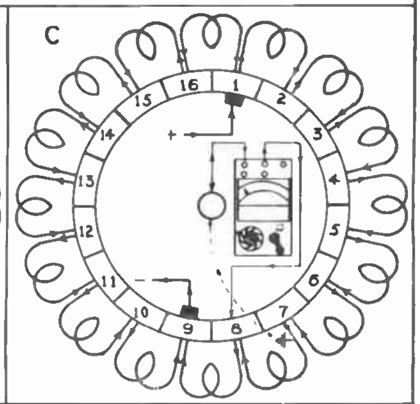
THIS SKETCH SHOWS HOW THE DIFFERENT FAULTS ABOVE LISTED ARE REMEDIED. THE LETTERS ON THE SKETCH REFER TO DIAGRAMS ABOVE IN WHICH THE FAULT IS GIVEN DETAILED TREATMENT. "A" SHOWS REMEDY FOR OPEN COIL, "B" FOR SHORTED COIL, "C" FOR GROUNDED COIL. DOTTED LINES BETWEEN BARS REPRESENT JUMPERS. NOTE THAT WITH A SHORTED COIL IT IS ESSENTIAL THAT THE COIL ITSELF BE CUT AS SHOWN IN "B" TO REMOVE THE SHORT CIRCUIT.

THE PURPOSE OF A GROWLER IS TO PRODUCE AN ALTERNATING MAGNETIC FIELD WHICH, CUTTING BACK AND FORTH THROUGH THE ARMATURE COILS, INDUCES IN THEM A LOW VOLTAGE MEASURABLE AT THE COMMUTATOR BARS WITH AN A.C. MILLIVOLTMETER. THE RESISTANCE "R" IS USED TO ADJUST THE READING TO APPROXIMATELY MIDSCALE. WHEN A SHORTED COIL IS PLACED BETWEEN THE GROWLER JAWS, THE HEAVY CURRENT SET UP IN THE COIL CAUSES PERIODIC MAGNETIZATION OF THE SLOT IN WHICH THE COIL LIES, RESULTING IN THE HACKSAW BLADE HELD NEAR THE SLOT BEING ALTERNATELY ATTRACTED AND RELEASED.

ARMATURE TESTS USING METER



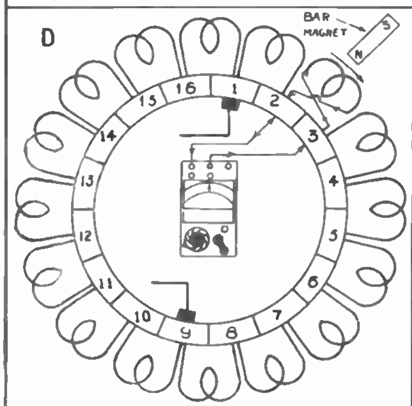


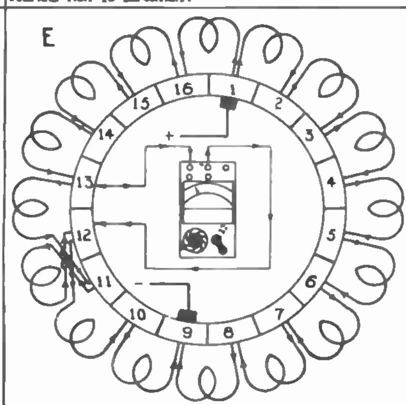


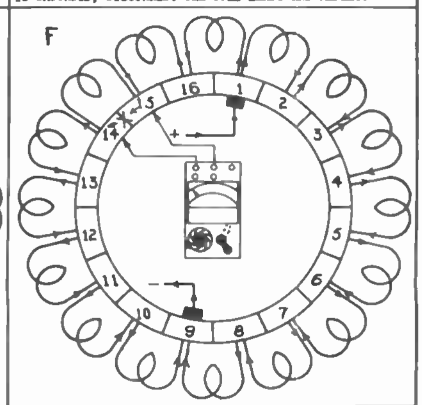
TROUBLE - OPEN COIL
TO PREVENT INJURY TO THE METER, THIS TEST MUST PRECEDE ALL OTHERS WHEN THE MILLIVOLT METHOD OF TESTING IS USED. SET METER ON THE 15 VOLT RANGE AND, WITH CURRENT FLOWING THROUGH THE ARMATURE, TAKE READINGS BETWEEN BARS 1-2, 2-3, 3-4, ETC., UNTIL ALL PAIRS OF SEGMENTS HAVE BEEN COVERED. A HIGH READING BETWEEN ANY PAIR OF BARS INDICATES AN OPEN COIL. NOTE THAT IN THIS METHOD OF TESTING THE METER IS USED TO MEASURE THE VOLTAGE DROP IN EACH ARMATURE COIL, AND THAT THIS IS DONE BY TAKING READINGS BETWEEN COMMUTATOR SEGMENTS.

TROUBLE - SHORTED COIL
FOR THIS TEST SET METER ON THE M.V. RANGE THAT GIVES THE BEST DEFLECTION, STARTING WITH THE 300 SETTING AND WORK DOWN TO THE 50 M.V. RANGE IF NECESSARY. ADJUST CURRENT THROUGH ARMATURE UNTIL APPROXIMATELY MIDSCALE DEFLECTION IS OBTAINED ON A NORMAL COIL AND MAKE A BAR-TO-BAR TEST ON ALL SEGMENTS. THE DEFECTIVE COIL WILL GIVE A LOW OR ZERO READING DEPENDING UPON HOW MANY TURNS ARE SHORTED. IT SHOULD HERE BE UNDERSTOOD THAT THIS METHOD OF TESTING IS MERELY A COMPARATIVE ONE, FOR IT IS HOW THE READINGS COMPARE THAT IS IMPORTANT.

TROUBLE - GROUNDED COIL
TO MAKE THIS TEST, SEND A CURRENT OF SUITABLE VALUE THRU THE ARMATURE AND MEASURE THE VOLTAGE DIFFERENCE BETWEEN EACH SEGMENT AND THE ARMATURE SHAFT. IF THE WINDING IS GROUNDED, A READING WILL BE OBTAINED THAT BECOMES GRADUALLY LESS AS THE BARS TO WHICH THE GROUNDED COIL IS CONNECTED ARE APPROACHED. THE READING WILL BE LOWEST ON THE BARS TO WHICH THE GROUNDED COIL IS CONNECTED. IT SHOULD ALSO BE NOTED THAT AS THE GROUNDED COIL IS PASSED THE METER READING WILL REVERSE. TO DETERMINE IF THE BAR IS GROUNDED, DISCONNECT THE COIL LEADS AND REPEAT.



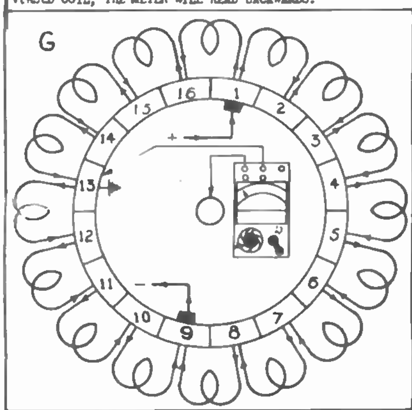


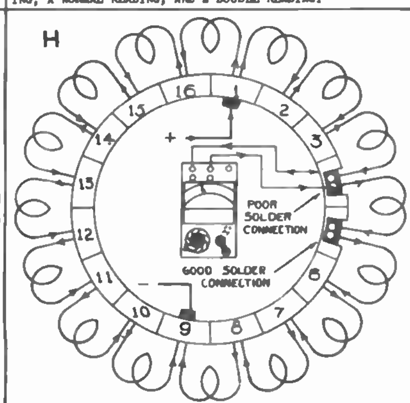


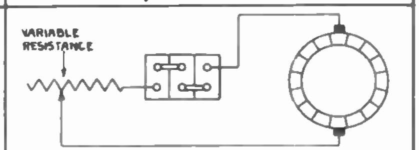
TROUBLE - REVERSED COIL LEADS
USUALLY ENCOUNTERED ON ARMATURES THAT HAVE JUST BEEN REWOUND, THIS FAULT REQUIRES A DIFFERENT TESTING METHOD. SET METER ON 50 M.V. RANGE, SELECT THE FIRST COIL TO BE TESTED, AND FIND THE SEGMENTS TO WHICH THE ENDS OF THIS COIL ARE CONNECTED. WITH THE METER LEADS ON THESE BARS DRAW A MAGNET SWIFTLY ACROSS THE SLOT IN WHICH ONE SIDE OF THE COIL LIES AND NOTE DEFLECTION ON THE METER. REPEAT THIS TEST ON ALL OTHER COILS, ALWAYS MOVING THE MAGNET IN THE SAME DIRECTION. WHEN DRAWN ACROSS A REVERSED COIL, THE METER WILL READ BACKWARDS.

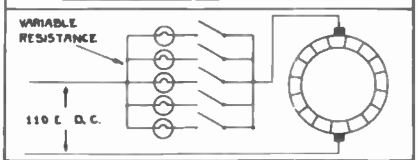
TROUBLE - REVERSED COIL LOOPS
USUALLY FOUND ONLY IN REWOUND MACHINES, THIS FAULT IS CHECKED BY THE REGULAR BAR-TO-BAR TEST. PROCEED IN EXACTLY THE SAME MANNER AS USED FOR LOCATING SHORTED COILS SINCE THE CURRENT IN PASSING FROM SEGMENT 10 TO SEGMENT 11 MUST FLOW THROUGH TWO COILS, IT FOLLOWS THAT THE VOLTAGE DROP BETWEEN BARS 10 AND 11 WILL BE DOUBLE THE VALUE OBTAINED ON A NORMAL COIL; THE SAME IS TRUE FOR BARS 12 AND 13. BARS 11 AND 12 WILL GIVE A NORMAL INDICATION; THUS REVERSED COIL LOOPS ARE INDICATED BY A DOUBLE READING, A NORMAL READING, AND A DOUBLE READING.

TROUBLE - SHORTED BARS
MAKE SAME TEST AS FOR SHORTED COIL. WITH CURRENT FLOWING THROUGH THE ARMATURE, MEASURE THE VOLTAGE DROP BETWEEN SEGMENTS. WHEN THE SHORTED BARS ARE ENCOUNTERED, THE METER WILL READ ZERO. INASMUCH AS THE SAME INDICATION WOULD BE OBTAINED IF THE COIL LEADS WERE SHORTED, IT WILL BE NECESSARY TO DISCONNECT THE LEADS FROM THE COMMUTATOR SEGMENTS BEFORE IT CAN BE DETERMINED WHETHER THE LOW READING WAS CAUSED BY SHORTED BARS OR SHORTED COIL LEADS. IF AFTER THE COIL IS DISCONNECTED A ZERO READING IS OBTAINED, THE BARS ARE SHORTED.







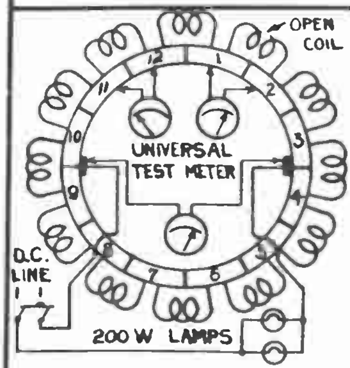


TROUBLE - GROUNDED BARS
TEST FOR THIS DEFECT IS THE SAME AS FOR A GROUNDED COIL. METER READING FROM BAR TO SHAFT WILL BE ZERO WHEN THE GROUNDED BAR IS CONTACTED. TO DETERMINE WHETHER THE BAR OR THE COIL IS GROUNDED, DISCONNECT THE COIL FROM THE BAR AND TEST AGAIN; IF BAR NOW TESTS CLEAR, COIL IS GROUNDED. WHEN MAKING THIS TEST, THE METER READINGS MAY CHANGE SO RAPIDLY AS THE GROUND IS APPROACHED, THAT A SATISFACUCRY DEFLECTION CANNOT BE OBTAINED WITHOUT TURNING TO A DIFFERENT RANGE. THEREFORE, AS THE READING FALLS, THE METER SWITCH SHOULD BE MOVED TO A LOWER RANGE.

TROUBLE - BAD CONNECTIONS
TROUBLE FREQUENTLY DEVELOPS IN ARMATURES AS THE RESULT OF POOR ELECTRICAL CONNECTIONS BETWEEN THE COIL LEADS AND THE COMMUTATOR SEGMENTS DUE EITHER TO POOR SOLDERING OR TO OVERHEATING OF THE ARMATURE WHILE IN SERVICE. HIGH RESISTANCE CONNECTIONS OF THIS TYPE ARE INDICATED BY HIGH READINGS ON THE MILLIVOLTMETER. TO POSITIVELY LOCATE WHICH BAR HAS THE POOR CONNECTION, MAKE THE TEST INDICATED ABOVE. A POORLY SOLDERED JOINT WILL PRODUCE A READABLE DEFLECTION ON THE METER, WHEREAS A GOOD JOINT WILL GIVE NO READING.

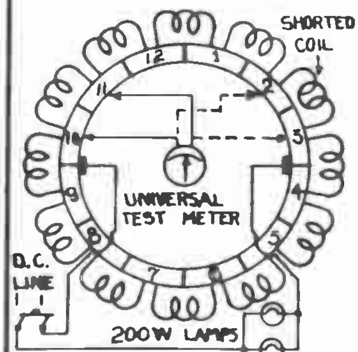
TESTING PROCEDURE
CONNECT THE ARMATURE TO A 6 VOLT, 110 VOLT, OR OTHER D.C. SUPPLY WITH A CONTROLLING RESISTANCE IN SERIES. THIS RESISTANCE MAY CONSIST OF A NUMBER OF PARALLEL-CONNECTED LAMPS ARRANGED TO BE SWITCHED IN OR OUT OF THE CIRCUIT AT WILL. FEED CURRENT INTO ARMATURE THROUGH BARS EXACTLY ONE POLE PITCH APART, AND ADJUST CURRENT UNTIL THE MILLIVOLTMETER GIVES A MIDSCALE READING ON A NORMAL COIL. THE AMOUNT OF D.C. CURRENT REQUIRED WILL VARY WITH THE SIZE OF THE ARMATURE, FRACTIONAL H.P. UNITS REQUIRING ABOUT 2-4 AMPS, MACHINES UP TO 20 H.P. ABOUT 10 AMPS, AND THE LARGEST ARMATURES CURRENTS AS HIGH AS 20 AMPS. AFTER THE CURRENT HAS BEEN ADJUSTED TO A SUITABLE VALUE, TAKE MILLIVOLT READINGS BETWEEN BARS 1-2, 2-3, 3-4, ETC. IF NO FAULTS ARE PRESENT, THE READINGS WILL BE APPROXIMATELY EQUAL. HIGH READINGS INDICATE HIGH RESISTANCE CONNECTIONS, USUALLY CAUSED BY POOR SOLDERING, WHILE LOW READINGS SHOW SHORTED COILS OR COMMUTATOR SEGMENTS. (Cont'd

ARMATURE AND FIELD TESTS



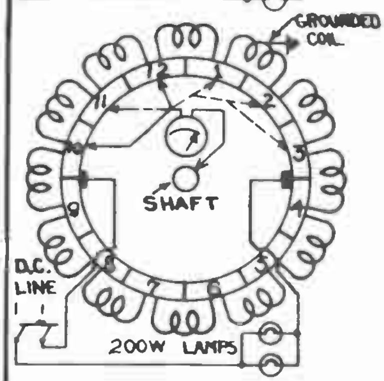
OPEN ARMATURE COIL TEST

Connect armature across line with current-limiting lamps in series. Place meter selector switch in the 50 volt or the 10 volt position and measure voltage across armature. Next make a bar-to-bar test; meter will read zero until open coil is bridged when total armature voltage will be registered. Example: 8E across armature; bars 11, 12 read zero; bars 1, 2 read 8E. To protect the meter, the test for spans should always be made before any other check involving bar-to-bar readings.



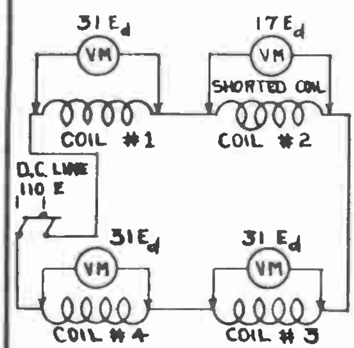
SHORTED ARMATURE COIL TEST

Connect armature to circuit, as directed above. Set meter selector switch to 250 M.A. and make a bar-to-bar test. If necessary, change selector switch to obtain about half-scale reading on a normal coil. A low or zero reading will then indicate a shorted coil; a high reading a poor connection - usually at the commutator riser. Example: Meter reads half scale on bars 11-12, 12-1, 1-2; gives low reading on 2-3, thereby indicating a shorted coil.



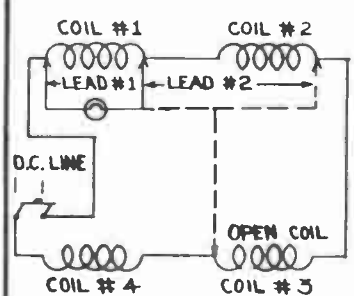
GROUNDED ARMATURE COIL TEST

With the test connection remaining the same as before, a meter reading between the commutator segments and the shaft indicates a grounded coil. As the segment to which the grounded coil is connected is approached, the reading will become less and will be minimum when the test prod is in contact with the segments connected to the grounded coil. Example: With meter selector switch set on 50 M.A., a reading from bar 10 to shaft is full-scale and this value is gradually reduced to a minimum on bars 1 and 2. Beyond this point, the reading reverses and starts to increase again.



SHORTED FIELD COIL TEST

Connect shunt field to line as shown in sketch and take the voltage drop across each field coil with a D.C. voltmeter. If the voltage across all coils is the same, the field is O.K. A reading below normal indicates a shorted or partially shorted coil. The normal voltage across any field coil is equal to the line voltage divided by the number of poles. Example: Coil 1, 31Ed; coil 2, 17E; coil 3, 31Ed; coil 4, 31Ed; coil 2 is shorted.

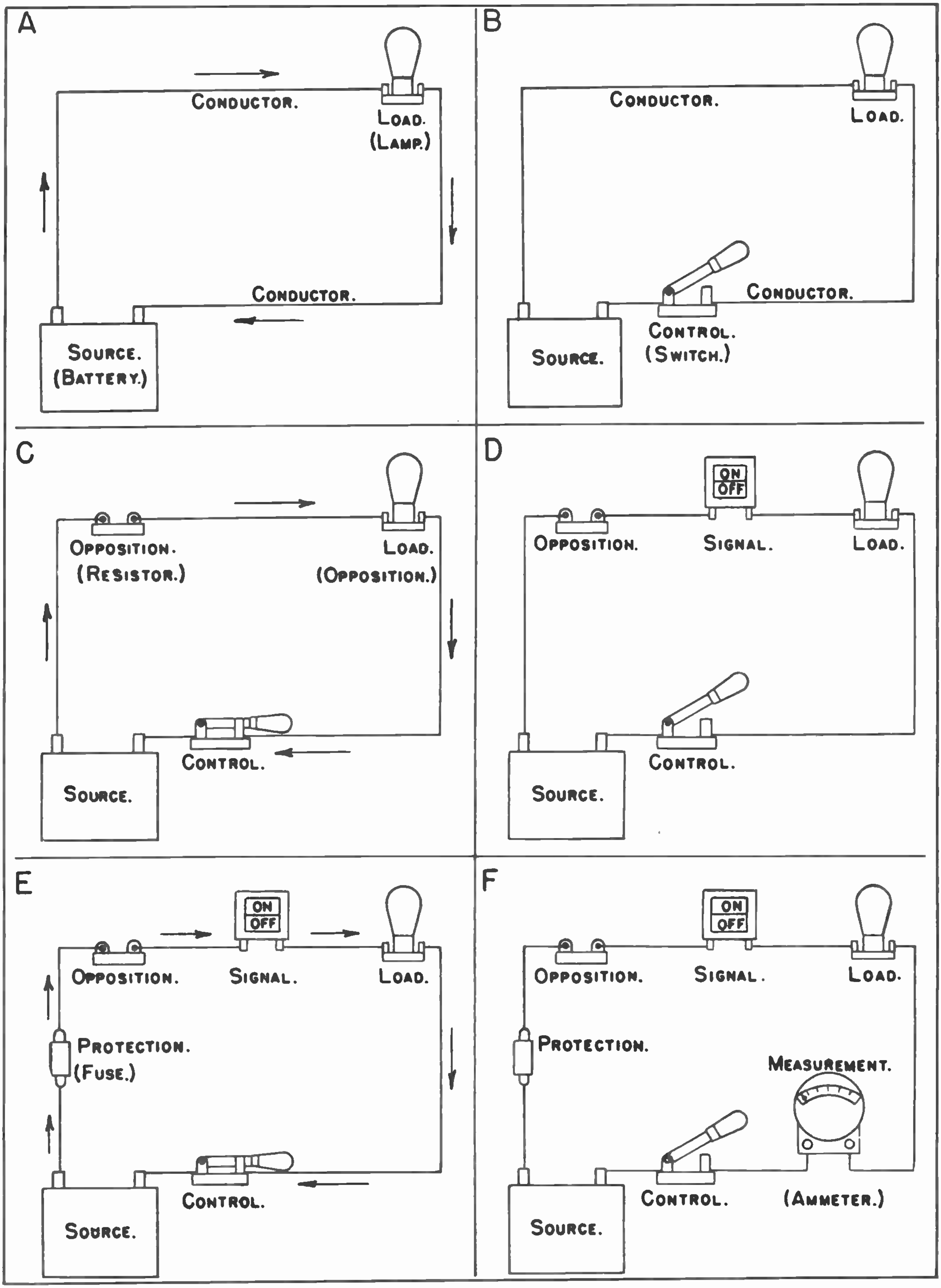


OPEN FIELD COIL TEST

Connect field as indicated in sketch and place voltmeter or test lamp across each field coil. If the field is open, no reading will be obtained until the open in the circuit is bridged. Then the open may be found by testing each coil individually, or by connecting one test lead to one of the circuit wires and moving the other lead around the field toward the other line until a light is obtained. The open will then be in between the point at which the light was obtained and the previous point tested.

GROUND FIELD TEST

Apply line voltage between the field leads and the frame with a suitable voltmeter or test lamp in series. If the meter indicates or the lamp lights, the field is grounded. To locate the ground, disconnect and test each coil separately.


A
Conductor.
Load.
(Lamp.)
Conductor.
Source.
(Battery.)
B
Conductor.
Load.
Conductor.
Control.
(Switch.)
Source.
C
Opposition.
(Resistor.)
Load.
(Opposition.)
Control.
Source.
D
ON
OFF
Opposition.
Signal.
Load.
Control.
Source.
E
ON
OFF
Opposition.
Signal.
Load.
Protection.
(Fuse.)
Control.
Source.
F
ON
OFF
Opposition.
Signal.
Load.
Protection.
Measurement.
Control.
(Ammeter.)
Source.

STEP BY STEP METHOD OF ELECTRICAL AND RADIO TROUBLE SHOOTING

Whether it is a door bell or a central power station, every electrical system begins with plans and layouts, followed by installation of the equipment and making of connections that place the system in operation. If every part of the system were then to operate indefinitely without trouble there would be no further work for electrical men. But sooner or later something will go wrong, and then begins the job of trouble shooting.

When electrical equipment fails to operate correctly, and you are called on to fix it, the people who call for help won't be able to tell you what really is wrong or exactly where the trouble lies. They will tell you simply that the motor won't start, that the lamp won't light, that the flat iron won't heat—and from there on it's up to you.

Trouble shooting — determining the kind of trouble and its exact location—usually is considered to be the most difficult of all electrical work. It actually is difficult for most men because they go at the job in a hit or miss fashion, hoping that luck will be with them and that some fortunate twist of a screw or pull on a wire will start things going again. The fact that they do not thus really locate the trouble and its cause means that it will reappear in a short time, which won't help the reputation of the man who "fixed" it.

Like all other problems, trouble shooting can be made much easier and the results more positive and lasting if you work according to definite plans. Working logically and systematically will quickly eliminate one possibility after another until the real fault is found. The first step in working out a trouble shooting system is to investigate electric circuits in general.

We must understand electric circuits because nearly any kind of trouble allows either too much or too little current to flow in the circuit. Trouble shooting is the process of determining whether a circuit will carry too much or too little current, and of interpreting the results of systematic tests so that we may locate the kind of trouble and its position.

THE PARTS OF A CIRCUIT

Electric circuits of the kind we are interested in are paths composed wholly of conductors through which current may flow. At some point in the conductive path is a source of electromotive force or voltage. This force causes current to leave the source, pass through the entire path outside the source, and return to the source. In addition to the source of emf all practical circuits include some kind of load. A load is any equipment in which electric power does useful work. A load may be a motor which causes mechanical motion, it may be a lamp which produces light, it may be a heater which raises temperatures, or it may be any other of a long list of things which are electrically operated.

A circuit containing the fewest possible parts is shown at "A" in Fig. 1. The source of voltage and current is a battery, the load is a lamp, and between the source and load are wires. Current leaves one terminal of the source, flows to and through the lamp, then returns to the source. At "B" we have added a control, in the form of a switch that allows turning the lamp on and off.

In case the voltage of the battery is so high as to force excessive current overload and possibly burn out the lamp we may add opposition to current flow, the resistor of diagram "C" in Fig. 1. Suppose the lamp is where it cannot be seen when operating the switch, we may add a signal in some other part of the circuit, as at "D." Next, wishing to prevent overheating of devices in our circuit because of excessive current, we add protection in the form of a fuse in diagram "E." Finally, in order to determine just how much current flows in the circuit, we provide measurement by means of the ammeter in diagram "F."

All of the parts in ordinary direct-current circuits may be classified as one of the types that we have used in Fig. 1. To the list we should add insulation, which prevents escape of current and voltage from the conductors, and which frequently acts at the same time as a means of support.

Now let's examine the alternating-current circuit shown by Fig. 2, noting whether we find parts which perform in general the same functions performed by parts in Fig. 1.

First in the a-c circuit we have a source, which is the a-c generator. We have a load which consists of the motor. There are connecting wires and insulation. For control we have an automatic relay that closes the generator circuit only after the generator voltage reaches a value suitable for operating the load. To protect the relay winding against excessive current we have opposition in the form of a resistor. A lamp connected across the generator acts as a signal to show whether the generator is in operation. Protection against overheating of the motor due to overload is furnished by an automatic circuit breaker that opens after excessive current has continued for a predetermined time. Measurement of voltage in the motor circuit is provided with a voltmeter.

In the alternating current circuit of Fig. 2 we have one kind of device not found in the direct-current circuit of Fig. 1, we have a transformer

FIG. 2.

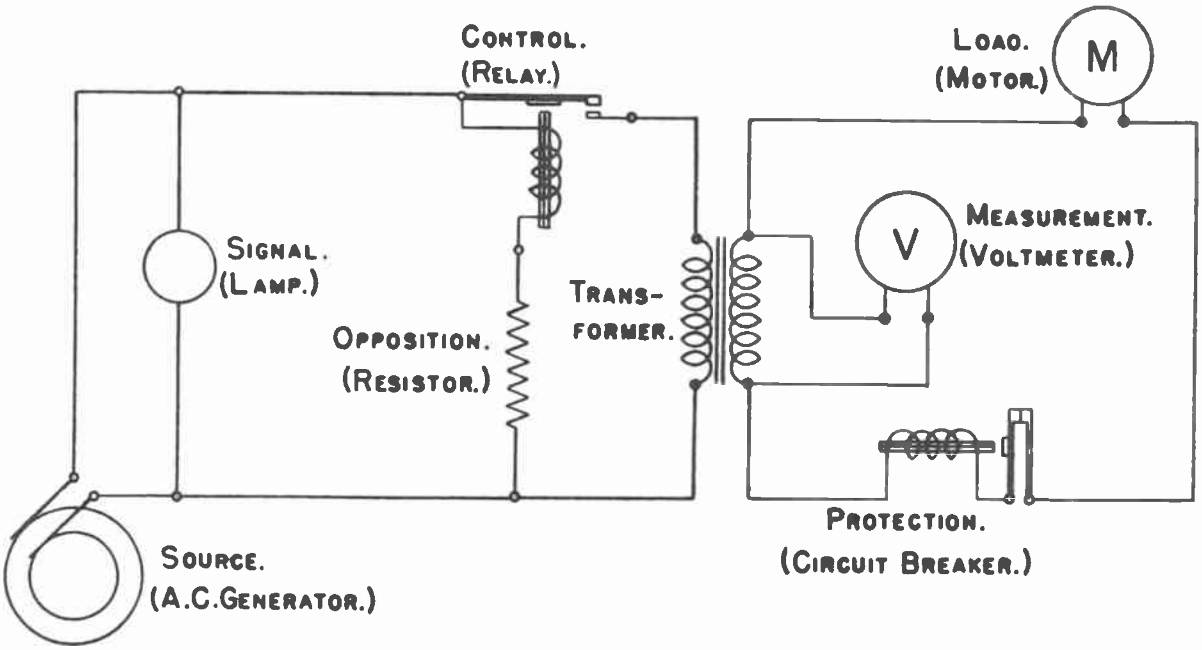


FIG. 3.

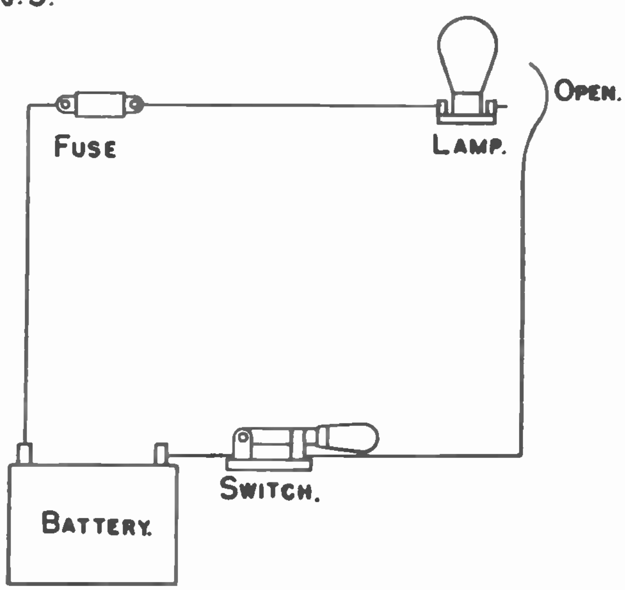
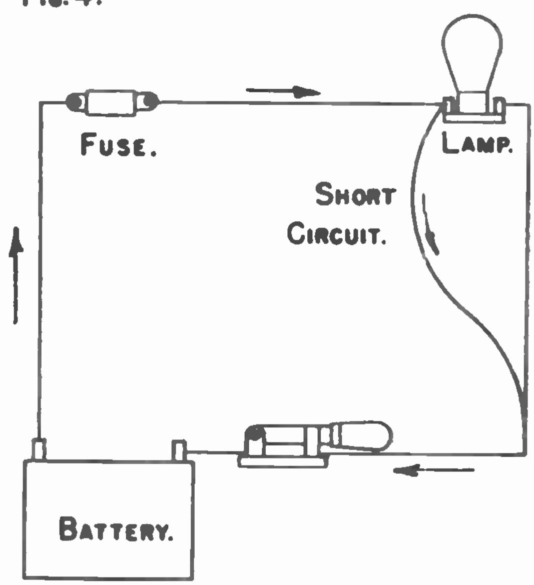


FIG. 4.



that changes the voltage from the generator into a voltage suitable for the motor. This we may classify as translation equipment.

Now we may list as follows all the general classes of equipment found in electric circuits:

1. Sources: Batteries, generators, power lines, thermocouples, etc.
2. Loads: Motors, lamps, heaters and other power-consuming equipment.
3. Conductors: Wires and other metallic and conductive parts for current.
4. Insulation: Often in the form of supports as well as wire coverings.
5. Controls: Switches, relays, starters, controllers and similar devices.
6. Opposition to current flow. Resistors, coils, capacitors, etc.
7. Signals: Lamps, bells, buzzers, annunciators, sounders, etc.
8. Protective devices: Fuses, circuit breakers. Sometimes transformers.
9. Measuring devices: Meters of various types.
10. Translation devices: Chiefly transformers and converters.

The general types of parts just listed may be combined in countless ways to form electric circuits. We may have one or more than one of any of these parts in a circuit. The circuit of Fig. 2 certainly looks entirely unlike those of Fig. 1, yet when we consider the parts according to their functions we have the same general kinds in both cases.

KINDS OF TROUBLE

Just as we classified switches, relays and starters under the one heading of controls, and just as we classified many other devices under some one general heading, so we must classify electrical troubles themselves into groups if we are to develop a workab'e system of trouble shooting.

Considering individual or particular electrical troubles we might have a burned out lamp, a burned out resistor, a blown fuse, a disconnected wire, a sticking contactor, or corroded relay contacts. But in our method of locating faults all these would be classified as open circuits. They would be classified as open circuits because they prevent flow of current in the circuit—from the standpoint of current flow the circuit is open, and when a circuit is open at any point and for any reason no current can flow in any part of that circuit.

We group all these troubles, and many others, together because it is relatively easy to determine when there is an open circuit and then to locate it as existing in some one section of the circuit. Knowing the general class of trouble present, and knowing its approximate position, we simply examine the parts to see which of them is out of order in the one particular manner.

Fig. 3 illustrates an open circuit caused by a wire end disconnected from one side of the lampsocket or lampholder. Even with the switch closed no current can flow in any of the conductors of the circuit.

Such things as dirty or corroded contacts and weak springs in automatic switches might not keep the circuit completely open but might introduce abnormally high resistance. The contacts might come together, but instead of making a full and clean connection they might make a connection through only a limited area, and through the dirt and corrosion instead of through clean metal surfaces. Abnormally high resistance, from any cause, is our second general classification of circuit troubles.

An open circuit prevents flow of any current at all. High resistance allows only a relatively small current to flow. These two classes of trouble are somewhat similar in that both reduce the flow of current, and they are identified and located by the same general methods of testing.

SHORT CIRCUITS AND GROUNDS

In Fig. 4 the wire that became disconnected from the lamp socket terminal in Fig. 3 has made contact on the other lamp socket terminal. Now current from the battery flows, as shown by arrows, through the fuse, the accidental connection at the socket terminal, the switch, and back to the battery. The relatively high resistance of the lamp filament no longer is included in the current path, and the current will increase to a very high value. The excessive current will almost instantly blow the fuse. The blown fuse will protect the battery from excessive discharge, but the real trouble still remains and if a new fuse is put in it will blow just like the first one.

Fig. 4 illustrates a short circuit, which is a circuit in which current from the source may flow and return to the source without going through the load. This is our third general class of circuit troubles. A short circuit may result from any one of many particular faults. In our testing method we are able to determine that there is a short circuit, and are able to determine its approximate location in the circuit. After that it is just a case of examining parts at this location for such faults as allow conductors on opposite sides of the circuit to come together.

At "A" in Fig. 5 we have a one-wire circuit or ground-return circuit. Instead of the entire circuit being completed through insulated wires a portion of it between the battery and lamp is completed through any metallic supports or framework that extend from near the battery to near the lamp. A connection to ground is indicated by a symbol consisting of several horizontal lines.

At "B" in Fig. 5 one of the wires has come off the lamp socket and the bare end of the wire has fallen against the metallic ground. Now current from the battery flows, as shown by the arrows, through the fuse and the metallic ground back to the battery—without going through the lamp. As you will recognize, this accidental ground is simply

Fig. 5.

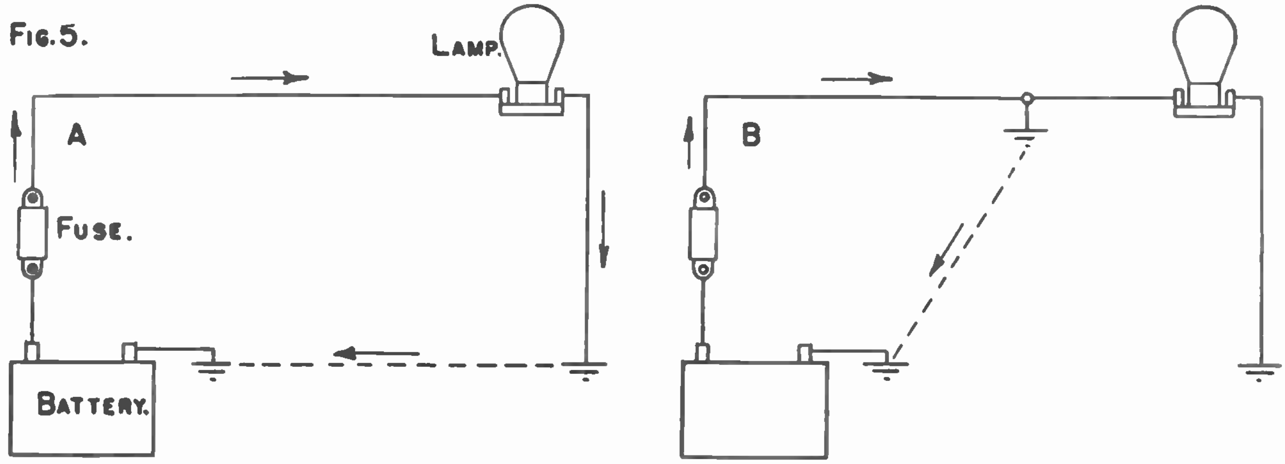


Fig. 6.

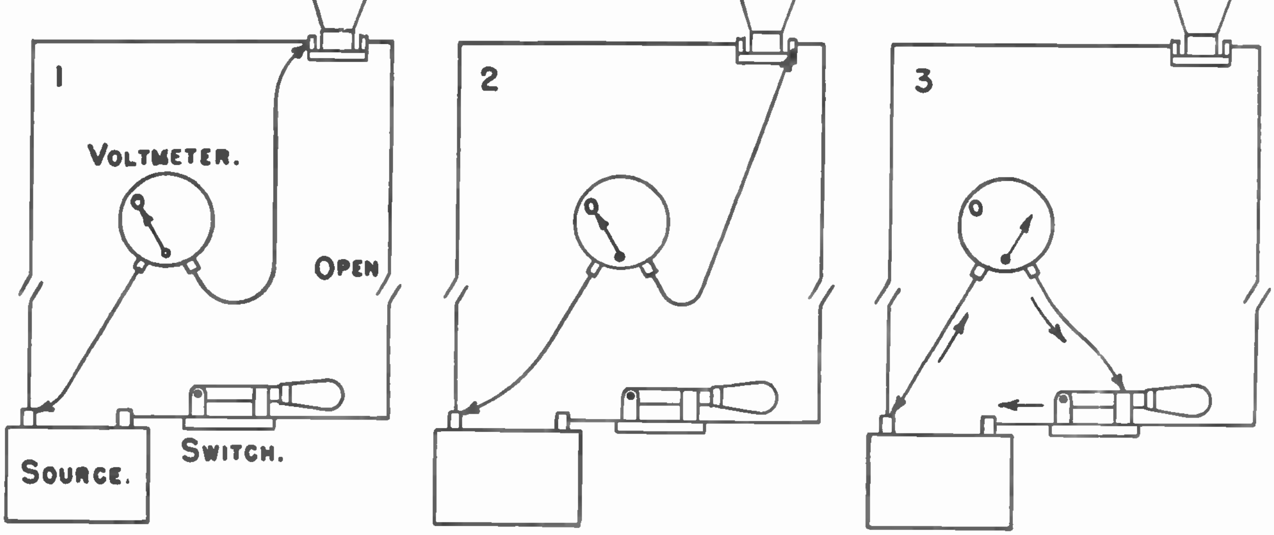
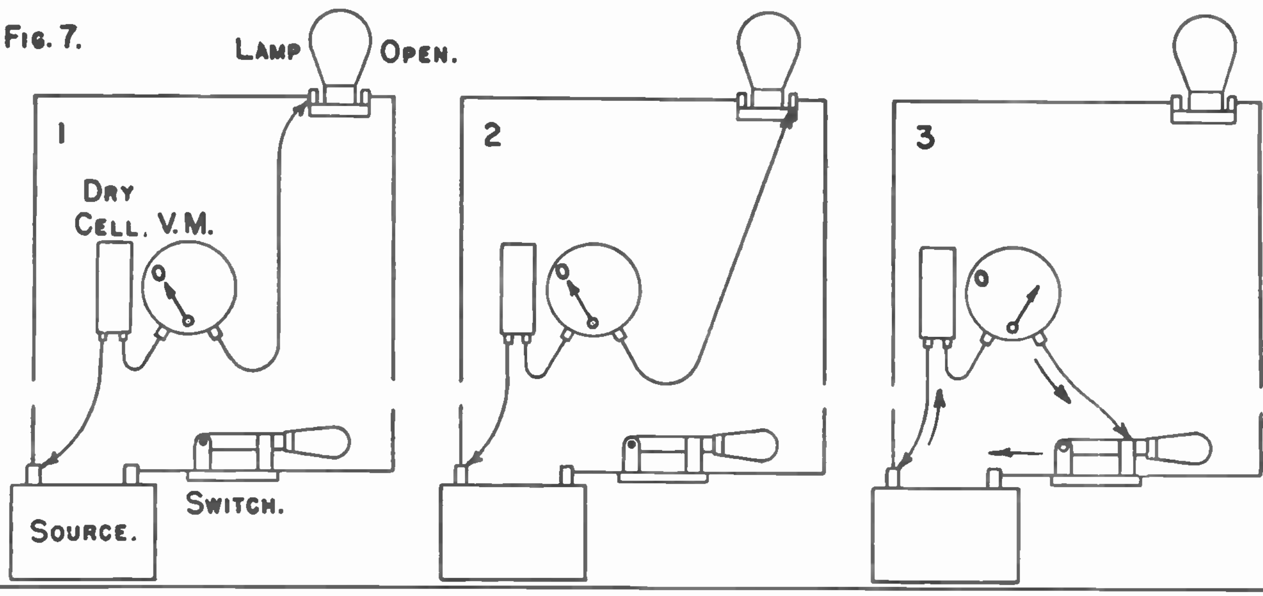


Fig. 7.



a variety of short circuit. An accidental ground permits current to leave the source and return to it without going through the load. This is our fourth general class of circuit troubles.

1. Open circuits. No current in any part of the circuit.
2. High resistances. Abnormally small current in the circuit.
3. Short circuits. Abnormally large current until some protective device acts.
4. Accidental grounds. A variety of short circuit occurring through ground.

While our four classes of circuit troubles will cover nearly all faults that affect the flow of current in circuits, they will not cover all electrical troubles. For example, in the case of motor troubles we would not cover such faults as uneven air gaps, wrong brush positions, reversed phase connections, and many other faults. However, the great majority of electrical troubles are circuit troubles, and the simpler the equipment or device the more likely it is that any existing fault is either an open circuit, a high resistance, a short circuit, or an accidental ground.

CIRCUIT TESTERS

For testing a circuit or part of a circuit that is suspected of being in trouble we require a source of voltage and current, also some means for indicating the flow of current or the lack of it, or a means for showing the presence of a voltage or potential difference.

The source of voltage or of voltage and current for testing may be the same source regularly used for the circuit being tested. That is, for a circuit normally operated from a power line or from the power and light wiring in a building we might use the same line for our testing source. For a circuit normally operated from a battery we might use the same battery. Of course, these sources can be used only if they themselves are not in trouble.

Many kinds of electrical equipment which normally are operated from batteries, radio sets for example, are conveniently tested with voltage and current taken from a power line. Similarly any portable appliances which may be disconnected from the light and power circuits of the building then may be tested with voltage and current from the building line.

A separate source of testing voltage and current, used only for testing, may be a battery. The battery may be connected to the tester only when there is trouble shooting to be done, or it may be mounted within the tester and be a self-contained part of the testing device. Still another source is a small hand-operated magneto, a small alternating-current generator. Magnetos are commonly used in telephone work, also for tests on long lines or long circuits of any kind.

When it comes to indicators for testing voltage and current we have a wide choice. We may use a bell, a buzzer, an incandescent lamp, a neon lamp, a voltmeter, a milliammeter, or a telephone receiver of the type we call a headphone.

With the great variety of sources and indicators for voltage and current it is possible to make up a great many different kinds of test equipment. In a general way the methods of recognizing open circuits, high resistances, short circuits and grounds are the same regardless of the kind of testing equipment used. Before discussing the particular advantages and disadvantages of the several testers we shall talk about the methods of making systematic tests.

LOCATING OPEN CIRCUITS

To locate the position of an open circuit we may proceed as in Fig. 6, where the accidental open point is in the right-hand vertical wire. For a tester we use a voltmeter, and for a source of testing voltage we use the regular source which supplies the circuit in trouble.

First, as in diagram "1," we disconnect a circuit wire from one side of the source, and to this side of the source connect one of the leads from our testing meter. Starting from the point at which the test meter has been connected to the source we now shall follow along the circuit, and every time we come to a terminal or other point at which the conductors are exposed we shall touch that point with the free lead of the testing meter.

The first test point is the left-hand terminal of the lamp socket. With the tester connected to this point, as in diagram "1" of Fig. 6, the meter reads zero. The next test point as we follow along the circuit is the right-hand terminal of the lamp socket. Here also the test meter reads zero, as shown by diagram "2."

Still following along the circuit we come next to the right-hand terminal of the switch. With the test lead connected here, as in diagram "3," the meter reads the full voltage of the source. Current to actuate the meter flows as shown by the broken-line arrows.

The open point in the circuit is somewhere between the last point at which the meter read zero and the first point at which we had a voltage reading. Thus we determine in which section of the circuit there is an open.

Note that had the circuit not been disconnected from one side of the source before commencing to make tests there would have been a complete conductive path through the circuit wiring between the points at which the test leads are connected. In Fig. 6 no current would flow through this path, because of the open farther along the circuit, and the meter still would read zero in diagram "1" and "2" even had one end of the circuit not been disconnected from the source. But had the circuit been of some more complex type, and had it been possible for some current to flow in the sections bridged by the meter, then the meter would show some voltage drop and the indications might be misleading.

In Fig. 7 we have the same kind of a circuit and have the same open point as in Fig. 6, but instead of using the regular circuit source for our testing voltage we have a "self-contained" tester consisting of a dry cell attached to and connected in series with the testing meter. The connections and the meter indications are exactly the same as in Fig. 6—the meter continues to read zero until we pass the open point, then gives a voltage reading.

Fig. 8 shows what would happen if we failed to disconnect one end of the circuit when using a self-contained tester. With the test connections of diagram "1" the meter would indicate voltage, with current flowing as shown by broken-line arrows. With the test connections of diagram "2" the meter still would read voltage. Therefore, we would have no means of locating the position of the open point in the circuit—the meter would give the same indications no matter where connected.

If we fail to disconnect the circuit being tested, the test indications may or may not be reliable. If we disconnect one end of the circuit the indications always are reliable. Therefore, the safe thing to do is always disconnect one end of the circuit if this is at all possible.

Now let's see what will happen if we proceed to test around the circuit in a direction the opposite of that followed in Figs. 6 and 7. This might mean simply reversing the order of tests; commencing with the test connections of diagrams "3," then making the connections of diagrams "2," and ending with those of diagram "1." With this order of testing the testing meter would indicate voltage with all connections before reaching the open point, and would read zero with all connections beyond the open.

One order of tests would give indications just as reliable as those with the other order, but since the indications are reversed you would have to keep constantly in mind the order in which you are proceeding. The more things of this kind you have to remember the more difficult will be your work, so it is wise to adopt one order or the other and stick to it. Generally it is better, as shown in Figs. 6 and 7, to disconnect one end of the circuit, connect one side of your tester at this end, then proceed from there around the circuit. Then remember that you get a reading after the open point has been passed.

In Fig. 9 we have two opens in the same circuit. One of the open points is a blown fuse, the other is a break in the wire at the right-hand side of the circuit. The successive test connections and the indications are shown by the test meter positions numbered from "1" to "5." With test "2" we have passed an open point in the circuit, yet still have a zero reading of the meter. The zero reading results from the second open point farther along in the circuit. Tests "3" and "4" likewise will give zero readings, but test "5" wil show voltage because we now have passed the last open point in the circuit.

You might conclude that the only open point is the one disclosed by test "5." This would be the same kind of error made by men who just "hunt" for trouble without making systematic tests. The thing to do in every case is to repair whatever trouble you first locate, then repeat the tests right through from the beginning. In the present case the second series of tests would locate the blown fuse, because with the connections for test "2" you would have a voltage reading and would know that an open point existed between tests "1" and "2." Having replaced the fuse you then should start over again with the series of tests. Not until all the tests indicate no opens should you consider the job complete. This rule applies no matter what your method of testing and no matter what kind of equipment you are using.

The methods of testing so far discussed might be called progressive tests, in which we connect one side of the tester to a certain point and then progress from that point around the circuit. With a self-contained circuit tester, having its own battery or other source of voltage and current, it is possible to test each part and section of a circuit individuallv.

Individual tests for opens are shown by Fig. 10. The leads from the tester are bridged across one portion of the circuit after another until you have gone all the way around or have located and repaired a trouble that permits the circuit to act normally again. In each test the indicator will show voltage if the parts tested are not open, and will show no voltage if the parts are open. Current will flow and voltage will be indicated through any portion of the circuit that is complete. If the portion tested is not complete, or is open, there can be no current flow and no voltage will be indicated. No voltage will be indicated because every voltmeter takes some flow of curent in order to move its pointer.

In Fig. 10, tests number 1, 3, 5 and 7 check sections of the wiring, and would disclose an open in whichever section is bridged by the test leads. Test number 2 would show up a blown fuse, test number 4 a burned out lamp, and number 6 would show defective contact in the switch. When making individual tests the circuit being tested must be disconnected from the source, at least at one end. Otherwise, voltage from the source will reach the tester when an open point is bridged, and easily may ruin the testing equipment.

A very long circuit, or one containing many devices which might be open, may be checked in large sections as illustrated in Fig. 11. Here both ends of the circuit are disconnected from the source. One side of the circuit tester is connected to any point about midway of the circuit being checked. Then the other test lead is touched first to one of the disconnected circuit wires and then to the other of these wires. With a connection at "1" in Fig. 11 we would check for opens in any part of the circuit from this point around to the right-hand terminal for one of the lamps in the upper line—the point

Fig. 8.

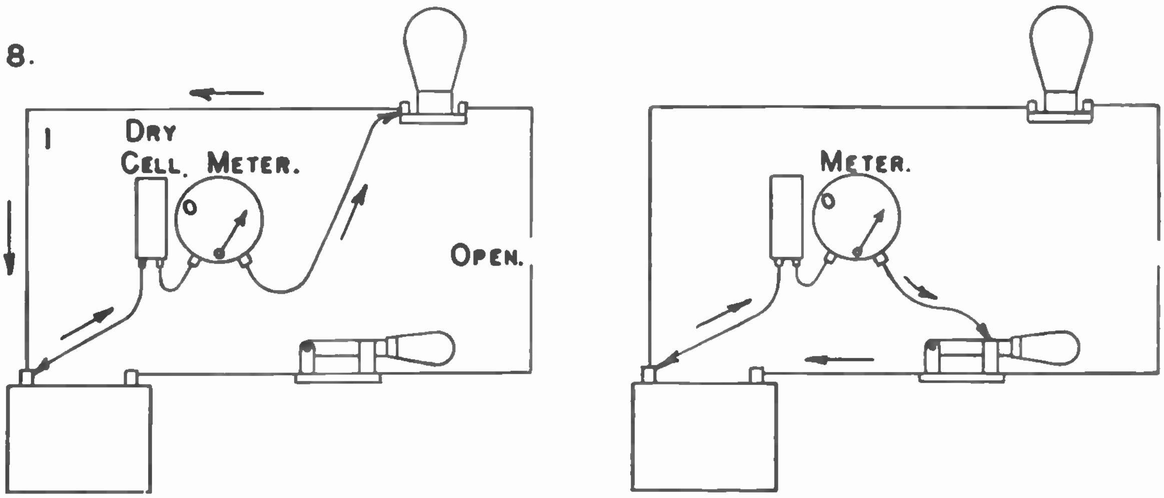


Fig. 9.

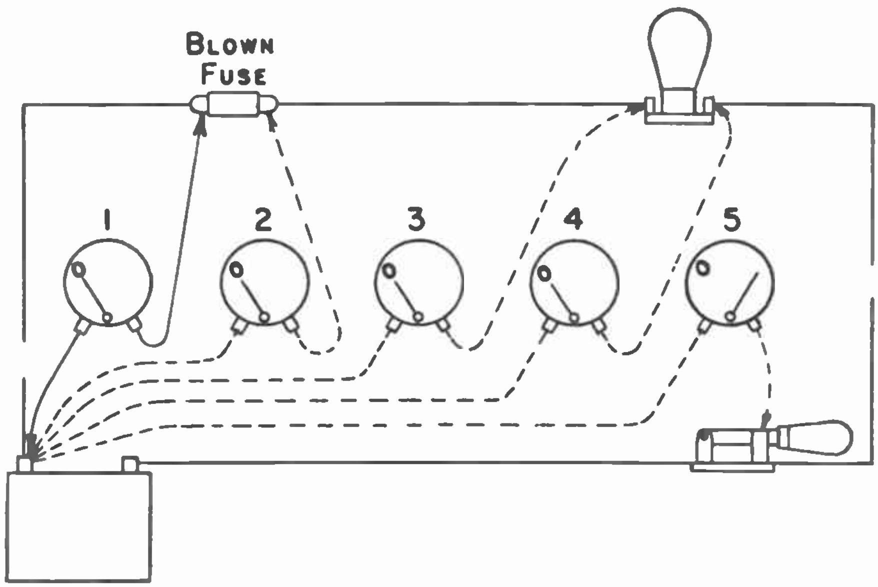
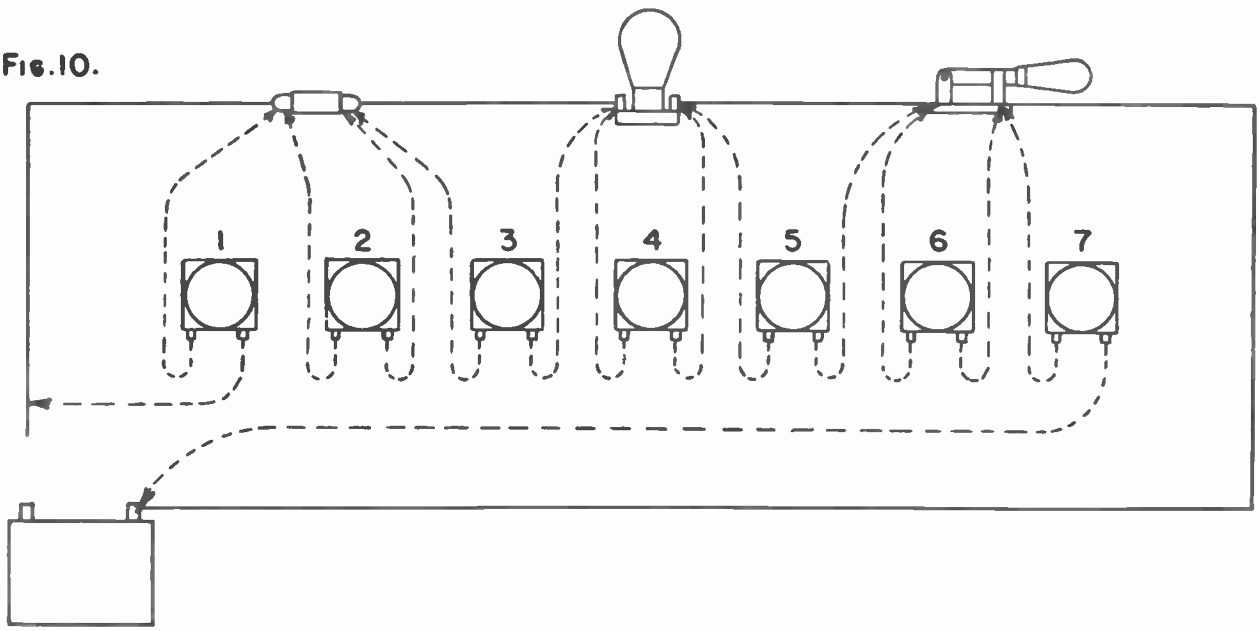


Fig. 10.



where the other side of the tester is attached. With the tester connection at "2" we would check for opens in the remainder of the circuit.

If these preliminary tests should show that an open existed in the section first checked we might further sub-divide that section of the circuit by moving the test lead from between the two lamps to a point between the resistor and signal. Again checking at point "1" would show trouble between this point and the test connection between resistor and signal, while checking at "2" would show trouble existing between the original connection (between the lamps) and the new connection between resistor and signal. This general principle may be used to divide a circuit into any number of sections, a method which may save much time in comparison with either progressive tests all around the circuit or with individual tests.

In all of the tests so far outlined the tester itself has ben shown as having a meter for its indicator. A lamp or any other of the indicating means previously mentioned might be used instead of the meter. The source of testing voltage and current might be any of those mentioned earlier. The principles of the tests would not be altered by the kind of test equipment employed.

Fig. 12 shows what probably is the simplest of all tests for open circuits. With this method the circuit being tested remains connected to the source. The tester consists of only an incandescent lamp having a voltage rating the same as the source voltage. For instance, in a 115-volt circuit we would use a 115-volt test lamp. Leads from the test lamp are connected successively across parts of the circuit. When the test lamp bridges a section of circuit or some device that contains an open the lamp will light. Current from the source goes around the open point and through the lamp as shown in diagram "1" of Fig. 12. When the test lamp bridges a part of the circuit that is complete the current will flow through the relatively low resistance of the circuit conductors rather than through the much higher resistance of the test lamp, and the lamp will not light.

There are two objections to this method of testing. One objection is that the source must be in condition to deliver normal voltage and current, but the chief objection is that should the circuit contain more than one open point the test indicates nothing. The reason is shown by diagram "2" of Fig. 12. Here the test lamp is bridging an open point, but because of the second open in the circuit no current can flow and the lamp remains out, just as though there were no open point at all. This method of testing is frequently used for locating blown fuses and tripped circuit breakers.

TESTS FOR HIGH RESISTANCE

All tests for locating points of abnormally high resistance, but points which are not open completely open-circuited, are carried out just as are tests for open circuits. But, since we wish to note the reduced current brought about by the high resistance, it is not enough to use an indicator that merely shows the presence or absence of current. Rather we need an indicator that shows the full current through the low resistance of a circuit in good condition, and which shows the greatly reduced current due to abnormally high resistance.

A tester which is effective for checking high resistances consists of a small incandescent lamp and a battery that will light the lamp to normal brilliancy. When extra circuit resistance is in the tested circuit the lamp will become dim. An ohmmeter which indicates circuit resistance directly in ohms is an excellent testing instrument for locating points in high resistance. Still another suitable arrangement consists of a milliammeter, a battery, and a resistor which limits the current to the full range of the meter. High resistance in the circuit checked will reduce the current through the milliammeter.

When using the method of Fig. 12, a point of fairly high resistance will cause the test lamp to light more dimly than usual when the lamp bridges such a point. This is because some current flows through the high resistance of the circuit and some flows through the high resistance of the lamp. Such a test for high resistance is not so reliable as those made with other types of indicators, it is too difficult to form judgments according to slight changes in lamp brilliancy.

SHORT CIRCUITS

Before commencing to talk about the methods used in locating short circuits and accidental grounds it will be advisable to examine a few general principles applying to these clases of trouble. In diagram "1" of Fig. 13 we have a circuit containing three pieces of equipment marked A, B and C. These units are shown as consisting simply of resistances, but they might represent any kind of equipment since whatever uses electric power has more resistance than the line wires. It is the combined resistance of units A, B and C that opposes flow of current from the source through the circuit, and that limits the current to a value that does not blow one or both of the fuses through which current enters and leaves the circuit.

Diagram "2" of Fig. 13 shows wires disconnected from two of the circuit units. Note that opening this circuit at any point will prevent flow of current from the source into and through the circuit. No current will flow in any part of a series circuit that is opened at any point.

In diagram "3" of Fig. 13 we have represented by a broken line a short circuit that has occurred between one terminal of unit B and one terminal of Unit C. The resistance of unit B has been "shorted out," so current from the source goes through unit A, the short circuit, unit C, and back to the source. The lessened resistance in the circuit, due to B being shorted out, allows excessive current to flow. This excessive current blows one of the fuses.

So long as the short circuit remains it will do no good to replace the blown fuse with a good one, for

Fig. 11.

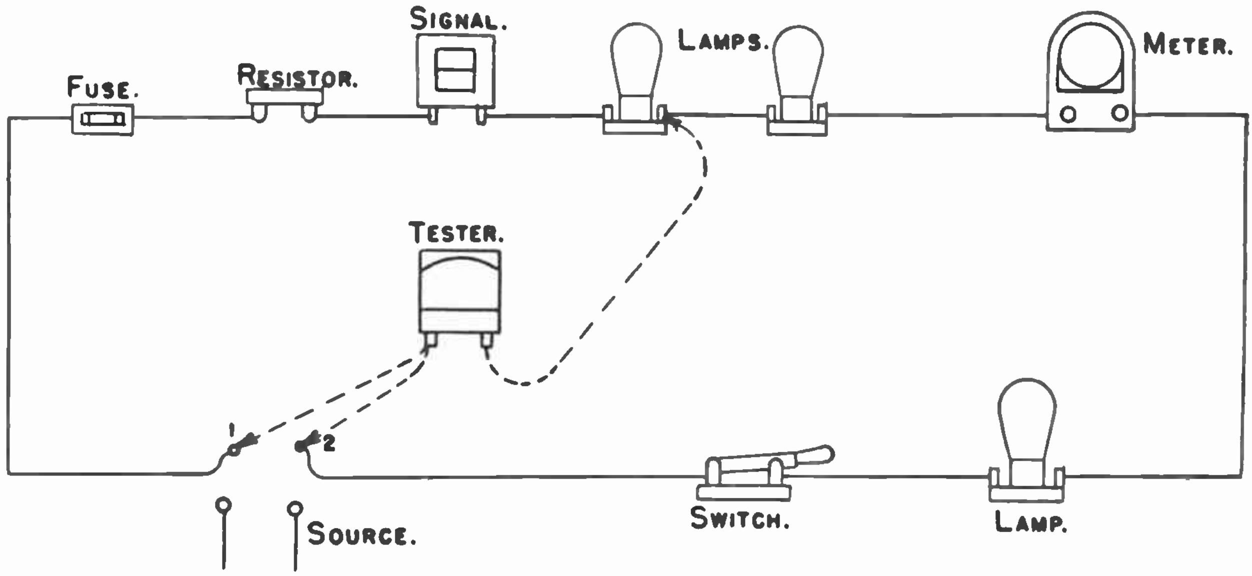
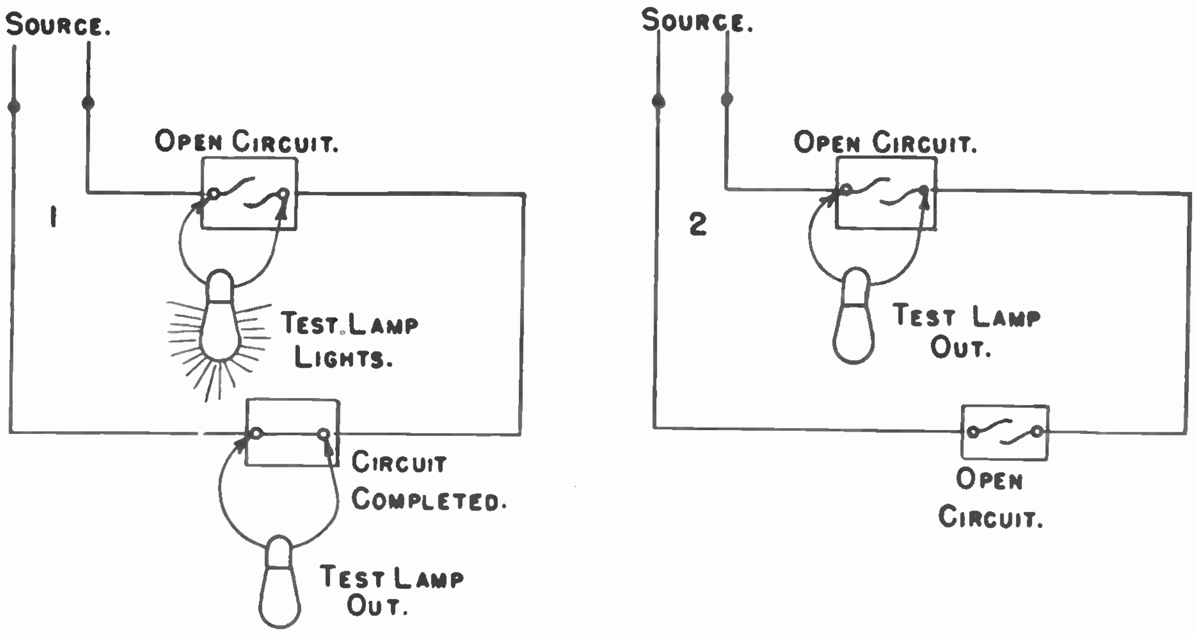

Signal.
Lamps.
Meter.
Fuse.
Resistor.
Tester.
1
2
Source.
Switch.
Lamp.

Fig. 12.


Source.
Open Circuit.
1
Test Lamp Lights.
Circuit Completed.
Test Lamp Out.
Source.
Open Circuit.
2
Test Lamp Out.
Open Circuit.

the new fuse will be blown by excessive current allowed by the short circuit. Instead of replacing the fuse we connect a test lamp in the place of the fuse, as shown by diagram "4" of Fig. 13. This test lamp must be of a voltage rating the same as the supply voltage.

Now current flows as shown by the small arrows in diagram "4," passing through the test lamp, unit A, the short circuit, unit C, and back to the source. The resistance of the lamp limits the current that may flow. This reduced current is enough to light the lamp but is not enough to blow the remaining fuse. Now we are ready to proceed with our tests.

LOCATING THE SHORT CIRCUIT

The usual method of locating the position of a short circuit is illustrated by Fig. 14. With the test lamp connected in place of the blown fuse, or connected in any manner between the source and the circuit being tested, the lamp will light. Working away from the point at which the lamp is connected we open each accessible point in the circuit. So long as we have not passed the short circuit, each point opened or disconnected will cause the test lamp to go out, as indicated in diagram "1." As each point is disconnected the lamp is observed, if the lamp goes out the connection is replaced to close the circuit at that point and the following point is temporarily opened.

As soon as we pass the short-circuited point, as in diagram "2" of Fig. 14, opening any following points in the circuit will leave the test lamp lighted. This is because current from the source continues to flow through the test lamp and through the short circuit.

The short circuit exists between the last disconnected point at which the test lamp goes out and the fisrt disconnected point at which the lamp remains lighted—this as we proceed along the circuit from the position where the test lamp is connected.

A method of locating a short circuit by using a self-contained tester is illustrated in Fig. 15. A self-contained tester is any type that has its own source of voltage and current, together with the indicating means, in one unit. The circuit being tested must be disconnected from the source, but need be disconnected on only one side if it is inconvenient to disconnect both sides. Then the tester leads are attached to the two ends of the circuit being ested.

With the tester in place we commence disconnecting any accesible points in the circuit, working around in either direction, or starting from either end of the circuit. Each time we open the circuit the tester will indicate zero current so long as the shorted point has not been passed. This is shown by diagram "1" of Fig. 15. As soon as the shorted point has been passed, opening the circuit at any following point will allow the tester to continue showing current. This is shown by diagram "2."

The short circuit exists between the last disconnected point at which the tester reading drops to zero and the first disconnected point at which the tester continues to show current. Compare this rule with the one for checking with a test lamp (Fig. 14). Except that in one case we have a test lamp and in the other have a self-contained tester, the rules and the indications are the same.

As shown by Fig. 16, a self-contained tester may be connected into a circuit at any point around the circuit provided the circuit is first disconnected from the regular source and the source terminals of the circuit are connected together. Comparing Figs. 15 and 16 will show that they amount to the same kind of connection for the tester, in both cases the circuit is complete all the way around, and is completed through the self-contained tester.

LOCATING ACCIDENTAL GROUNDS

An accidental ground is a type of short circuit in which the short part for current is between a conductor which normally should be insulated and the ground metal which forms part of the circuit. Since a ground is merely one kind of short, the test for locating grounds are essentially the ame as those for locating shorts.

Fig. 14 shows the use of a test lamp for locating shorts in an insulated return circuit. Fig. 17 shows the same method of test applied to a ground return circuit. Fig. 15 shows a self-contained tester used for locating short circuits. Fig. 18 shows the same tester used for locating an accidental ground in a ground return circuit. It is apparent that the testers will give the same indications for accidental grounds as they give for shorts between normally insulated conductors. The section of the circuit that is completed through ground or through metallic frameworks is the equivalent of a length of wire conductor.

The general type of ground return circuit shown in Figs. 17 and 18, also by Fig. 5, is the type commonly used for automobile wiring, some radio wiring, for some instrument and meter wiring, and in any cases where the metallic ground takes the place of an insulated copper wire and makes it possible to use less of the insulated wire in completing the circuit.

In the power and light circuits for buildings and distribution systems we have grounded conductors which are grounded for safety reasons, not for reducing the amount of insulated wire required. In these grounded systems of wiring the metallic grounds carry no current except when faults develop that allow contact of the ungrounded conductors with those that are grounded or with the metallic grounds.

The principle of grounding for safety reasons is illustrated by Fig. 19. Here we have a complete two-wire circuit from the source through to the lamp, which represents any load or loads on the circuit. One of the conductors, called the insulated conductor, contains the fuse or other protective device for the circuit, also any switches used for opening the circuit. The other conductor is connected

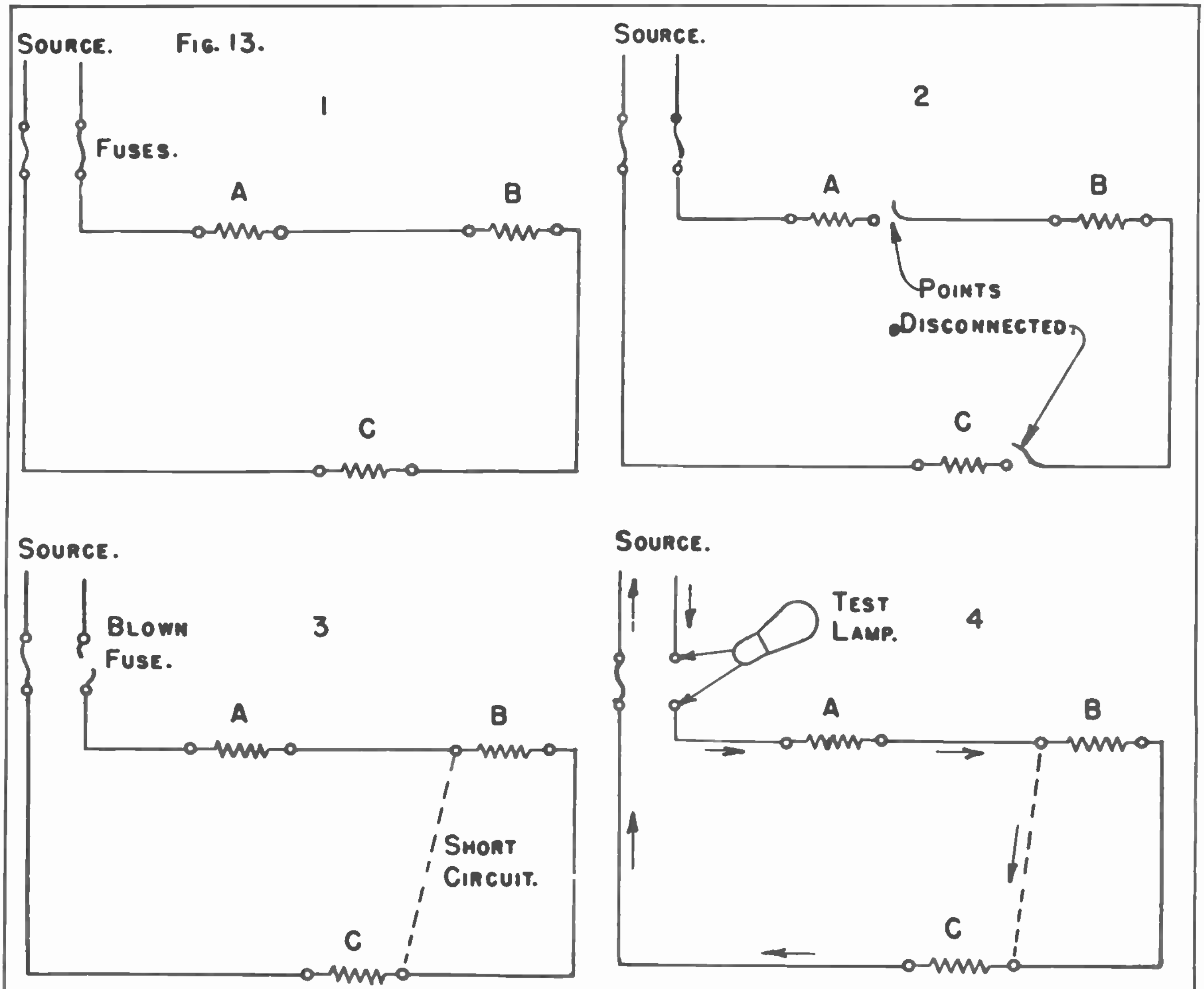

Source.
1
Fuses.
A
B
C
Source.
2
A
B
Points
Disconnected.
C
Source.
Blown
Fuse.
3
A
B
Short
Circuit.
C
Source.
Test
Lamp.
4
A
B
C

Fig. 13.

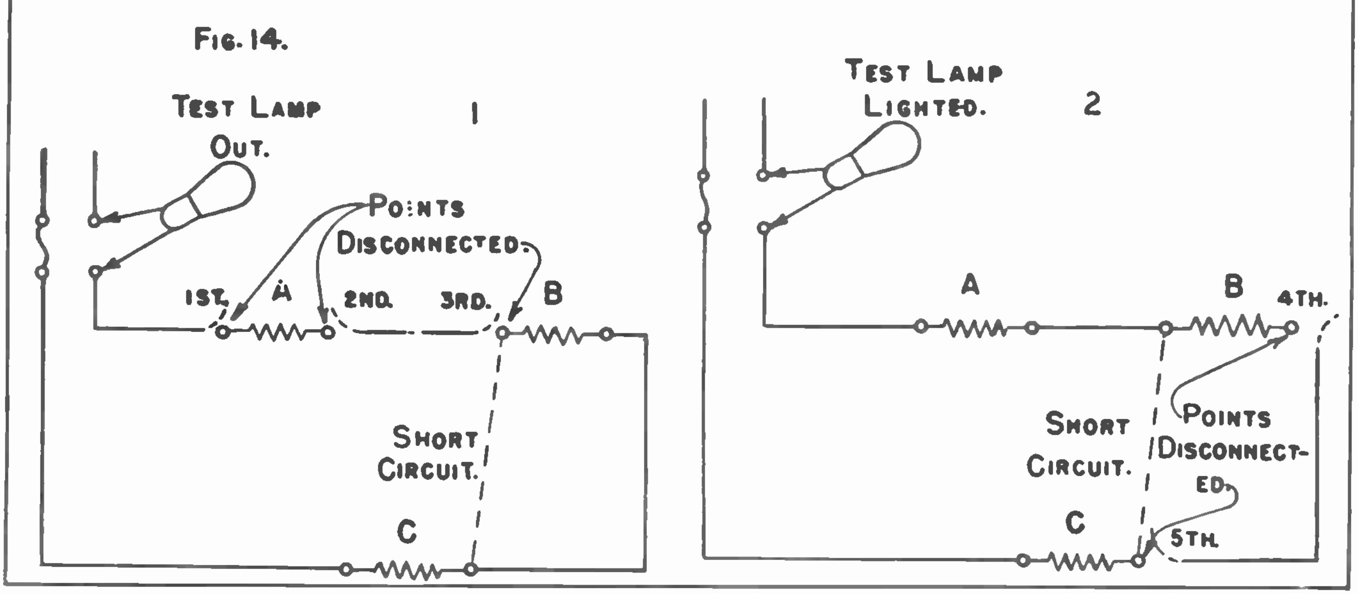

Test Lamp
Out.
1
Points
Disconnected.
1st.
A
2nd.
3rd.
B
Short
Circuit.
C
Test Lamp
Lighted.
2
A
B
4th.
Short
Circuit.
Points
Disconnect-
ed.
C
5th.

Fig. 14.

Fig. 15.

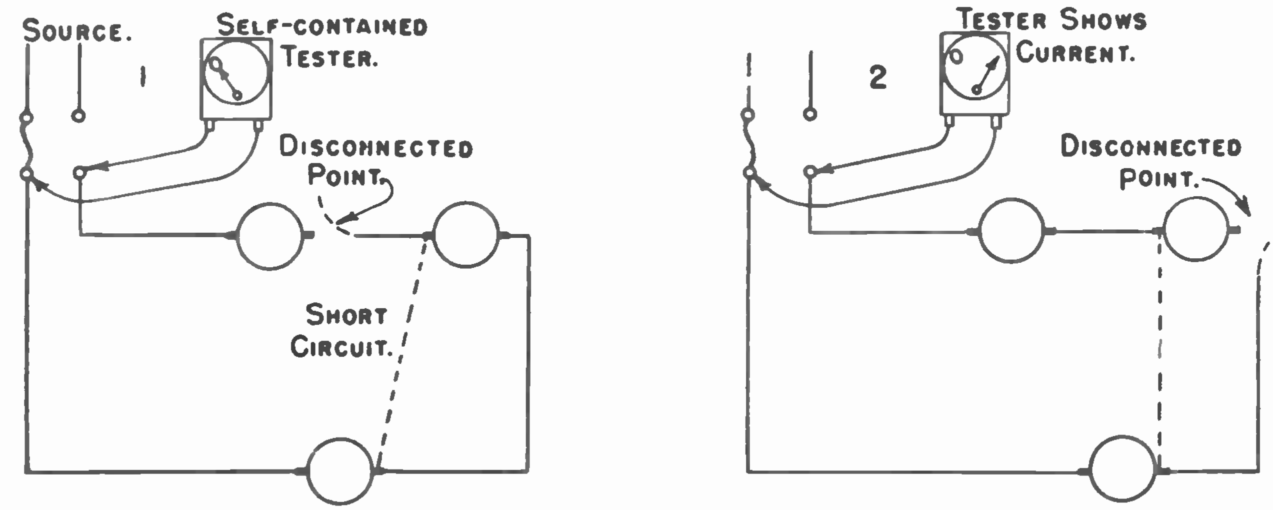


Fig. 16.

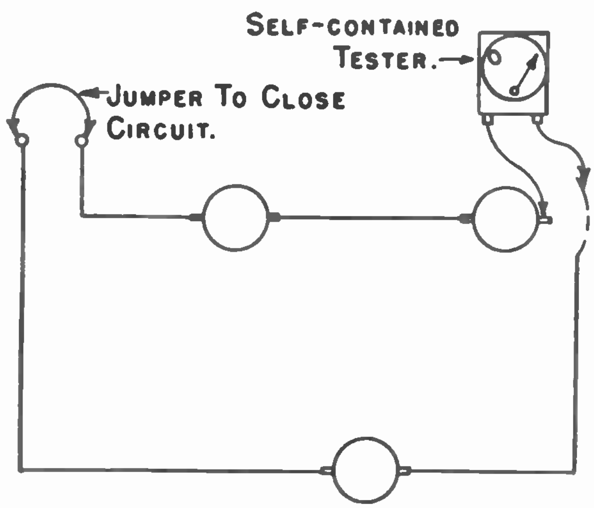


Fig. 17.

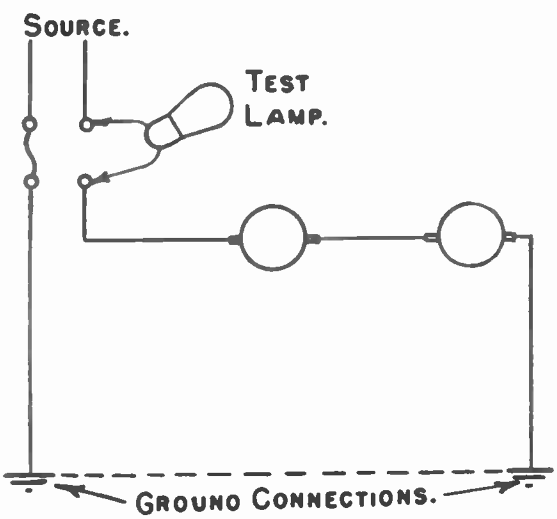
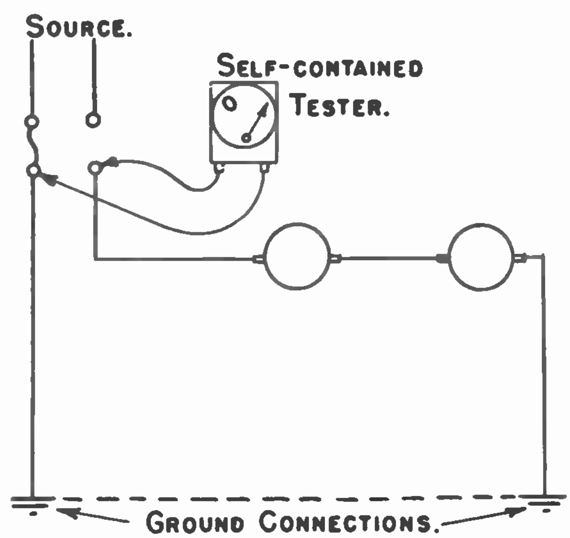


Fig. 18.



to a ground, usually to the cold water piping in the building but sometimes to artificial grounds. The runs of wire in the building are protected by and supported by metallic conduit, boxes and fittings or by other types of metallic raceways. All of these metallic enclosures for the wiring, also the frames and supports of all stationary connected equipment and appliances are grounded through the equipment ground. Since the system ground and the equipment ground connect to the same final ground that enters the surrounding earth, all of the metallic enclosures and frameworks and all of the grounded conductors are connected together into one conductive path.

In wiring installations such as represented in Fig. 19 it is apparent that even the insulated conductor is connected to ground through the lamp filament or through the resistance of any other loads. If we disconnect this wiring from the source, then test from ground to the various conductors we shall find that all of them are grounded. However, the insulated conductors are grounded only through the relatively high resistance of the loads. An accidental ground occurs when an exposed part of the insulated conductors comes in contact with either a grounded conductor or with the metallic enclosures or frameworks. With such an accidental ground there is a path of low resistance from the insulated to the grounded sides. Excessive current through this low-resistance path will blow a fuse or trip a circuit breaker. Note that what we have called an accidental ground between the insulated and grounded conductors really is a short circuit between these two kinds of conductors. It acts like a ground because one of the conductors is grounded.

TESTS IN BUILDING WIRING

The first test for grounds or shorts in building wiring is shown by Fig. 20, with the test lamp or other indicator connected across the clips for the blown fuse or the opened circuit breaker. If there is a short between insulated and grounded conductor, the short circuit, the grounded conductor, and back to the source. If there is an accidental ground, current from the source will flow through the test lamp, the insulated conductor, the accidental ground, the metallic raceway, the equipment ground, the system ground, and back to the source. Lighting of the test lamp will indicate that either a short or a ground exists, but will not tell which kind of trouble is present.

With the test lamp still in the same place the next step is to open one or both of the ground connections as shown by Fig. 21. This may be done at the service equipment for the building. If the test lamp still lights, the trouble is a short circuit between wires, because current no longer can flow through the ground connections. If the test lamp now goes out there probably is an accidental ground.

To check for the presence of an accidental ground on the insulated conductors the test lamp now is connected in either of the ground leads, as shown by Fig. 22. After thus connecting the test lamp, the fuse is replaced or the circuit breaker closed. Replacing the fuse or closing the breaker before inserting the test lamp, with its high resistance, will simply blow the new fuse or re-open the breaker. If the test lamp now lights there certainly is an accidental ground.

The three tests of Figs. 20 to 22 should be performed in this numbered order. If the test of Fig. 20 shows the circuit to be clear there is no use in making the others. Even though the test of Fig. 21 shows a short circuit, the test for ground in Fig. 22 still should be made, because there may be both kinds of trouble.

The tests shown for building wiring may be made with a test lamp or other regular loads may be left in place. The test lamp takes so much current to light it that it will not light or will glow but dimly on any current that goes also through the regular loads, but will light brightly on current through a low-resistance short or ground. A bell or buzzer could be used provided the bell or buzzer were designed for the supply voltage—but this seldom would be the case. An ohmmeter should not be used because it will be subject to the supply line voltage. A voltmeter should not be used because it will indicate full voltage with the current that passes through the regular loads, such as lamps.

LAMPS AS TEST INDICATORS

Having examined many of the more common methods for locating circuit troubles we now are in a position to appreciate the advantages and disadvantages of some types of test indicators. First we shall consider incandescent lamps and neon lamps.

When used with the regular source for testing voltage and current, an incandescent lamp should be a rated voltage as high as, or even higher than the supply voltage. The lamp should be of low candlepower or low wattage, bulbs of 6 to 25 watts being generally satisfactory. With small lamps the testing current is small and is unlikely to do any harm. The test lamp should be of the carbon filatype because such filaments withstand much more abuse that do tungsten filaments. The test lamp socket should be of the weatherproof type, with a molded composition body from which extend two wire leads. Metal brackets are likely to cause shorts and grounds through themselves, while porcelain sockets are easily broken.

The simplest and least expensive self-contained tester is made with one or two dry cells and a small incandescent lamp as shown by Fig. 23. The lamp should be rated at 1½ or 2 volts for a single dry cell and at 3 to 4 volts for two cells. Flash light bulbs may be used, but 3-4 volt automobile tail or dash light bulbs with two dry cells usually are more satisfactory. The dry cells should be of num-

Fig. 19.

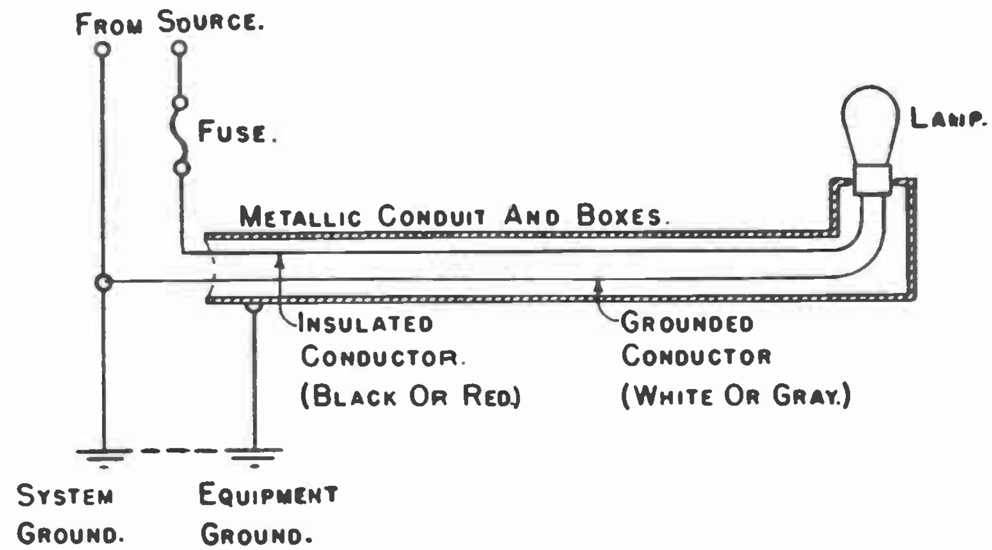


Fig. 20.

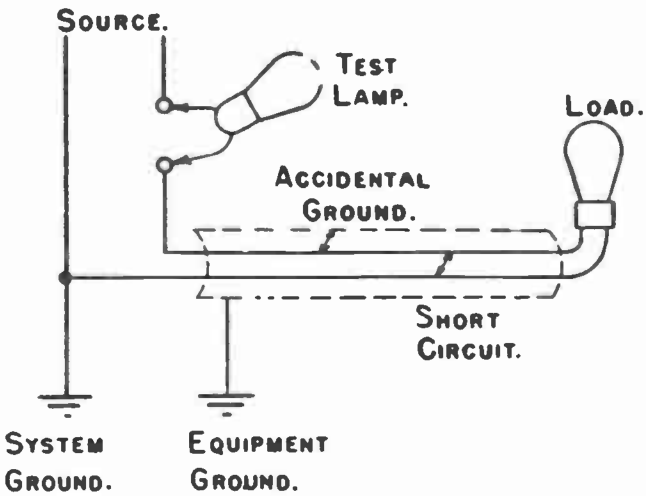


Fig. 21.

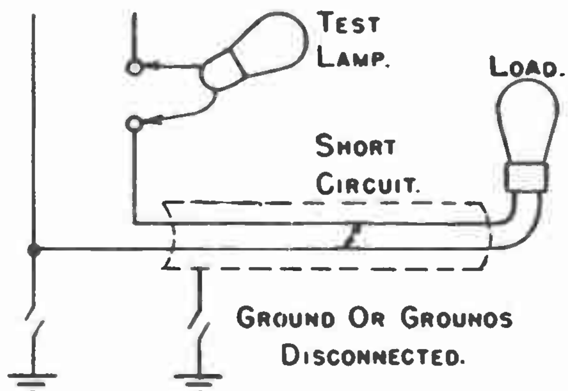
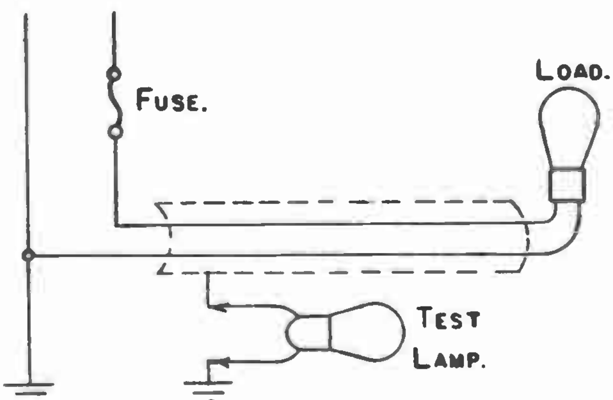


Fig. 22.



ber 6 size, since any smaller sizes discharge quickly and then cause unreliable indications.

Neon lamp bulbs such as used for night lamps and signal lamps come in ratings of one-quarter to three watts for operation on 110-120 volts. These bulbs will light on either direct or alternating current, both plates or electrodes lighting on alternating current and only one of them on direct current. It takes a rather high voltage, such as supply line voltage, to "break down" a neon lamp and cause it to glow, but once the glow is established it will continue with a current of only a few milliamperes or, in the small bulbs, with a current measured in micro-amperes.

When used with an alternating-current source a neon bulb will light and continue to glow with current that passes through the capacitance between adjacent insulated conductors, so will glow on current through an open circuit. With direct-current supply of voltage high enough to operate the lamp, the neon lamp will flash but will not continue to glow with current through such an open circuit. In general, the neon lamp is too sensitive or takes too little current to make it reliable for ordinary circuit testing.

BELLS AND BUZZERS

A vibrating type of doorbell or buzzer may be used in a self-contained tester made up with two number 6 dry cells, the connections to the bell or buzzer being the same as to the lamp bulb of Fig. 23. Bells and buzzers of usual styles take so much current to operate them that they will not ring or buzz through a circuit containing even moderately high resistance, but they will operate through a low-resistance short or ground. The large currents taken by these indicators will quickly discharge even the large size dry cells. The chief advantage of ordinary bells and buzzers is that they give an audible signal and make it unnecessary to watch the indicator while making test connections.

High-frequency low-current buzzers which operate on four to six volts make satisfactory test indicators for self-contained testers using three or four dry cells or a dry cell battery of equivalent overall voltage. The only real objections to such buzzers are their high cost for good types, and their failure to buzz in the cheaper types.

MAGNETO TEST SET

A magneto test set, shown in principle by Fig. 24, consists of an alternating-current generator or a magneto, operated by a hand crank, and connected in series with a polarized bell and the terminals for the test leads. A polarized bell has a permanent-magnet armature and will ring on alternating current. Most magnetos are designed to ring their bells through a circuit resistance of 20,000 to 40,000 ohms, and, of course, through any smaller resistance.

Among the advantages of the magneto test set are ease of operation a signal that is clearly audible, and the ability to test through circuits of high resistance. One disadvantage is that circuits containing large self-inductances, such as coil windings, have large opposition to alternating current and may prevent the bell from ringing. Another disadvantage is that the aternating current will act through capacitances, and when a circuit contains either condensers or long closely spaced insulated conductors the bell ringing current will pass through these parts even though there would be an open circuit for direct current.

VOLTMETERS FOR INDICATORS

A voltmeter for use in direct-current circuits consists of a meter movement in which the pointer moves all the way across the scale with a current of from one to 10 milliamperes in most designs. Within the meter case or attached to it, and in series with the movement, is a resistor of high enough value so that application of the full-scale voltage to the meter terminals will limit the current to just enough for full-scale travel of the pointer. Such a meter is shown by Fig. 25.

The voltmeter alone may be used just as a lamp or other indicator is used when the source of testing voltage and current is a line supply, or it may be used with any other source temporarily connected in place of the line of supply. In any case, the full-scale range of the meter must be at least as high as the maximum voltage from the test source.

For a self-contained tester the voltmeter is connected in series with a dry-cell battery as shown in Fig. 25. The terminal voltage of the battery must be no higher than the full-scale range of the meter.

An advantage of the voltmeter is that its own high resistance prevents any but small currents in the circuit tested. Large currents through equipment tested, especially when they are direct currents, may either magnetize soft iron cores that should not be magnetized, or may partially demagnetize some parts that should have definite magnetic polarities. The small current required to move the meter pointer allows using a battery of small capacity with assurance of reasonably long service. A disadvantage of the voltmeter for some tests is that it will indicate nearly full voltage through a rather high external resistance or a high circuit resistance. Thus it is not easy to recognize the presence of abnormally high resistances in the circuit tested.

Voltmeters for testing with alternating-current line power as the source usually are of the rectifier type. A rectifier meter consists of the same type of movement shown by Fig. 25 and of a current-limiting resistor. Between the movement and the terminals of the meter is a rectifier which changes alternating current into pulsating direct current that will operate the meter movement. There are other types of alternating-current voltmeters, but they take so much current for thei rown operation that we lose most of the advantages of a voltmeter

Fig. 23.

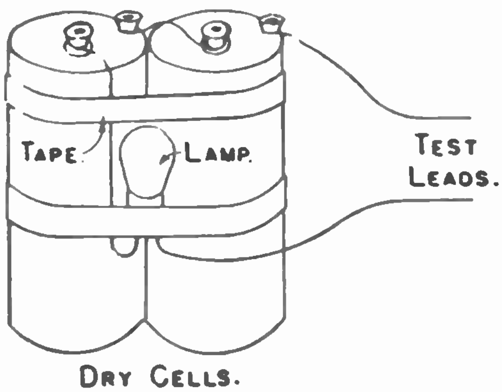


Fig. 24.

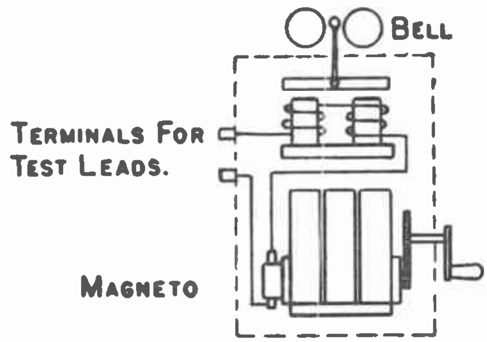


Fig. 25.

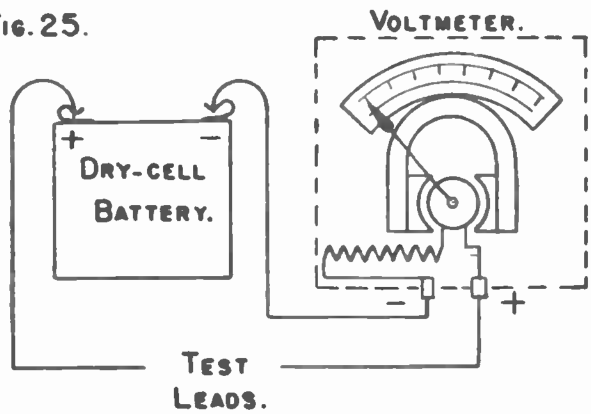


Fig. 26.

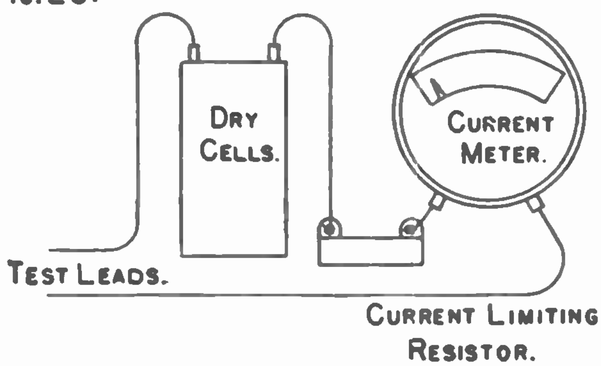
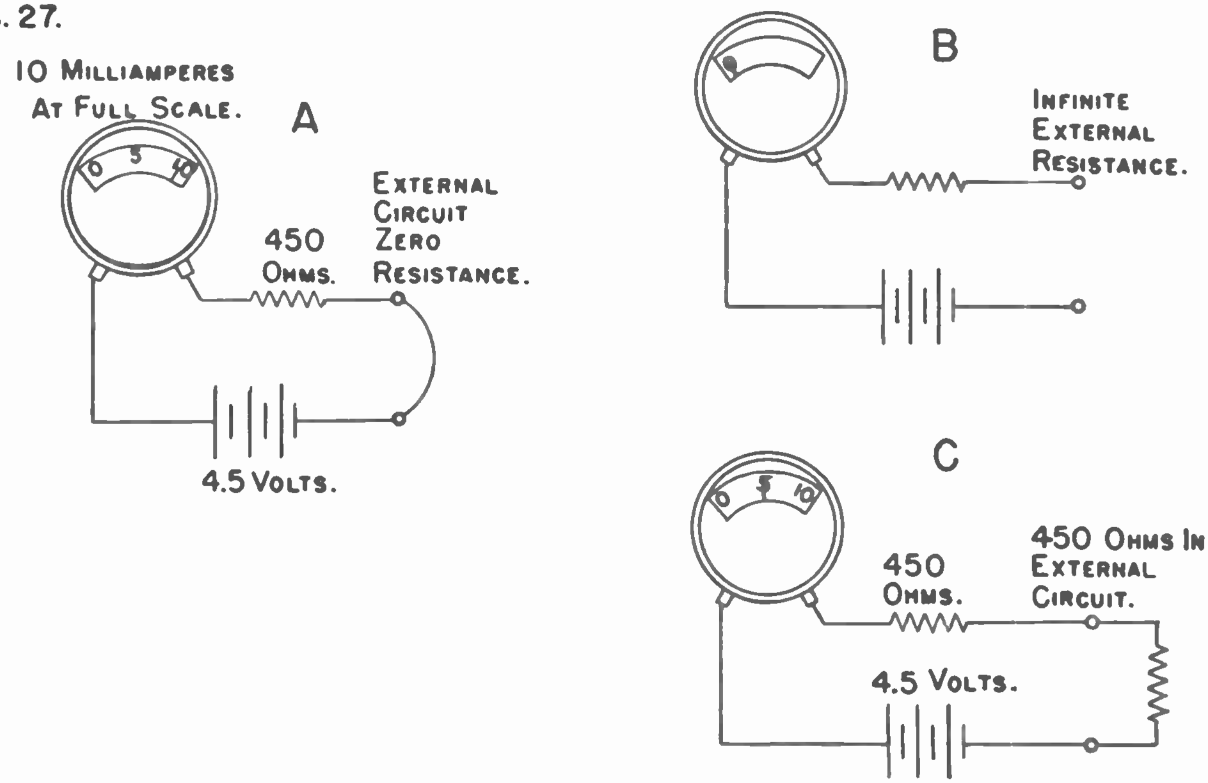


Fig. 27.



and might almost as well employ a small test lamp.

An alternating-current voltmeter would not be used in a self-contained tester, since they only practicable source of alternating current would be a magneto or small a.-c. generator. With a magneto we might better use a polarized bell.

CURRENT METERS FOR INDICATORS

If an ammeter or milliammeter is used as a test indicator there must be permanently connected in series with the meter, and close to the meter, a resistor which will limit current to the full-scale value of the meter when the highest possible testing voltage is applied. Neglecting the small internal resistance of the meter itself, the number of ohms in the limiting resistor must be equal to the maximum of applied volts divided by the full-scale current of the meter as measured in amperes, not in milliamperes.

Unless it is necessary to measure current in amperes or milliamperes during tests, a current-meter should not be employed. There is too much danger of applying excessive voltage and of burning out the meter. A delicate milliammeter without a protective resistor may be burned out by connecting it to a single flash light cell.

A milliammeter, a current-limiting resistor, and a dry cell battery may be asembled into a self-contained tester as shown by Fig. 26. The number of ohms required for the resistor is found by multiplying the battery volts by 1,000, then dividing the product by the full-scale milliamperes of the meter. Such a resistor will limit the meter current to the full-scale value when testing a short circuit and when the battery is fresh. The tester thus assembled is practically the same as the self-contained voltmeter type of Fig. 25, except that the limiting resistor is a part of the voltmeter and is added to the milliammeter.

A milliammeter of the rectifier type might be used when testing with alternating current as the source. Again it would be absolutely necessary to permanently connect a current-limiting resistor in series with the meter, so again it would be better to use a voltmeter rather than a current meter.

OHMMETERS

Fig. 27 illustrates the basic principle of a commonly used style of ohmmeter, an instrument that indicates on its dial scale the ohms of resistance in a circuit to which it is connected. At "A" in Fig. 27 we have a milliammeter which reads 10 milliamperes at full scale, a 3-cell 4½-volt dry cell battery, and a 450-ohm resistor, all in series between the terminals to which is connected an external circuit here shown as having zero resistance.

Ohm's law shows that the current is 10 milliamperes through 450 with 4½ volts applied, so, neglecting the small internal resistance of the meter itself, we have a full-scale reading of the meter. At "B" we have disconnected the external circuit from the terminals, so no current can flow and the meter reads zero. With the terminals open we have between them an external resistance so great that it is called infinite resistance.

At "C" in Fig. 27 the terminals are connected to an external circuit having a resistance of 450 ohms, the same as the resistance of the resistor in the ohmmeter. Now the total resistance in series with the meter and battery is 900 ohms. Ohm's law shows that this resistance allows a current of 5 milliamperes with 4½ volts applied. Thus we have a half-scale reading of the meter.

The dial scale of an ohmmeter is graduated in ohms rather than in current values. Infinite external resistance is indicated by the pointer all the way to the left, zero resistance is indicated by the pointer all the way to the right, and intermediate resistances are indicated by intermediate readings. The graduations are farthest apart at the low-resistance right-hand end of the scale and get closer and closer together as they go toward the high-resistance left-hand end.

In a practical ohmmeter there is allowance for the internal resistance of the meter movement, also adjustments for battery voltage and to compensate for gradual fall of voltage as the battery discharges.

One of the best of all test instruments may be made with parts such as shown in Fig. 27 enclosed in a case with terminals for test leads. Unless we wish to measure exact numbers of ohms it is not necessary to allow for movement resistance nor to provide adjustment for battery voltage or battery discharge. The number of ohms in the fixed resistor inside the ohmmeter case is found by multiplying the battery voltage by 1,000, and dividing this product by the full-scale milliamperes of whatever meter is used. Because of the extra resistance of the movement the pointer will not go to full scale even with the terminals connected together through a short copper wire, but the pointer will go almost to full scale. A half-scale reading always will indicate an external resistance approximately equal to the fixed resistance used in the ohmmeter.

A self-contained tester of this type will indicate an open circuit by its pointer remaining at the left-hand end of the meter scale, will indicate a "dead" short or a low-resistance ground by the pointer going almost all the way to the right, and will indicate resistance by the pointer going to some intermediate position on the scale.

TELEPHONE RECEIVER FOR TEST INDICATOR

Fig. 28 shows the connections for a telephone receiver or radio headphone used as a tester. One or two dry cells are connected in series with the receiver and the test leads, preferably with cords long enough so that the dry cells may be carried in your pocket with the headband and receiver in place on your head, thus leaving both hands free to work with the test leads.

When one lead is connected to one side of a circuit being tested, and the other lead is lightly

Fig. 28.

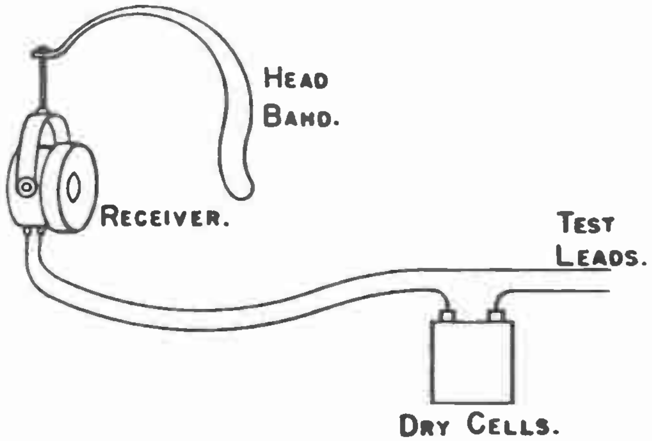


Fig. 29.

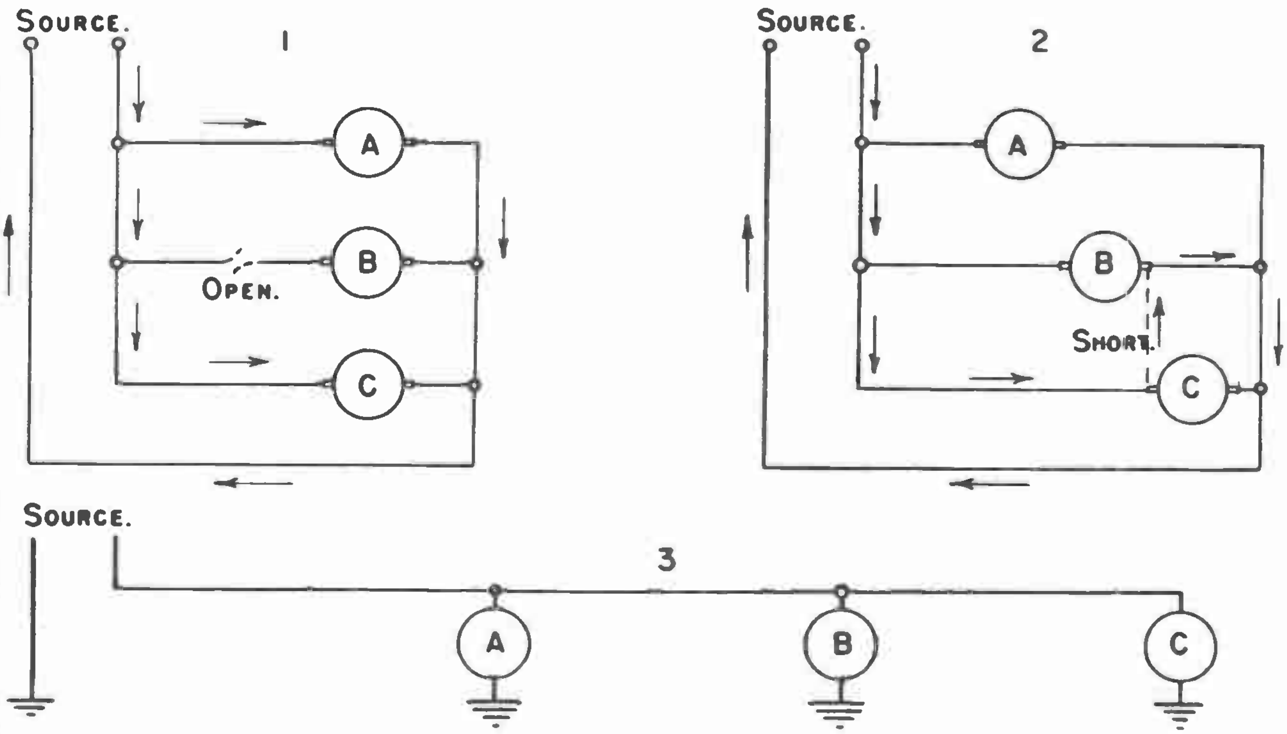
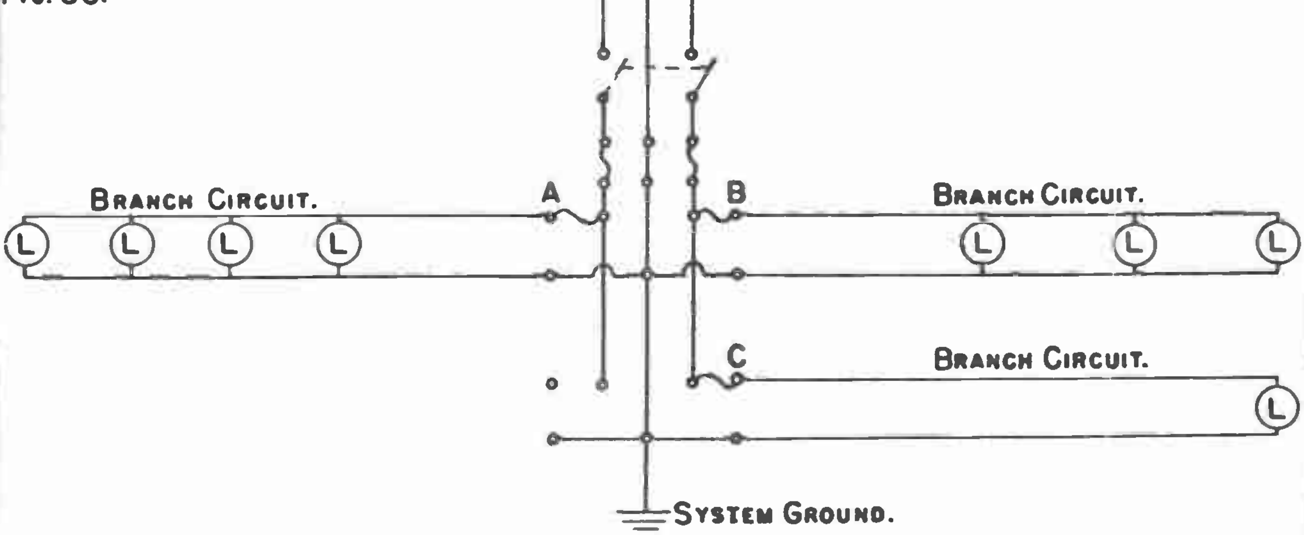


Fig. 30.



touched to and withdrawn from the other side of the circuit, there will be pronounced click in the receiver if the circuit is complete, and there will be no click or only a weak one if the circuit is open. If the circuit being tested contains high resistance the click will be weaker as the resistance increases.

Some circuits have quite a bit of capacitance, either in the form of condensers or capacitors, or else between adjacent insulated conductors in long circuits. When the telephone receiver is used for testing such circuits there will at first be a loud click as the capacitance takes a charge. If one lead then is removed and quickly reconnected the click will be weaker, but if much time intervenes between taps the click will be as loud as before if the capacitance is due to long insulated wires.

After enough experience in using the telephone receiver so that its indications may be quite surely recognized, this makes a decidedly useful tester, but at first the clicks or absence of clicks is likely to be misleading.

TESTS ON PARALLEL CIRCUITS

Up to this point all our diagrams of circuits tested have shown series circuits. A series circuit is one in which all the current flowing in any one part must flow also through every other part of the circuit. It is a circuit in which all the parts are connected "end-to-end", and in which the two outer ends of the circuit are connected to the source.

A parallel circuit consists of two or more current paths connected across the same source. Fig. 29 shows loads A, B and C connected across a source. The voltage of the source is applied equally to all the loads connected in parallel, and the total current from the source divides between the loads connected in parallel.

In diagram "1" of Fig. 29 there is an open circuit in the branch line for load B, but, as shown by the arrows, current still flows as usual through loads A and C. We might be able to locate the open circuit by measuring the change of resistance across the source, but this would require knowing the original resistance of the circuit when in good condition—a knowledge we seldom would have.

In diagram "2" of Fig. 29 there is a short circuit between terminals on loads B and C. Current from the source folows the path shown by arrows, passing through none of the loads but going entirely through the low-resistance wire conductors. No current to speak of flows through any of the loads. The excesive current through the wire conductors will blow a fuse or trip a circuit breaker, just as will the short-circuit current in any other circuit.

Diagram "3" in Fig. 29 shows a ground return circuit with the three loads in parallel across the source. Opens and shorts in this circuit would act generally as they do in any other circuit, and accidental grounds would act like short circuits—just as they do in a series connection.

To locate opens, shorts and accidental grounds in parallel circuits, or with loads connected in parallel we nearly always must disconnect the parallel branches from one another and test each branch as a series circuit, which it is when disconnected from other branches. Then the tests for various kinds of faults are exactly the same as those we already have studied.

Lighting and appliance branch circuits in buildings ordinarily are wired according to the principle shown in Fig. 30, where the symbols marked L represent lamps or appliances. In each branch the lamps or appliances are in parallel between the two wire lines, but the relatively high resistance of lamps between the two sides of the branch circuit allows testing the branch like a series circuit when it is disconnected from other branches. Each branch may be disconnected from the service equipment by removing the fuse or opening the circuit breaker that protects the branch. The left-hand branch of Fig. 30 would be disconnected by removing fuse A, then testing this branch according to the methods of Figs. 20 to 22. The upper right-hand branch would be disconnected by fuse B, and the lower right-hand branch by fuse C.

Parallel circuits having exposed conductors running between separate pieces of equipment may be broken up into series sections after inspecting the connections. When the conductors are concealed, as with the internal wiring of appliances and other electrical apparatus, it usually is necessary to have a wiring diagram of the equipment before it is possibeto carry out positive tests for circuit troubles.

DETERMINING THE PROBABLE TROUBLE

Blown fuses, tripped circuit breakers, and evidences that equipment and insulation have been overheated indicate that the circuit troubles are shorts or grounds. When such symptoms are present you should commence your work with tests for shorts circuits and accidental grounds rather than with tests for open circuits.

If lamps, appliances and other equipment fail to operate, and if fuses or circuit breakers are not open, it is probable that there is an open circuit and it is for such trouble that you first should make tests. When any equipment refuses to start or to operate, the correct procedure is to check for voltage at the equipment terminals with switches turned on. You can make this check with a test lamp having a voltage rating the same as that of the supply line. If the lamp lights brightly there is voltage at the equipment and there are no open circuits in lines coming to the equipment. If the lamp lights dimly there probably is high resistance somewhere in the lines, and if the lamp fails to light at all there is an open circuit.

Before making instrument tests for open circuits look for any switches which may have been opened in lines between the supply source and the equipment, and look for blown fuses or open circuit breakers in the lines. If switches, fuses and circuit breakers are closed, check for voltage all the way back to the source or to the point at which the circuits connect to a supply line.

TESTING INTERNAL CONNECTIONS

All of the diagrams that have illustrated circuits and methods of testing them have shown the loads or circuit units as though they were well separated from one another and had exposed wires running between them. Exactly the same methods are used for testing internal connections and internal circuits in any kind of electrical equipment. Whether you are checking a circuit between lamps in separate rooms of a building, or one between adjacent tubes in a radio set makes no change in the general principles of testing for circuit troubles.

When testing the circuit and connections inside any one piece of electrical equipment much time will be saved if you have a wiring diagram or a schematic circuit diagram for the equipment, especially if the construction it at all complicated. it would be relatively easy to check the internal connections of something so simple as a vacuum cleaner containing only a motor, control switches and their connections. It would be more difficult to test an electric range with its many additional control switches and thermostats.

CHOICE OF TESTING METHODS

With the various kinds of testing equipment we may employ either alternating or direct current supplies; taking alternating current from a supply line or a magneto, and direct current from batteries in most cases but sometimes from a d-c line. When you have a choice it is a good idea to use alternating current for testing circuits and equipment that normally operate with such current, and to use direct current for those that normally operate with direct current. However, unless the circuit being tested contains coils that provide considerable inductance, or capacitors that provide considerable capacitance, direct-current testing equipment is just as good as alternating current in every case.

The voltage used for testing should preferably be as high as the normal operating voltage of the circuit tested, at least when you are using lamps, bells or buzzers for the test indicator. It is entirely possible for a short circuit or accidental ground to allow large leakage currents on 110 volts and yet not allow enough leakage to light a test lamp or ring a bell on voltage from one or two dry cells. When using more sensitive indicators, such as votmeters and ohmmeters, any voltage that operates the test instrument is sufficiently high for all usual tests.

When you use a high testing voltage, such as line voltage, always limit the testing current to the smallest possible value that will operate the indicator being used. A 6-watt lamp, taking but a small fraction of an ampere of current on a lighting and power circuit, gives indications that are just as positive and just as reliable as those of any larger lamp that takes much more current. The advantage of using a high testing voltage is in the fact that the high voltage will force current through faults in the circuit, but the least possible current is just as effective as a big curenrt so far as test indications are concerned.

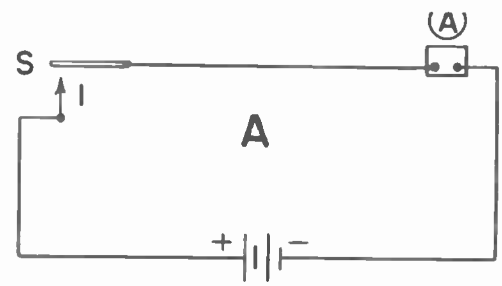
Test leads should be of very flexible wire with conductors formed from braided strands covered with flexible insulation such as a thin layer of rubber and two layers of braided fabric. It is convenient to have a spring clip at the end of one test lead. This clip may be firmly attached at one point in the circuit tested. At the end of the other lead should be a pointed test prod enclosed almost to its tip with rubber, fibre or composition insulating tubing. It is advisable also to have a sleeve of soft rubber over the spring clip. Unless the end of the test leads are protected with insulation clear to the tips with which connections are made, the exposed conductors of the leads will cause plenty of shorts and accidental grounds while you are making tests.

A test lamp used alone, with line power for the testing voltage and current, should have insulated spring clips on both leads so that it may be connected securely between terminals or fuse clips while you check for circuit troubles. When connecting such a lamp to the circuit do not take hold of both clips at the same time and attach them. By doing this you are likely to get a severe shock. Use only one hand at a time, clip one lead in place, let go of it, then clip the other lead in place. The same general method of making test connections should be followed with any test equipment that employs high voltage or line voltage.

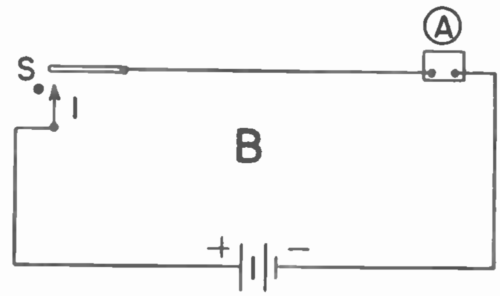
TRACING CIRCUITS.

THIS SHEET SHOWS HOW TO TRACE ELECTRICAL CIRCUITS. IF THE STEP BY STEP PROCEDURE GIVEN BELOW IS FOLLOWED, LITTLE DIFFICULTY WILL BE EXPERIENCED.

a. Mark the polarity of the source of supply, putting a (+) mark at the point of highest electrical pressure, and a (-) mark at the point of lowest electrical pressure.

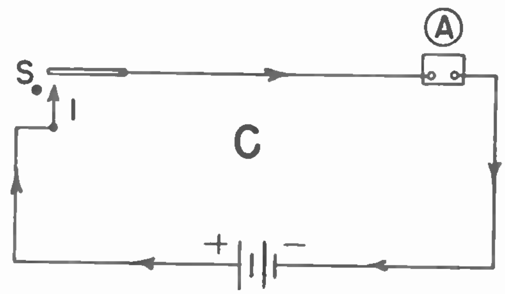


b. See if there is a complete path from (+) to (-). In this case the path can be completed only by closing the switch S. To indicate that this switch is closed, place a dot beside it as shown.



c. Now trace the circuit, using the arrows to indicate the direction of current flow around the circuit from the high pressure point (+) to the low pressure point (-).

d. Mark the number of the circuit alongside or inside the diagram and show the color of the arrow used to trace it thus:
Circuit #1

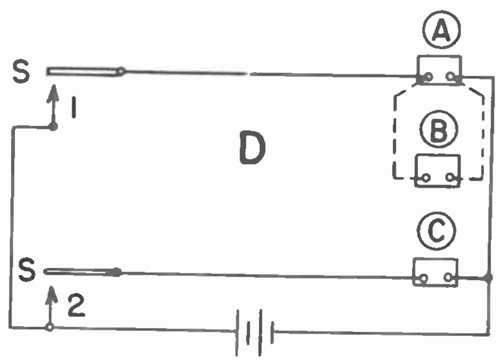


a. Mark the polarity of the battery (+) (-).

b. Close switch #1 with a lead pencil dot, and trace circuit controlled by this switch in the same color.

c. Mark number of circuit alongside diagram and show colored arrow used to trace it thus: Circuit #1

d. Close switch #2 with a red dot and trace the circuit controlled by this switch in red.



CIRCUIT No. 1

CIRCUIT No. 2

NUMBER OF CONDUCTORS IN CONDUIT OR TUBING*

Lead-Covered Types RL and RHL—600 V.

Size AWG MCM	Number of Conductors in One Conduit or Tubing: Single Conductor Cable 1	2	3	4	2-Conductor Cable 1	2	3	4	3-Conductor Cable 1	2	3	4
14	½	¾	¾	1	¾	1	1	1¼	¾	1¼	1½	1½
12	½	¾	¾	1	¾	1	1¼	1¼	1	1¼	1½	2
10	½	¾	1	1	¾	1¼	1¼	1½	1	1½	2	2
8	½	1	1¼	1½	1	1¼	1½	2	1	2	2	2½
6	¾	1¼	1½	1½	1¼	1½	2	2½	1¼	2½	3	3
4	¾	1¼	1½	1½	1¼	2	2½	2½	1½	3	3	3½
3	¾	1¼	1½	2	1¼	2	2½	3	1½	3	3	3½
2	1	1¼	1½	2	1¼	2	2½	3	1½	3	3½	4
1	1	1½	2	2	1½	2½	3	3½	2	3½	4	4½
0	1	2	2	2½	2	2½	3	3½	2	4	4½	5
00	1	2	2	2½	2	3	3½	4	2½	4	4½	5
000	1¼	2	2½	2½	2	3	3½	4	2½	4½	4½	6
0000	1¼	2½	2½	3	2½	3	3½	4½	3	5	6	6
250	1¼	2½	3	3	...	...	...	...	3	6	6	...
300	1½	3	3	3½	...	...	...	...	3½	6	6	...
350	1½	3	3	3½	...	...	...	...	3½	6	6	...
400	1½	3	3	3½	...	...	...	...	3½	6	6	...
500	1½	3	3½	4	...	...	...	...	4	6	...	...
600	2	3½	4	4½	...	...	...	...	...	...	...	...
700	2	4	4	5	...	...	...	...	...	...	...	...
750	2	4	4	5	...	...	...	...	...	...	...	...
800	2	4	4½	5	...	...	...	...	...	...	...	...
900	2½	4	4½	5	...	...	...	...	...	...	...	...
1000	2½	4½	4½	6	...	...	...	...	...	...	...	...
1250	3	5	5	6	...	...	...	...	...	...	...	...
1500	3	5	6	6	...	...	...	...	...	...	...	...
1750	3	6	6	...	...	...	...	...	...	...	...	...
2000	3½	6	6	...	...	...	...	...	...	...	...	...

The above sizes apply to straight runs or with nominal offsets equivalent to not more than two quarter-bends.

(* 1947 N. E. Code. Table 5)

PROPERTIES OF COPPER CONDUCTORS*

Size AWG	Area Cir. Mils	Concentric Lay Stranded Conductors: No. Wires	Diam. Each Wire Inches	Bare Conductors: Diam. Inches	*Area Sq. Inches	D.C. Resistance Ohms/M Ft. At 25 C. 77 F.: Bare Cond.	Tin'd. Cond.
18	1624	Solid	.0403	.0403	.0013	6.510	6.77
16	2583	Solid	.0508	.0508	.0020	4.094	4.25
14	4107	Solid	.0641	.0641	.0032	2.575	2.68
12	6530	Solid	.0808	.0808	.0051	1.619	1.69
10	10380	Solid	.1019	.1019	.0081	1.018	1.06
8	16510	Solid	.1285	.1285	.0130	.641	.660
6	26250	7	.0612	.184	.027	.410	.426
4	41740	7	.0772	.232	.042	.259	.269
3	52640	7	.0867	.260	.053	.205	.213
2	66370	7	.0974	.292	.067	.162	.169
1	83690	19	.0664	.332	.087	.129	.134
0	105500	19	.0745	.373	.109	.102	.106
00	133100	19	.0837	.418	.137	.0811	.0844
000	167800	19	.0940	.470	.173	.0642	.0668
0000	211600	19	.1055	.528	.219	.0509	.0524
	250000	37	.0822	.575	.260	.0431	.0444
	300000	37	.0900	.630	.312	.0360	.0371
	350000	37	.0973	.681	.364	.0308	.0318
	400000	37	.1040	.728	.416	.0270	.0278
	500000	37	.1162	.814	.520	.0216	.0225
	600000	61	.0992	.893	.626	.0180	.0185
	700000	61	.1071	.964	.730	.0154	.0159
	750000	61	.1109	.998	.782	.0144	.0148
	800000	61	.1145	1.031	.835	.0135	.0139
	900000	61	.1215	1.093	.938	.0120	.0124
	1000000	61	.1280	1.152	1.042	.0108	.0111
	1250000	91	.1172	1.289	1.305	.00864	.00890
	1500000	91	.1284	1.412	1.566	.00719	.00740
	1750000	127	.1174	1.526	1.829	.00617	.00636
	2000000	127	.1255	1.631	2.089	.00539	.00555

* Area given is that of a circle having a diameter equal to the over-all diameter of a stranded conductor.

The values given in the table are those given in Circular 31 of the National Bureau of Standards except that those shown in the last column are those given in Specification B33 of the American Society for Testing Materials.

The resistance values given in the last two columns are applicable only to direct current.

(* 1947 N. E. Code. Table 18.)

COPPER WIRE TABLE

GAGE No.	DIAM. Inches	CROSS SECTION: Circular Mils	Square Inches	RESISTANCE at 68° F.: Ohms per 1,000 Ft.	Feet per Ohm
0000	0.4600	211,600	.1662	0.0490	20,400
000	.4096	167,800	.1318	.0618	16,180
00	.3648	133,100	.1045	.0779	12,830
0	.3249	105,500	.08289	.0983	10,180
1	.2893	83,690	.06573	.1239	8,070
2	.2576	66,370	.05213	.1563	6,400
3	.2294	52,640	.04134	.1970	5,075
4	.2043	41,740	.03278	.2485	4,025
5	.1819	33,100	.02600	.3133	3,192
6	.1620	26,250	.02062	.3951	2,531
7	.1443	20,820	.01635	.4982	2,007
8	.1285	16,510	.01297	.6282	1,592
9	.1144	13,090	.01028	.7921	1,262
10	.1019	10,380	.008155	.9989	1,001
11	.09074	8,234	.006467	1.260	794
12	.08081	6,530	.005129	1.588	630
13	.07196	5,178	.004067	2.003	499.3
14	.06408	4,107	.003225	2.525	396.0
15	.05707	3,257	.002558	3.184	314.0
16	.05082	2,583	.002028	4.016	249.0
17	.04526	2,048	.001609	5.064	197.5
18	.04030	1,624	.001276	6.385	156.6
19	.03589	1,288	.001012	8.051	124.2
20	.03196	1,022	.000802	10.15	98.5
21	.02846	810.1	.000636	12.80	78.11
22	.02535	642.4	.000505	16.14	61.95
23	.02257	509.5	.000400	20.36	49.13
24	.02010	404.0	.000317	25.67	38.96
25	.01790	320.4	.0002517	32.37	30.90
26	.01594	254.1	.0001996	40.81	24.50
27	.01420	201.5	.0001583	51.47	19.43
28	.01264	159.8	.0001255	64.90	15.41
29	.01126	126.7	.0000995	81.83	12.22
30	.01003	100.5	.0000789	103.2	9.691
31	.008928	79.70	.0000626	130.1	7.685
32	.007950	63.21	.0000496	164.1	6.095
33	.007080	50.13	.0000394	206.9	4.833
34	.006305	39.75	.0000312	260.9	3.833
35	.005615	31.52	.0000248	329.0	3.040
36	.005000	25.00	.0000196	414.8	2.411
37	.004453	19.83	.0000156	523.1	1.912
38	.003965	15.72	.0000124	659.6	1.516
39	.003531	12.47	.0000098	831.8	1.202
40	.003145	9.88	.0000078	1049.	.953
41	.00280	7.845	.0000062	1323	.756
42	.00250	6.250	.0000049	1659	.603
43	.00220	4.850	.0000038	2138	.467
44	.00200	4.000	.0000031	2592	.386
45	.00175	3.063	.0000024	3390	.295
46	.00150	2.250	.0000018	4610	.217

RESISTANCE WIRE—NICHROME

660 ohms per circular mil-foot at 68° F.

SIZE A.W.G.	Ohms per Foot	Ohms per Pound	Feet per Pound	Lbs. per 1000 Ft.
8	.0408	.903	22.2	45.0
9	.0509	1.416	27.8	36.0
10	.0639	2.205	34.5	29.0
11	.0805	3.500	43.5	23.0
12	.1018	5.66	55.6	18.0
13	.1278	8.93	69.9	14.3
14	.1610	14.25	88.5	11.3
15	.2036	22.19	109	9.18
16	.2556	35.50	139	7.19
17	.3220	57.62	179	5.58
18	.4072	92.00	226	4.42
19	.5112	142.6	279	3.58
20	.6485	228.3	353	2.83
21	.8175	364.6	446	2.24
22	1.031	582.3	565	1.77
23	1.292	916.0	709	1.41
24	1.634	1455	893	1.12
25	2.060	2310	1123	.890
26	2.611	3729	1429	.700
27	3.274	5830	1786	.560
28	4.159	9438	2273	.490
29	5.168	14740	2857	.350
30	6.600	23870	3623	.276
31	8.333	37950	4566	.219
32	10.31	58190	5650	.177
33	13.10	94160	7194	.139
34	16.62	150700	9091	.110
35	21.02	240900	11490	.0871
36	26.40	381700	14490	.0690
37	32.67	583000	17860	.0560
38	41.24	916300	22220	.0450
39	54.10	1591000	29410	.0340
40	73.33	2566000	40000	.0250
41	87.30	4140000	47600	.0210
42	105.6	6230000	58900	.0169
43	130.4	9310000	71500	.0140
44	165.0	15000000	91000	.0110
45	215.7	26900000	125000	.0080
46	293.3	48700000	166700	.0060

RESISTANCE WIRE—MANGANIN

270 ohms per circular mil-foot at 68° F.

SIZE A.W.G.	Ohms per Foot	Ohms per Pound	Feet per Pound	Lbs. per 1000 Ft.
10	0.026	0.88	34.8	28.6
12	.041	2.22	54.5	18.2
14	.066	5.62	89.5	11.5
15	.083	9.40	109.0	9.20
16	.103	14.9	139	7.20
17	.133	23.8	179	5.60
18	.168	39.6	226	4.42
19	.203	60.4	279	3.58
20	.263	96.6	353	2.83
21	.332	153	446	2.24
22	.421	247	565	1.77
23	.528	379	709	1.41
24	.668	653	893	1.12
25	.843	983	1123	.89
26	1.068	1580	1429	.70
27	1.339	2380	1786	.56
28	1.700	4020	2273	.440
29	2.114	6250	2857	.350
30	2.700	10100	3623	.276
31	3.409	16100	4566	.219
32	4.219	24700	5656	.177
33	5.357	39500	7194	.139
34	6.801	64000	9091	.110
35	8.598	102000	11490	.087
36	10.80	162000	14490	.069
37	13.36	238000	17860	.056
38	16.87	389000	22220	.045
39	22.13	675000	29410	.034
40	30.00	1240000	40000	.025

CONDUCTOR AND RESISTOR MATERIALS

Kind of Material or Trade Name	Ohms per Circ. Mil-ft. at 68° F.	Temperature Coefficient of Resistance per Degree F.
Advance	294	0.00001
Aluminum	17	.0022
Brass, common	49	.001
high brass	41	
low brass	35	
Carbon	21000	- 0.00028
Chromel	540	
Constantan	294	.000005
Copper, annealed	10.4	.00218
USS	10.55	.002
hard drawn	10.65	.00212
German silver, 18%	198	.00018
Graphite	4800	
Ideal	295	.000005
Iron, pure	60	.0031
cast	540	
wrought	84	
Lead	115	.0023
Lucerno	275	.001
Magnesium, pure	277	.0022
Manganin	270	.00001
Nickel	52	.0027
Nickel silver, 30%	240	.0001
Nichrome II	660	.00013
III	540	.0001
IV	625	.00006
Novar	296	
Platinum	72	.0021
Silver	9.75	.0021
Steel, crucible	115	
galvanized	67	.0017
hard	162	.001
manganese	420	.0005
Tungsten	33.2	.0025
Zinc	38	.0021

ALLOWABLE CURRENT-CARRYING CAPACITIES OF CONDUCTORS IN AMPERES*

Not More Than Three Conductors in Raceway or Cable

(Based on Room Temperatures of 30 C. 86 F.)

Size AWG MCM	Rubber Type RW Type RU (14-6) / Thermo-plastic Type T (14 4/0) Type TW (14-4/0)	Rubber Type RH	Paper / Thermo-plastic Asbestos Type TA / Var-Cam Type V / Asbestos Var-Cam Type AVB	Asbestos Var-Cam Type AVA Type AVL	Impreg-nated Asbestos Type AI (14-8) Type AIA	Asbestos Type A (14-8) Type AA
14	15	15	25	30	30	30
12	20	20	30	35	40	40
10	30	30	40	45	50	55
8	40	45	50	60	65	70
6	55	65	70	80	85	95
4	70	85	90	105	115	120
3	80	100	105	120	130	145
2	95	115	120	135	145	165
1	110	130	140	160	170	190
0	125	150	155	190	200	225
00	145	175	185	215	230	250
000	165	200	210	245	265	285
0000	195	230	235	275	310	340
250	215	255	270	315	335	...
300	240	285	300	345	380	...
350	260	310	325	390	420	...
400	280	335	360	420	450	...
500	320	380	405	470	500	...
600	355	420	455	525	545	...
700	385	460	490	560	600	...
750	400	475	500	580	620	...
800	410	490	515	600	640	...
900	435	520	555	...	...	...
1,000	455	545	585	680	730	...
1,250	495	590	645	...	...	...
1,500	520	625	700	785	...	...
1,750	545	650	735	...	...	...
2,000	560	665	775	840	...	...

NOTES ON THE TWO PRECEDING TABLES

1. **Aluminum Conductors.** For aluminum conductors, the allowable current-carrying capacities shall be taken as 84 per cent of those given in the table for the respective sizes of copper conductor with the same kind of insulation.

2. **Bare Conductors.** If bare conductors are used with insulated conductors, their allowable current-carrying capacity shall be limited to that permitted for the insulated conductor with which they are used.

3. **Application of Table.** For open wiring on insulators and for concealed knob-and-tube work, the allowable current-carrying capacities of Table 2 shall be used. For all other recognized wiring methods, the allowable current-carrying capacities of Table 1 shall be used, unless otherwise provided in this code.

4. **More Than Three Conductors in a Raceway.** Table 1 gives the allowable current-carrying capacity for not more than three conductors in a raceway or cable. If the number of conductors in a raceway or cable is from 4 to 6, the allowable current-carrying capacity of each conductor shall be reduced to 80 per cent of the values in Table 1. If the number of conductors in a raceway or cable is from 7 to 9, the allowable current-carrying capacity of each conductor shall be reduced to 70 per cent of the values in Table 1.

5. **Neutral Conductor.** A neutral conductor which carries only the unbalanced current from other conductors, as in the case of normally balanced circuits of three or more conductors, shall not be counted in determining current-carrying capacities as provided for in the preceding paragraph.

In a 3-wire circuit consisting of two phase wires and the neutral of a 4-wire, 3-phase system, a common conductor carries approximately the same current as the other conductors and is not therefore considered as a neutral conductor.

ALLOWABLE CURRENT-CARRYING CAPACITIES OF CONDUCTORS IN AMERES*

Single Conductor in Free Air

(Based on Room Temperature of 30 C. 86 F.)

Size AWG MCM	Rubber Type R Type RW Type RU (14-6) / Thermo-plastic Type T Type TW	Rub-ber Type RH	Thermo-plastic Asbestos Type TA / Var-Cam Type V / Asbestos Var-Cam Type AVB	As-be tos Var-Cam Type AVA Type AVL	Impreg-nated As-bestos Type AI (14-8) Type AIA	As-bestos Type A (14-8) Type AA	Slow-Burn-ing Type SB / Weath-er-proof Type WP Type SBW
14	20	20	30	40	40	45	30
12	25	25	40	50	50	55	40
10	40	40	55	65	70	75	55
8	55	65	70	85	90	100	70
6	80	95	100	120	125	135	100
4	105	125	135	160	170	180	130
3	120	145	155	180	195	210	150
2	140	170	180	210	225	240	175
1	165	195	210	245	265	280	205
0	195	230	245	285	305	325	235
00	225	265	285	330	355	370	275
000	260	310	330	385	410	430	320
0000	300	360	385	445	475	510	370
250	340	405	425	495	530	...	410
300	375	445	480	555	590	...	460
350	420	505	530	610	655	...	510
400	455	545	575	665	710	...	555
500	515	620	660	765	815	...	630
600	575	690	740	855	910	...	710
700	630	755	815	940	1005	...	780
750	655	785	845	980	1045	...	810
800	680	815	880	1020	1085	...	845
900	730	870	940	....	....	...	905
1000	780	935	1000	1165	1240	...	965
1250	890	1065	1130	....	....	...	....
1500	980	1175	1260	1450	....	...	1215
1750	1070	1280	1370	....	....	...	....
2000	1155	1385	1470	1715	....	...	1405

o. **Ultimate Insulation Temperature.** In no case shall conductors be associated together in such a way with respect to the kind of circuit, the wiring method employed, or the number of conductors, that the limiting temperature of the conductors will be exceeded.

7. **Use of Conductors With Higher Operating Temperatures.** If the room temperature is within 10 degrees C of the maximum allowable operating temperature of the insulation, it is desirable to use an insulation with a higher maximum allowable operating temperature; although insulation can be used in a room temperature approaching its maximum allowable operating temperature limit if the current is reduced in accordance with the table of correction factors for different room temperatures.

8. **Voltage Drop.** The allowable current-carrying capacities in Tables 1 and 2 are based on temperature alone and do not take voltage drop into consideration.

9. **Overcurrent Protection.** If the standard ratings and settings of overcurrent devices do not correspond with the ratings and settings allowed for conductors, the next higher standard rating and setting may be used, but not exceeding 150 per cent of the allowable carrying capacity of the conductor.

10. **Deterioration of Insulation.** It should be noted that even the best grades of rubber insulation will deteriorate in time, so eventually will need to be replaced.

CORRECTION FACTOR FOR ROOM TEMPERATURES OVER 30 C. 86 F.

C.	F.							
40	104	.82	.88	.90	.94	.95	...	...
45	113	.71	.82	.85	.90	.92	...	...
50	122	.58	.75	.80	.87	.89	...	...
55	131	.41	.67	.74	.83	.86	...	...
60	140	...	.58	.67	.79	.83	.91	...
70	158	...	.35	.52	.71	.76	.87	...
75	167	...	...	.43	.66	.72	.86	...
80	176	...	...	.30	.61	.69	.84	..
90	194	...	...	...	.50	.61	.80	...
100	212	...	...	...	...	51	.77	...
120	248	...	...	...	...	..	.69	...
140	284	...	...	...	...	..	.59	..

* 1947 N. E. Code

DIMENSIONS OF RUBBER-COVERED AND THERMOPLASTIC COVERED CONDUCTORS*

Size AWG MCM	Types RF-32, R, RH, RW Approx. Diam. Inches	Types RF-32, R, RH, RW Approx. Area Sq. Ins.	Types TF, T, TW, RU** Approx. Diam. Inches	Types TF, T, TW, RU** Approx. Area Sq. Ins.
18	.146	.0167	.106	.0088
16	.158	.0196	.118	.0109
14	2/64 ins. .171	.0230	.131	.0135
14	3/64 ins. .204*	.0327*	....	.....
12	2/64 ins. .188	.0278	.148	.0172
12	3/64 ins. .221*	.0384*	....	.....
10	.242	.0460	.168	.0224
8	.311	.0760	.228	.0408
6	.397	.1238	.323	.0819
4	.452	.1605	.372	.1087
3	.481	.1817	.401	.1263
2	.513	.2067	.433	.1473
1	.588	.2715	.508	.2027
0	.629	.3107	.549	.2367
00	.675	.3578	.595	.2781
000	.727	.4151	.647	.3288
0000	.785	.4840	.705	.3904
250	.868	.5917	.788	.4877
300	.933	.6837	.843	.5581
350	.985	.7620	.895	.6291
400	1.032	.8365	.942	.6969
500	1.119	.9834	1.029	.8316
600	1.233	1.1940	1.143	1.0261
700	1.304	1.3355	1.214	1.1575
750	1.339	1.4082	1.249	1.2252
800	1.372	1.4784	1.282	1.2908
900	1.435	1.6173	1.345	1.4208
1000	1.494	1.7531	1.404	1.5482
1250	1.676	2.2062	1.577	1.9532
1500	1.801	2.5475	1.702	2.2748
1750	1.916	2.8895	1.817	2.5930
2000	2.021	3.2079	1.922	2.9013

* The dimensions for Type RW conductors; also these dimensions to be used for new work in computing the size of conduit or tubing for combinations of conductors not shown in Table 4.

** Type RU conductors recognized in sizes No. 14 to No. 6. No. 18 to No. 8, solid; No. 6 and larger, stranded.

(* 1947 N. E. Code, Table 13.)

DIMENSIONS OF ASBESTOS-VARNISHED-CAMBRIC INSULATED CONDUCTORS*

Types AVA AVB, and AVL

Size AWG MCM	Type AVA Approx. Diam. Inches	Type AVA Approx. Area Sq. In.	Type AVB Approx. Diam. Inches	Type AVB Approx. Area Sq. In.	Type AVL Approx. Diam. Inches	Type AVL Approx. Area Sq. In.
14	.245	.047	.205	.033	.320	.080
12	.265	.055	.225	.040	.340	.091
10	.285	.064	.245	.047	.360	.102
8	.310	.075	.270	.057	.390	.119
6	.395	.122	.345	.094	.430	.145
4	.445	.155	.395	.123	.480	.181
2	.505	.200	.460	.166	.570	.255
1	.585	.268	.540	.229	.620	.300
0	.625	.307	.580	.264	.660	.341
00	.670	.353	.625	.307	.705	.390
000	.720	.406	.675	.358	.755	.447
0000	.780	.478	.735	.425	.815	.521
250	.885	.616	.855	.572	.955	.715
300	.940	.692	.910	.649	1.010	.800
350	.995	.778	.965	.731	1.060	.885
400	1.040	.850	1.010	.800	1.105	.960
500	1.125	.995	1.095	.945	1.190	1.118
550	1.165	1.065	1.135	1.01	1.265	1.26
600	1.205	1.140	1.175	1.09	1.305	1.34
650	1.240	1.21	1.210	1.15	1.340	1.41
700	1.275	1.28	1.245	1.22	1.375	1.49
750	1.310	1.35	1.280	1.29	1.410	1.57
800	1.345	1.42	1.315	1.36	1.440	1.63
850	1.375	1.49	1.345	1.43	1.470	1.70
900	1.405	1.55	1.375	1.49	1.505	1.78
950	1.435	1.62	1.405	1.55	1.535	1.85
1,000	1.465	1.69	1.435	1.62	1.565	1.93

Note: No. 14 to No. 8, solid, No. 6 and larger, stranded; except AVL where all sizes are stranded.

(* 1947 N. E. Code, Table 17.)

DIMENSIONS OF CONDUIT OR TUBING*

Size	Internal Diameter Inches	Area Square Inches	Size	Internal Diameter Inches	Area Square Inches
1/2	.622	.30	3	3.068	7.38
3/4	.824	.53	3 1/2	3.548	9.90
1	1.049	.86	4	4.026	12.72
1 1/4	1.380	1.50	4 1/2	4.506	15.95
1 1/2	1.610	2.04	5	5.047	20.00
2	2.067	3.36	6	6.065	28.89
2 1/2	2.469	4.79			

(* 1947 N. E. Code, Table 19.)

CONDUIT SIZES

CABLES ABOVE 600 VOLTS, ALSO CONTROL CABLES

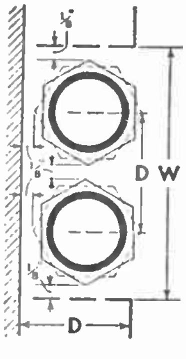
Cables of Equal Diameter

Number of Cables in Conduit	1/2"	3/4"	1"	1 1/4"	1 1/2"	2"	2 1/2"	3"	3 1/2"	4"	4 1/2"	5"
	Nominal Size of Conduit* — Maximum Cable Diameter in Inches											
1	.46	.61	.78	1.03	1.20	1.54	1.84	2.29	2.67	3.01	3.37	3.77
2	.25	.33	.42	.55	.64	.82	.98	1.22	1.42	1.61	1.80	2.02
3	.23	.31	.39	.52	.60	.77	.92	1.15	1.33	1.50	1.68	1.89
4	.20	.26	.33	.44	.51	.65	.78	.97	1.13	1.27	1.42	1.59
5		.22	.28	.37	.43	.55	.66	.82	.95	1.08	1.21	1.35
6		.20	.26	.34	.40	.51	.61	.76	.89	1.00	1.12	1.25
7		.19	.24	.32	.37	.47	.57	.70	.82	.93	1.04	1.16
8			.22	.30	.35	.44	.53	.66	.76	.86	.97	1.08
9			.21	.28	.33	.42	.50	.62	.72	.81	.91	1.02

EXAMPLE: A 1 1/2" conduit will accommodate 3 cables with diam. .52" to .60".

* Conduit sizes are based on a straight run of 200', 100' with 2-90° bends or 50' with 3-90° bends. For installations exceeding these limiting conditions use one or two conduit sizes larger.

SPACE REQUIREMENTS FOR CONDUITS—DIAMETERS IN INCHES



Conduit Sizes	1/2" D	1/2" W	3/4" D	3/4" W	1" D	1" W	1 1/4" D	1 1/4" W	1 1/2" D	1 1/2" W	2" D	2" W	2 1/2" D	2 1/2" W	3" D	3" W	3 1/2" D	3 1/2" W
1/2"	1 1/4	2 5/8	1 3/8	2 7/8	1 1/2	3 1/8	1 11/16	3 1/2	1 13/16	3 3/4	2 1/8	4 3/8	2 7/16	5	2 3/4	5 5/8	3 1/8	6 3/8
3/4"	1 3/8	2 7/8	1 1/2	3 1/8	1 5/8	3 3/8	1 13/16	3 3/4	1 15/16	4	2 1/4	4 5/8	2 9/16	5 1/4	3	6 1/8	3 1/4	6 5/8
1"	1 1/2	3 1/8	1 5/8	3 3/8	1 3/4	3 5/8	1 15/16	4	2 1/16	4 3/8	2 3/8	4 7/8	2 11/16	5 1/2	3	6 1/8	3 3/8	6 7/8
1 1/4"	1 11/16	3 1/2	1 13/16	3 3/4	1 15/16	4	2 1/8	4 3/8	2 1/4	4 5/8	2 9/16	5 1/4	2 7/8	5 7/8	3 1/4	6 5/8	3 9/16	7 1/4
1 1/2"	1 13/16	3 3/4	1 15/16	4	2 1/16	4 1/4	2 1/4	4 5/8	2 3/8	4 7/8	2 11/16	5 1/2	3	6 1/8	3 3/8	6 7/8	3 11/16	7 1/2
2"	2 1/8	4 3/8	2 1/4	4 5/8	2 3/8	4 7/8	2 3/8	4 7/8	2 11/16	5 1/2	3	6 1/8	3 5/16	6 3/4	3 5/8	7 3/8	4	8 1/8
2 1/2"	2 7/16	5	2 9/16	5 1/4	2 11/16	5 1/2	2 7/8	5 7/8	3	6 1/8	3 5/16	6 3/4	3 5/8	7 3/8	3 15/16	8	4 5/16	8 3/4
3"	2 3/4	5 5/8	3	6 1/8	3	6 1/8	3 1/4	6 5/8	3 3/8	6 7/8	3 5/8	7 3/8	3 15/16	8	4 7/16	9	4 3/4	9 5/8
3 1/2"	3 1/8	6 3/8	3 1/4	6 5/8	3 3/8	6 7/8	3 9/16	7 1/4	3 11/16	7 1/2	4	8 1/8	4 5/16	8 3/4	4 3/4	9 5/8	5	10 1/8

VOLTAGE DROP TABLE*

Circuit Footage for 3 Per Cent Drop

Size A.W.G.	3 Amp.	6 Amp.	15 Amp.	20 Amp.	25 Amp.	35 Amp.	50 Amp.	70 Amp.	80 Amp.	90 Amp.	100 Amp.	125 Amp.
18	83											
16	131	66										
14	209	104	42									
12	330	166	66	50								
10	528	264	105	79	63							
8	840	420	168	126	100	72						
6	1336	668	267	200	160	114	80					
4	2125	1062	424	318	255	182	127	91				
3	2680	1340	536	402	321	229	160	114	100			
2	3379	1689	679	507	405	289	202	144	126	112		
1	4262	2131	852	639	511	365	255	182	159	142	127	
0	5372	2686	1074	806	644	460	322	230	201	179	161	128
00	6778	3389	1355	1016	813	581	405	290	254	225	203	162
000	8543	4272	1709	1281	1025	732	512	366	320	284	256	205
0,000		5387	2155	1616	1293	923	646	461	404	359	323	258
250,000			2546	1911	1527	1091	763	545	477	424	381	305
300,000			3055	2291	1833	1309	916	654	572	509	458	366
350,000				2673	2138	1526	1069	763	667	594	534	427
400,000				3055	2444	1746	1222	873	763	679	611	488
500,000					3055	2182	1527	1091	934	848	763	611
600,000						2619	1833	1309	1145	1018	916	733
700,000						3055	2138	1527	1336	1188	1069	855

* Compiled by A. M. Miller, Richmond, Va.

Size A.W.G.	150 Amp.	175 Amp.	225 Amp.	250 Amp.	275 Amp.	300 Amp.	325 Amp.	400 Amp.	450 Amp.	500 Amp.	525 Amp.
00	135										
000	170	146									
0,000	215	184	143								
250,000	254	218	169	152							
300,000	305	261	203	183	166						
350,000	356	305	237	213	194	178					
400,000	407	349	271	244	220	203	188				
500,000	509	436	339	305	277	254	235	190			
600,000	611	523	407	366	333	305	282	229	203		
700,000	71z	611	475	427	389	356	329	267	237	213	
750,000	763	654	509	458	416	381	352	286	254	229	218
800,000	814	698	543	488	444	407	376	305	271	244	232
900,000	916	785	611	550	500	458	423	343	305	275	261
1,000,000	1018	873	679	611	555	509	470	381	339	305	291
1,100,000	1120	960	746	672	611	560	517	420	373	336	320
1,200,000	1222	1047	814	733	666	611	564	458	407	366	349
1,300,000	1324	1134	882	794	722	662	611	496	441	397	378
1,400,000	1425	1222	950	855	777	712	657	534	475	427	407
1,500,000	1527	1309	1018	916	832	763	705	572	509	458	436
1,600,000	1628	1396	1064	976	888	814	752	611	532	488	465
1,700,000	1728	1484	1154	1038	944	864	799	649	577	519	495
1,800,000	1832	1571	1222	1110	1000	916	846	687	611	555	523
1,900,000	1932	1664	1290	1160	1054	966	892	725	645	580	555
2,000,000	2036	1746	1358	1222	1110	1018	940	763	679	611	582

Size A.W.G.	550 Amp.	600 Amp.	650 Amp.	690 Amp.	730 Amp.	770 Amp.	810 Amp.	850 Amp.	890 Amp.	930 Amp.	970 Amp.	1010 Amp.	1050 Amp.
800,000	222												
900,000	250	229											
1,000,000	277	254	235										
1,100,000	305	280	258	243									
1,200,000	333	305	282	265	251								
1,300,000	361	331	305	287	272	258							
1,400,000	388	356	328	309	292	277	264						
1,500,000	416	381	352	332	313	297	282	269					
1,600,000	444	407	376	354	334	339	301	287	274				
1,700,000	472	432	399	376	355	361	320	305	291	279			
1,800,000	500	458	423	398	376	382	339	323	308	295	283		
1,900,000	527	483	446	420	397	403	358	341	325	312	299	287	
2,000,000	555	509	470	442	418	424	377	359	343	328	315	302	291

Notes: Table calculated for 110 volts, direct current. The footages shown are approximate for single-phase and two-phase at unity power factor. For 3-phase the above footage may be increased by approximately 12 per cent.

The following factors may be used for other voltages: 220 volts, multiply by 2; 440 volts, multiply by 4; 550 volts, multiply by 5; 2200 volts, multiply by 20.

For 1 per cent drop allow one-third the footage shown. For 2 per cent drop allow two-thirds the footage shown.

(By Courtesy of International Association of Inspectors.)

Aluminum Solid Wire Hard Drawn

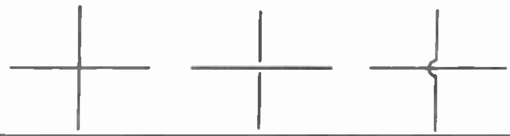
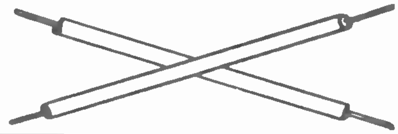
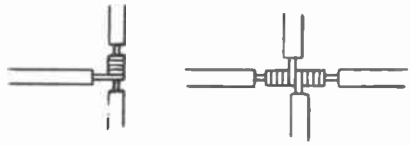
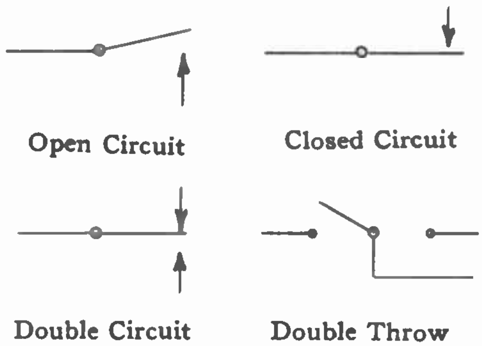
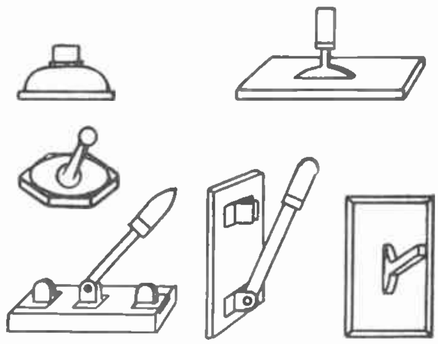
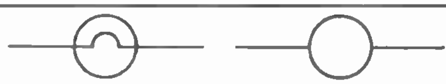
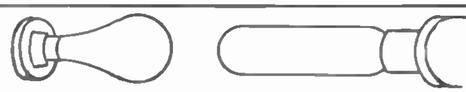
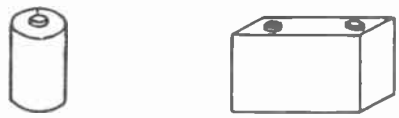
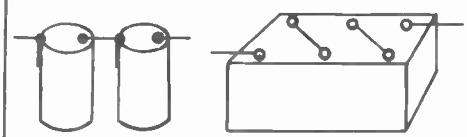
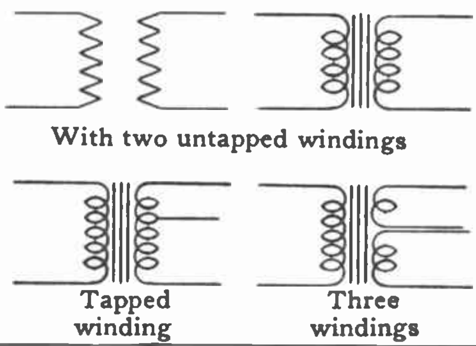
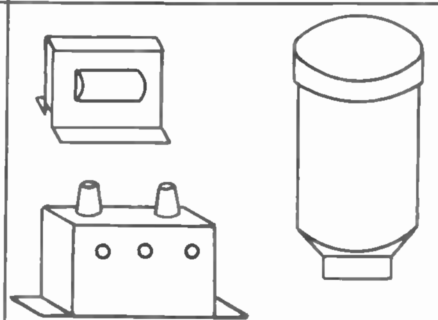
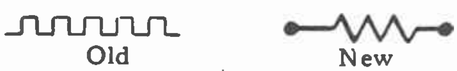
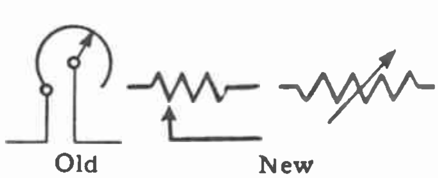
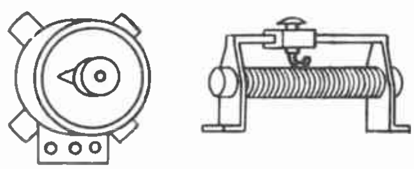
Resistance (61% at 20° C.)

Am. Gauge B. & S. No.	Ohms per 1000 Feet	Ohms per Mile	Feet per Ohm	Ohms per Pound
0000	.0804	.4245	12400.	.000414
000	.101	.5333	9860.	.000656
00	.128	.6758	7820.	.001043
0	.161	.8501	6200.	.001659
1	.203	1.072	4920.	.002636
2	.256	1.352	3900.	.004195
3	.323	1.705	3090.	.006676
4	.408	2.154	2450.	.010617
5	.514	2.714	1950.	.016821
6	.648	3.421	1540.	.026859
7	.817	4.314	1220.	.042755
8	1.03	5.438	970.	.067806
9	1.30	6.864	770.	.107595
10	1.64	8.660	610.	.171465
11	2.07	10.93	484.	.272450
12	2.61	13.78	384.	.433023
13	3.29	17.37	304.	.689730
14	4.14	21.86	241.	1.09708
15	5.22	27.56	191.	1.74555
16	6.59	34.80	152.	2.76589
17	8.31	43.88	120.	4.41782
18	10.5	55.44	95.5	6.99992
19	13.2	69.70	75.7	11.1355
20	16.7	88.18	60.0	17.7155
21	21.0	110.9	47.6	28.1586
22	26.5	139.9	37.8	44.7100
23	33.4	176.4	29.9	71.2819
24	42.1	222.3	23.7	113.400
25	53.1	280.4	18.8	180.255
26	67.0	353.8	14.9	286.806
27	84.4	445.6	11.8	456.211
28	106.0	559.7	9.39	723.676
29	134.0	707.5	7.45	1150.10
30	169.0	892.3	5.91	1828.09
31	213.0	1125.	4.68	2910.66
32	269.0	1420.	3.72	4618.20
33	339.0	1790.	2.95	7342.85
34	428.0	2260.	2.34	11672.4
35	540.0	2851.	1.85	18615.6

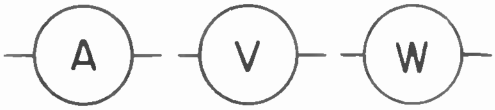
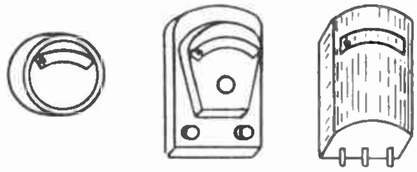
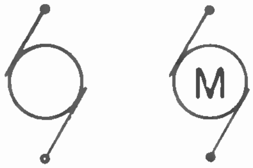
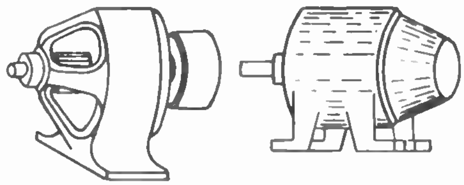
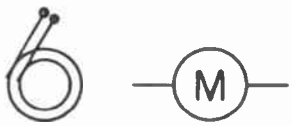
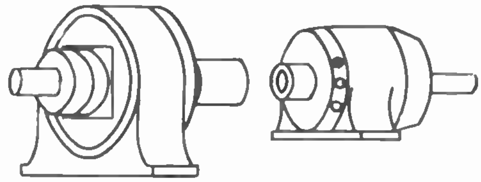
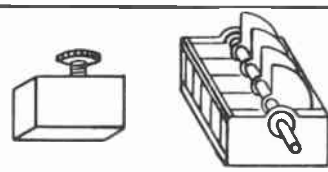
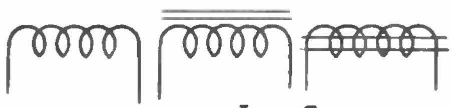
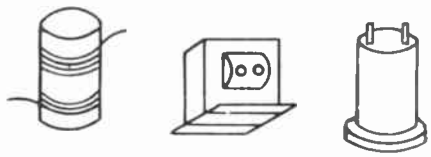
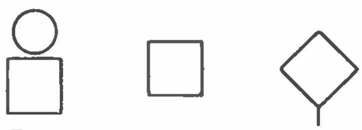
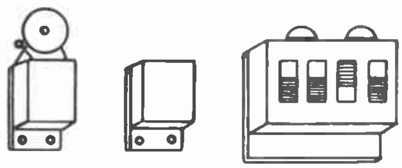
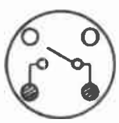
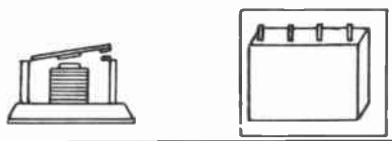
Aluminum and Copper Solid Wire

Dimensions and Weight

Am. Gauge B. & S. No.	Diam. Mils.	AREA Circular Mils. (d²) 1 mil. = .001 inch	AREA Square Mils. (d²x.7854)	Pounds per 1000 Feet Aluminum	Pounds per 1000 Feet Copper	Feet per Pound Aluminum	Feet per Pound Copper
0000	460.000	211600.00	166190.	195.	641.	5.120	1.560
000	409.640	167805.00	131790.	154.	509.	6.490	1.965
00	364.800	133079.40	104520.	122.	403.	8.200	2.480
0	324.860	105534.00	82886.	97.1	320.	10.30	3.125
1	289.300	83694.20	65733.	77.0	253.	12.98	3.950
2	257.630	66373.00	52130.	61.1	202.	16.35	4.950
3	229.420	52634.00	41339.	48.4	159.	20.66	6.290
4	204.310	41742.00	32784.	38.4	126.	26.04	7.930
5	181.940	33102.00	25998.	30.4	100.	32.90	10.00
6	162.020	26250.50	20617.	24.2	79.	41.30	12.65
7	144.280	20816.00	16349.	19.2	63.	52.10	15.88
8	128.490	16509.00	12966.	15.2	50.	65.70	20.00
9	114.430	13094.00	10284.	12.1	39.	82.60	25.06
10	101.890	10381.00	8153.2	9.55	32.	104.8	31.25
11	90.742	8234.00	6467.0	7.57	25.	132.2	40.00
12	80.808	6529.90	5128.6	6.00	20.	166.7	50.00
13	71.961	5178.40	4067.1	4.76	15.7	210.0	63.70
14	64.084	4106.80	3146.9	3.78	12.4	264.5	80.64
15	57.068	3256.70	2557.8	2.99	9.8	334.4	102.1
16	50.820	2582.90	2028.6	2.38	7.9	420.2	126.6
17	45.257	2048.20	1608.6	1.88	6.2	531.9	161.3
18	40.303	1624.30	1275.7	1.495	4.9	668.8	208.3
19	35.890	1288.10	1011.66	1.185	3.9	843.0	256.4
20	31.961	1021.50	802.28	.940	3.1	1063.	322.6
21	28.462	810.10	636.25	.745	2.5	1343.	400.0
22	25.347	642.70	504.78	.590	1.9	1695.	526.3
23	22.571	509.45	400.12	.469	1.5	2132.	666.5
24	20.100	404.01	317.31	.372	1.2	2688.	813.0
25	17.900	320.40	251.64	.294	.97	3402.	1031.
26	15.940	254.01	199.50	.234	.77	4273.	1298.
27	14.195	201.50	158.26	.185	.61	5405.	1640.
28	12.641	159.79	125.50	.147	.48	6802.	2083.
29	11.257	126.72	99.526	.117	.39	8540.	2564.
30	10.025	100.50	78.933	.0924	.31	10808.	3226.
31	8.928	79.71	62.604	.0733	.24	13643.	4167.
32	7.950	63.20	49.637	.0582	.19	17182.	5263.
33	7.080	50.13	39.372	.0461	.15	21692.	6670.
34	6.304	39.74	31.212	.0365	.12	27397.	8333.
35	5.614	31.52	24.756	.0290	.095	34483.	10526.

SYMBOLS USED IN WIRING DIAGRAMS		
NAME OF PART	SYMBOLS	PICTURES
WIRES CROSSING (Not Connected)		
WIRES JOINED OR CONNECTED		
SWITCHES		
LAMPS		
CELLS One, of any type		
BATTERY Two or more cells		
TRANSFORMERS With iron cores		
RESISTOR, FIXED		
RESISTOR, ADJUSTABLE OR VARIABLE RHEOSTATS		

SYMBOLS USED IN WIRING DIAGRAMS

NAME OF PART	SYMBOLS	PICTURES
METERS	 Ammeter Voltmeter Wattmeter	
DIRECT-CURRENT MACHINES	 Generator Motor	
ALTERNATING-CURRENT MACHINES	 Alternator Motor	
FIXED CAPACITOR OR CONDENSER	 Old New	
VARIABLE OR ADJUSTABLE CAPACITOR OR CONDENSER	 Old New	
INDUCTOR, REACTOR OR CHOKE COIL	 Air Core Iron Core	
GROUND CONNECTION		
SIGNALS	 Bell Buzzer Annunciator	
RELAY		

ELECTRICAL DIAGRAMS—WHAT THEY MEAN AND HOW TO READ AND USE THEM

THE EASY WAY TO LEARN

The language of electricity is written in electrical diagrams, and the best and quickest way to learn how to read and draw electrical diagrams is to start right in reading the kind of diagrams used by men in the electrical industry.

Instead of first trying to memorize all the little separate rules and methods that engineers use in making diagrams, then trying to fit these things together later on, it is far better to commence studying complete practical diagrams right in the beginning. Nothing could be better adapted to such study than the diagrams in this book, for they not only represent actual electrical practice, but they have been proved through constant use by hundreds of electrical men working and learning in the Coyne School shops.

SYMBOLS AND PICTURES

Electrical diagrams show wires and other connections between separate electrical devices, such as a lamp and a switch, or may show the connections inside some electrical device, such as those inside a motor. The wires are easily shown by simple lines on the diagram, but it is not always so easy to show the connected devices, such as lamps, switches and motors. These devices might be shown with pictures, but there is a better and simpler way.

The reading of all electrical diagrams is made relatively easy by using **symbols** instead of pictures to represent electrical parts. A symbol is a sort of simplified picture, a kind of sign writing. The difference between symbols and pictures is shown on the two pages at the beginning of the present section, where many common electrical devices are shown both ways.

A picture can show the external appearance of only one particular make or model of an electrical part, and in nearly every case fails to show how the part behaves electrically. Consider the pictures of switches shown on one of the pages of symbols. Except for the knife switches, where the working parts are exposed, any of these switch pictures might represent almost any type of switch—open circuit, closed circuit, double circuit or double throw. But the symbols for the switches indicate quite clearly how the switches work electrically, how they are supposed to open and close electrical circuits. The same differences between symbols and pictures show up with adjustable resistors and with other devices having moving parts.

SYMBOLS

For quite a few electrical parts we have a choice of two or more symbols which mean the same thing. For instance, wires that cross without being connected may be shown in any of three ways. Some engineers and draftsmen use one method, while others use a different one—it's just a matter of personal choice.

Other examples of different symbols for the same thing occur with cells and with batteries. The shorter lines may be of the same thickness as the longer lines, or the shorter ones may be much heavier. Transformers may be shown with zig-zag lines or with loops, resistors may be drawn to look like a dovetail joint or to look like saw teeth. The meaning of a symbol is not altered by the style used, any more than the meaning of words is altered by writing them sometimes slanting, sometimes vertical, and sometimes backhand.

The man who makes the diagram may specify, usually by a note on the diagram, that certain styles of symbols have special meanings on that one diagram. For example, it might be noted that resistors shown like a dovetail indicate those constructed with cast iron "grids," and that those shown by a saw-tooth line indicate those that are wire-wound. But these are special cases and they do not alter the general meanings of the symbols.

Compared with pictures, symbols are easier to draw, are easier to recognize even though roughly or crudely drawn, and with symbols it usually is easier to follow current paths through the parts. As a consequence, practically all electrical diagrams make use of symbols.

WHAT EACH SYMBOL MEANS

Because the symbols shown on the two pages of symbols and pictures are used in so many electrical diagrams you should become well acquainted with the meaning of each of them. The following explanations tell just what each symbol signifies.

Wires Crossing (Not Connected): Wires which are not electrically connected together, but which must cross one another in a diagram, are shown by any of these symbols. The left-hand symbol generally is preferred, especially in engineering work, but the one at the right indicates the crossing most clearly.

Wires Joined or Connected: Wires which are electrically connected together, so that current may flow from one to the other, are shown by these symbols. Note that a small black dot indicates the point of joining.

Switch, Open Circuit: This symbol may indicate a press-button switch or other type normally held open by a spring, and closed by pressing a button or a lever. The switch opens again when the button or lever is released. The circuit in which the switch is connected normally remains open. This type may be called a normally open switch.

Switch, Closed Circuit: This is a switch normally held closed by a spring, and opened by pressing a button or operating a lever. The circuit in which the switch is connected normally remains closed. This type may be called a normally closed switch.

Switch, Double Circuit: This switch has three wire terminals, one connected to the movable blade of the switch, another to the contact point with which the blade is held in contact by a spring, and the third connected to the contact which normally is separated from the movable blade. A circuit normally remains closed between the movable blade and one contact point, and upon pressing the button or lever the connection is shifted to the other contact. This may be called a two-way switch.

Switch, Double Throw: This switch will connect one wire or one line to either of two other wires or lines, depending on which direction the switch handle or blade is moved.

Lamps: Either of these symbols may be used for any style of incandescent lamp. If some other style of lamp is to be indicated, such as a fluorescent type, a note to that effect should be made on the diagram, or else some special symbol should be used and plainly identified.

Cells: A cell is a single unit that produces emf and causes current to flow in a closed circuit. The longer line usually indicates the positive terminal of the cell, although this is not an invariable rule.

Battery: A battery consists of two or more cells which, when connected together in series as indicated by the symbol, deliver more emf or more voltage than a single cell. While the end of the battery shown by the longer line usually is considered to represent the positive terminal, it is better practice to mark the ends with plus (+) and minus (—) signs for polarity. The number of cells shown in the battery symbol does not necessarily indicate the number of cells in the actual battery. A few long and short lines may indicate any number of cells. One end of the symbol may be a long line and the other a short line, both ends may be long lines (this is good practice), or both ends may be short lines.

Transformers: Transformer windings may be indicated either with zig-zag lines or with loops. The zig-zag lines are preferred in commercial and industrial power and light circuits, while the loops are generally used in radio circuits. When using looped lines for the windings, one or more straight lines between the windings indicate an iron core. The absence of such straight lines means an air core. An iron core is assumed when using the symbol consisting of zig-zag lines, since power transformers always have iron cores.

Resistor, Fixed: A fixed resistor is one whose resistance cannot be altered while the resistor is in a circuit and is carrying current. The left-hand symbol, appearing like a dovetail joint, is the one used for resistors in commercial and industrial power circuits. The saw-tooth or zig-zag line is used for resistors in radio circuits. Provided there is no danger of confusing the resistor symbol with the one for transformer windings, the saw-tooth symbol may be used to indicate resistors in any circuit.

Resistor, Adjustable or Variable: An adjustable or variable resistor is one whose value in ohms, or whose resistance, may be altered while the resistor is in use and is carrying current. An adjustable resistor may be called a rheostat. These devices are used for adjusting or varying the voltage and current going to some piece of electrical equipment or to a circuit.

Meters: All kinds of meters are indicated by circles within which are letters identifying the kind of meter. In addition to the symbols shown, a circle with an inclosed "F" would indicate a frequency meter, one with "WH" would indicate a watt-hour meter, one with "MD" would indicate a maximum demand meter, and so on.

Direct-current Machines: Direct-current generators and motors are indicated by circles which represent their commutators, and with diagonal lines which represent the brushes. Without a letter in the circle the symbol usually means a generator or dynamo, although it is common practice to place a "G" within the circle to prevent possible misunderstanding. The letter "M" within the circle indicates a motor.

Alternating-current Machines: An alternator or alternating-current generator is indicated by two concentric circles representing the slip rings and by sloping lines that represent the brushes or collectors. There are so many varieties of alternating-current motors that the symbol is simply a circle with the letter "M" inside. The general type of circuit, the connected wires, and other equipment in the circuit will help to identify many of these simple symbols and to avoid confusion. As an example, there would be three wire connections running to a three-phase alternating-current motor.

Fixed Capacitor or Condenser: An electrostatic condenser is commonly called simply a condenser. Capacitor is the better name, because there are many other kinds of condensers. The left-hand symbol, consisting of two parallel lines, is the one generally used in radio work. The right-hand symbol, indicating the interleaved plates and dielectric of the capacitor, is generally used in commercial and industrial circuit diagrams.

Variable or Adjustable Capacitor or Condenser: Either of these symbols indicates a capacitor whose value or whose capacitance may be altered or changed while the capacitor is working in a live circuit. Both of these symbols originated in radio work, since it is only in this and similar fields that adjustable capacitors are generally used.

Inductor, Reactor or Choke Coil: Any coil or winding which possesses considerable self-inductance and inductive reactance may be shown by these symbols. The looped lines are the standard symbols for inductors or coils both in power diagrams and in radio diagrams.

Ground Connection: A ground connection is a connection either to a conductor that leads into the earth, or to the metallic framework and supports that carry electrical equipment. Two or more ground connections shown by symbols in the same diagram are assumed to be for the same ground, so that there is a continuous conductive path between the grounds shown on the diagram.

Signals: The symbols for bells, buzzers and annunciators are among those most commonly found in wiring diagrams. Other signal symbols will be shown on later sheets of symbols.

Relay: A relay is a switch whose contacts are operated by an electromagnet in which flows current that controls the relay. The contacts are in the same or a separate circuit. Relays often are shown by an outline having the shape of the part to which wire connections are made, and on which the relative positions of terminals are clearly shown.

KINDS OF ELECTRICAL DIAGRAMS

Before commencing the actual reading of electrical diagrams you should understand that different kinds of diagrams are intended for different purposes. Some diagrams are especially helpful when you are installing and wiring electrical apparatus, while others are arranged to help you locate and remedy circuit troubles. Some diagrams show only the external wires and connections between exposed terminals of electrical parts, others show the connections inside the parts.

CIRCUIT DIAGRAMS OR SCHEMATIC DIAGRAMS

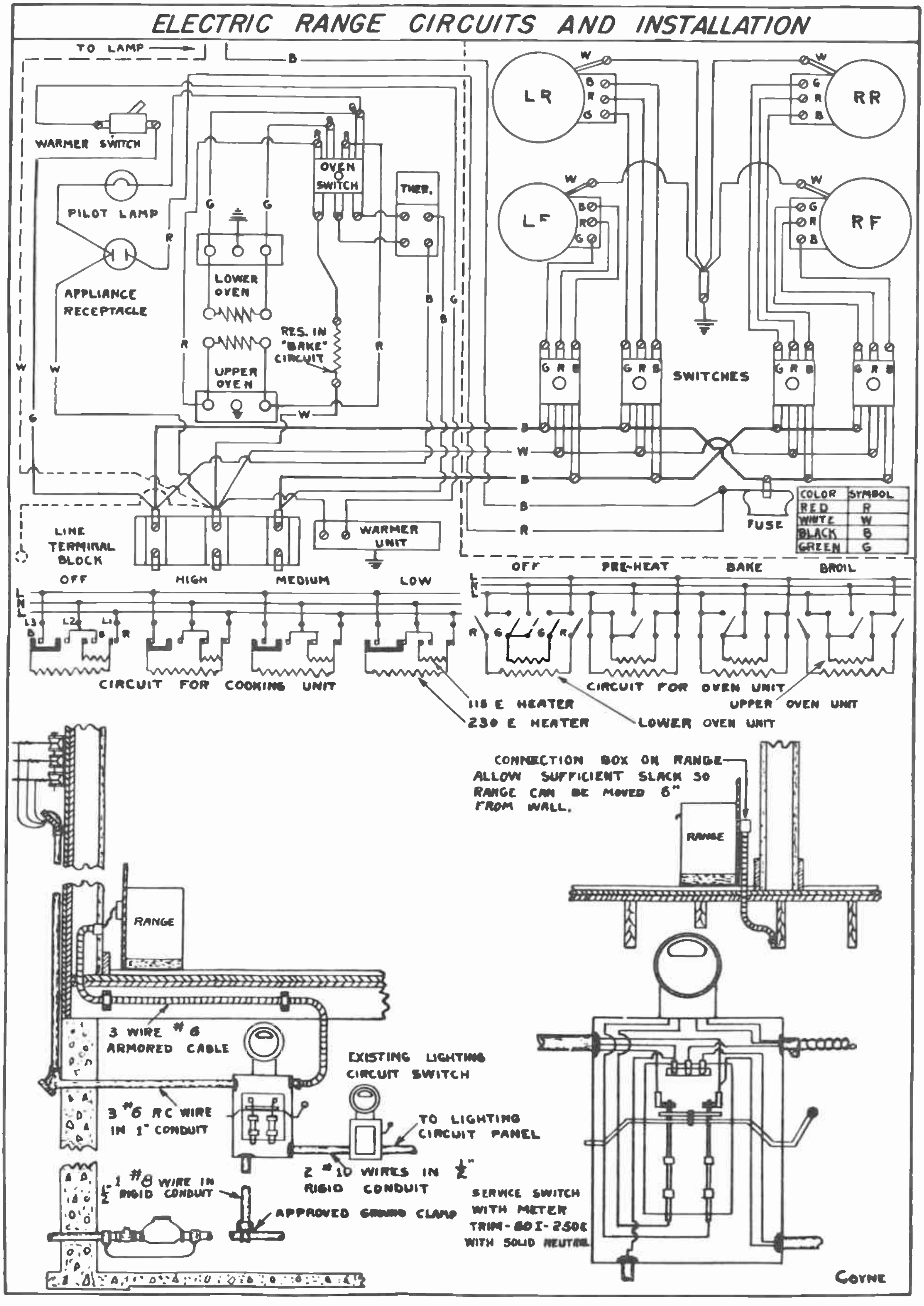
Running all across the following immediately below the large wiring diagram for the electric range, are two smaller diagrams. One is marked "Circuit for Cooking Unit," the other "Circuit for Oven Unit." These are not wiring diagrams, because the heater elements, switches and connections are not in the relative positions that they actually occupy on the range. But, on these **circuit diagrams,** it is easy to trace the paths for electric current all the way from the three main wires marked L, N and L through the switches and through the resistors which are heating elements, and back to the main wires. This style of diagram shows the paths for current very clearly, but does not place the parts in their true relative positions. A **circuit diagram**, which shows electrical circuits, may also be called a **schematic diagram,** because it shows the general scheme of things from the standpoint of electrical action.

It is plain that if you wish merely to check the connections of wires to the terminals of this electric range you will prefer to work with the large **wiring diagram** at the top of the page. But should one burner fail to operate and should you wish to check the paths through which the resistor in this burner gets its current, then it will help greatly to have a **circuit diagram** or **schematic diagram** showing just how the switches operate, and just which resistors should be carrying current for each of the several degrees of heat. At least it would save much time provided you knew how to read a circuit diagram. Before we get through with our studies you will know how to read every such diagram and will be able to correctly interpret its meaning.

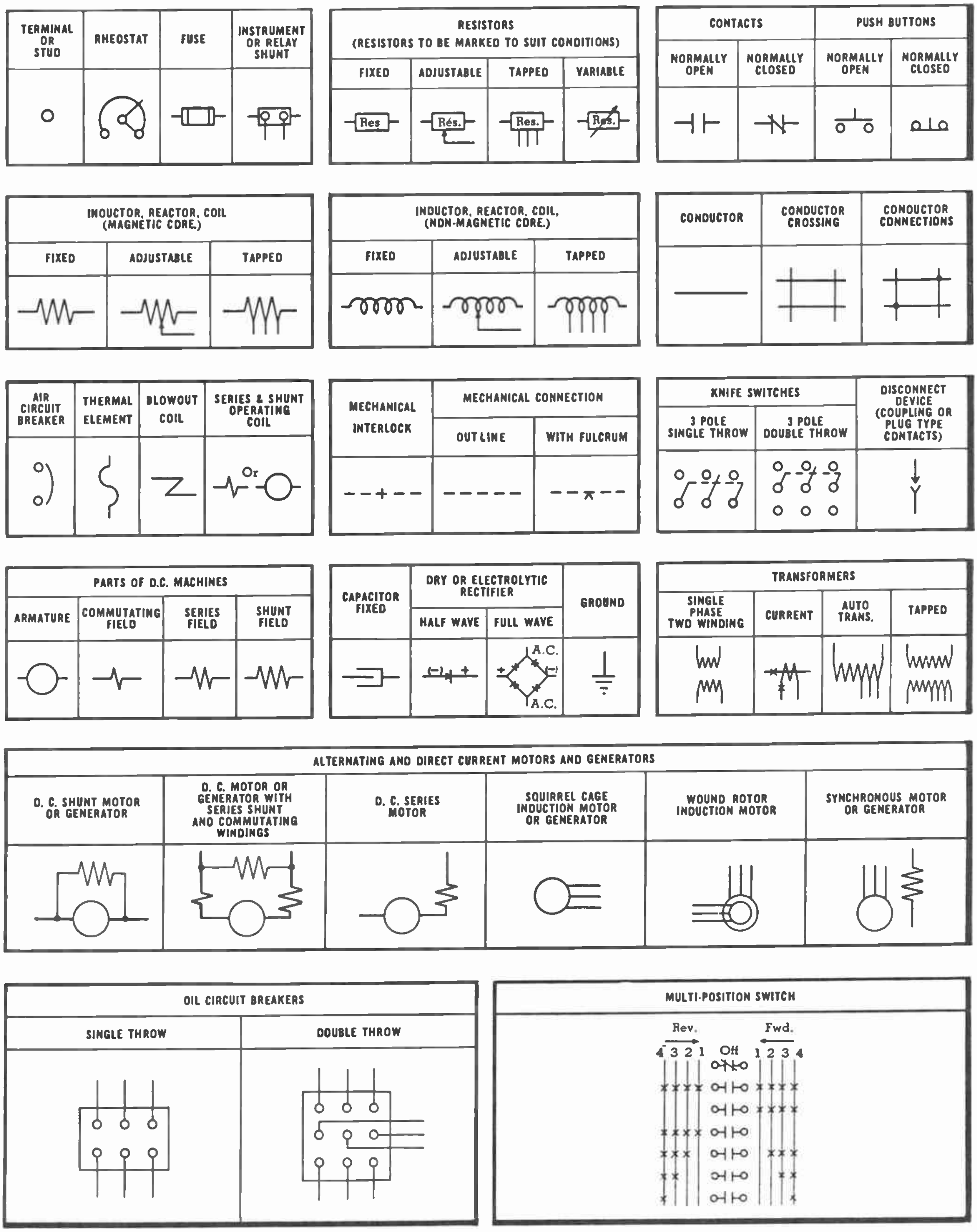
As a general rule the more expert and experienced the electrician the more he prefers to have circuit diagrams or schematic diagrams, and the less he depends on wiring diagrams. After getting acquainted with electrical apparatus in a general way, and when you have a particular piece of apparatus right in front of your eyes, it is not difficult to follow the wiring between exposed terminals. But no one can follow internal wiring without either taking the thing apart or having a good circuit diagram. With such a diagram it becomes easy to test for opens, high resistances, shorts and grounds by connecting your circuit tester to the exposed terminals--and to know from test indications just what is wrong inside the part on which you are working.

PICTORIAL DIAGRAMS

Sometimes a wiring diagram is a **pictorial diagram,** meaning that it consists of pictures showing the external appearance of the parts and of the wiring connections between them. On page 64, in the lower left-hand corner, the range installation diagram is a pictorial diagram. This diagram shows pictures of how conduit (pipe for enclosing wires) and armored cable (flexible metal covering for wires) are to be run between the electric range, the meter box, the switch box, the ground connection, and the outdoor service connection for the wires of the electric power company.


ELECTRIC RANGE CIRCUITS AND INSTALLATION
TO LAMP
WARMER SWITCH
PILOT LAMP
APPLIANCE RECEPTACLE
LOWER OVEN
UPPER OVEN
RES. IN "BAKE" CIRCUIT
OVEN SWITCH
THER.
LR
RR
LF
RF
SWITCHES
FUSE
LINE TERMINAL BLOCK
WARMER UNIT
COLOR | SYMBOL
RED | R
WHITE | W
BLACK | B
GREEN | G
OFF
HIGH
MEDIUM
LOW
CIRCUIT FOR COOKING UNIT
OFF
PRE-HEAT
BAKE
BROIL
CIRCUIT FOR OVEN UNIT
UPPER OVEN UNIT
115 E HEATER
230 E HEATER
LOWER OVEN UNIT
CONNECTION BOX ON RANGE
ALLOW SUFFICIENT SLACK SO RANGE CAN BE MOVED 6" FROM WALL.
RANGE
RANGE
3 WIRE #6 ARMORED CABLE
3 #6 RC WIRE IN 1" CONDUIT
EXISTING LIGHTING CIRCUIT SWITCH
TO LIGHTING CIRCUIT PANEL
2 #10 WIRES IN ½" RIGID CONDUIT
1 #8 WIRE IN ½ RIGID CONDUIT
APPROVED GROUND CLAMP
SERVICE SWITCH WITH METER TRIM-80I-250E WITH SOLID NEUTRAL
COYNE

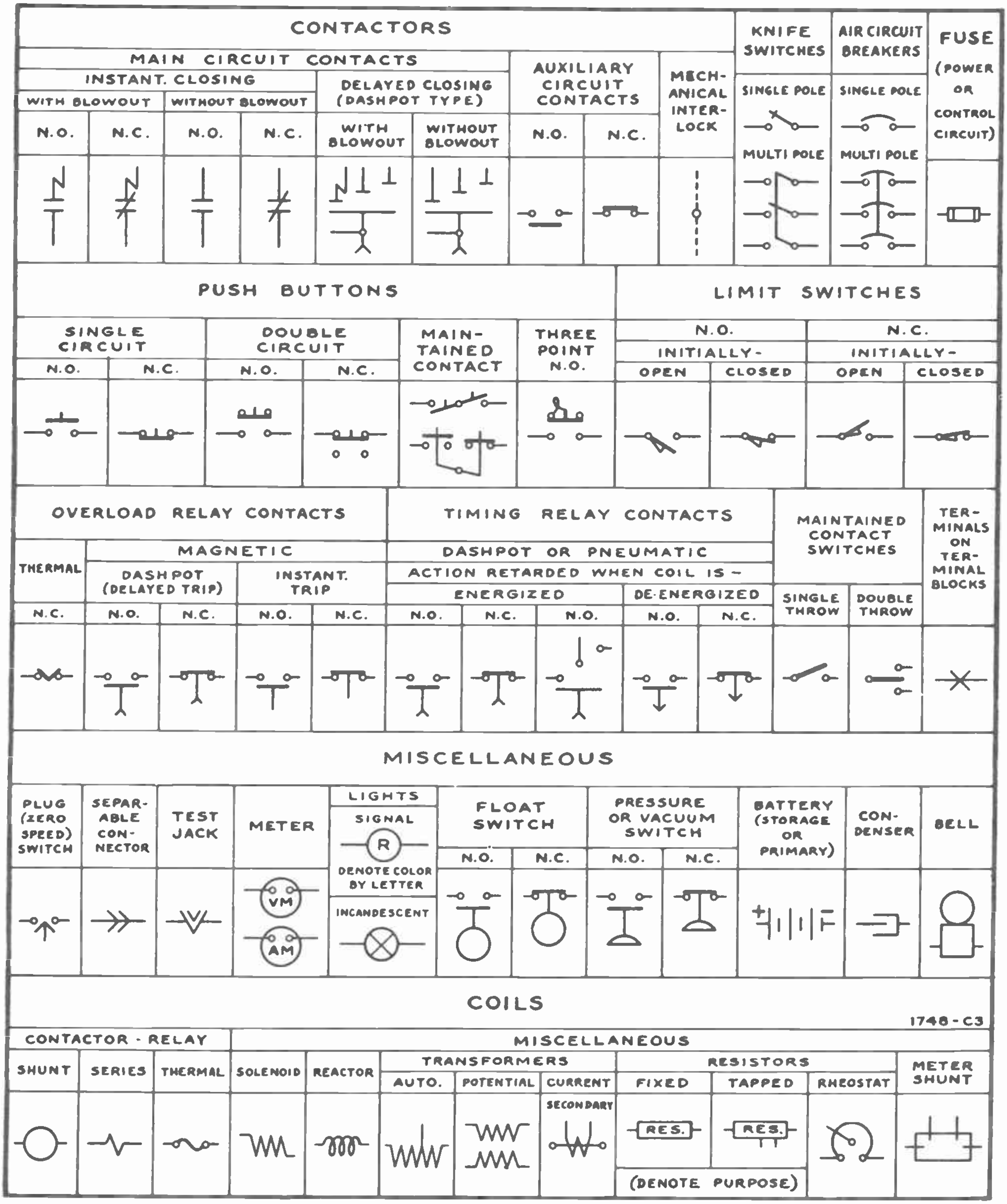
FUNDAMENTAL ELECTRICAL SYMBOLS



SYMBOLS COMMONLY USED FOR ONE LINE WIRING DIAGRAMS

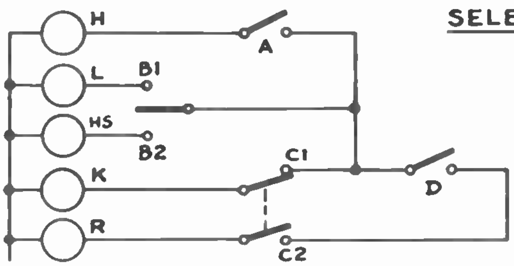
- Squirrel Cage Motor
- Synchronous Motor
- 3-Phase "Wye" Connection
- 3-Phase "Delta" Connection
- Wound Rotor Induction Motor
- D-C. Motor
- Shunt Field
- Series Field
- 1-Phase Power Transformer
- 3-Phase Power Transformer, Connected "Delta-Delta"
- 3—Single Phase Transf. in 3-Ph. Bank, Grounded Neutral
- Potential Transformer
- Current Transformer
- Oil Circuit Breaker, Automatic, Single Throw
- Oil Circuit Breaker, Non-Automatic
- Oil Circuit Breaker, Double Throw
- Oil Circuit Breaker, Truck Type
- Air Circuit Breaker, Automatic
- Air Circuit Breaker, Non-Automatic
- Air Circuit Breaker, Motor Operated
- Air Circuit Breaker, Solenoid Operated
- Disconnecting Switch, Single Throw
- Disconnecting Switch, Gang Operated
- Disc. Sw., Single Blade, Double Throw
- Automatic Throw-Over
- Disconnecting Fuse
- Reactor
- Resistor
- Static Condenser
- Valve Type Lightning Arrester
- Rheostat, Hand Operated
- Rheostat, Motor Operated
- Shunt
- Fuse
- Oil Fuse
- Battery
- Rectifier
- Ground
- Pothead, Non-Disconnecting
- Magnetic Contactor
- Ammeter with Current Transformer
- Ammeter (A), Voltmeter (V), Power Factor Meter (P.F.), etc. with Current and Potential Transformers
- Ammeter (A), Voltmeter (V), Wattmeter (W), etc. with Transformers, Overcurrent and Under-voltage Relays
- Auto-Transformer Motor Starter

Standard Line Diagram Symbols



Standard Line Diagram Symbols

SELECTOR SWITCH AND ACCOMPANYING TARGET TABLE

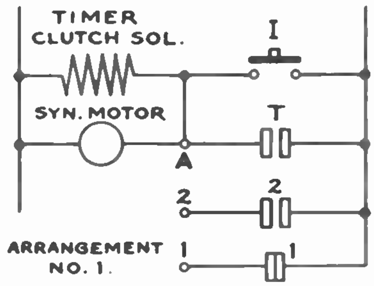


X - INDICATES CONTACTS CLOSED

DOUBLE CIRCUIT UNITS

FUNCTION	A	B1	B2	C1	C2	D
OFF				X		
HIGH	X		X	X		X
LOW		X			X	X
TORQUE					X	X

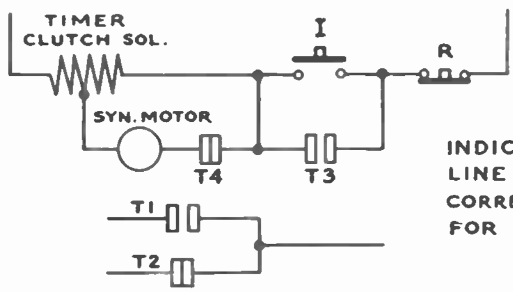
MICROFLEX TIMER



WITH EACH TIMER INDICATE EAGLE SIGNAL ARRANGEMENT NUMBER AND SHOW THE TARGET TABLE FOR THAT ARRANGEMENT:

SEQUENCE	CONTACT I	T	1	2
POWER OFF			X	
P. B. CLOSED	X	X		X
TIMING		X		X
TIMED OUT			X	

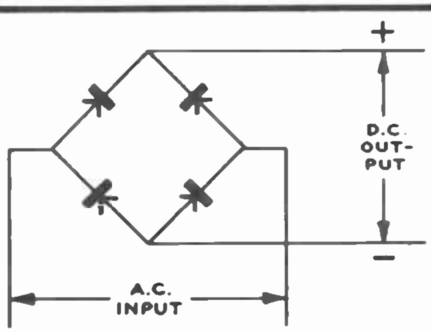
G.E. TIMER (CR 2820-1099)



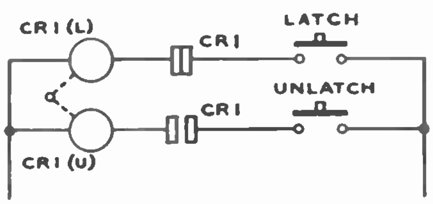
INDICATE ON OR WITH LINE DIAGRAM THE CORRECT TARGET TABLE; FOR EXAMPLE :

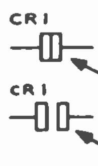
SEQUENCE	CONTACT T1	T2	T3	T4	I	R
POWER OFF		X		X		X
P. B. CLOSED		X	X	X	X	X
TIMING		X	X	X		X
TIMED OUT	X		X			X
RESET		X		X		

FULL WAVE RECTIFIER



MECHANICALLY HELD CONTACTORS





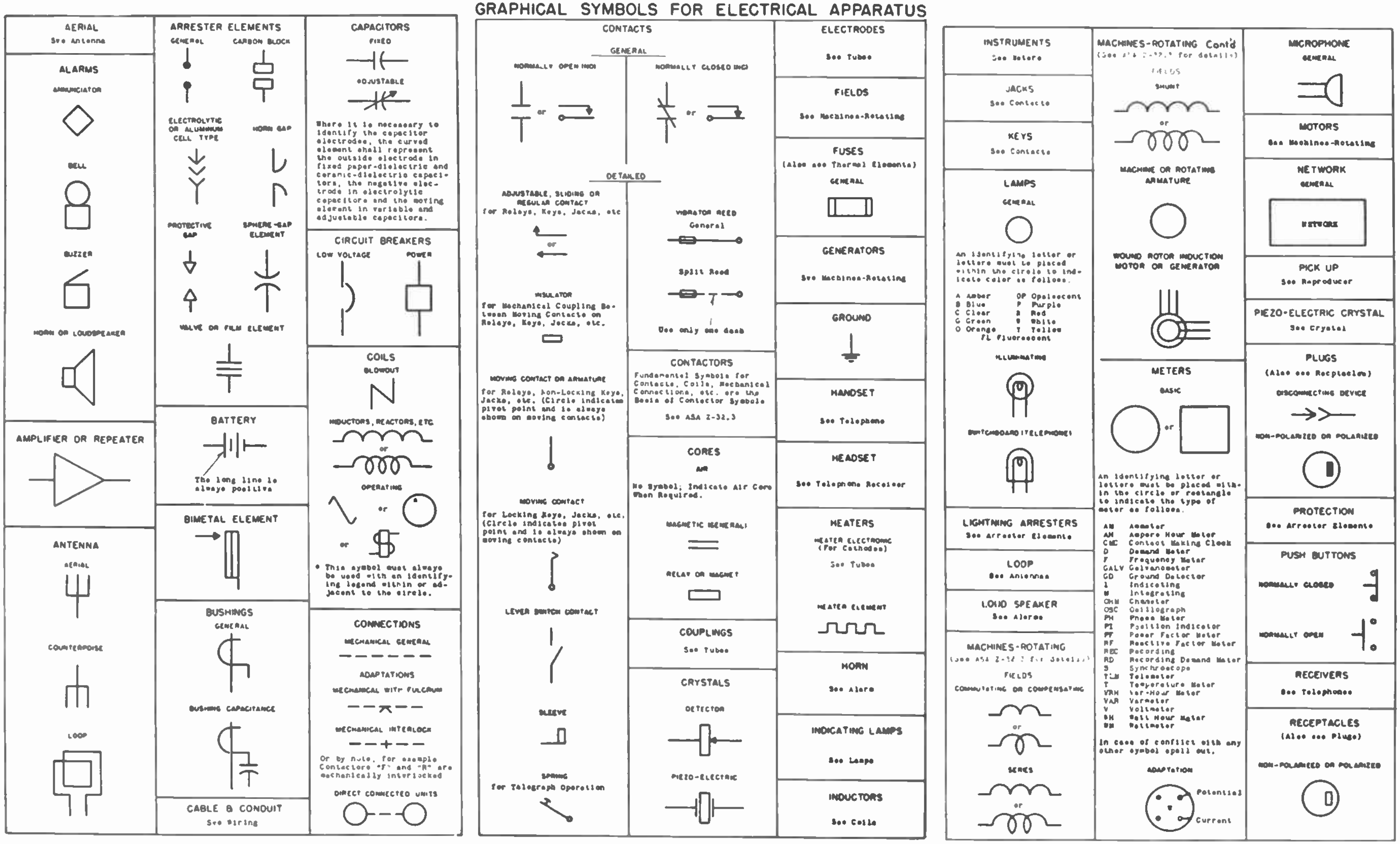
EACH INITIALLY CLOSED CONTACT SHOWN THUS.

EACH INITIALLY OPEN CONTACT SHOWN THUS.

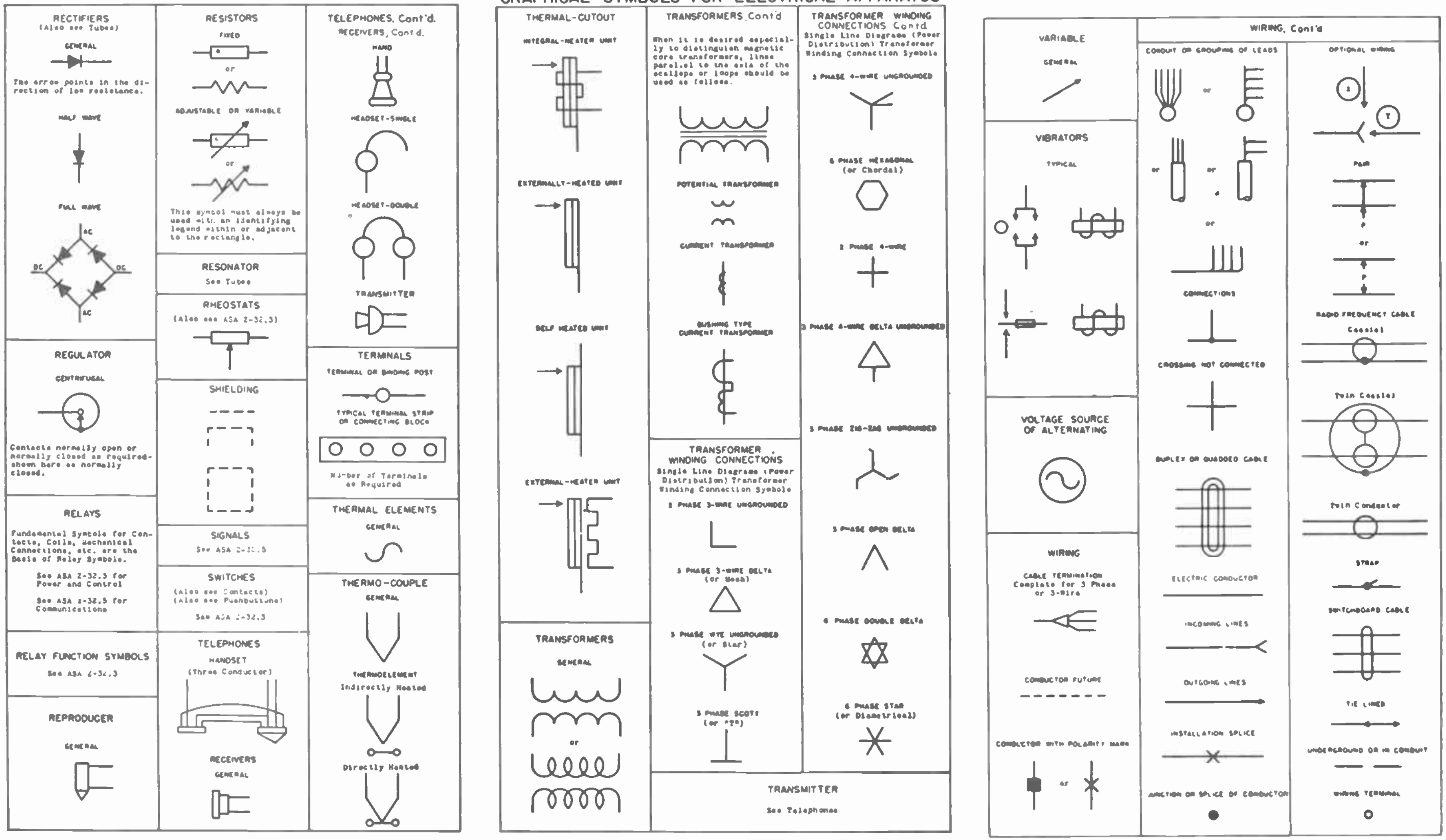
THIS RELAY IS SHOWN IN THE POSITION OBTAINED BY ENERGIZING COIL CR1 (U) LAST.

1748-C8.

GRAPHICAL SYMBOLS FOR ELECTRICAL APPARATUS



GRAPHICAL SYMBOLS FOR ELECTRICAL APPARATUS



American Standard

Rotation, Connections and Terminal Markings for Electrical Apparatus

1.0 Electric Power Apparatus

1.1 GENERAL

1.105 General Purpose

The purpose of applying markings to the terminals of electric power apparatus according to a standard is to aid in making up connections to other parts of the electric power system and to avoid improper connections which may result in unsatisfactory operation or damage.

1.110 Precautions

Though this system of terminal markings with letters and subscript numerals gives information facilitating the connecting of electric power apparatus, there is the possibility of finding terminals marked without system or according to some system other than standard. There is a further possibility that the internal connections may have been changed or that errors may have escaped detection. It is advisable, therefore, before connecting motors, generators, transformers, etc., to power supply systems, to make the usual check tests for phase rotation, phase relation, polarity, and equality of voltage.

1.115 Location of Markings

The markings are placed on or directly adjacent to terminals to which connections must be made from outside circuits or from auxiliary devices which must be disconnected for shipment. They are not intended to be used for internal machine connections.

NOTE—While certain locations of markings on a machine have advantages, and certain terminal groupings simplify or unify the making of connections, a different set of considerations from those covered by this project determines the preferred locations.

1.120 Markings

The markings consist of a capital letter of the alphabet followed by a subscript numeral (Arabic).

1.125 Significance of the Terminal Letter

The letter indicates the character or function of the winding which is brought to the terminal. 1.510 gives the terminal letters assigned to the different types of windings and their functions.

1.130 Significance of the Subscript Numeral

1. Subscript 0 (Zero)

A terminal letter followed by the subscript numeral 0 designates a neutral connection.

*2. Subscript Numerals on Terminals of All A-c Machines Except Polyphase Induction Motors

(a) The subscript numerals 1, 2, 3, etc., indicate the order in which the voltages at the terminals reach their maximum positive values (phase sequence) with clockwise shaft rotation when facing the connection end of the coil windings; hence for counter-clockwise shaft rotation (not standard) when facing the same end, the phase sequence will be 1, 3, 2.

(b) In a synchronous converter, the sequence of the subscript numerals 1, 2, 3, 4, 5, and 6 applied to the collector ring terminals M_1, M_2, M_3, M_4, M_5, and M_6 indicates that when the transformer leads on which phase sequence is 1, 2, 3, 4, 5, and 6 are connected to correspondingly numbered collector ring terminals on which the phase sequence is 1, 2, 3, 4, 5, and 6, the shaft rotation of the converter will be clockwise when viewed from the direct-current or commutator end.

*Terminal markings for polyphase induction motors will be determined by the rules under heading 3.7 Polyphase Induction Motors.

AMERICAN STANDARD

3. SUBSCRIPT NUMERALS ON TERMINALS OF D-C MACHINES AND CONVERTERS

(a) The markings on the terminals of a d-c machine will indicate the relation of circuits within the machine. All subscript numerals must be determined on the following fundamental basis which is advanced for the single purpose of selecting uniform subscript numbers:

The subscript numerals of all the terminals of d-c machines shall be selected so that with current direction in any single excitation winding from a lower to a higher subscript numeral, the voltage generated (counter emf in a motor) in the armature from this excitation shall, for counter-clockwise rotation, make armature terminal A_1 positive and A_2 negative.

NOTE—Machines with terminals numbered in accordance with the above standard can be connected as shown in diagrams in 3.105 and 3.110 for d-c generators, and in 3.205, 3.210 and 3.215 for d-c motors. The connections shown are for accumulative series fields. For differential connection of the series fields no change should be made on the field leads or terminal markings on the machine, but the connection of the series field to the armature should be shown reversed. The polarities shown on the generator diagrams, while preferred, are not standardized, and when convenience, sound engineering or sound economics so dictates, it is permissible to reverse the polarities of all terminals, thereby maintaining standard rotation. Polarity markings may be shown on motor diagrams, at the discretion of the manufacturer.

(b) In accordance with the fundamental basis, a standard rotation d-c motor or generator (as defined in Section 1.3, Rotor Rotation and Phase Sequence), with a single field winding will have current flow in both armature and field circuits in the same direction with respect to the subscript numeral sequence. Any other accumulative field winding will have current flow with respect to its numeral sequence in the same direction as the current in the main field winding. Any differential field winding will have current direction with respect to its subscript numeral sequence in the opposite direction to the current flow in the main field.

4. SUBSCRIPT NUMERALS ON TERMINALS OF TRANSFORMERS

(a) On single-phase transformers the subscript numerals indicate the polarity relation between terminals of the H winding and the other windings. Thus, during that part of the alternating-current cycle when H winding terminal H_1 is positive (+) with respect to H_2 then during the same part of the cycle the X winding terminal X_1 is positive with respect to X_2. The idea is further carried out in single-phase transformers having tapped windings, by so applying to the taps the subscript numerals 1, 2, 3, 4, 5, etc., that the potential gradient follows the sequence of the subscript numerals.

NOTE—When one winding of a transformer receives energy over the connecting leads, and another winding delivers energy to its connected circuit, the relation of current flow in the windings is reversed with respect to the polarity of the voltage at the terminals. Therefore, it is important to take note of the difference between the practice in applying subscript numerals to direct-current generators and motors where the subscript numerals are assigned according to direction of current flow, and to the case of single-phase transformers, where subscript numerals are assigned according to the terminal voltage.

(b) In the case of polyphase transformers, the terminal subscript numerals are so applied that if the phase sequence of voltage is in the time order H_1, H_2, H_3, etc., on the H winding terminals, it is in the time order X_1, X_2, X_3, etc., on the X winding terminals, and also in the time order Y_1, Y_2, Y_3, etc., on the third winding terminals, etc.

NOTE—Terminal markings of polyphase transformers afford information on how phase rotation is carried through the transformer, but do not disclose completely the phase relations between correspondingly numbered terminals. Consequently, additional information on internal connections is required before polyphase transformers can be safely paralleled.

1.140 Definition of Phase Sequence

Phase sequence is the order in which the voltages successively reach their maximum positive values between terminals.

1.150 Direction of Rotation of Vectors

Vector diagrams should be drawn so that advance in phase of one vector with respect to another is in the counter-clockwise direction. See Fig. 1 in which vector 1 is 120 degrees in advance of vector 2 and the phase sequence is 1, 2, 3. (See 1.140.)

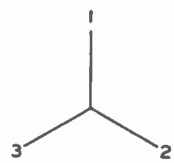


Fig. 1.

1.3 ROTOR ROTATION AND PHASE SEQUENCE

1.305 Direction of Rotation

1. (a) Standard direction of rotation for a-c generators is clockwise when facing the end of the machine opposite the drive.

(b) Standard direction of rotation for all a-c single-phase, all synchronous motors, and all universal motors shall be counter-clockwise when facing the end of the machine opposite the drive.

2. (a) The standard direction of rotation for d-c generators is clockwise when facing the end

of the machine opposite the drive (usually the commutator end).

(b) The standard direction of rotation for d-c motors is counter-clockwise when facing the end opposite the drive (usually the commutator end).

3. Unless otherwise specified, standard machines will be connected for standard direction of shaft rotation.

NOTE I—Any d-c machine can be used either as a generator or as a motor if the field design is suitable (consult manufacturer regarding this). For desired direction of rotation, connection changes may be necessary. The conventions for current flow in combination with the standardization of opposite directions of rotation for d-c generators and d-c motors work out so that any d-c machine can be called "generator" or "motor" without change in terminal markings.

NOTE II—Motor-generator sets consist of two or more machines (a-c or d-c or both) coupled together mechanically. When two machines only are coupled together at their *drive ends*, standard rotations of both machines as given in paragraphs 1(a) and (b) and 2(a) and (b) will apply to the motor-generator set without change in standard connections. When two or more machines are coupled together not at their drive ends, standard rotations as given in paragraphs 1(a) and (b) and 2(a) and (b) will not apply to all machines in the set. Hence, changes in standard connections will be necessary on the off-standard rotation machines. For this reason, it is recommended that on all motor-generator sets the correct direction of rotation be clearly indicated on the set itself.

NOTE III—This rule does not apply to two-phase and three-phase induction motors as most applications on which they are used are of such a nature that either or both directions of shaft rotation may be required, and the phase sequence of the power lines is rarely known.

1.310 Phase Sequence

The order of numerals on terminal leads does not necessarily indicate the phase sequence, but the phase sequence is determined by the direction of shaft rotation relative to the connection end of the coil winding. (See 1.130.)

1.320 Reversal of Rotation, Polarity, and Phase Sequence

1. Alternating-current generators driven counter-clockwise when facing the connection end of the coil windings will generate without change in connections, but the terminal phase sequence will be 1, 3, 2.

2. Synchronous condensers and synchronous motors may be operated with counter-clockwise shaft rotation viewed from the connection end of the coil windings by connecting them to leads in which the phase sequence is 1, 2, 3, in the following manner:

Power Leads	1, 2, 3
Machine Terminals	1, 3, 2

3. Direct-current generators, with connections properly made up for standard shaft rotation (clockwise), will not function if driven counter-clockwise as any small current delivered by the armature tends to demagnetize the fields and thus prevent the armature from delivering current. If the conditions call for reversed shaft rotation, connections should be made up with either the armature leads transposed or the field leads transposed.

4. The polarity of a direct-current generator, with accompanying direction of current flow in the several windings, is determined by the "N" and "S" polarity of the residual magnetism. An accident or special manipulation may reverse this magnetic polarity. Though the generator itself will function as well with either polarity, an unforeseen change may cause disturbance or damage when the generator is connected to other generators or devices.

5. The direction of shaft rotation of d-c motors depends on the relative polarities of the field and armature and, therefore, if the polarities of both are reversed, the direction of rotation will be unchanged. Since the field excitation of motors is obtained from an external source, residual magnetism has no practical effect on polarity.

6. Reversal of the shaft rotation of a direct-current motor is obtained by a transposition of the two armature leads, or by a transposition of the field leads. With such reversed shaft rotation (clockwise), when the polarity of supply makes the direction of the current in the armature from terminal 2 to terminal 1, it will be flowing in the field windings from terminal 1 to terminal 2 and vice versa.

7. With synchronous converters, the practice of alternating-current starting eliminates residual magnetism as the factor determining the direct-current polarity. Proper polarity for connection to other apparatus is, therefore, secured either by separate excitation of the field, or by special manipulation of a switch which permits the converter to reverse its direct-current polarity, thus correcting a start with wrong polarity.

8. Synchronous converter shaft rotation, when viewed from the commutator end, may be changed to a counter-clockwise direction by reversing the "shunt" and "series" fields and the phase sequence of the applied alternating voltages.

NOTE I—Consideration must be given to the effect on the direct-current brush gear of a change in direction of shaft rotation. This gear is usually suitable for one direction of shaft rotation only.

NOTE II—The reversal of the phase sequence of the voltages applied to the converter by the X winding of a three-phase to six-phase transformer may be accomplished by either of two methods:

(1) Connect H winding leads as follows:

Power leads	1, 2, 3
Transformer H winding leads	3, 2, 1

and connect transformer X winding leads as follows:

Transformer X winding leads	1,	2,	3,	4,	5,	6
Converter rings	M_1,	M_2,	M_3,	M_4,	M_5,	M_6

(2) Connect transformer H winding leads to systems in which phase sequence is 1, 2, 3, as follows:

Line	1, 2, 3
Transformer H winding leads	1, 2, 3

and connect transformer X winding leads as follows:

Transformer X winding leads	2,	3,	4,	5,	6,	1
Converter rings	M_6,	M_5,	M_4,	M_3,	M_2,	M_1

AMERICAN STANDARD

1.5 CONNECTION DIAGRAMS

1.505 Application of Terminal Markings

1. To illustrate further the application of the terminal markings with letters and subscript numerals adopted as standard for electric power apparatus, and described herein, there follow illustrations of the application of these markings to a selection of the most common cases of:

(a) D-c generators. (See 3.105-3.115.)
(b) D-c motors. (See 3.205-3.215.)
(c) A-c generators and synchronous motors. (See 3.305.)
(d) Single-phase motors. (See 3.505-3.510.)
(e) Polyphase induction motors. (See 3.705-3.745.)
(f) Synchronous converters. (See 3.905-3.915.)
(g) Constant potential transformers. (See 5.105-5.950.)
(h) Feeder voltage regulators. (See 6.105-6.110.)
(i) Industrial control. (See 7.105-7.110.)
(j) Instrument transformers. (See 8.110-8.130.)
(k) Reactors. (See 9.110.)
(l) Attachment plugs. (See Sec. 15.)

2. By following the standard conventions and illustrations, diagrams can be easily derived for further cases.

3. Terminal letters assigned to different types of windings and their functions are given in 1.510.

1.510 Terminal Letters Assigned

These markings are used only for terminals to which connection must be made from outside circuits or from auxiliary devices which must be disconnected for shipment. They are not intended to be used for internal machine connections.

The approved methods of applying these markings to various types of apparatus and control are shown in the following sections, and the significance of the subscript numerals is given in 1.130.

ROTATING APPARATUS AND CONTROL
(EXCLUSIVE OF RAILWAY MOTORS)

Booster Field	BF_1, BF_2
Brake	B_1, B_2, B_3, etc.
Brush on Commutator (Armature)	A_1, A_2, A_3, etc.
*Brush on Collector Ring (Except d-c field)	M_1, M_2, M_3, etc.
Capacitor	J_1, J_2, J_3, etc.
Dynamic Braking Resistor	DR_1, DR_2, DR_3, etc.
Field (Commutating)	C_1, C_2
Field (Series)	S_1, S_2
Field (Shunt)	F_1, F_2
Line	L_1, L_2, L_3, etc.
Resistance (Armature and Miscellaneous)	R_1, R_2, R_3, etc.
Resistance (Shunt Field Adjusting)	V_1, V_2, V_3, etc.
Shunt Brake Resistor	BR_1, BR_2, BR_3, etc.
*Stator	T_1, T_2, T_3, etc.
Equalizing Lead	(equality sign)
Neutral Connection	Terminal letter with subscript numeral 0

*For alternating current only.

On a d-c machine, when an armature lead passes through the commutating, compensating, or series field or any combination of these fields before being brought out for connection to the externa. circuit, the terminal marking of this lead shall be an "A", provided all internal connections are permanently made and that no parallel circuit, such as an equalizer, is also brought out for connection to an external circuit. If parallel circuits are brought out, the one used as an equalizer should be marked with an equality sign =, and all other leads not used as equalizers shall be marked with the letter or letters designated for the winding or windings to which the leads are connected.

TRANSFORMERS

Winding Identification	Lead Markings	Winding Designation
Winding No. 1	H_1, H_2, H_3, etc.	H Winding
Winding No. 2	X_1, X_2, X_3, etc.	X Winding
Winding No. 3	Y_1, Y_2, Y_3, etc.	Y Winding
Winding No. 4	Z_1, Z_2, Z_3, etc.	Z Winding

RAILWAY MOTORS

Armature (connected to brush holder)	A
Armature (connected to brush holder or to commutating pole)	AA
Main Field	F, FF
Field Control Lead	M
Additional Field Control Lead	MM
When commutating field windings are not permanently connected to the armature, the external leads shall be marked	C, CC
Compensating field	D, DD

SYMBOLS FOR WIRING PLANS

GENERAL OUTLETS

	CEILING	WALL
Outlet		
Capped Outlet		
Drop Cord		
Electrical Outlet—for use when confused with columns, plumbing symbols, etc.		
Fan Outlet		
Junction Box		
Lamp Holder		
Lamp Holder with Pull Switch		
Pull Switch		
Outlet for Vapor Discharge Lamp		
Exit Light Outlet		
Clock Outlet (Lighting Voltage)		

CONVENIENCE OUTLETS

- Duplex Convenience Outlet
- Convenience Outlet other than Duplex. 1=Single, 3=Triplex, etc.
- Weatherproof Convenience Outlet
- Range Outlet
- Switch and Convenience Outlet
- Radio and Convenience Outlet
- Special Purpose Outlet (describe in specifications)
- Floor Outlet

SWITCH OUTLETS

- Single Pole Switch .... $\$$
- Double Pole Switch .... $\$_2$
- Three Way Switch .... $\$_3$
- Four Way Switch .... $\$_4$
- Automatic Door Switch .... $\$_D$
- Electrolier Switch .... $\$_E$
- Key Operated Switch .... $\$_K$
- Switch and Pilot Lamp .... $\$_P$
- Circuit Breaker .... $\$_{CB}$
- Weatherproof Circuit Breaker .... $\$_{WCB}$
- Momentary Contact Switch .... $\$_{MC}$
- Remote Control Switch .... $\$_{RC}$
- Weatherproof Switch .... $\$_{WP}$

SPECIAL OUTLETS

Any standard symbol with the addition of a subscript letter designates some special variation of standard equipment.

List the key of symbols on each drawing and describe in specifications.

a, b, c - etc.

a, b, c - etc.

$\$$ a, b, c - etc.

PANELS, CIRCUITS & MISCELLANEOUS

- Lighting Panel
- Power Panel
- Branch 2-Wire Circuit — Ceiling or Wall
- Branch 2-Wire Circuit—Floor
  Indicate a greater number of wires: (3 wires), (4 wires), etc.
- Feeders. Use heavy lines and designate by number from Feeder Schedule
- Underfloor Duct & Junction Box — Triple System. For double or single systems eliminate one or two lines
- Generator
- Motor
- Instrument
- Transformer
- Controller
- Isolating Switch

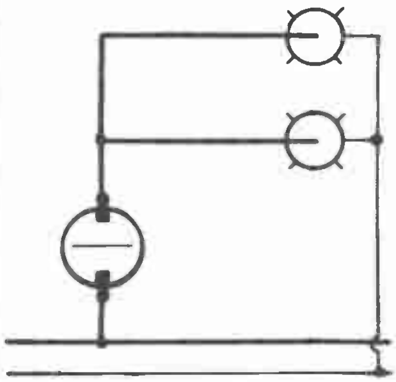
AUXILIARY SYSTEMS

- Push Button
- Buzzer
- Bell
- Annunciator
- Telephone
- Telephone Switchboard
- Clock (Low Voltage)
- Electric Door Opener .... D
- Fire Alarm Bell .... F
- Fire Alarm Station .... F
- City Fire Alarm Station
- Fire Alarm Central Station .... FA
- Automatic Fire Alarm Device .... FS
- Watchman's Station .... W
- Watchman's Central Station .... W
- Horn .... H
- Nurse's Signal Plug .... N
- Maid's Signal Plug .... M
- Radio Outlet .... R
- Signal Central Station .... SC
- Interconnection Box
- Battery
- Auxiliary System 2-Wire Circuit

For a greater number of wires designate with numerals — 12-No. 18W-¾"-C., or by listing in schedule.

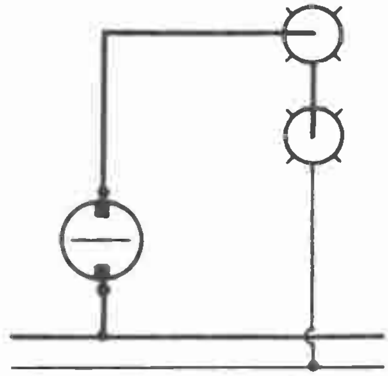
ELECTRIC SWITCHES & THEIR USES

1



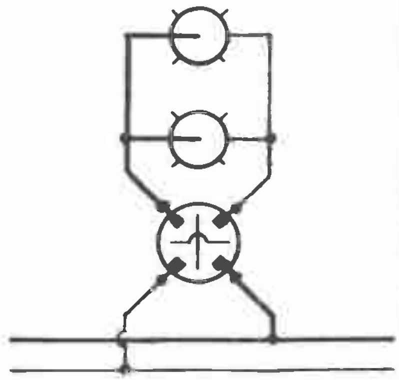
A single-pole switch used to control two lights in parallel.

2



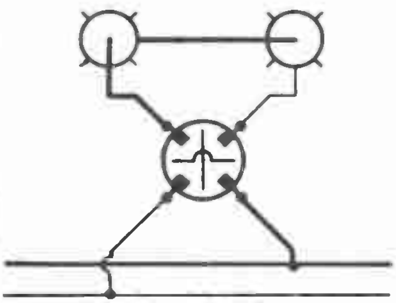
A single-pole switch used to control two lights in series.

3



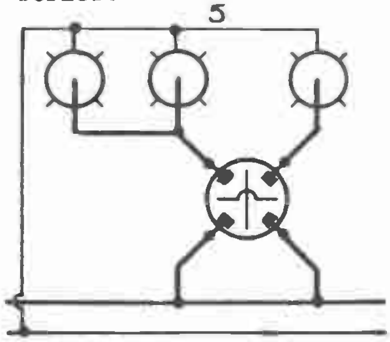
A double-pole switch used to control two lights in parallel.

4



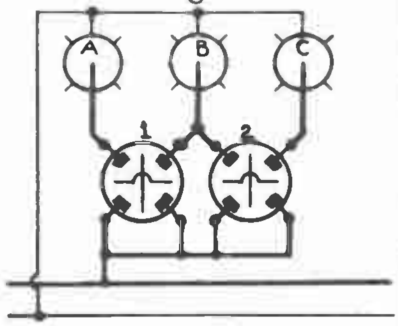
A double-pole switch used to control two lights in series.

5



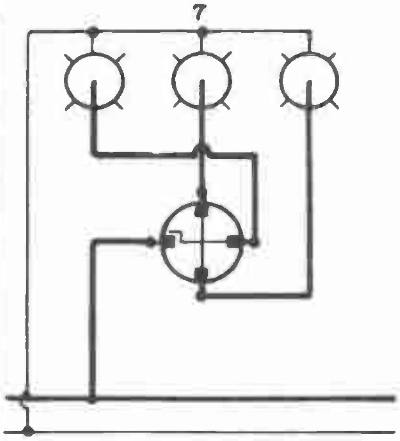
A double-pole switch used to take the place of two single-pole switches giving control to two distinct circuits.

6



A selective control provided by 2 double-pole switches. Lights A and B are controlled by switch #1; lights B and C are controlled by switch #2.

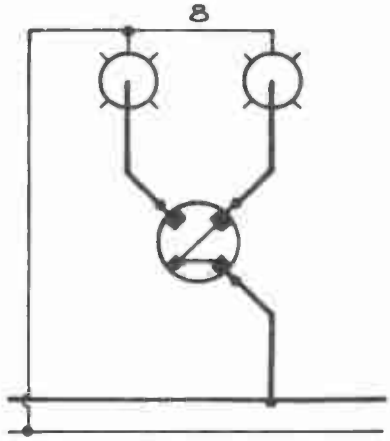
7



Electrolier switch used to control three separate lights from one place.

1st position lamp #1 on
2nd " " #2 "
3rd " " #3 "
4th " all off.

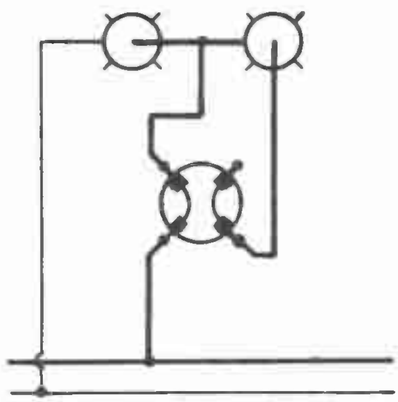
8



A 3-way switch used to control 2 lights alternately. One or the other will be lighted.

1st position lamp #1 on.
2nd " " #1 and #2 on.
3rd " " #1, #2 and #3 on.
4th " " all off.

9

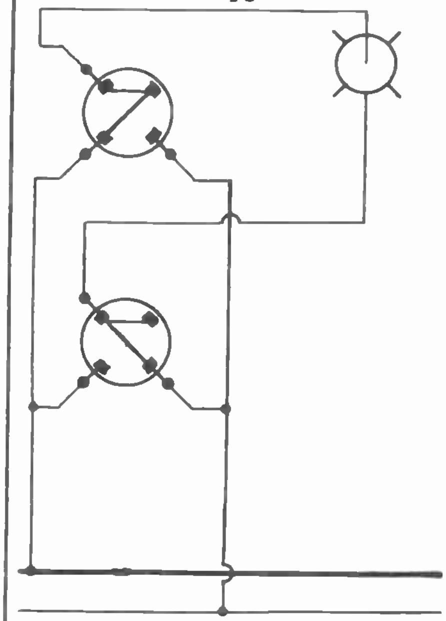


A 4-way switch used to control one light only, or 2 lights in series.

COYNE

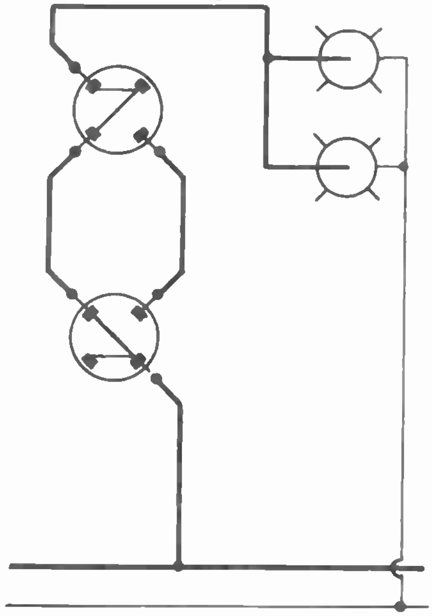
ELECTRIC SWITCHES & THEIR USES

10



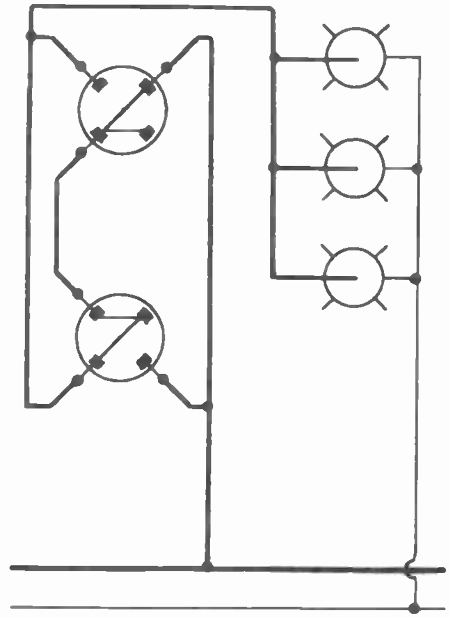
This is the "Carthweise" method used to control lights from 2 places, using two 3-way switches. This system is not approved by the Code for 110E systems, but may be used on 32E systems.

11



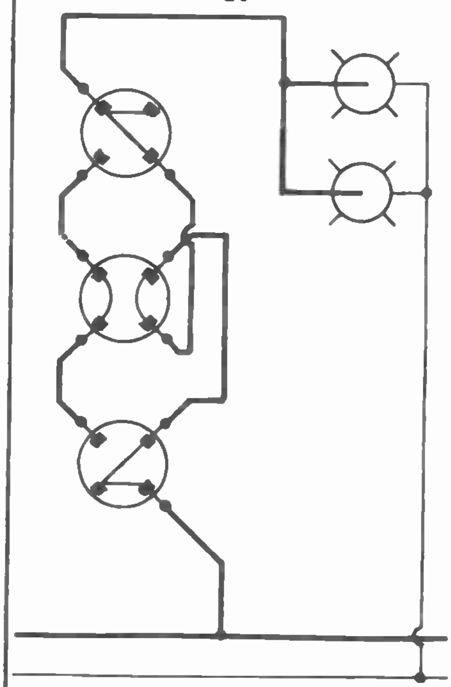
This circuit is the "Standard" method for two-place control using two 3-way switches and is approved by the Code for 110E.

12



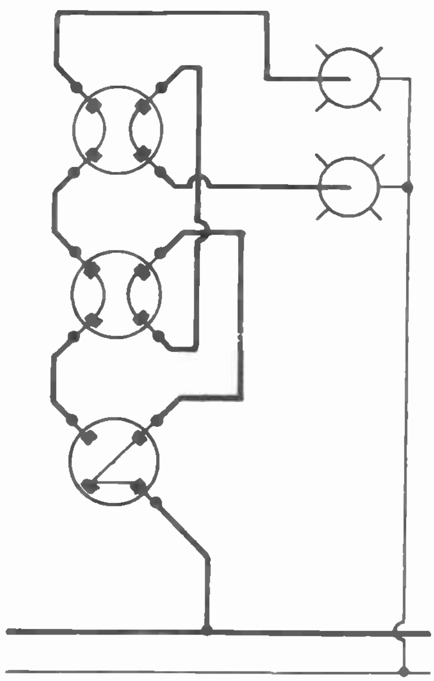
This shows another method of controlling lights from 2 places.

13



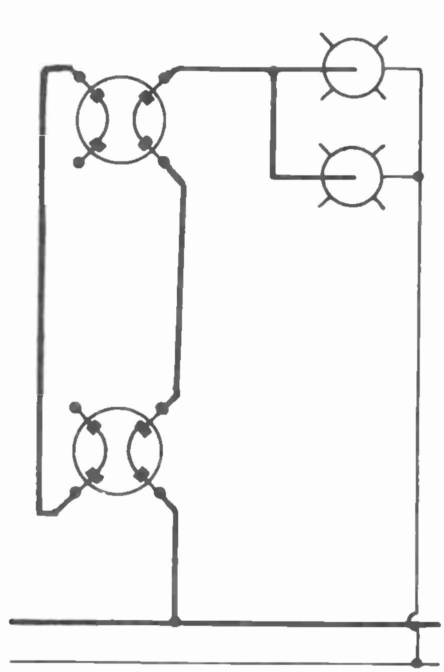
Method used to control one or more lights from three places.

14



This diagram shows how to control each light alternately from three different places.

15

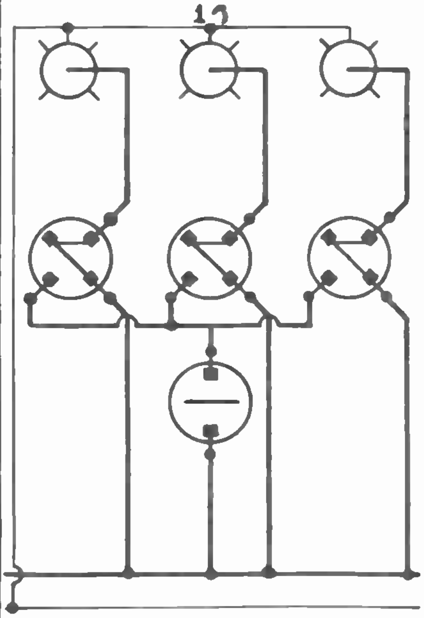


Possible circuit used to control two lights in parallel from two places using two 4-way switches.

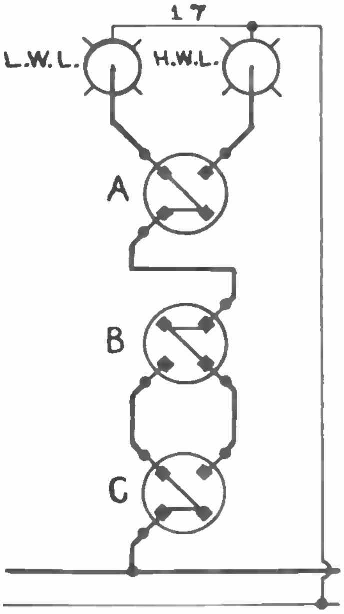
COYNE

ELECTRIC SWITCHES & THEIR USES

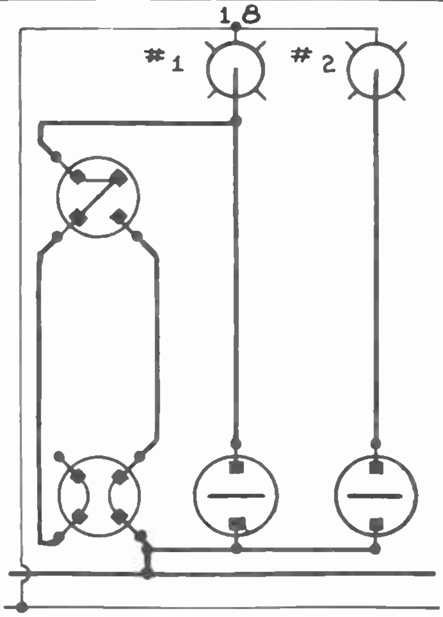
16



17



18

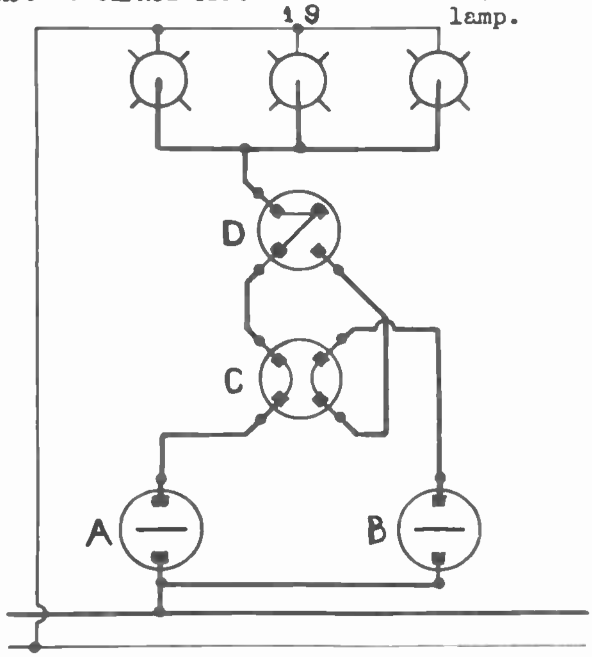


This shows 3 lights, each one individually controlled from one place, using a three-way switch as a single-pole switch. The one single-pole switch is used as a master switch when the master switch is on; the other lights cannot be turned off.

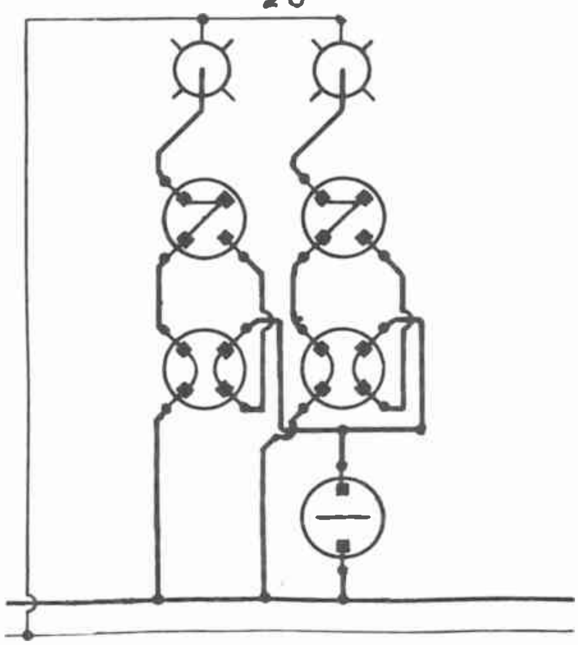
An additional 3-way switch used when it is desired to use a low wattage lamp part of the time. Switches B and C will control the circuit and switch A will select either the high or low wattage lamp.

A 3-way switch and a 4-way switch used to control lamp #1 with a single-pole switch as a master switch. Lamp #2 has separate control.

19



20



By means of 2 single-pole switches at A and B, it is possible to prevent turning the lights on or off at switches C and D. When switches A and B are closed, the lamps cannot be turned off. When switch A is on and B is off, the lamps may be controlled from switches C and D.

When the single-pole switch is open, each of the 2 lights may be controlled from 2 places. When the single-pole switch is closed, all the lamps will remain lighted regardless of the position of the other switches.

SPECIFICATIONS FOR WIRING OF BUNGALOW

GENERAL CONDITIONS

The standard form of "General Conditions of Contract" of the American Institute of Architects, copies of which are on file with the Owner, shall govern and is hereby considered and acknowledged a part of the specifications covering this work.

PROGRESS OF INSTALLATION

The Electrical Contractor shall keep himself informed of the progress of the general construction of the building so that he may begin his work at the earliest opportunity in order to avoid delaying the progress of the work as a whole. He shall provide a working crew of adequate numbers to install the work as rapidly as may be consistent with the class of work required. He shall co-operate with all other contractors on the job to serve the best interests of the owner.

CODE RULES

All material and work shall conform in all respects to the latest rules and requirements of the National Electric Code and the Public Service Company requirements.

BIDS

This bid shall be based on armored cable (B.X.) with conduit used only from point of entrance to the service switch.

SERVICE

The Electric Company shall bring the main wires to the weatherhead and connect them to the service wires which shall be installed by the contractor. The contractor shall furnish an approved type service switch and wire for the meter. The meter to be furnished and installed by the Public Service Company.

MATERIALS

All materials shall be new, and shall bear the Underwriter's label. Outlet boxes for walls and ceiling lights shall be fitted with a fixture stud. Wall switches shall be of the toggle type and shall be either single pole or three-way to suit the plan requirements. Whenever two or three switches are adjacent to one another they shall be arranged for gang or tandem cover plates. Wall or base outlets shall be of the double or duplex flush type.

FIXTURES

Fixtures and hanging of same will be done under separate contract.

SERVICE (Conduit)

	unit cost	2 cir. 2 wire		4 cir. 3 wire	
		quantity	cost	quantity	cost
1/2" conduit		15'		15'	
3/4" conduit		20'			
1" conduit				20'	
#8 wire		45		65'	
Ground wire		20'		20'	
2w. Service sw.		1			
3w. Service sw.				1	
* 3/4" Service head		1		1	
* 3/4" LB Fitting		1		1	
Ground clamp		1		1	
Fuse plugs		3			
Fuse plugs				6	
Miscellaneous					
Labor-hours		7		9	
Total					

* For a 3 wire service these items should be 1"

SUMMARY

quantity	Items	unit cost	total
	ceil/wall outlet		
	convenience out.		
	S. P. switch		
	3 way switch		
	Service		
	Permit		
	Total		

%		total
65	Labor and material	
25	Overhead	
10	Profit	
100%	Total	

CONTRACT

Estimate number Date

I (We) hereby propose to furnish labor and material necessary to install the wiring system in and about the premises located at for the sum of Dollars.

Payment shall consist of 80% of the total when the work is roughed in, the balance to be paid after final inspection.

The work done and the material furnished under this proposal shall comply with all local requirements governing this class of work and in accord with the latest rules and requirements of the National Electric Code.

The work done and the materials furnished under this proposal shall comply with the specifications and drawings submitted.

All changes shall be made in writing and signed by both parties hereto, which said writings shall set out and contain in full the character, extent, cost and conditions of said change.

Accepted Owner Date Contractor

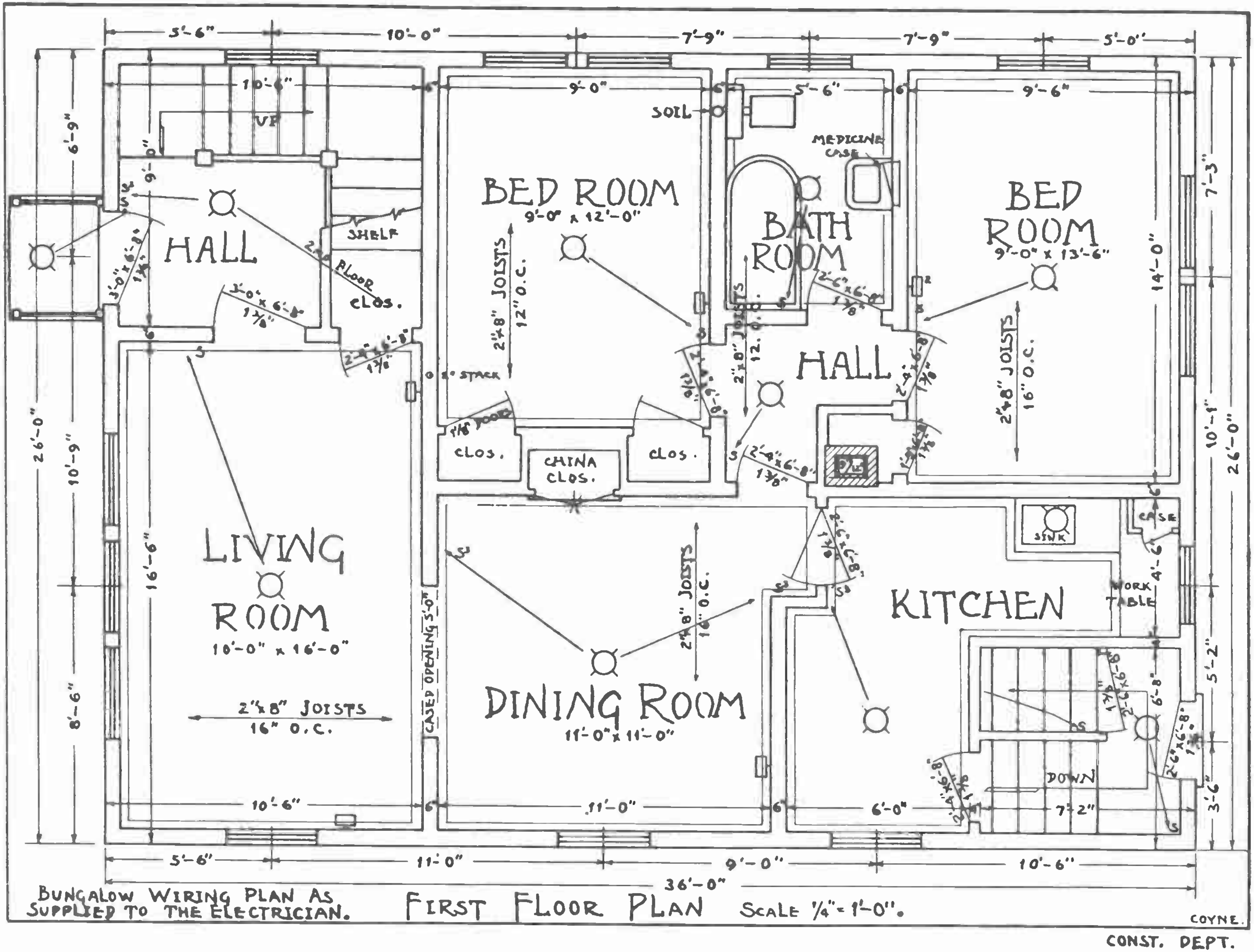
ESTIMATING JOB

ARMORED CABLE WORK (B.X.) NEW HOUSE

Items	unit cost	ceiling/wall		convenience out		s. p. switch		3. w. switch	
		quantity	cost	quantity	cost	quantity	cost	quantity	cost
#14-2 wire B.X.		17'		13'		14'		8'	
#14-3 wire B.X.								12'	
Cutlet box		1							
Box support		1							
3/8" fixture stud		1							
Switch box				1		1		1	
Switch box support				1		1		1	
B.X. connector		2		2		2		2	
3/8" pipe straps		9		3		3		5	
Convenience outlet				1					
S. P. Switch						1			
3 way switch								1	
Miscellaneous									
Labor-hours		.55		.66		.66		.88	
Total									

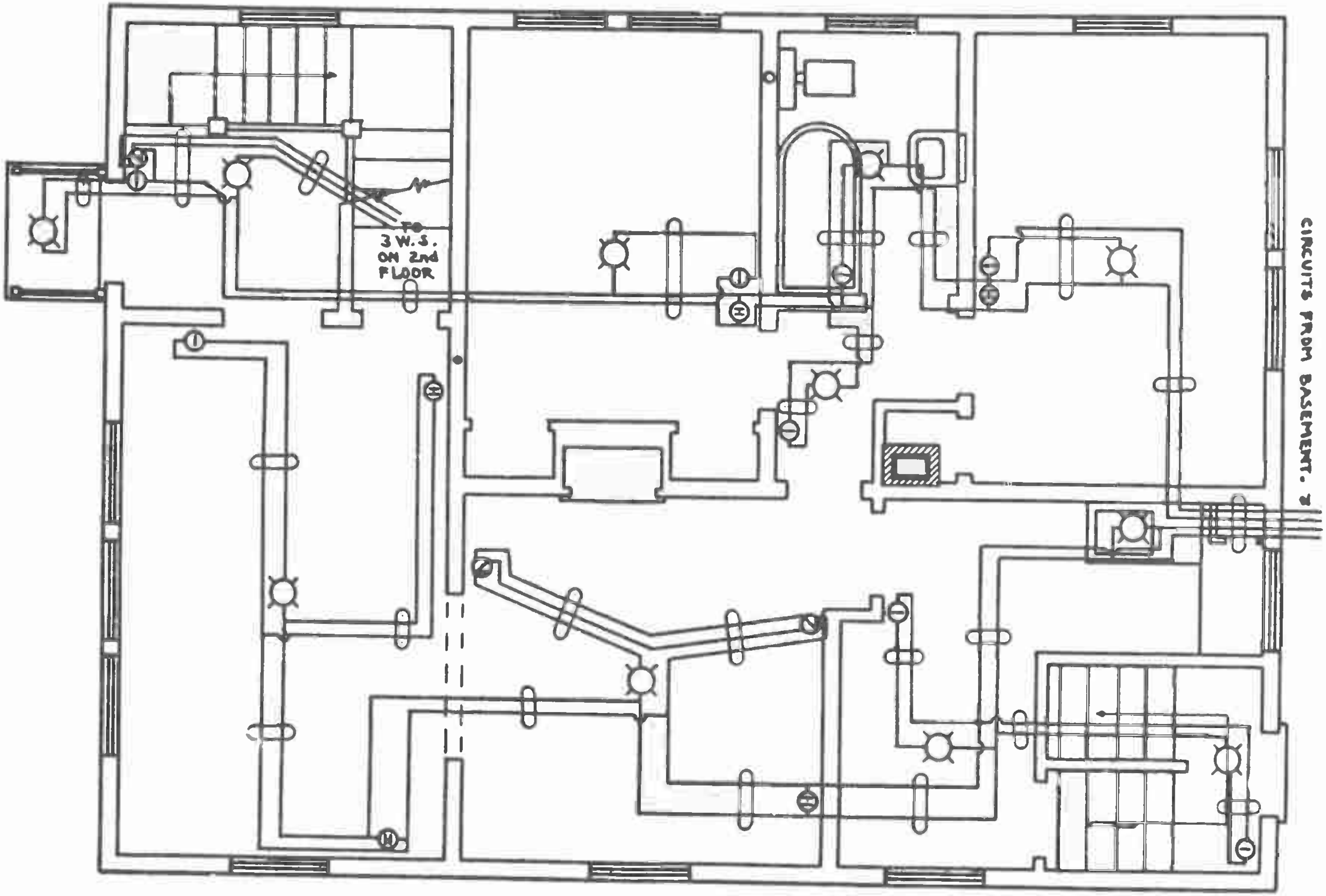
ARMORED CABLE WORK (B.X.) OLD HOUSE

	unit cost	ceiling/wall		convenience out		s. p. switch		3 way switch	
		quantity	cost	quantity	cost	quantity	cost	quantity	cost
#14-2 wire B.X.		22'		20'		20'		9'	
#14-3 wire B.X.								12'	
Shallow outlet box		1							
Old work hanger		1							
Switch box				1		1		1	
B.X. connector		2		2		2		2	
3/8" pipe strap		3		3		3		3	
Convenience outlet				1					
S. P. switch						1			
3 way switch								1	
Miscellaneous									
Labor-hours		1.55		1.9		1.9		2	
Total									



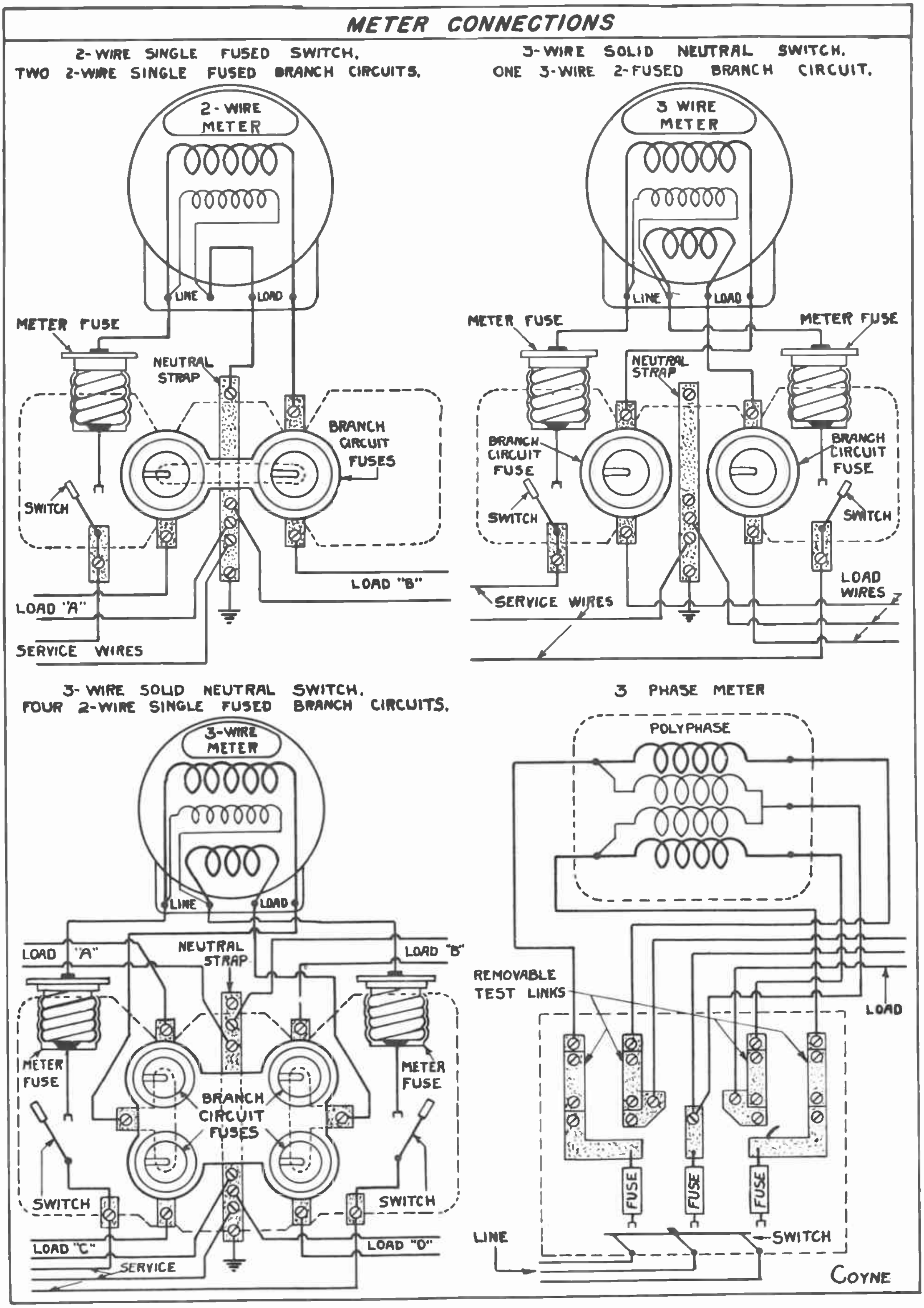
BUNGALOW WIRING PLAN AS SUPPLIED TO THE ELECTRICIAN.

FIRST FLOOR PLAN SCALE 1/4" = 1'-0".

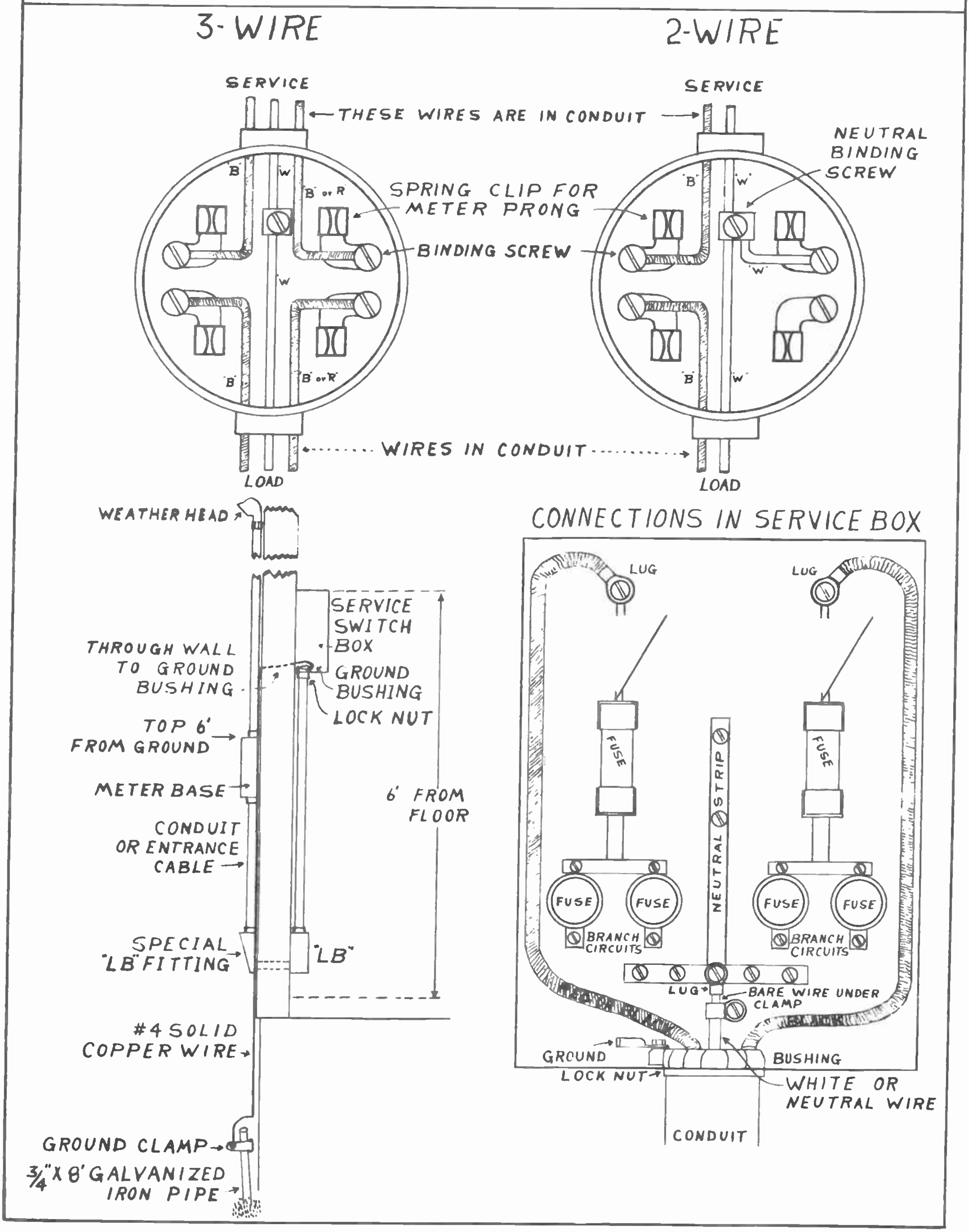


CIRCUIT WIRING DIAGRAM OF BUNGALOW WIRING SYSTEM.

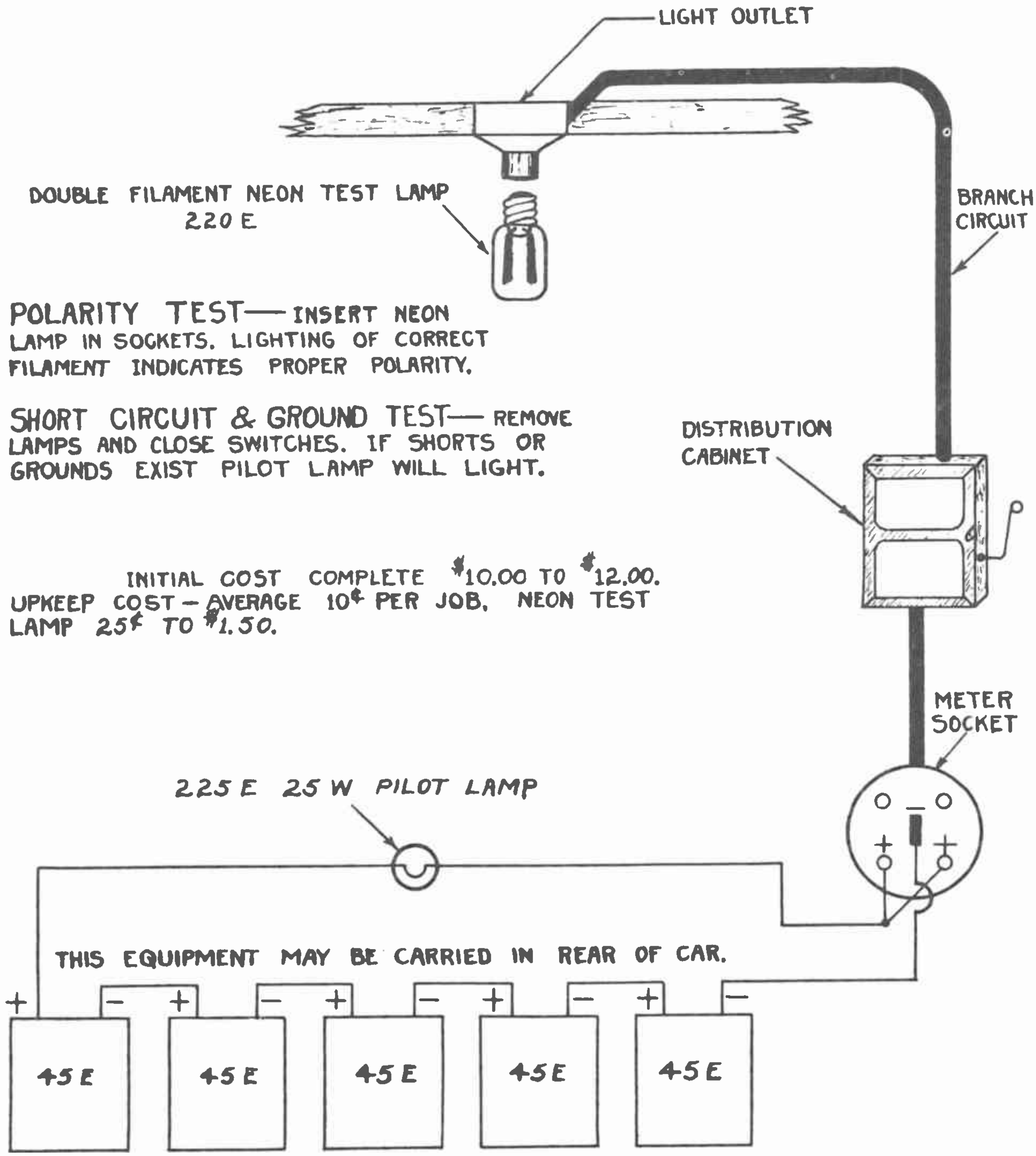
COYNE.


METER CONNECTIONS
2-WIRE SINGLE FUSED SWITCH.
TWO 2-WIRE SINGLE FUSED BRANCH CIRCUITS.
2-WIRE METER
LINE
LOAD
METER FUSE
NEUTRAL STRAP
BRANCH CIRCUIT FUSES
SWITCH
LOAD "A"
LOAD "B"
SERVICE WIRES
3-WIRE SOLID NEUTRAL SWITCH.
ONE 3-WIRE 2-FUSED BRANCH CIRCUIT.
3 WIRE METER
LINE
LOAD
METER FUSE
METER FUSE
NEUTRAL STRAP
BRANCH CIRCUIT FUSE
BRANCH CIRCUIT FUSE
SWITCH
SWITCH
LOAD WIRES
SERVICE WIRES
3-WIRE SOLID NEUTRAL SWITCH.
FOUR 2-WIRE SINGLE FUSED BRANCH CIRCUITS.
3-WIRE METER
LINE
LOAD
LOAD "A"
LOAD "B"
NEUTRAL STRAP
METER FUSE
METER FUSE
BRANCH CIRCUIT FUSES
SWITCH
SWITCH
LOAD "C"
LOAD "D"
SERVICE
3 PHASE METER
POLYPHASE
REMOVABLE TEST LINKS
LOAD
FUSE
FUSE
FUSE
LINE
SWITCH
COYNE

WIRING METER BASE FOR SOCKET TYPE METER



HIGH VOLTAGE TEST SET FOR WIRING INSTALLATIONS R.E.A. RECOMMENDATIONS



POLARITY TEST — INSERT NEON LAMP IN SOCKETS. LIGHTING OF CORRECT FILAMENT INDICATES PROPER POLARITY.

SHORT CIRCUIT & GROUND TEST — REMOVE LAMPS AND CLOSE SWITCHES. IF SHORTS OR GROUNDS EXIST PILOT LAMP WILL LIGHT.

INITIAL COST COMPLETE $10.00 TO $12.00. UPKEEP COST — AVERAGE 10¢ PER JOB. NEON TEST LAMP 25¢ TO $1.50.

SUPPLY FOR TESTING — FIVE 45 E HOT-SHOT BATTERIES

ANY D.C. SUPPLY OF 220 E MAY BE USED, SUCH AS THE POWER PACK USED IN AUTO RADIO. THEN THE CAR BATTERY COULD BE USED AS A SOURCE. MALLORY VIBRAPACK # V.P. 552 MAY BE USED IN CONJUNCTION WITH A CAR BATTERY. THIS VIBRATOR POWER PACK HAS AN OUTPUT OF 225 VOLTS AND UP, AND 100 M.A. CAPACITY. MAY BE PURCHASED FOR $11.00.

STANDARDS OF ILLUMINATION FOR STORES, COMMERCIAL AND PUBLIC INTERIORS

Recommended by Nela Park Laboratories

(These foot-candle values represent order of magnitude rather than exact levels of illumination)

	Foot-Candles
Armories — Drill Sheds and Exhibition Halls	10
Art Galleries:	
General	5
On Paintings	B*
Auditoriums	5
Automobile Show Rooms	20
Banks:	
Lobby	15
Cages	B*
Offices	20
Barber Shops and Beauty Parlors	20
Churches:	
Auditoriums	5
Sunday School Rooms	10
Pulpit or Rostrum	20
Club and Lodge Rooms:	
Lounge and Reading Rooms	20
Auditoriums	5
Court Rooms	10
Dance Halls	5
Depots:	
Waiting Rooms	10
Ticket Offices—	
General	10
Ticket Rack and Counters	B*
Rest Rooms, Smoking Rooms	10
Baggage Checking Office	10
Storage	5
Concourse	5
Platforms	2
Drafting Rooms:	
Prolonged Close Work, Art in Detail	C*
Drafting and Designing Rough Drawing and Sketching	30
Fire Engine Houses:	
When alarm is turned in	10
At other times	2
Garages—Automobile:	
Storage—Dead	2
Live	5
Repair and Washing Departments	C*
Hangars—Aeroplane:	
Storage—Live	10
Repair Department	C*
Hospitals:	
Corridors	2
Laboratories	20
Lobby & Reception Room	5
Operating Room	
General	20
Operating Table	
Major Operations	1000
Minor Operations	200
Private Rooms (with local illumination)	20
Wards (with local illumination)	20
Hotels:	
Lobby	10
Dining Room	5
Kitchen	20
Guest Rooms	10
Corridors	2
Writing Rooms	20
Library:	
Reading Room	20
Stack Room	10
Moving Picture Theatre:	
During Intermission	5
During Pictures	0.1
Museums:	
General	10
Special Displays	B*
Night Clubs and Bars	5
Office Buildings:	
Bookkeeping, Typing and Accounting	30
Business Machines—Power Driven (Transcribing & Tabulating)—	
Calculators, Key Punch, Bookkeeping	B*
Conference Room—	
General Meetings	10
Office Activities — See Desk Work	
Corridors and Stairways	5
Desk Work—	
Intermittent Reading and Writing	20
Prolonged Close Work, Computing, Studying, Designing, etc.	C*
Reading Blueprints and Plans	30
Office Buildings, (continued)	
Drafting—	
Prolonged Close Work—Art Drafting and Designing in Detail	C*
Rough Drawing and Sketching	30
Filing and Index References	20
Lobby	10
Mail Sorting	20
Reception Rooms	10
Stenographic Work—	
Prolonged Reading Shorthand Notes	C*
Vault	10
Post Office:	
Lobby	10
Sorting, Mailing, etc.	20
Storage	10
Offices—Private & General	20
File Room and Vault	10
Corridors and Stairways	2
Professional Offices:	
Waiting Rooms	10
Consultation Rooms	20
General Offices	20
Dental Chairs and Doctors' Examination Rooms	A*
Restaurants, Lunch Rooms and Cafeterias:	
Dining Areas	10
Food Displays	C*
Schools:	
Auditoriums and Lecture Rooms—	
General	10
Special Exhibits	C*
Class and Study Rooms—	
Desks & Blackboards	20
Corridors and Stairways	5
Drawing Room	C*
Gymnasium	20
Laboratories:—	
General	15
Close Work	C*
Library and Offices	20
Manual Training—	
General	20
Close Work	B*
Sewing Room	B*
Sight-Saving Classes	C*
Service Space:	
Corridors	5
Service Space, continued:	
Elevators—Freight and Passenger	10
Halls and Stairways	5
Storage	5
Toilets and Wash Rooms	5
Show Cases	B*
Show Windows:	
Large Cities—	
Brightly Lighted Districts	200
Secondary Business Locations	100
Neighborhood Stores	50
Medium Cities—	
Brightly Lighted District	100
Neighborhood Stores	50
Small Cities and Towns	50
Lighting to Reduce Daylight Window Reflections	200–1000
Special Displays Inside Store:	
Light Colored	C*
Medium Colored	B*
Dark Colored	A*
Stores:	
Large Cities—	
Brightly Lighted Districts	20
Secondary Business Locations	20
Neighborhood Stores	15
Medium Cities—	
Brightly Lighted Districts	20
Neighborhood Stores	15
Small Cities and Towns	15
Telephone Exchanges:	
Operating Rooms	5
Terminal Rooms	15
Cable Vaults	5
Theatres:	
Auditoriums	5
Foyer	10
Lobby	15
Transportation:	
Cars—	
Baggage, Day Coach Dining, Pullman	15
Mail—	
Bag Racks and Letter Cases	20
Storage	5
Street Railway, Trolley Bus and Subway	15
Motor Bus	10

**In these areas many of the machines require one or more supplementary lighting units mounted on them in order to effectively direct light toward the working points.

*Lighting recommendations for the more difficult seeing tasks, as indicated by A, B, and C in the foregoing table, are as follows:

GROUP A — These seeing tasks involve (a) the discrimination of extremely fine detail under conditions of (b) extremely poor contrast, (c) for long periods of time. To meet these requirements, illumination levels above 100 foot-candles are recommended.

To provide illumination of this order a combination of at least 20 foot-candles of general lighting plus specialized supplementary lighting is necessary. The design and installation of the combination systems must not only provide a sufficient amount of light but also must provide the proper direction of light, diffusion, eye protection and, insofar as possible, must eliminate direct and reflected glare as well as objectionable shadows.

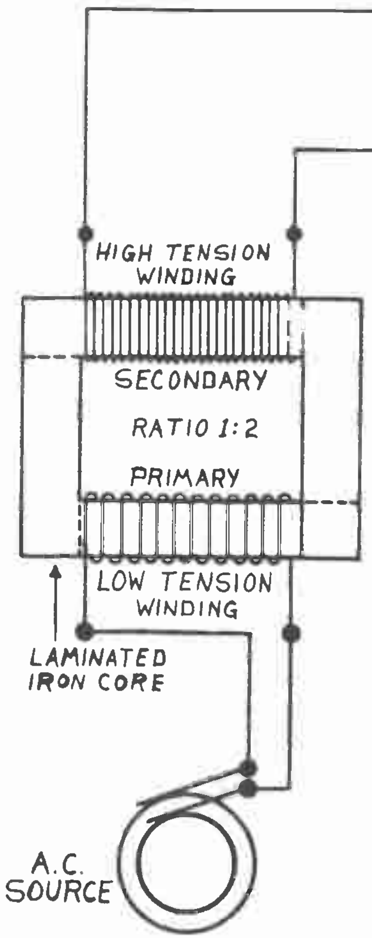
GROUP B — This group of visual tasks involves (a) the discrimination of fine detail under conditions of (b) a fair degree of contrast (c) for long periods of time. Illumination levels from 50 to 100 foot-candles are required.

To provide illumination of this order a combination of 10 to 20 foot-candles of general lighting plus specialized supplementary lighting is necessary. The design and installation of the combination systems must not only provide a sufficient amount of light but also must provide the proper direction of light, diffusion, eye protection and, insofar as possible, must eliminate direct and reflected glare as well as objectionable shadows.

GROUP C — The seeing tasks in this group involve (a) the discrimination of moderately fine detail under conditions of (b) better than average contrast (c) for intermittent periods of time. The level of illumination required is of the order of 30 to 50 foot-candles and in some instances it may be provided from a general lighting system. Oftentimes, however, it will be found more economical and yet equally satisfactory to provide from 10 to 20 foot-candles from the general system and the remainder from specialized supplementary lighting. The design and installation of the combination systems must not only provide a sufficient amount of light but also must provide the proper direction of light, diffusion, eye protection and, insofar as possible, must eliminate direct and reflected glare as well as objectionable shadows.

Standards For Indoor Recreational Lighting

	Foot-Candles
Billiards:	
General	10
On Tables	50
Bowling:	
General	10
On Pins	50
Boxing:	
Seats	2
Boxing, continued:	
Ring: Amateur	100
Professional	200
Championship	500
Gymnasium:	
Exercising Room	15
Shower Rooms	10
Locker Rooms	5
Gymnasium, continued:	
Fencing, Boxing, Wrestling, Basket Ball	20
Soft Ball	30
Skating Rink	10
Table Tennis—Ping Pong	30
Tennis: Recreational	20
Tournament	30
Other Sports:	
Badminton, Handball, Racquet, Squash	30
Basket Ball, Volley Ball	20



STEP UP TRANSFORMER

LINE

A TRANSFORMER is a device to either step-up or step-down A.C. voltage. It usually consists of two separate windings of insulated wire wound on a laminated iron core. One is known as the high tension winding and the other the low tension winding.

The HIGH TENSION (high voltage) WINDING has the greater number of turns and smaller wire.

The LOW TENSION (low voltage) WINDING has fewer turns and larger wire.

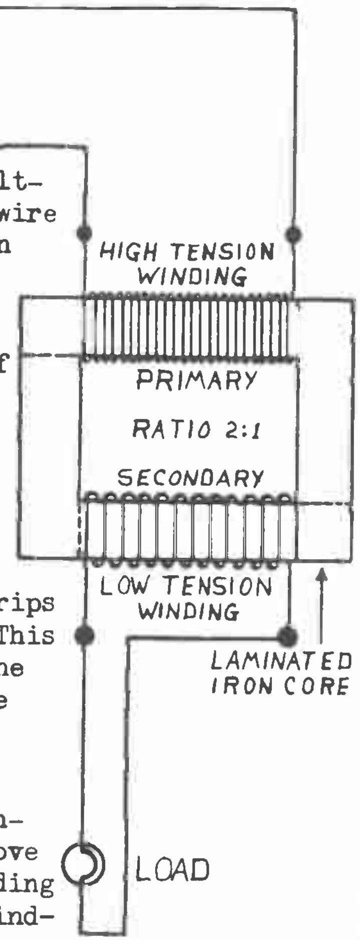
LAMINATED iron core means a stack or bundle of thin sheets or strips of iron, which are insulated from each other by an oxide film. This arrangement of thin sheets or strips tends to limit or confine the eddy currents induced in the iron and thus reduces heating of the iron.

When connecting a transformer, either the low tension or high tension winding can be used as the PRIMARY. (Illustrated in the above diagram) When used as a step-up transformer the low tension winding is connected to the source as the primary and the high tension winding to the load as the secondary

The PRIMARY is always the side connected to the source.

The SECONDARY is always the side to which the load is connected.

The VOLTAGE INDUCED in the secondary will depend upon the ratio of turns and the voltage applied to the primary.



STEP DOWN TRANSFORMER

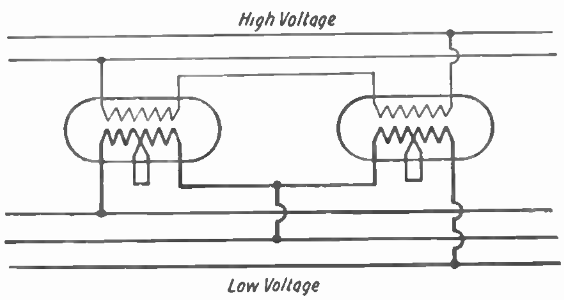
WESTINGHOUSE ELECTRIC CORPORATION

TRANSFORMER CONNECTIONS

In making transformer connections, safety should never be forgotten. DO NOT TAKE A CHANCE. PLAY SAFE. Do not assume that a transformer is de-energized (dead). Make sure breaker or switch is open before doing work. After work is completed, make sure all is clear before energizing. YOUR OWN LIFE AND THE LIVES OF OTHERS MAY DEPEND ON THIS.

It is well to remember in making emergency connections, especially for phase transformation, that a comparatively small "off ratio" will cause a large circulating current. This circulating current will depend not only on the "off ratio" but also on the impedance. This condition may become more dangerous than the operator realizes, especially when the transformers involved are normally carrying full load.

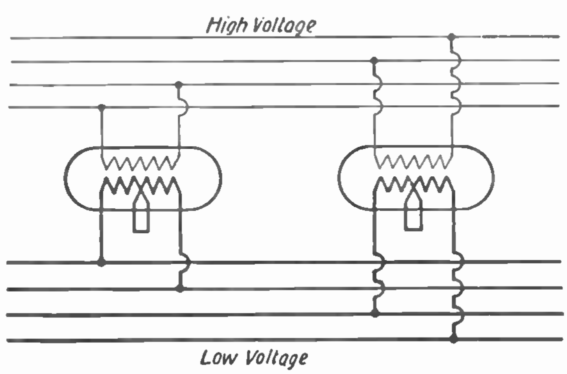
60-CYCLE TRANSFORMERS ON 25 CYCLES



When using a 60-cycle transformer on a 25-cycle circuit a transformer whose normal rated voltage is double the voltage of the circuit would be required. This is to prevent the magnetic saturation of the iron core. The same result can be accomplished by connecting two transformers of the same voltage in series. Placing the secondary side on a 3-wire circuit would tend to keep the voltage on the two transformers balanced.

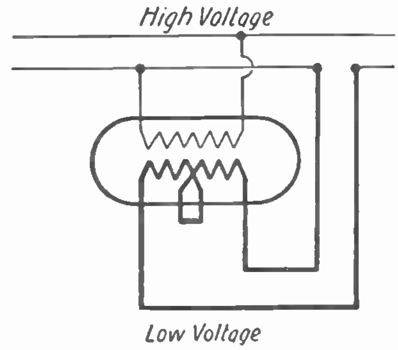
TWO-PHASE CONNECTIONS

TWO-PHASE—FOUR-WIRE



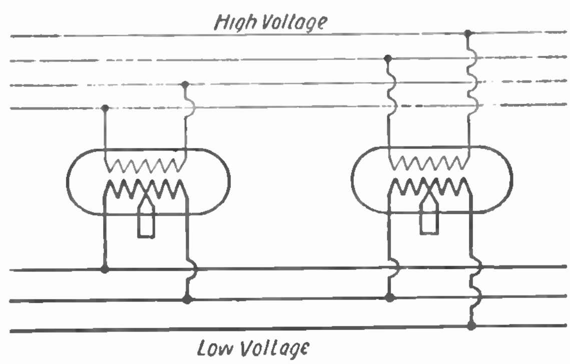
In this connection 2-phase, 4-wire is transformed by the use of two transformers to 2-phase, 4-wire of a different voltage and there is no connection between the two phases.

STANDARD TRANSFORMER AS BOOSTER



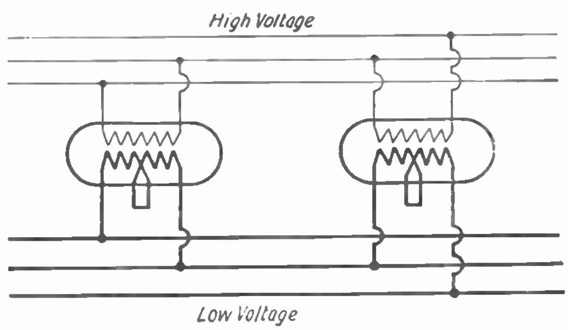
The purpose of a booster transformer is to raise the voltage of the circuit from which the transformer is excited. The primary winding is connected in multiple with the line, and the secondary winding is connected in series with the line. By reversing the secondary winding its action can be changed from boosting to bucking. The low voltage winding is subjected to the stresses going with the emf. of the high voltage circuit, and this must be taken into consideration when using this connection.

TWO-PHASE—FOUR-WIRE; TWO-PHASE—THREE-WIRE



The two phases on the low-voltage side are electrically tied together. The common third wire is sometimes grounded. Caution. If in the load, the two phases are inter-connected in a different manner than here shown at the transformers, a short circuit will result.

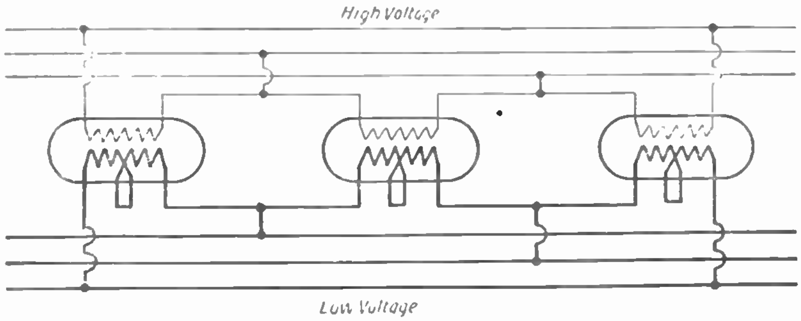
TWO-PHASE—THREE-WIRE INTERCONNECTED



In this connection the two phases are electrically tied together by the common third wire. This is permissible in certain cases and not in others. This third or common wire is sometimes grounded. Caution. If the generator or any transformers back of the transformer group shown above are interconnected in a manner not identical to the transformer bank, a short circuit will result.

The same applies to the load on the secondary side, for example, a motor.

THREE-PHASE CONNECTIONS—STANDARD—THREE-PHASE—CLOSED DELTA

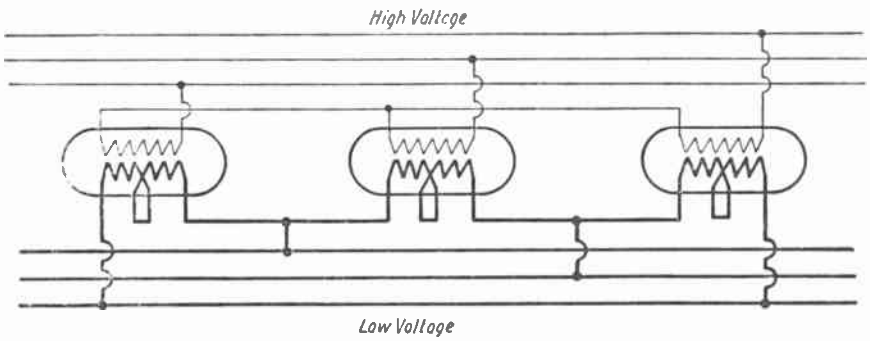


When three transformers are operated in a closed delta bank care should be taken to make certain that the impedances of the three units are practically the same. Transformers having more than 10 per cent difference in impedance rating should not be operated together in a closed delta bank unless a reactor is used to increase the impedance of the unit having the lower impedance rating to a value equal to the other units.

It is always best before connecting up three transformers in closed delta to insert a fuse wire between the ends of the two transformers closing the delta bank. The fuse wire should be of sufficient size to carry the exciting current of the transformers. The use of this fuse wire offers a very simple means of making certain that the transformers have the proper polarity.

If the voltage ratio of all three of the transformers is not the same, there will be a voltage tending to circulate a current inside the delta. The current will be limited by the impedance of the three transformers considered as a series circuit.

STANDARD THREE-PHASE — STAR, THREE-WIRE—HIGH VOLTAGE — DELTA, THREE-WIRE—LOW VOLTAGE



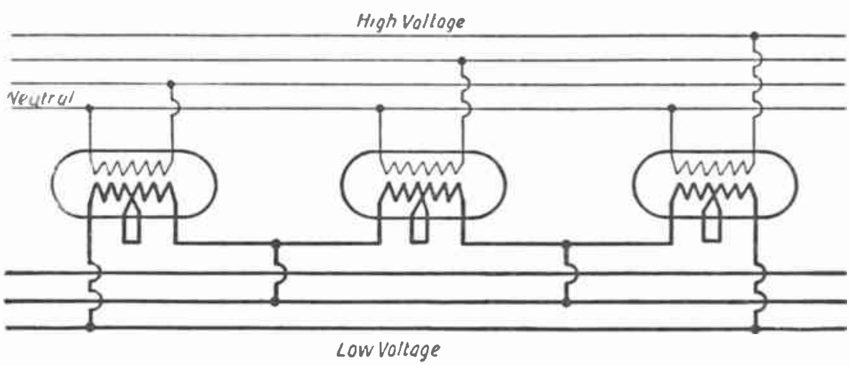
When three transformers are operated with their high-voltage windings in star the incoming line voltage is the $\sqrt{3}$ or 1.732 x the transformer winding voltage.

This connection is very popular and presents a very convenient way of boosting the transmission voltage without purchasing additional transformers.

In general, all distribution transformers of the 7820-volt class and less are insulated for star connection on the high-voltage windings. In this connection it is not necessary that the impedance of the three transformers be the same.

At least the bad effects of the unbalanced impedances will not be so marked as with the delta-delta connection.

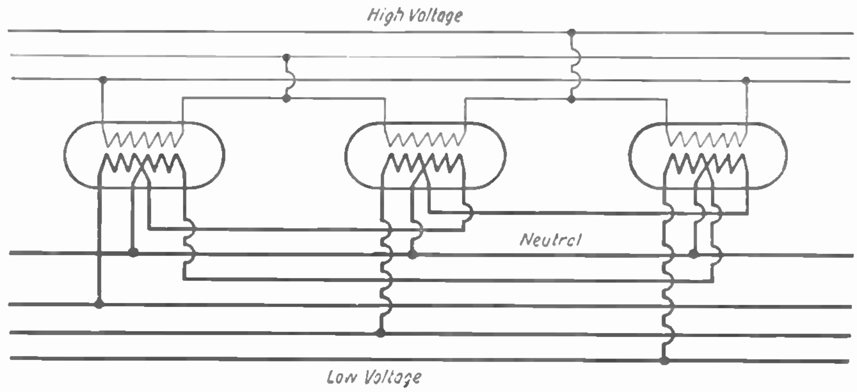
THREE-PHASE — STAR, FOUR-WIRE—HIGH VOLTAGE — DELTA, THREE-WIRE—LOW VOLTAGE



This connection permits 3-phase power to be transmitted at the star voltage. At the same time single-phase power may be taken from the mains by connecting a single-phase transformer between the neutral and any of the three phase wires.

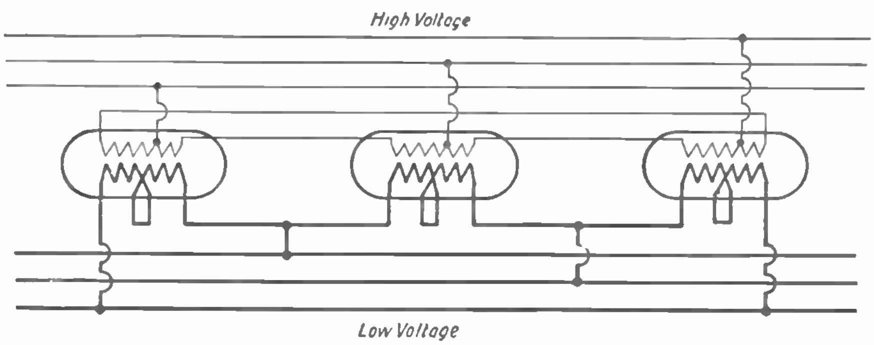
In this connection it is not necessary that the impedance of the three transformers be the same.

THREE-PHASE—STAR, INTERCONNECTED



The primary side of this group may be connected either in star or in delta. Each half of the secondary winding of each transformer has a voltage of ¾ of the interconnected star voltage. A bank of transformers designed for connection in this manner will have a capacity 7½% greater than the Kv-a. transformed. The purpose of the interconnected star winding is to permit the unbalanced d-c. current from the third wire of the three-wire circuit of a rotary converter to get back into the alternating current system feeding the converter. Since this d-c. current divides into two equal parts in each transformer and also these parts flow in opposite directions magnetically in the two parts; the d-c. current does not magnetize the core. If this current would flow in one direction through the winding the d-c. magnetic flux would add to the a-c. flux and perhaps saturate the core.

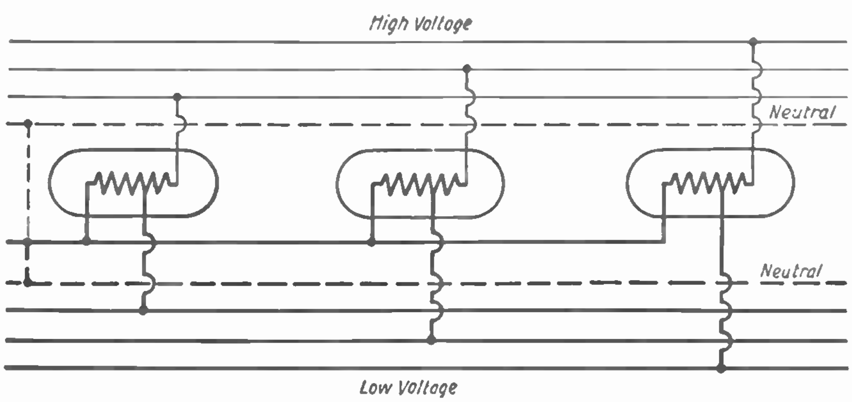
THREE-PHASE INSIDE DELTA TAPS—HIGH VOLTAGE CLOSED DELTA—LOW VOLTAGE



The purpose of this connection is to permit the use of a tap without re-connecting the transformers at the corners of the delta. There are two objections to the use of inside delta taps.

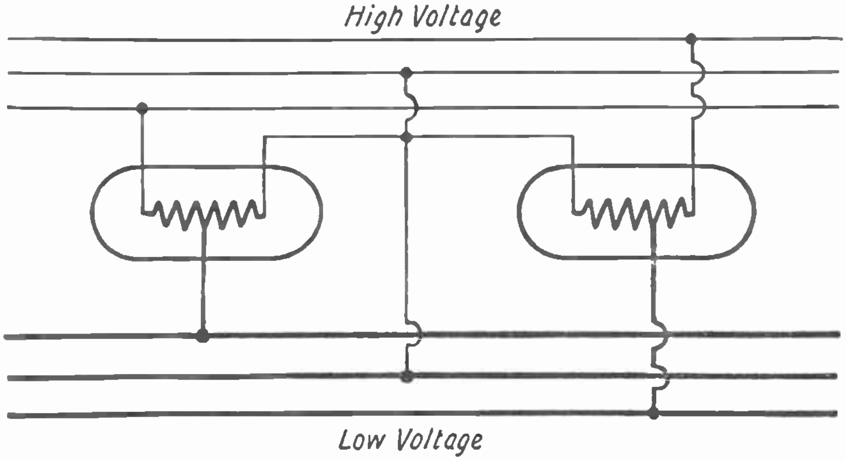
1. All of the winding is in circuit even when it is not needed.
2. There is a phase shift between the primary and secondary voltages, which would not be present if the straight delta connection was used. This shift in voltage is objectionable if the transformer is to be paralleled with a straight delta-delta transformer.

THREE-PHASE—FOUR-WIRE, STAR-STAR WITH AUTO-TRANSFORMERS



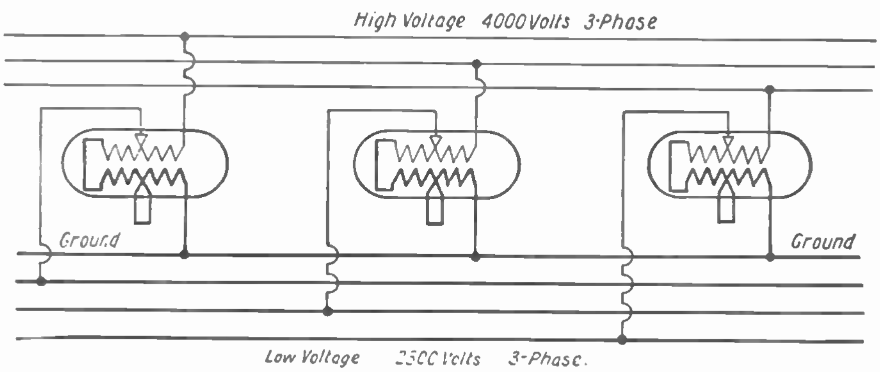
In this connection the high and low-voltage windings are electrically connected together, and for this reason the low-voltage side is the same voltage relative to ground as the high-voltage circuit. The material in the auto transformer is less than that in a two winding transformer, transforming the same power. The saving in material is quite large when there is but a small difference in the primary and secondary voltages, and the saving becomes less and less as the difference between the primary and secondary voltages increases.

THREE-PHASE—THREE-WIRE—OPEN DELTA WITH AUTO-TRANSFORMER



In this connection the high and low-voltage windings are electrically connected together, and for this reason the low-voltage side is the same voltage relative to ground as the high-voltage circuit. The material in the auto-transformer is less than that in a two winding transformer, transforming the same power. The saving in material is quite large when there is but a small difference in the primary and secondary voltages, and the saving becomes less and less as the difference between the primary and secondary voltage increases.

4000 TO 2300 VOLTS BY USE OF STANDARD 2-WINDING, CLASS 400 TRANSFORMERS



This diagram gives a method of hooking up three standard 2300-volt, class 400 transformers to transform from 4000 to 2300 volts, three-phase.

Find the middle point of the high-voltage winding which is generally available either at the terminal block or on a crossover lead of the coils. Connect the left-hand, high-voltage lead to this point and connect outside the case as indicated.

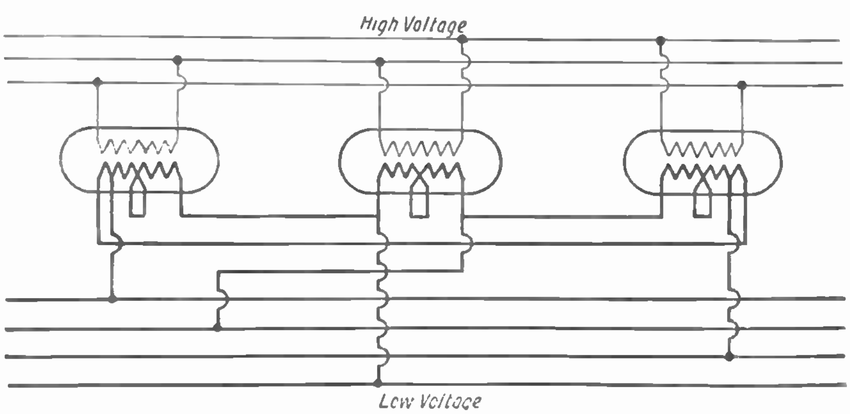
Connect inside the case the left-hand end of high-voltage winding to the left-hand end of the low-voltage winding as indicated.

Connect low-voltage coils in series as indicated. Follow schematic diagram. Note that actual voltages of 4730 and 2790 bear the same ratio as 4000 and 2300; therefore, if 4000 only is impressed then the required 2300 volts will be delivered.

Transformers over 50 Kv-a. are not adapted for connection in this manner for motor starting.

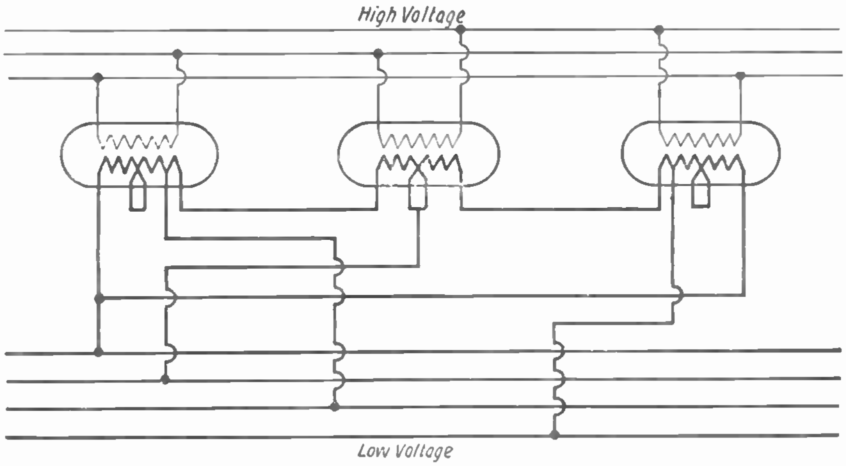
Caution—The neutral point must be grounded. Do not impress a higher voltage than 4000 volts, as the insulation is not built to withstand higher stresses.

PHASE TRANSFORMATION—FORTESCUE CONNECTION



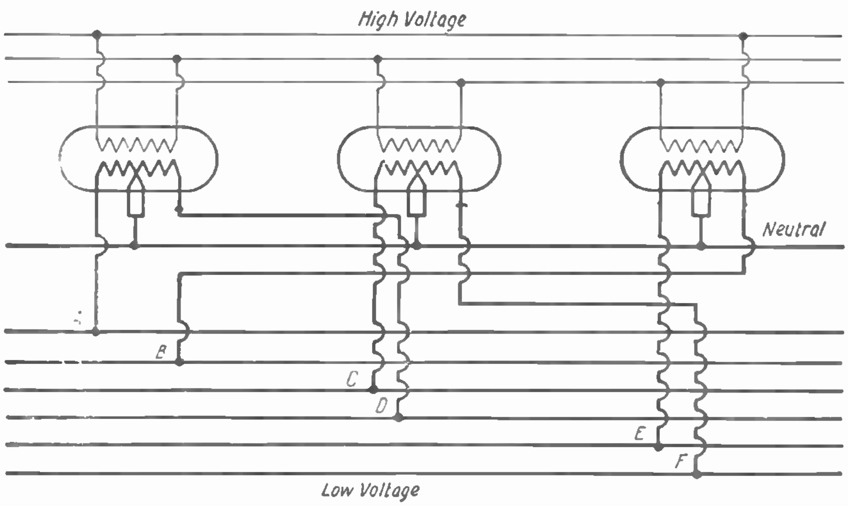
This is a transformation from three-phase to two-phase, by the use of three transformers, one of which is standard, and the other two have special taps on the low-voltage side. One advantage of this connection is that both two and three-phase current may be delivered at the same time. The sum of the power delivered at two-phase and at three-phase must be somewhat less than the normal rating of the transformers, in order not to overload the transformers.

PHASE TRANSFORMATION—TAYLOR CONNECTION



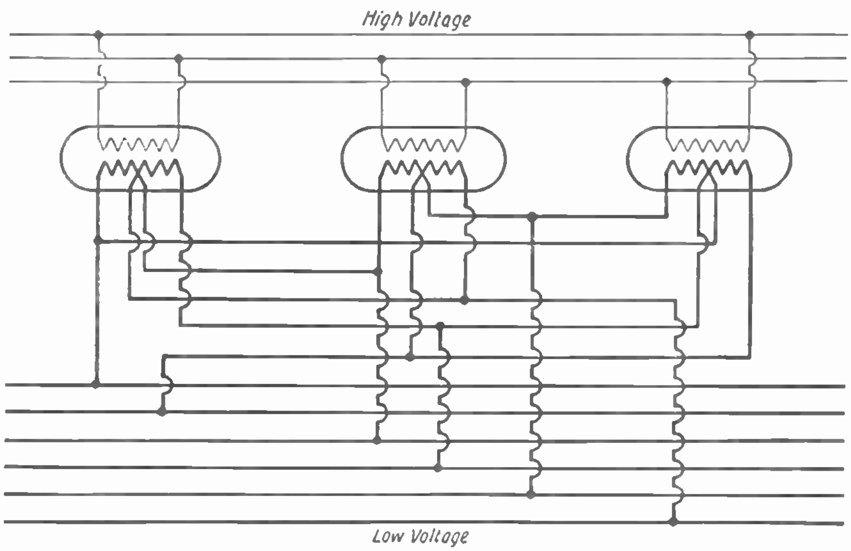
This connection is very similar as far as results go to the Fortescue connection. One standard and two special transformers are used.

SIX-PHASE—DIAMETRICAL



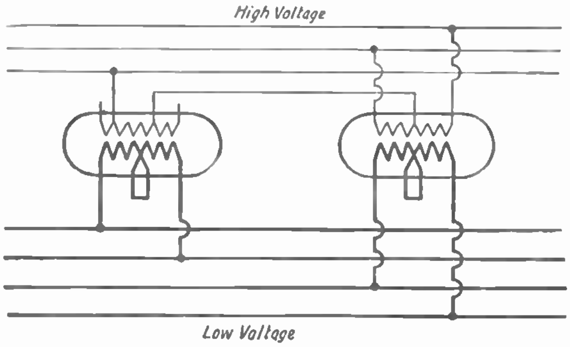
This connection requires one low-voltage winding on each transformer, which is connected to diametrically opposite points on the converter winding. The middle points of the diametrical windings can be connected together and brought out for the third wire of a d-c. circuit. When full output is required at the same voltage at either 3-phase or 6-phase, the double-delta connection is usually used.

SIX-PHASE—DOUBLE DELTA



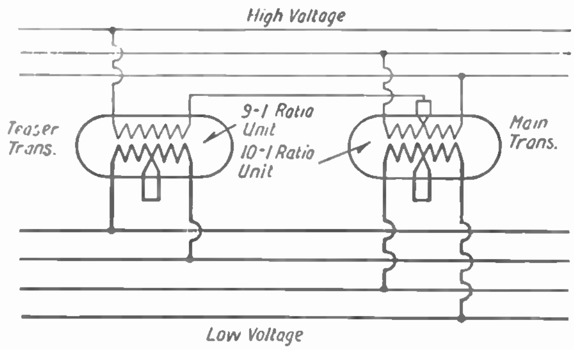
This connection requires two independent low-voltage windings in each transformer. Both sets are connected in delta, but one is reversed in comparison with the other, so that the two deltas are displaced 180 degrees in phase relation from each other, for operating synchronous converters.

SCOTT TRANSFORMATION—STANDARD 10 TO 1 RATIO USED



If a Scott transformation is desired, and a transformer having an 86.6% tap is not available, a unit having a 10% tap or two 5% taps may be used to give approximate results. With this arrangement the 2-phase voltages will be unbalanced by about the same amount as when using a 9 to 1 ratio transformer. See Fig. 19.

SCOTT TRANSFORMATION—STANDARD 9 TO 1 RATIO USED

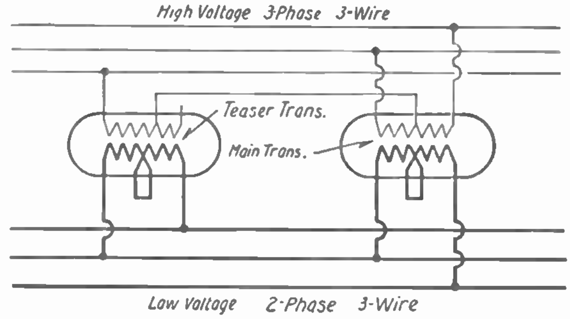


If a transformer with an 86.6% tap is not available in making a Scott transformation, a 9 to 1 ratio transformer may be used for the teaser unit and give an approximate 3-phase to 2-phase transformation. The main unit of course must have a 50% tap or the transformation cannot be made.

Suppose it is required to transform from 2300, 3-phase to 230, 2-phase. For the teaser unit use a 9 to 1 ratio transformer. The primary voltage applied to this unit will be .866 x 2300 or 1990 volts. The 2-phase voltage on the secondary side of this unit will be 1990 ÷ 9 or 221 volts. The voltage of the other phase will be 230 volts. Therefore, the two phases will be unbalanced by this amount, which is about 4%. This unbalance, however, is generally of little consequence, especially if the transformers are used to drive motors.

PHASE TRANSFORMATION

SCOTT: 2-PHASE, 3-WIRE TO 3-PHASE, 3-WIRE OR SCOTT; 3-PHASE, 3-WIRE TO 2-PHASE, 3-WIRE

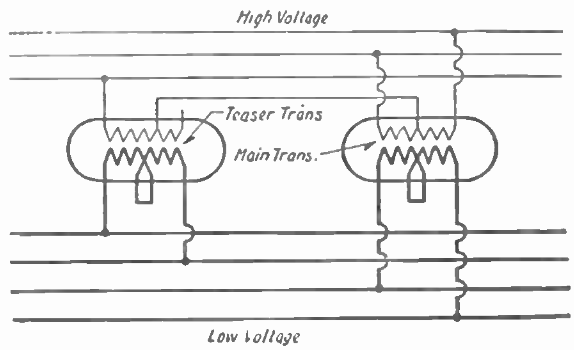


This is a phase transformation, from 3-phase to 2-phase, or from 2-phase to 3-phase. Either the primary or secondary side may be made 3-phase. The 3-phase side must have special taps. One unit must have an 86.6% tap, and the other unit a 50% tap. A 3-wire circuit is used on the 2-phase side. This is formed by joining two of the wires forming the 2-phases. In this manner the 2 phases are electrically connected.

Distribution transformers are ordinarily designed so that the full rated capacity of the bank can be utilized without exceeding normal temperature rises.

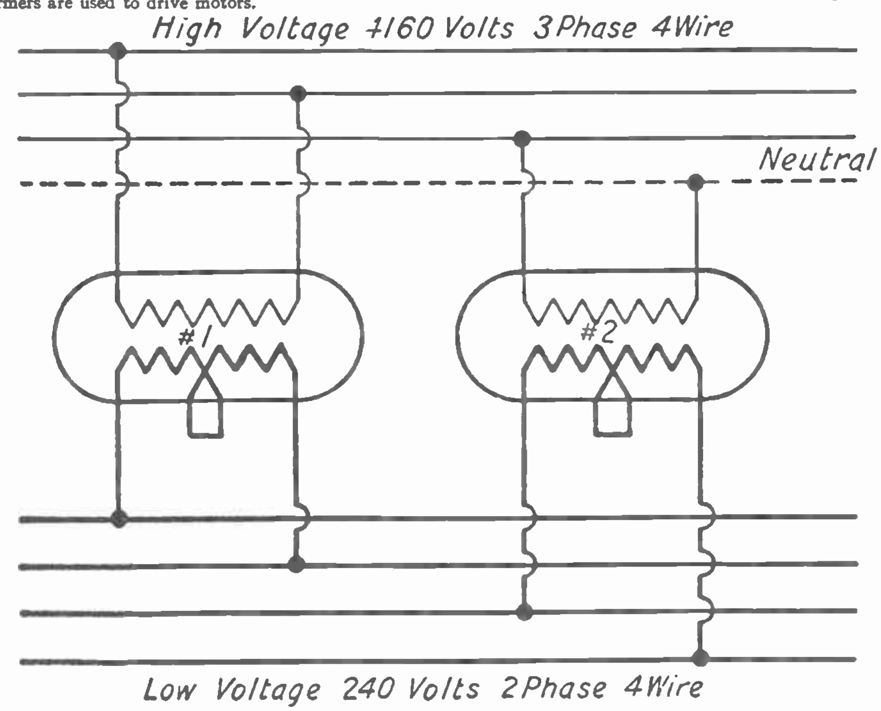
If the transformers are to be used with motors interconnected at mid-points, the connection shown above cannot be used and 4-wire connection, in Fig. 17, is recommended.

SCOTT; 3-PHASE, 3-WIRE TO 2-PHASE, 4-WIRE OR SCOTT; 2-PHASE, 4-WIRE TO 3-PHASE, 3-WIRE



This connection is exactly the same as the previous one except the two-phase side is made 4-wire. In this manner the two two-phase circuits are electrically separated.

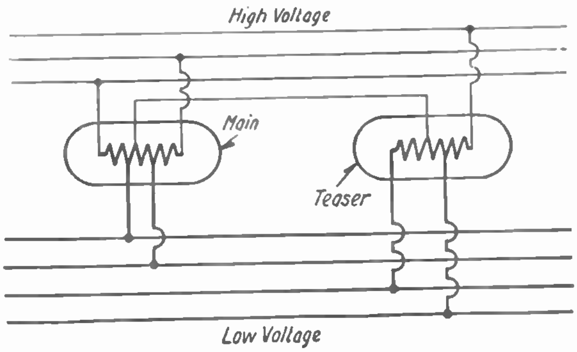
PHASE TRANSFORMATION USING STANDARD TRANSFORMERS OF DIFFERENT VOLTAGE RATINGS



This is a phase transformation from 3-phase to 2-phase employing standard transformers. Transformer #1 is rated 4160 volts to 240-120 volts. Transformer #2 is rated 2400 to 240-120 volts. Each transformer will have a rating equal to one-half the 2-phase load.

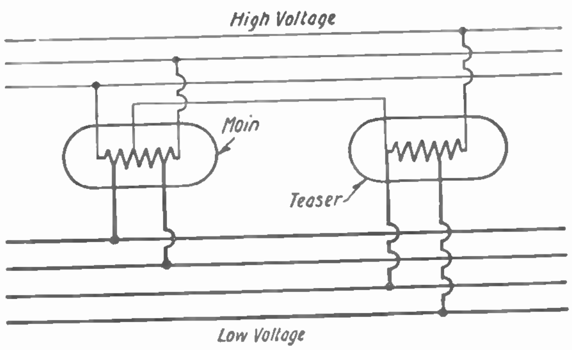
AUTO TRANSFORMERS FOR PHASE TRANSFORMATION

3-PHASE TO 2-PHASE, 4-WIRE INTERCONNECTED



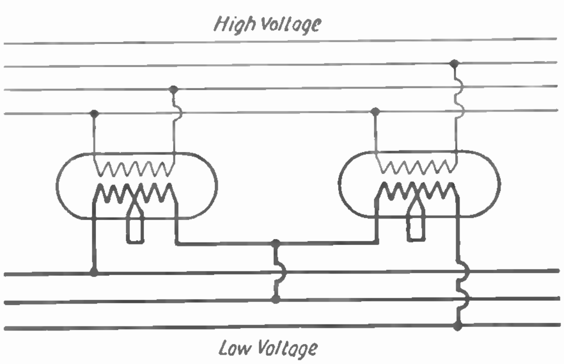
When a phase transformation is desired without any considerable stepping up or down of voltage, the auto transformer is the simplest and cheapest arrangement. The connection shown has the windings on the two-phase side electrically connected together at their middle point.

3-PHASE TO 2-PHASE, 4-WIRE



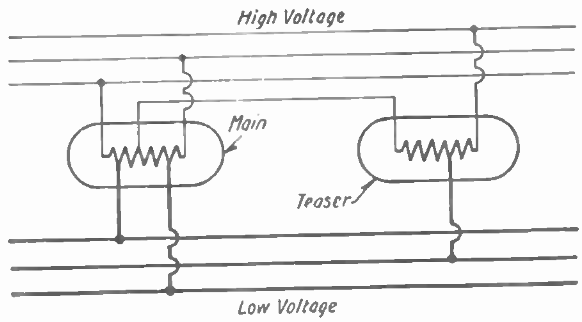
This connection is the same as the one shown previously except that the windings on the two-phase side are not connected together at their middle points, but the end of one phase is connected to the middle of the other phase. The two phases are not, therefore, electrically separated.

THREE-PHASE—STAR, FOUR-WIRE, ONE LEG OUT—HIGH VOLTAGE, OPEN DELTA, THREE-WIRE—LOW VOLTAGE



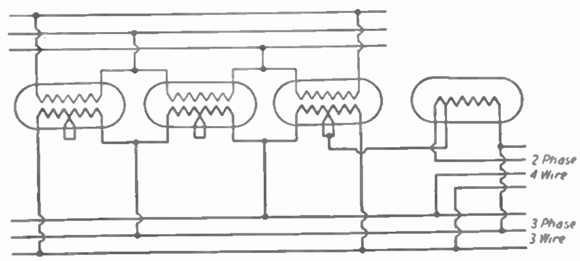
This is similar to a V connection. The primary of the two transformers is connected between the neutral and each of the three-phase wires. The secondaries are connected to the secondary mains, the same as for the delta connection, except that the third transformer is not used. (The secondaries are in open delta). 86.6% of the rated capacity of the two transformers can be obtained.

AUTO TRANSFORMERS—3-PHASE TO 3-PHASE, 3-WIRE



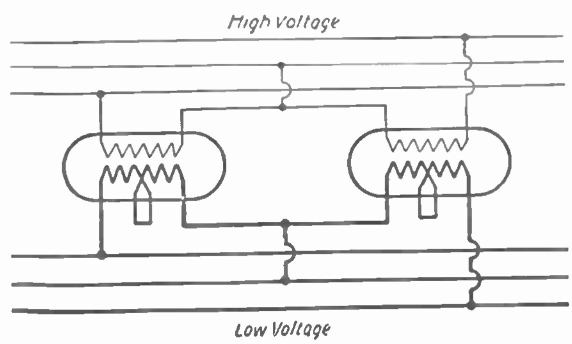
Where the voltage change from primary to secondary is small, the use of an auto transformer for a voltage transformation is cheaper than the use of two winding transformers. The primary and secondary windings are tied together electrically, which may be an objection in some cases.

PHASE TRANSFORMATION 3-PHASE TO 2-PHASE USING AN AUTO TRANSFORMER



This shows how 2-phase voltages may be taken from a delta bank by the simple application of an auto transformer. The auto is connected between the apex of the delta and the mid-point of the opposite side. This gives a 1 to 1 ratio which means that the 2-phase and 3-phase voltages on the L.V. side are equal. The H.V. winding of the bank may be connected star or delta. The 2-phase, and 3-phase loads may be taken off simultaneously. If no load is drawn off at 3-phase, approximately 75% of the bank rating may be taken off at 2-phase.

THREE-PHASE—OPEN DELTA



Three-phase to 3-phase may be transformed by the use of two similar transformers in open delta. In this connection the units will transform 86 per cent of their rating, i.e., two 100 kv-a. units in open delta transforming 3-phase, 2300 volts to 3-phase 230-115 volts will have a bank capacity of 172 kv-a.

In the open delta connection it is not necessary that the impedance characteristics be the same, although it is preferable, as when it becomes necessary to close the open delta bank with a third unit then all three units must have identical impedances.

The open delta connection is often used as a temporary expedient pending a contemplated increase of load and offers a very simple means of handling this matter as you will note by adding a third 100 kv-a. unit in the above mentioned example the resultant bank capacity will be increased from 172 kv-a. to 300 kv-a.

The regulation of an open delta bank is not as good as a closed delta bank. The drop across the open delta is greater than across each of the separate transformers.

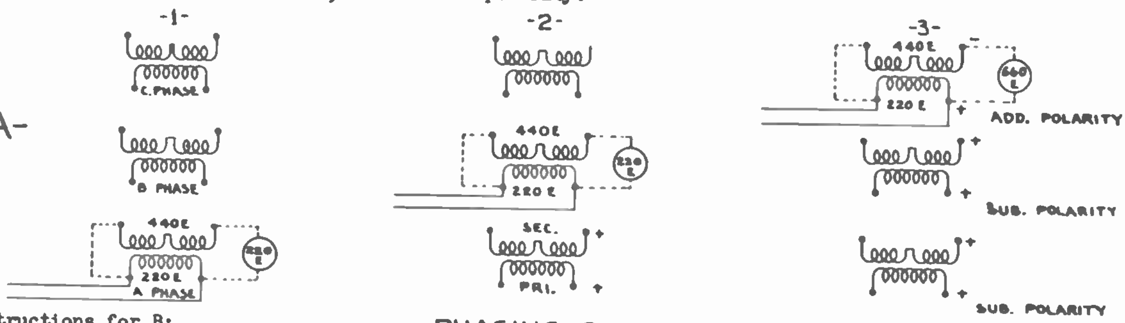
PARALLELING THREE PHASE TRANSFORMERS

Instructions for A:

POLARIZING

1. Connect primary of one phase of the transformer to a suitable A.C. supply - rated voltage or less - as shown in Section A.
2. Measure both primary and secondary voltages.
3. Connect voltmeter as shown in 1, 2, and 3, Section A, and note whether instrument indicates the sum or the difference of the primary and secondary voltages. If sum is given, additive polarity is indicated; if difference, subtractive polarity.

-A-

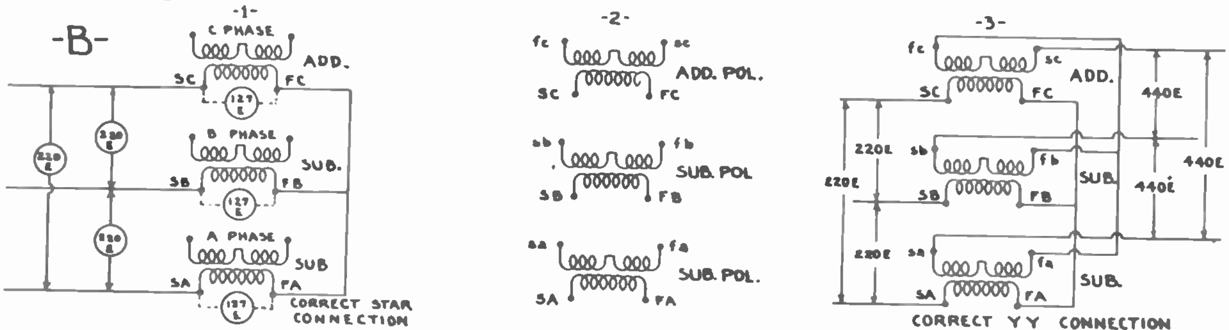


Instructions for B:

PHASING OUT

1. Assume three ends of the three primary phases to be "finishes" and join them together. Connect the three assumed "starts" to the line. (1-B)
2. Take a voltmeter reading on each primary phase.
3. If the readings are not equal, reverse the leads of one phase and test again. If still unequal, replace the leads and reverse the next phase. Repeat until equal readings are obtained, and then mark the ends connected together "F" and those attached to the line "S". The starts and finishes of the secondary winding may be determined from the transformer polarity as indicated in Diagram 2-B.

-B-

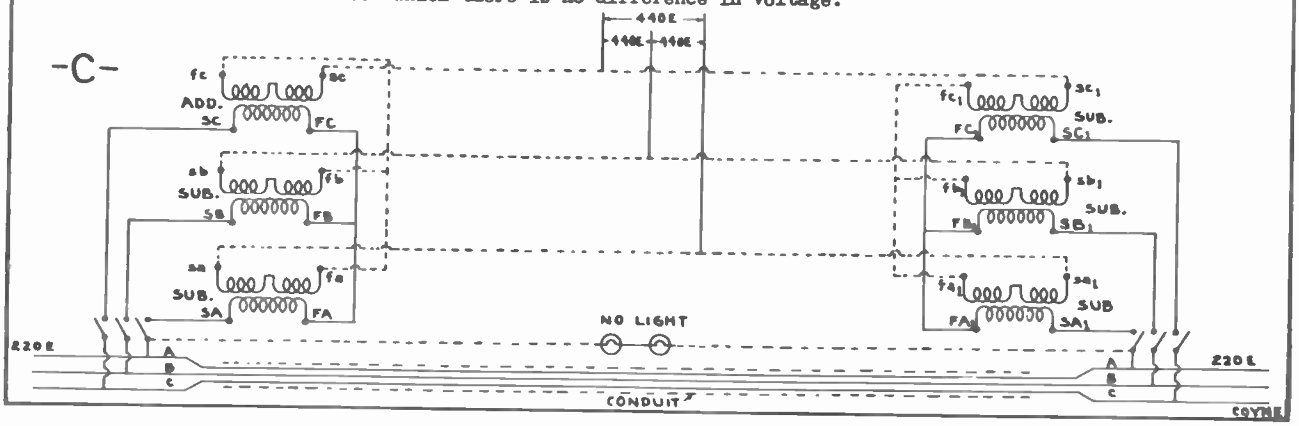


Instructions for C:

PARALLELING

1. After the transformers have been polarized, phased out, and the leads properly marked, they may be paralleled. Identification of each line will be necessary before the primary windings are connected, and a symmetrical arrangement of the transformer leads is essential.
2. After the ends of each line have been found and marked, connect the primary leads "SC" and "SA1" to the same line; "SB" and "SB1" to the next wire; and "SC" and "SC1" to the remaining line. Connect the primary finishes together.
3. The secondary connections are made by joining the secondary finishes together and then connecting corresponding ends of the different phases together, "sa" to "sa1", "sb" to "sb1", and "sc" to "sc1". To prevent an incorrect connection, connect only one secondary wire, say from "sa" to "sa1", and check the voltage between the remaining secondary terminals. Connect together only those terminals between which there is no difference in voltage.

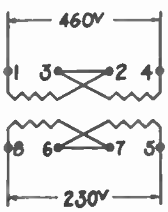
-C-



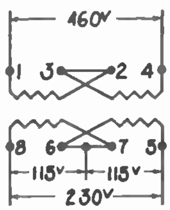
Air-Cooled Transformer Connections

The connection diagrams below illustrate the standard methods for connecting Wagner (type AC) air-cooled transformers for both single-phase and three-phase circuits. These connections are in accordance with the wiring requirements of most power companies and represent the standard wiring practices of large industrial concerns.

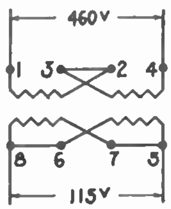
SINGLE-PHASE CONNECTIONS



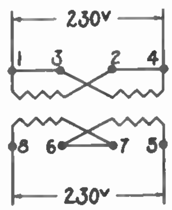
460 to 230 Volt
2 Wire



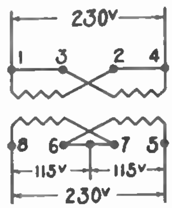
460 to 230 Volt
2 Wire, or
460 to 230/115 Volt
3 Wire



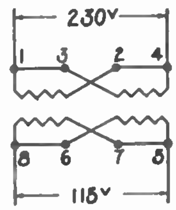
460 to 115 Volt
2 Wire



230 to 230 Volt
2 Wire

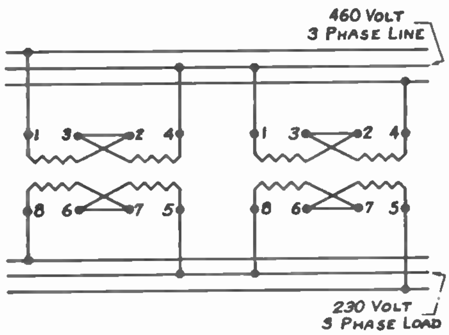


230 to 230 Volt
2 Wire, or
230 to 230/115 Volt
3 Wire

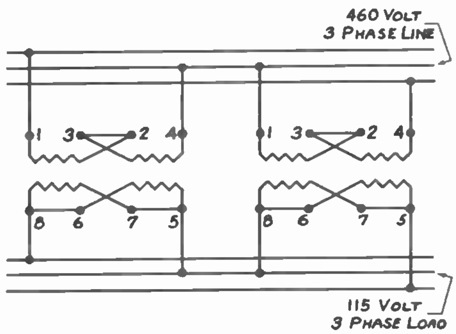


230 to 115 Volt
2 Wire

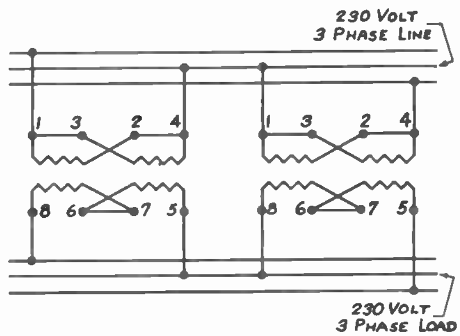
THREE-PHASE CONNECTIONS



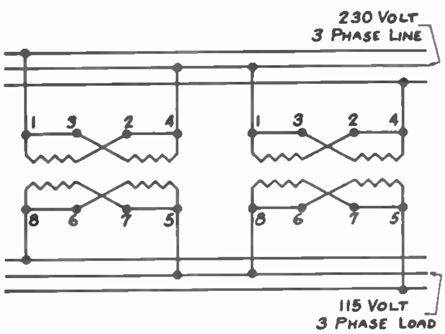
460 to 230 Volt Open-Delta*



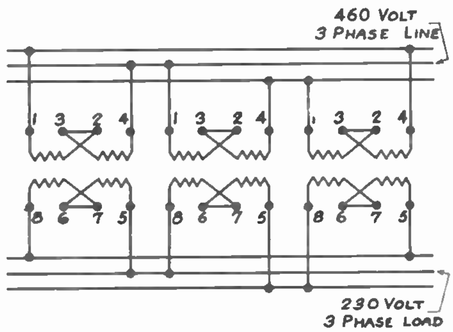
460 to 115 Volt Open-Delta*



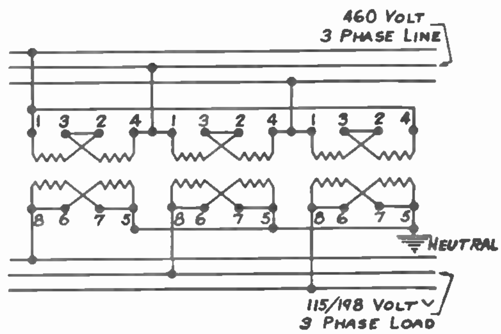
230 to 230 Volt Open-Delta*



230 to 115 Volt Open-Delta*



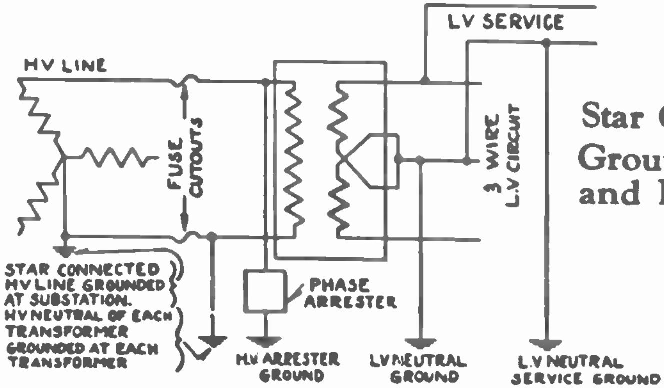
460 to 230 Volt Delta Connection
For 230 to 230 Delta Connections
connect (1 to 3 and 2 to 4)
otherwise same as above.



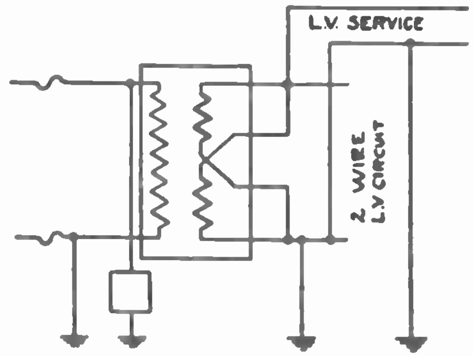
460 to 115/198 Volt Y Connection
(Additive Polarity)
For 230 to 115/198 Y Connections
connect (1 to 3 and 2 to 4)
otherwise same as above.

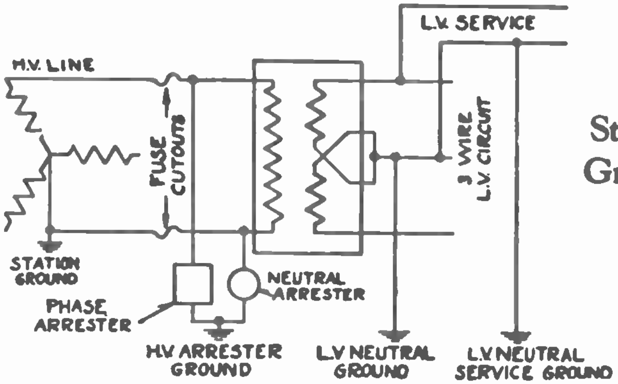
*For three-phase open-delta connections, transformers can only be loaded to 85% of their rated capacity and the regulation is rather poor.

CONVENTIONAL INSTALLATIONS

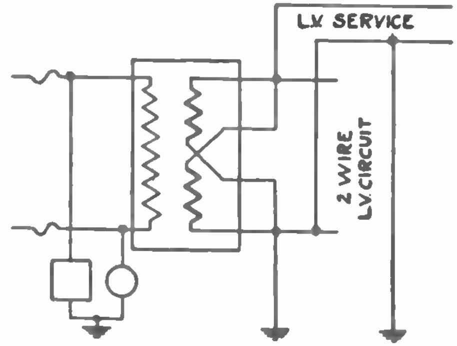


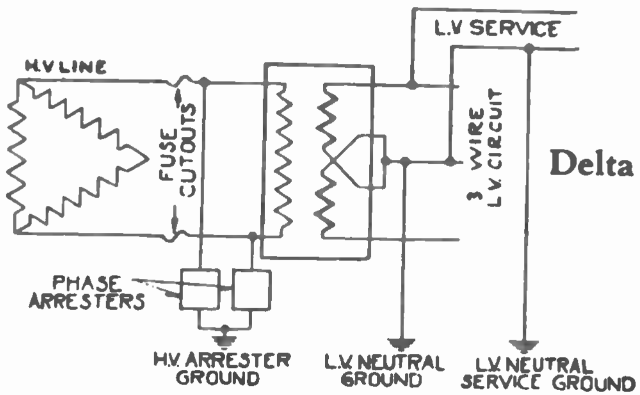
Star Connected System Grounded at Substation and Each Transformer



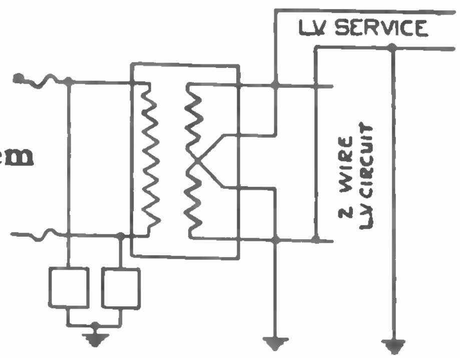


Star Connected System Grounded at Substation Only

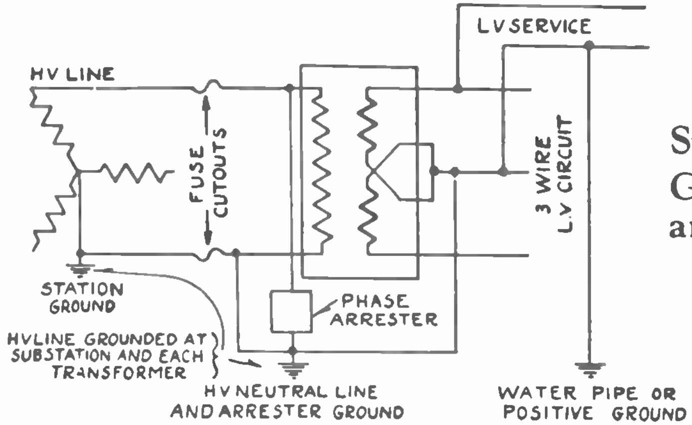




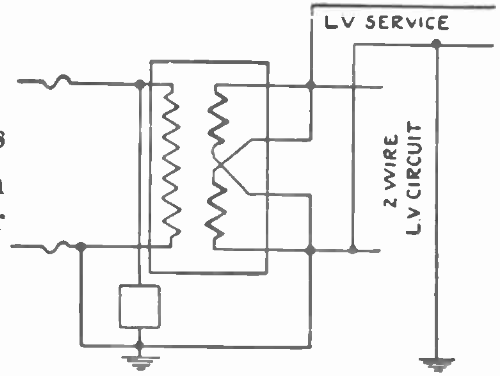
Delta Connected System

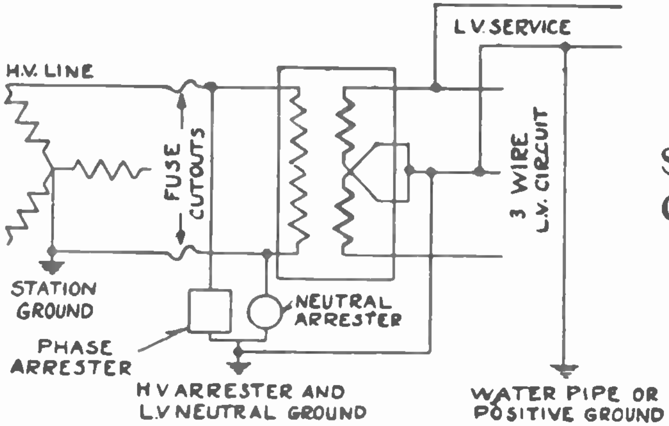


INTERCONNECTION

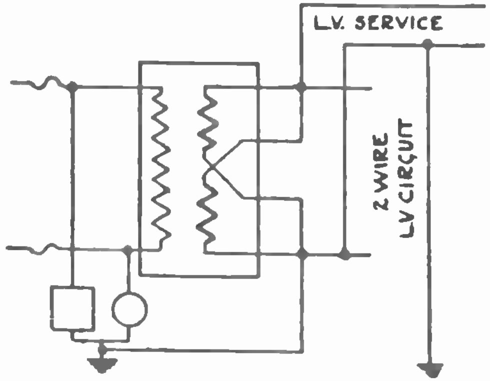


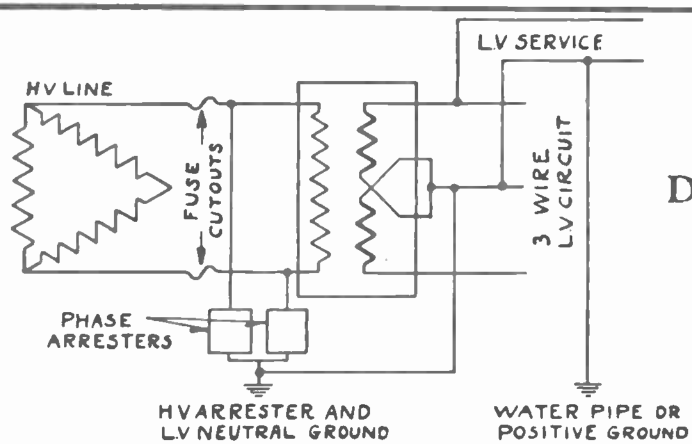
Star Connected Systems Grounded at Substation and Each Transformer



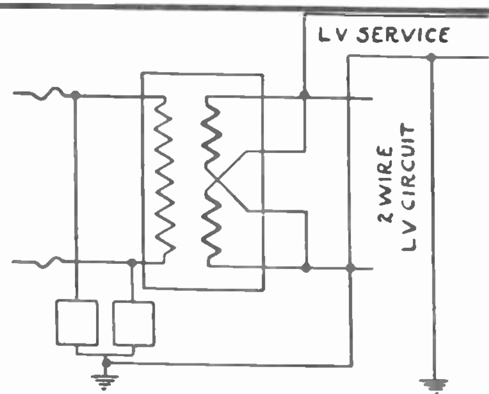


Star Connected Systems Grounded at Substation Only

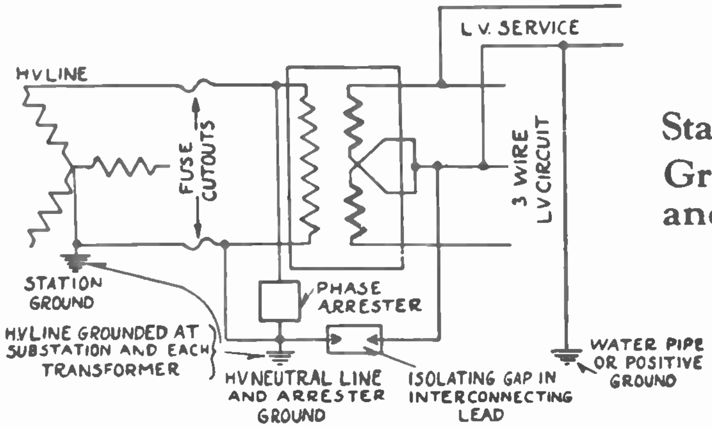




Delta Connected Systems



INTERCONNECTION WITH ISOLATING GAP



Star Connected Systems Grounded at Substation and Each Transformer

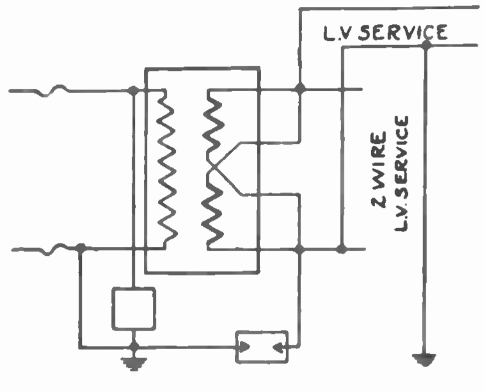
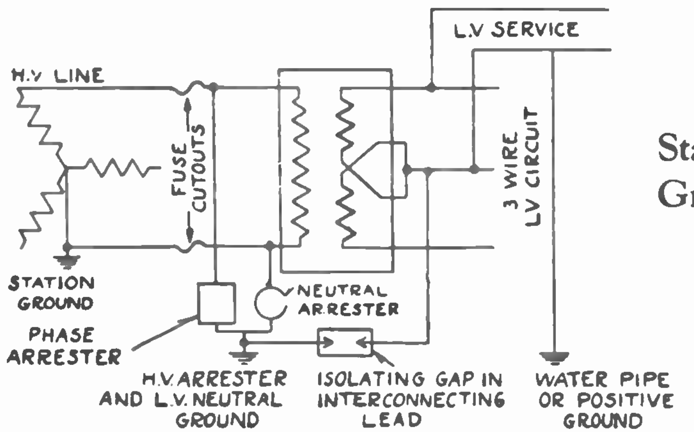


FIG 3A (2 WIRE SERVICE)



Star Connected Systems Grounded at Substation Only

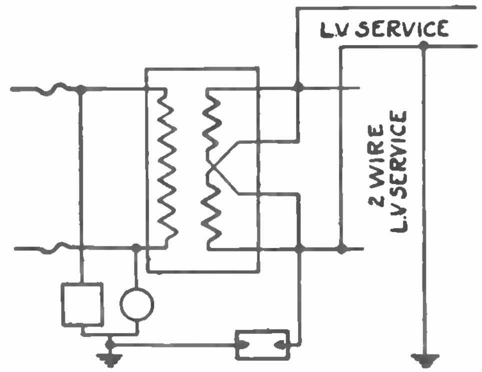
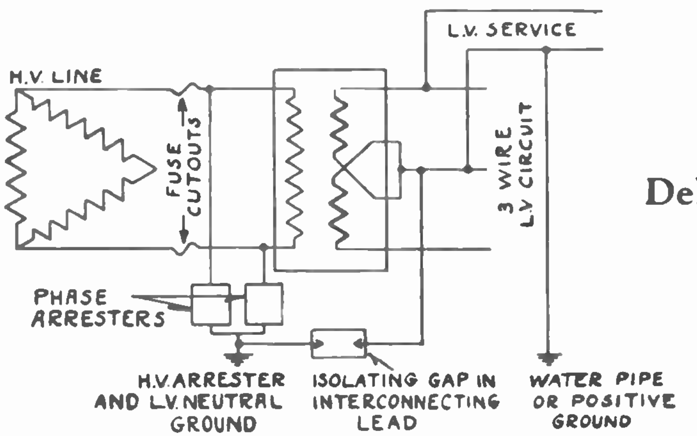


FIG. 3A (2 WIRE SERVICE)



Delta Connected Systems

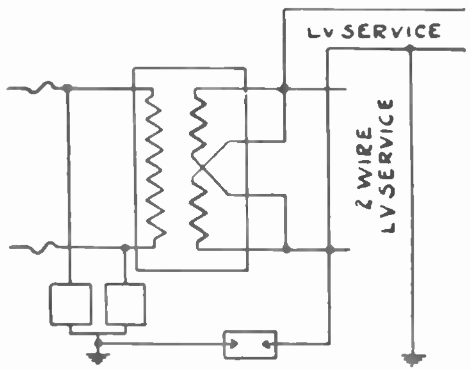


FIG 3A (2 WIRE SERVICE)

HOW THE NEUTRALIZER QUENCHES A FAULT

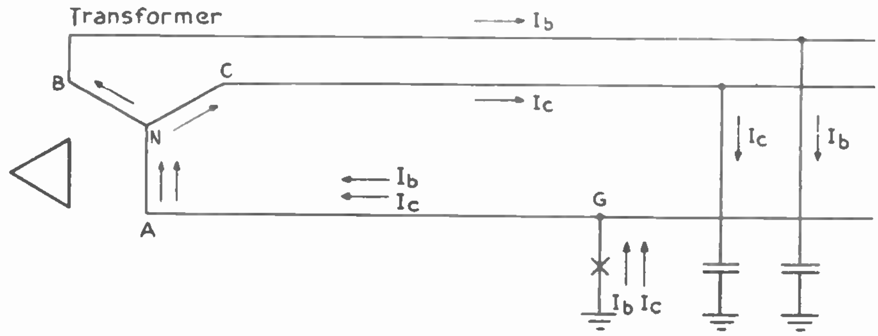


Fig. 2. Ground-fault currents, isolated-neutral system

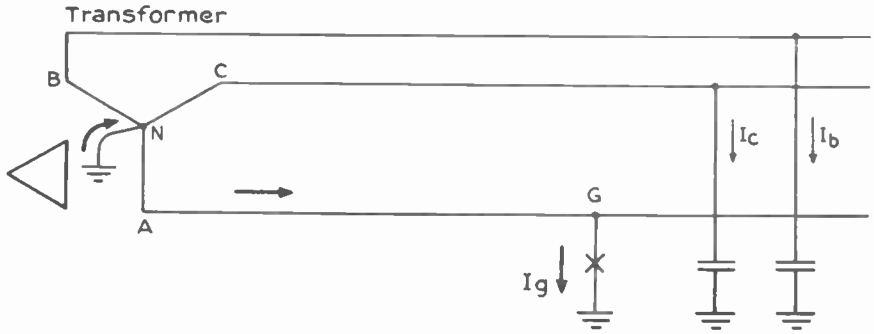


Fig. 3. Ground-fault currents, solidly grounded neutral system

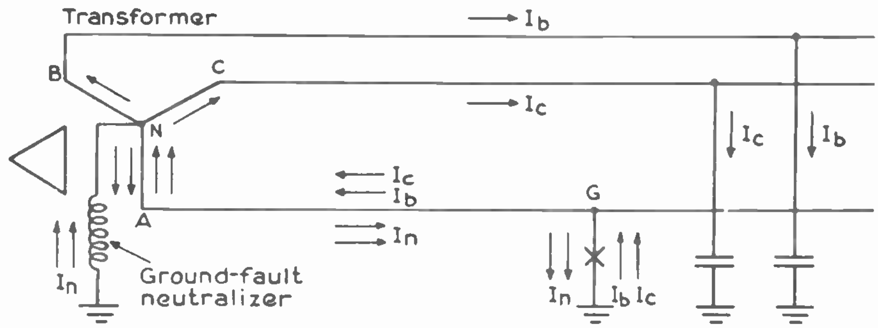


Fig. 4. Ground-fault currents, with neutralizer

● **When the System Neutral Is Isolated,** the current in a line-to-ground fault consists solely of charging current through the line-to ground capacitances of the other two line conductors (Fig. 2). However, operating experience shows that such disturbances frequently result in transient overvoltages sufficient to cause a second flashover on one of the unfaulted phases, thus causing a short circuit and an interruption to service. Relaying is difficult because the second fault usually occurs at a point remote from the first—frequently in terminal apparatus—necessitating expensive repairs.

● **When the System Neutral Is Solidly Grounded,** a line-to-ground fault short-circuits the faulted phase, causing current to flow through the fault, as shown in Fig. 3. This short-circuit current, I_g, is lagging, and is usually so much greater than the charging current of the unfaulted lines (I_b and I_c) that the effect of the latter is negligible. The fault persists until the circuit-breaker is tripped. This means a service interruption.

● **When the System Neutral Is Grounded through a Ground-fault Neutralizer,** transitory arcs to ground are extinguished without an outage, without even a momentary interruption of service, and without the aid of any moving parts. The line-to-ground fault causes line-to-neutral voltage to be impressed across the neutralizer, which then passes an inductive current, I_n, 180 degrees out of phase and approximately equal in magnitude to the resultant of the system-charging currents from the two unfaulted phases, I_b and I_c (Fig. 4). These inductive and capacitive currents neutralize each other, and the only remaining current in the fault is due, mainly, to corona, insulator leakage, etc. This current is relatively small, and, as it is in phase with the line-to-neutral voltage, the current and voltage reach a zero value simultaneously, hence, the arc is extinguished without restriking. In this way, flashovers are quenched without removing the faulted line section from service.

5.0 Constant Potential Transformers

5.1 GENERAL

5.105 Scope

These rules specify the markings of leads brought out of the case but not the markings of winding terminals inside of the case, except that these terminals shall be marked with numbers in any manner which will permit of convenient reference and which cannot be confused with the markings of the leads brought out of the case.

NOTE—It is recognized that special conditions will arise from time to time which these rules will not cover and which it would be very difficult to cover by any set of general rules.

5.110 Markings of Leads and Identification of Windings

1. In general the windings of a transformer shall be distinguished from one another by identifying them as winding No. 1, winding No. 2, winding No. 3, etc. The highest voltage winding shall always be No. 1, except for three-phase to six-phase transformers. (See 5.705.)

NOTE—The sequence of winding numbers after No. 1 may be by voltage or by kva.

2. In general the leads shall be distinguished from one another by marking each lead with a capital letter followed by a subscript number. The letters to be used are H for the leads of winding No. 1, X for the leads of winding No. 2, Y for the leads of winding No. 3 and Z for the leads of winding No. 4. The subscript numbers to be used are 1, 2, 3, etc.

3. After the letters have been assigned to identify the leads, the winding to which the respective leads are connected then may be referred to or designated by the same letter; e.g., winding No. 2 may also be referred to as the X winding.

4. A neutral lead of a three-phase transformer shall be marked with the proper letter followed by subscript 0; e.g., H_0, X_0, etc.

NOTE—A lead brought out from the middle of the winding for some other use than that of a neutral lead (e.g., a 50 per cent starting tap) shall be marked as a tap lead.

5. In case of transformers having a two-wire secondary with one terminal grounded, the other being ungrounded, the X_2 terminal should be grounded.

5.115 Diagrammatic Sketch of Connections

The manufacturer shall furnish with each transformer, a complete diagram showing the leads and internal connections and their markings and the voltages obtainable with the various connections. This diagram should preferably be on a metal plate attached to the transformer case.

5.3 SINGLE-PHASE TRANSFORMERS

5.305 Order of Numbering Leads in Any Winding

1. The leads of any winding brought out of the case shall be numbered 1, 2, 3, 4, 5, etc., the lowest and highest numbers marking the full winding and the intermediate numbers marking fractions of winding or taps. All numbers shall be so applied that the potential difference from any lead having a lower number toward any lead having a higher number shall have the same sign at any instant. (Refer to 5.905, Figs. 1, 2, 3, 4, 16 and 17.)

2. If a winding is divided into two or more parts for series-parallel connections, and the leads of these parts are brought out of the case, the above rule shall apply for the series connection with the addition that the leads of each portion of the winding shall be given consecutive numbers. (Refer to 5.905, Figs. 5 and 6, for four or more leads brought out; Figs. 8, 9, 10, 11, 20 and 21 for two or three leads brought out.)

3. When two leads are brought out of the case through one bushing (to minimize inductive effect) the terminals shall be marked in accordance with Figs. 16 and 17. When in addition a lead must be brought out from the midpoint, for three-wire operation, the terminals shall be identified in accordance with Figs. 20 and 21.

5.310 Order of Numbering Leads of Different Windings

1. The numbering of the leads of the H winding and the leads of the X winding shall be applied so that when H_1 and X_1 are connected together and voltage applied to the transformer, the voltage between the highest numbered H lead and the highest numbered X lead shall be less than the voltage of the H winding.

2. When more than two windings are used, the same relationship shall apply between each pair of windings.

5.315 Polarity

When leads are marked in accordance with the foregoing rules, the polarity of a transformer is:

1. Subtractive when H_1 and X_1 are adjacent. (Refer to 5.905, Figs. 1, 3, 5, 7, 10, 12, 14, 16, 18 and 20.)
2. Additive when H_1 is diagonally located with respect to X_1. (Refer to 5.905, Figs. 2, 4, 6, 9, 11, 13, 15, 17, 19 and 21.)
3. The same rule applies between the H and Y winding, and between the H and Z winding; i.e., when Y_1 or Z_1 is on the left when facing the Y or Z side of the case, respectively, the polarity is subtractive, and additive if on the right.

5.320 Location of H_1 Lead

1. To simplify the connections of transformers in parallel, the H_1 lead shall be brought out on the right hand side facing the highest voltage side of the case and other H leads shall be brought out in numerical order from right to left.

2. When the high-voltage winding has only one terminal brought out through a rated voltage bushing (the other terminal to be grounded) the rated voltage terminal shall be designated as H_1. For polarity marking and testing, the H_1 terminal shall be regarded as located on the right, regardless of its actual location.

Exception—If two alternative positions are provided for the single rated voltage bushing, the two positions shall be identified by terminal markings in accordance with paragraph 1.

3. When the high-voltage terminals are brought out through two bushings of different insulation levels, the bushing having the higher voltage level shall be designated as H_1 and shall be located on the right hand side facing the high-voltage side of the case. (Refer to 5.920 and 5.925.)

5.325 Parallel Operation

Transformers having leads marked in accordance with these rules may be operated in parallel by connecting similarly marked leads together, provided their ratios, voltages, resistances, reactances and ground connections are such as to permit parallel operation.

NOTE—In some cases designs may be such as to permit parallel operation, although due to a difference in the number of tap leads, the leads to be connected together are not similarly marked.

5.335 Autotransformers

Single-phase autotransformer leads shall, as far as practicable, be marked in accordance with the requirements for subtractive polarity. (Refer to 5.905, Fig. 7.)

5.5 THREE-PHASE TRANSFORMERS

5.505 Marking of Full Winding Leads

The three leads for each winding which connect to the full phase windings shall be marked H_1, H_2, H_3, X_1, X_2, X_3, Y_1, Y_2, Y_3, etc., respectively.

5.510 Relation Between Highest Voltage Winding and Other Windings

1. The markings shall be so applied that if the phase sequence of voltage on the highest voltage winding is in the time order H_1, H_2, H_3, it will be in the time order of X_1, X_2, X_3, and Y_1, Y_2, Y_3, etc., on the other windings.

2. In order that the markings of lead connections between phases of three-phase transformers shall indicate definite phase relations, they shall be made in accordance with one of the three-phase groups shown in Figs. 1 to 5 inclusive, 5.915. The angular displacement between the H winding and the X winding is the angle in each of the voltage vector diagrams (Figs. 1 to 5 inclusive, 5.915) between the lines passing from its neutral point through H_1 and X_1, respectively.

3. When more than one low-voltage winding is used, the angular displacement between the H winding and each of the other low-voltage windings is established in the same manner, using H_1 and Y_1; H_1 and Z_1; etc., respectively.

5.515 Tap Leads

1. General

Where tap leads are brought out of the case (neutral lead excepted) they shall be marked with the proper letter followed by the figures 4, 7, etc., for one phase, 5, 8, etc., for another phase, and 6, 9, etc., for the third phase. (See Fig. 5, 5.915.)

AMERICAN STANDARD

2. DELTA CONNECTION

The order of numbering tap leads shall be as follows: 4, 7, etc., from lead 1 toward lead 2; 5, 8, etc., from lead 2 toward lead 3; and 6, 9, etc., from lead 3 toward lead 1. (See Fig. 5, rule 5.915.)

3. STAR CONNECTION

The order of numbering tap leads shall be as follows: 4, 7, etc., from lead 1 toward neutral; 5, 8, etc., from lead 2 toward neutral; and 6, 9, etc., from lead 3 toward neutral. (See Fig. 5, rule 5.915.)

5.520 Interphase Connections Made Outside of Case

1. Where the interphase connections are made outside the case, the leads shall be marked with the proper letter followed by the numbers 1, 4, 7, 10, etc., for one phase; 2, 5, 8, 11, etc., for the second phase; and 3, 6, 9, 12, etc., for the third phase.

2. The markings shall be so applied that when a star connection is made by joining together the highest numbered leads of each phase all rules here given apply except paragraph 4 of rule 5.110.

5.525 Parallel Operation

Transformers having leads marked in accordance with the foregoing rules may be operated in parallel by connecting similarly marked leads together, provided their angular displacements are the same and provided also their ratios, voltages, resistances, reactances and ground connections are such as to permit parallel operation.

NOTE—In some cases designs may be such as to permit parallel operation although, due to a difference in the number of tap leads, the leads to be connected together are not similarly marked.

5.530 Location of External Leads

1. To simplify the work of connecting transformers in parallel, the H_1 lead shall be brought out on the right hand side of the case facing the highest voltage side of the case. The H_2 and H_3 leads shall be brought out so that the three leads are arranged in numerical order reading from right to left when facing the highest voltage side of the case. (See rule 5.930.)

2. The X_1 lead shall be brought out on the left hand side of the case facing the X winding side of the case. The X_2 and X_3 leads shall be brought out so that the three leads are arranged in numerical order reading from left to right when facing the X winding side of the case. (See rule 5.930.)

3. The Y winding and Z winding leads, if present, shall be brought out and numbered in the same manner as the X winding leads.

4. The location of the external leads specified in Paragraphs 1, 2 and 3 shall apply to only one connection, such as a Y or a delta, of a given winding.

5.7 THREE-PHASE TO SIX-PHASE TRANSFORMERS

5.705 Basis of Rules

The rules for three-phase to six-phase transformers are set up on the basis that the three-phase winding is always the H winding.

5.710 Marking of Full Winding Leads

The three leads which connect to the three-phase winding shall be marked H_1, H_2, H_3 and the six leads which connect to the full six-phase winding shall be marked X_1, X_2, X_3, X_4, X_5, X_6. (Figs. 1 to 4 inclusive, 5.940.)

5.715 Relation Between Three-Phase and Six-Phase Windings

1. The markings shall be so applied that if the phase sequence of voltage on the three-phase terminals is in the order H_1, H_2, H_3, it is in the time order X_1, X_2, X_3, X_4, X_5, X_6, on the six-phase terminals.

2. In order that the markings of lead connections between phases shall indicate definite phase relations, they shall be made in accordance with one of the four six-phase groups shown in Figs. 1 to 4, inclusive, 5.940. The angular displacement between the three-phase and six-phase windings is the angle in each of the voltage vector diagrams from its neutral through H_1 and X_1, respectively.

5.720 Tap Leads

Where tap leads from the six-phase windings are brought out of the case (neutral lead excepted), they shall be marked as follows:

(1) Diametrical Connection. Tap leads shall be marked from the two ends of each phase winding toward the middle or neutral point in the following order:

X_7, X_{13}, etc., from X_1 toward neutral;
X_8, X_{14}, etc., from X_2 toward neutral;
X_9, X_{15}, etc., from X_3 toward neutral;
X_{10}, X_{16}, etc., from X_4 toward neutral;
X_{11}, X_{17}, etc., from X_5 toward neutral;
X_{12}, X_{18}, etc., from X_6 toward neutral.
(See Fig. 5, 5.940.)

A tap from the middle point of any phase winding, not intended as a neutral, shall be given a number determined by counting from X_1, X_2 or X_3 and not from X_4, X_5 or X_6; e.g., if the only taps brought out are 50 per cent starting taps, they shall be numbered X_7, X_9, and X_{11}.

(2) Double-Delta Connection. Tap leads shall be marked in the following order:

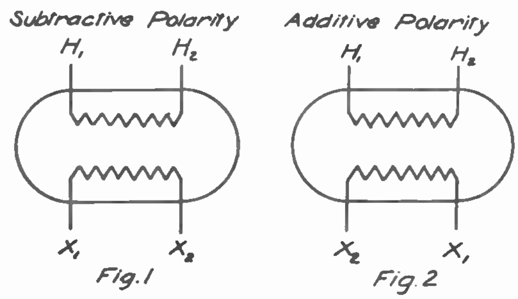
X_7, X_{13}, etc., from X_1 toward X_3;
X_8, X_{14}, etc., from X_2 toward X_4;
X_9, X_{15}, etc., from X_3 toward X_5;
X_{10}, X_{16}, etc., from X_4 toward X_6;
X_{11}, X_{17}, etc., from X_5 toward X_1;
X_{12}, X_{18}, etc., from X_6 toward X_2.
(See Fig. 6, 5.940.)

NOTE—For starting purposes it is generally customary to bring out only two taps from one delta and start three-phase.

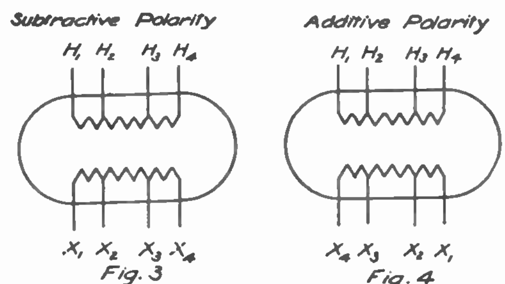
5.9 CONNECTION DIAGRAMS

5.905 Lead Markings—Single-Phase Transformers

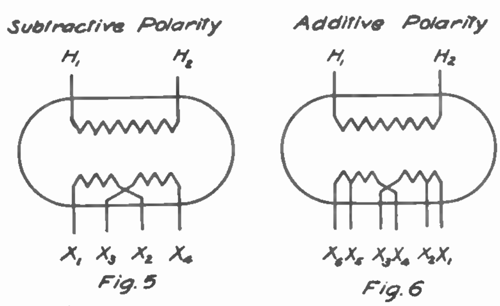
(The ground connection shown in broken lines applies to single-phase installations only.)



Simple H and X Windings Without Taps



Simple H and X Windings With Taps



Series Multiple X Winding Without Taps

Series Multiple X Winding With Taps

NOTE I—The above figures illustrate the application of the rules on lead markings to transformers having subtractive and additive polarity.

NOTE II—See rule 1.510 for the terminal letters assigned to different types of windings, and rule 1.130 for the significance of the subscript numerals.

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Subtractive Polarity **Additive Polarity**

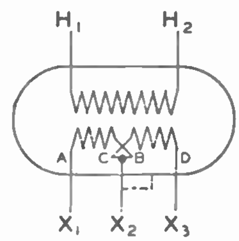


FIG. 8

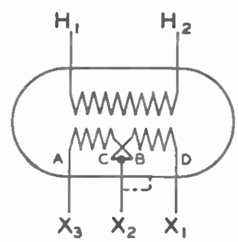


FIG. 9

Three-Wire Series Connection
Transformers having neutral brought out between outside leads

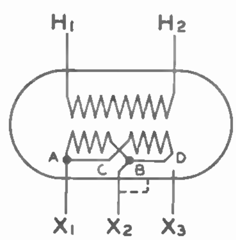


FIG. 10

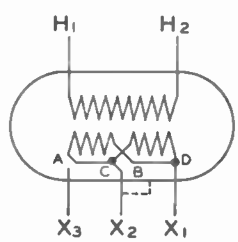


FIG. 11

Two-Wire Parallel Connection

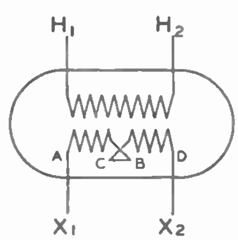


FIG. 12

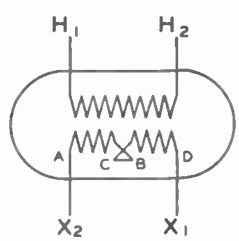


FIG. 13

Two-Wire Series Connection

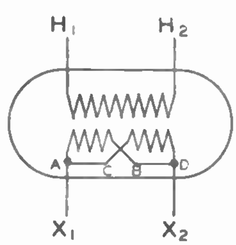


FIG. 14

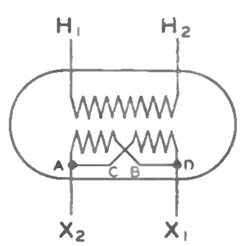


FIG. 15

Two-Wire Parallel Connection

Subtractive Polarity **Additive Polarity**

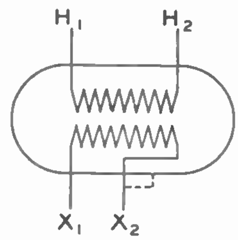


FIG. 16

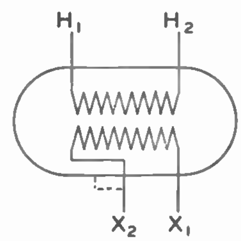


FIG. 17

120 Volt Class Connection

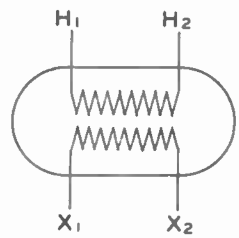


FIG. 18

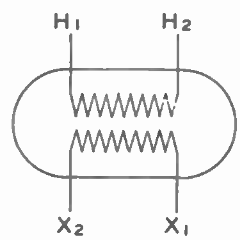


FIG. 19

Above 120 Volt Class Connection

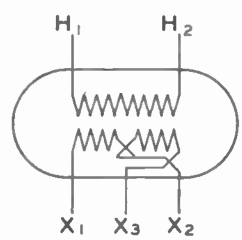


FIG. 20

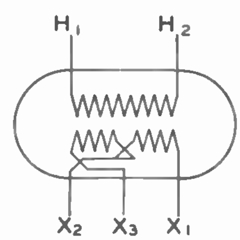


FIG. 21

Three-Wire Series Connection
Transformers having neutral brought out to side

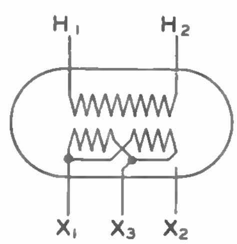


FIG. 22

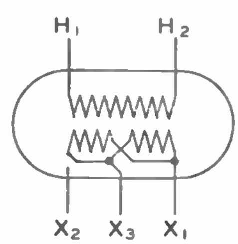


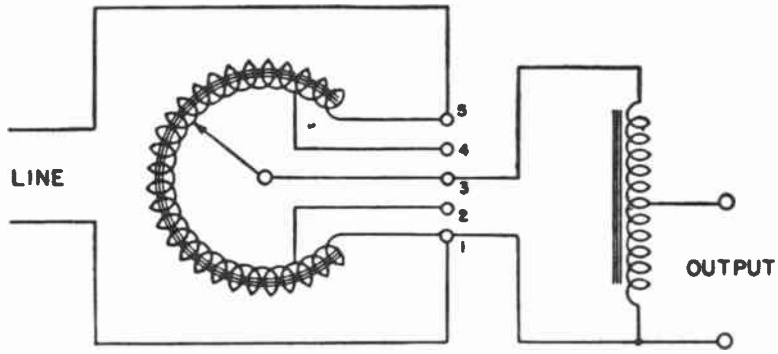
FIG. 23

Two-Wire Parallel Connection
Transformers where neutral is brought out to side

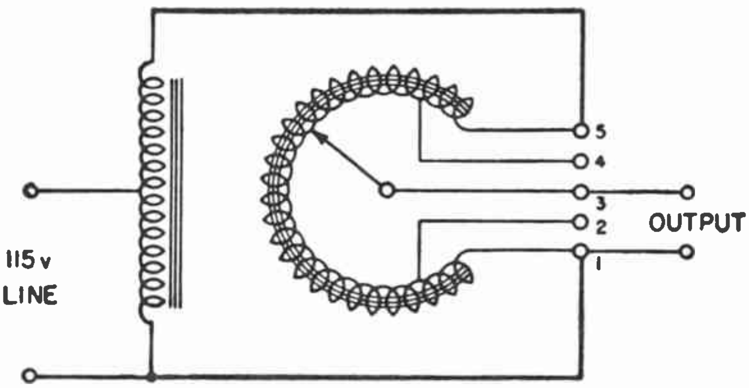
NOTE 1—The above figures illustrate the application of the rules on lead markings to transformers having subtractive and additive polarity.

VARIAC CONTINUOUSLY ADJUSTABLE TRANSFORMERS - GENERAL RADIO COMPANY

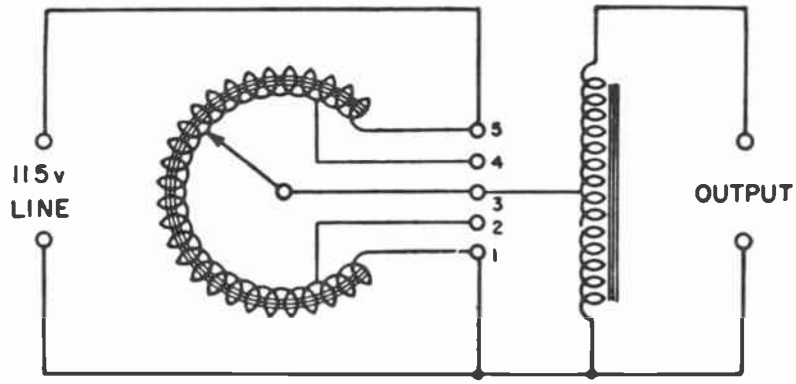
To obtain high currents at low voltages this connection may be used with any Variac. The output from the Variac is connected to a step-down transformer.



If it is desired to draw full rated current from a 230-volt Variac when only a 115-volt line is available these connections can be used. The auxiliary step-up transformer is used to supply input to the Variac at its rated voltage. Maximum current can be drawn at maximum output voltage.

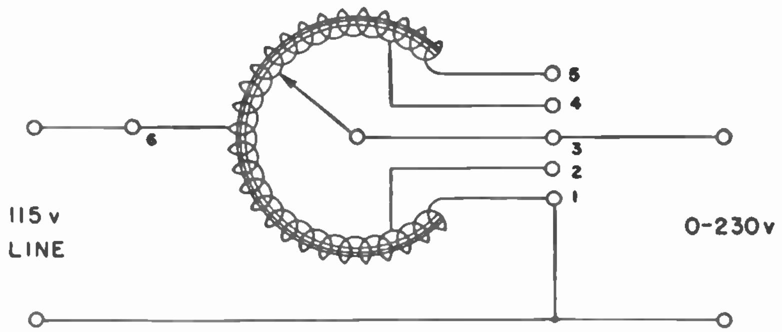


This connection is a variation of the method shown above. The auxiliary step-up transformer is used on the output side of the Variac. This system is particularly useful when the output voltage is too high to be handled by the Variac. The output power available, for a resistive load, will be the volt-ampere rating of the Variac multiplied by the efficiency of the auxiliary transformer.

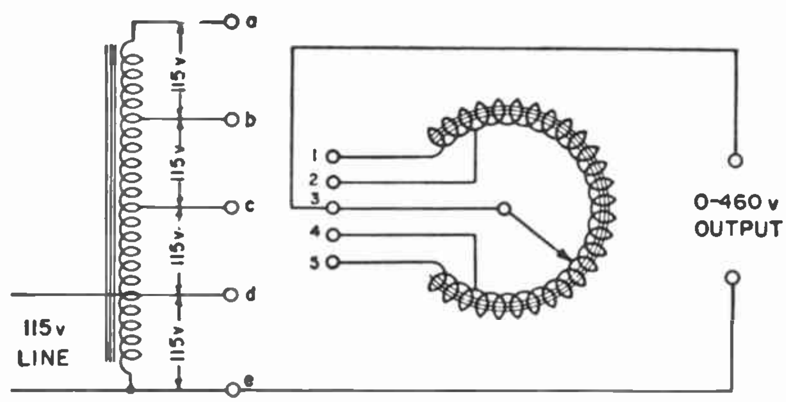


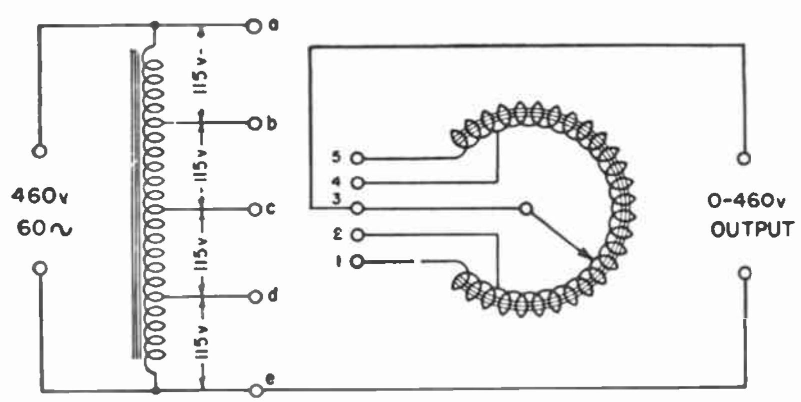
VARIAC CONTINUOUSLY ADJUSTABLE TRANSFORMERS - GENERAL RADIO COMPANY

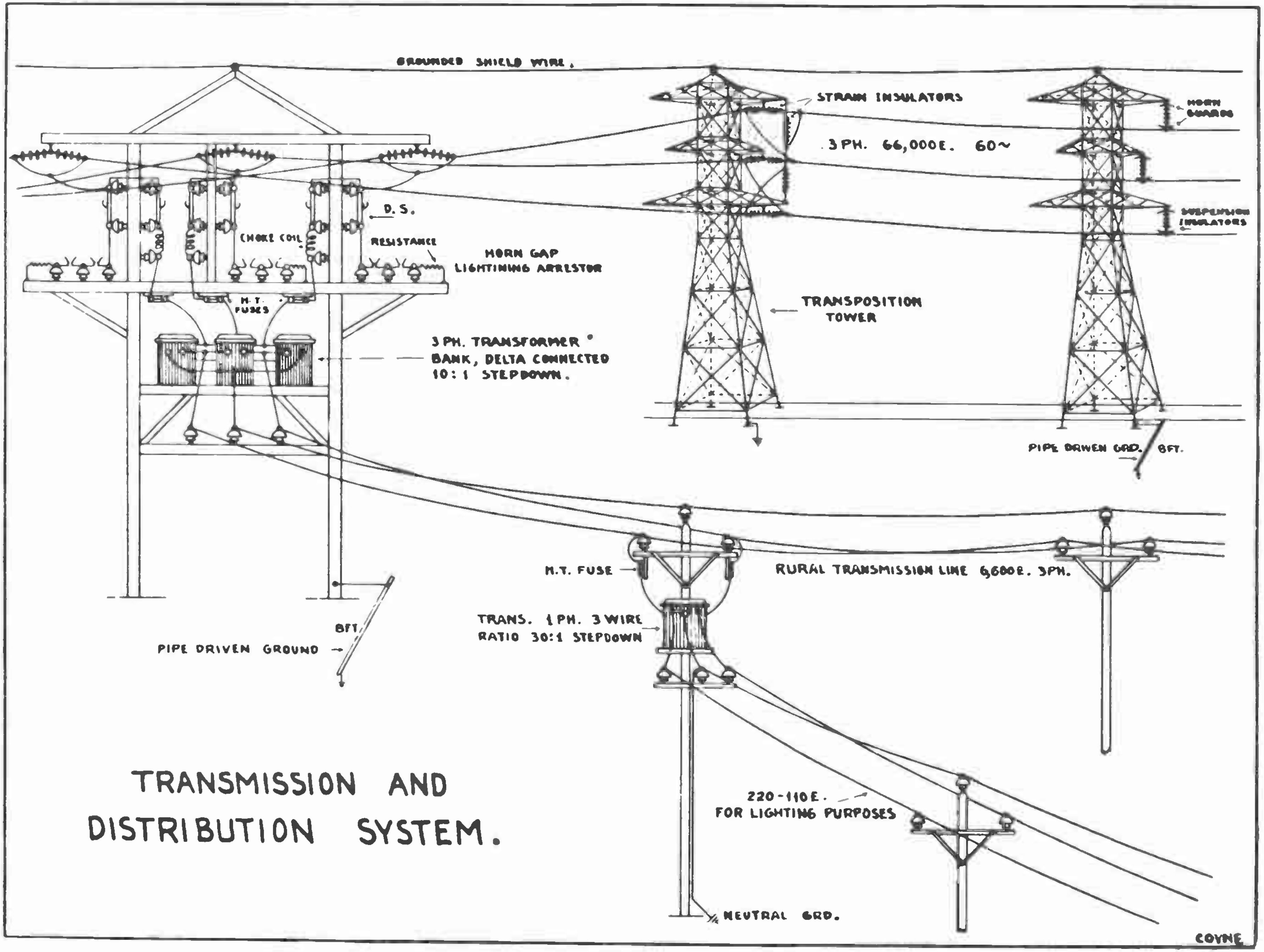
To obtain 230 volts from a 115-volt line a 230-volt Variac can be connected as shown. The Variac acts as a 2-to-1 step-up transformer with output voltage continuously variable from 0 to 230 volts. In this case the current which can be safely drawn at the highest voltage is one-half the rated current.



These connections allow drawing rated current from the Variac at voltages above rated output voltage. The auxiliary transformer gives maximum voltage desired. Secondary taps give voltages, between adjacent taps, not greater than rated voltage of the Variac. With suitable switches the Variac can be connected from tap to tap and the output voltage can be varied from zero to maximum without interruption of the circuit. With terminal 1 connected to tap e and terminal 5 connected to tap d, rotation of the brush of the Variac increases the output voltage from 0 to 115 volts. If terminal 1 then is switched to tap c and the brush is rotated in the opposite direction, the output is raised from 115 to 230 volts. Finally, when terminal 1 is switched to tap a and terminal 5 to tap b, the output voltage is variable from 345 to 460 volts. When output voltage is high it is advisable to insulate the Variac from ground to eliminate danger of voltage breakdown.

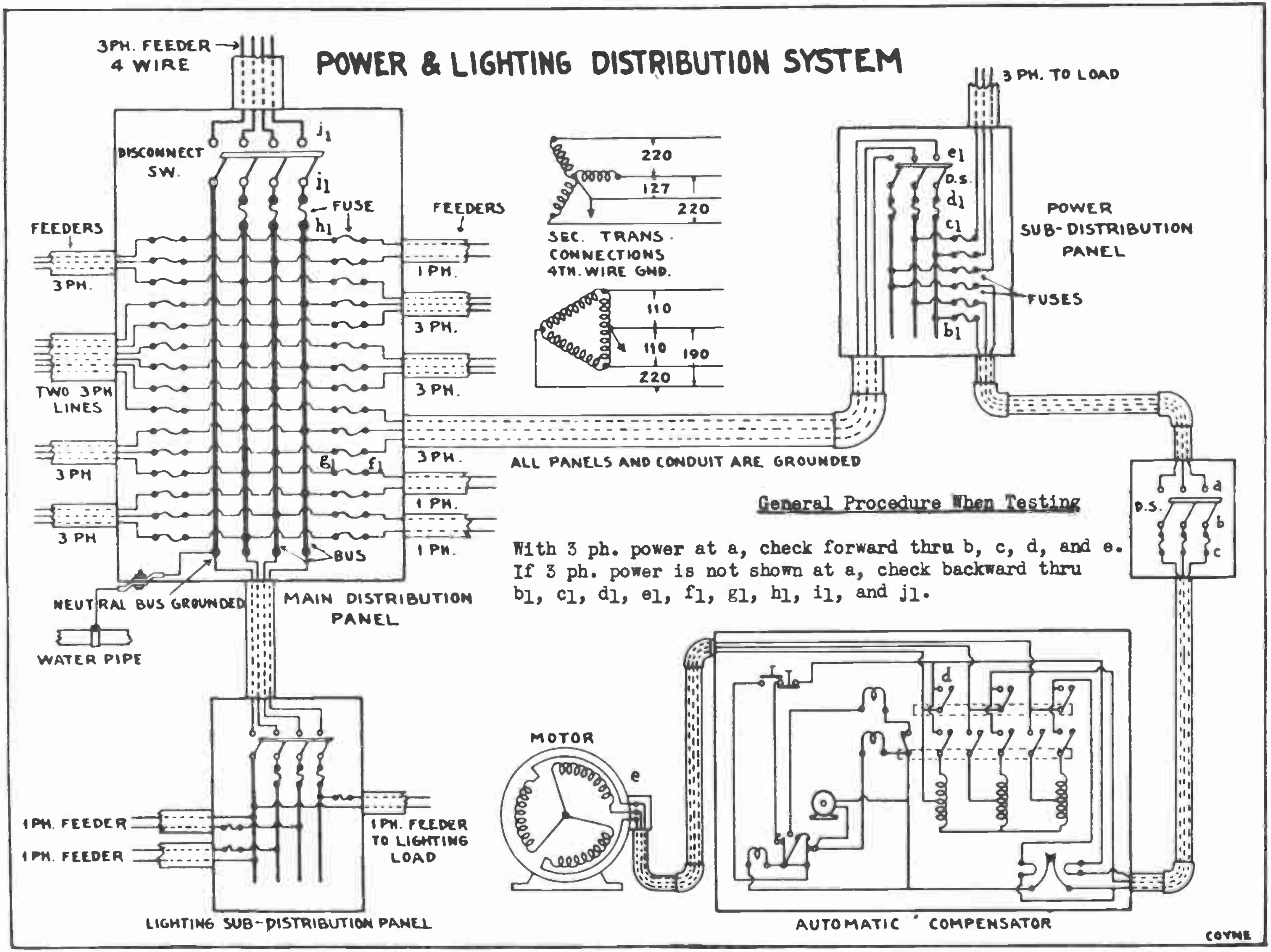






TRANSMISSION AND DISTRIBUTION SYSTEM.

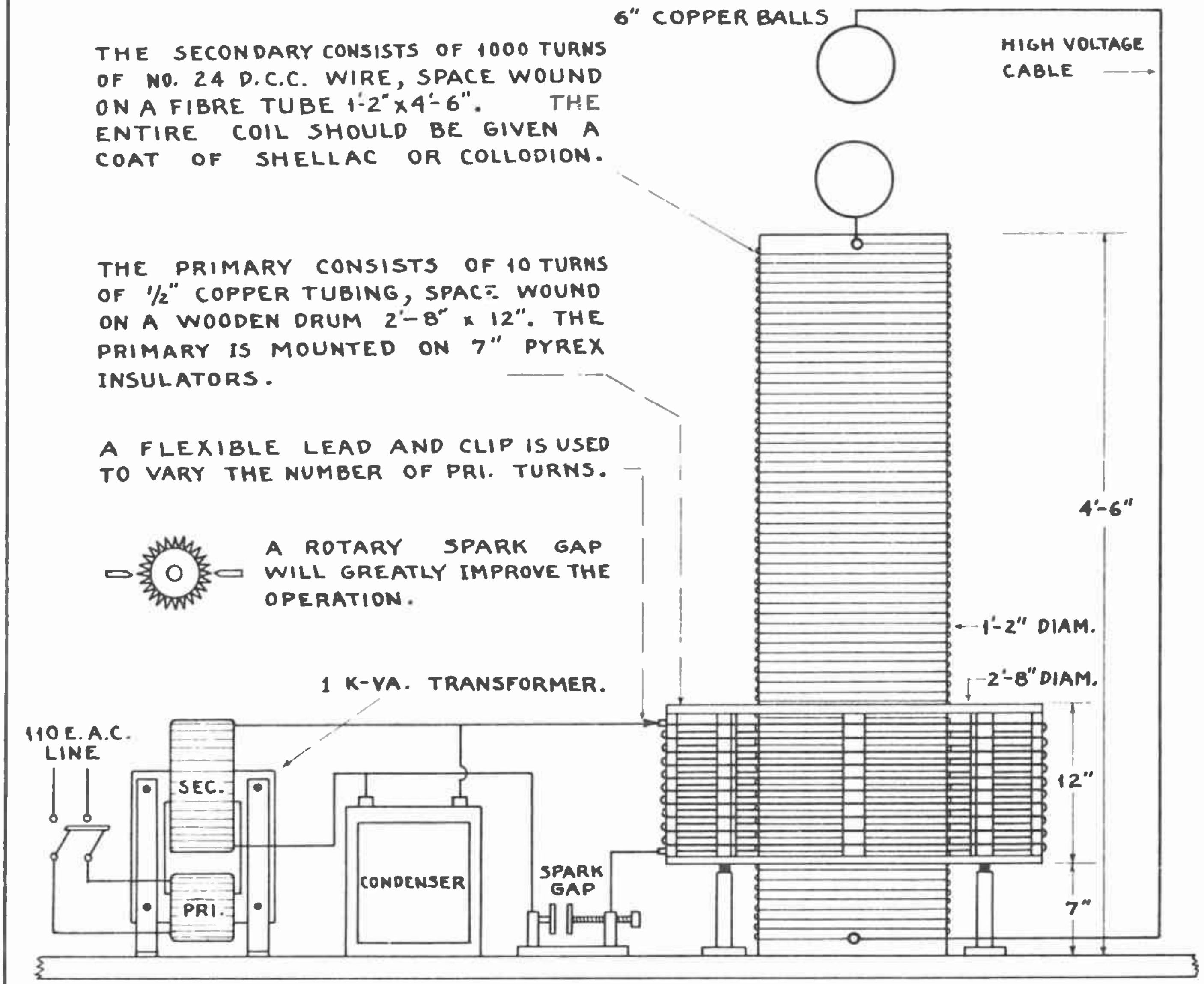
POWER & LIGHTING DISTRIBUTION SYSTEM

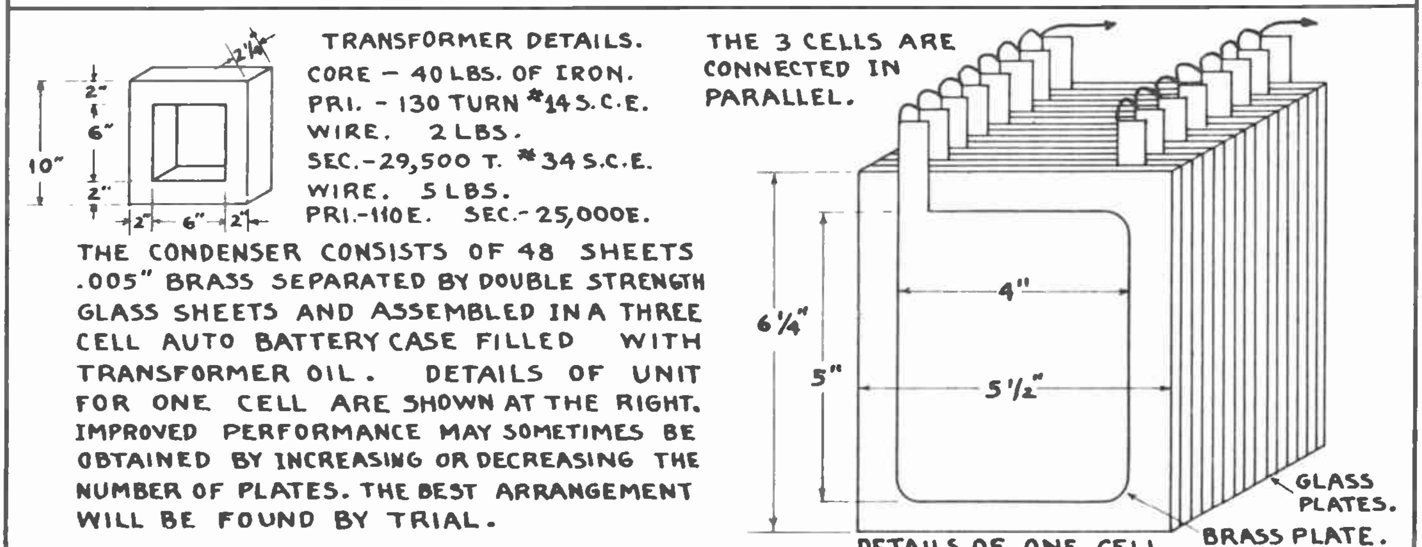


General Procedure When Testing

With 3 ph. power at a, check forward thru b, c, d, and e. If 3 ph. power is not shown at a, check backward thru b_1, c_1, d_1, e_1, f_1, g_1, h_1, i_1, and j_1.

Design Data for Tesla Coil - Experimental apparatus for developing high-voltage, high frequency energy.

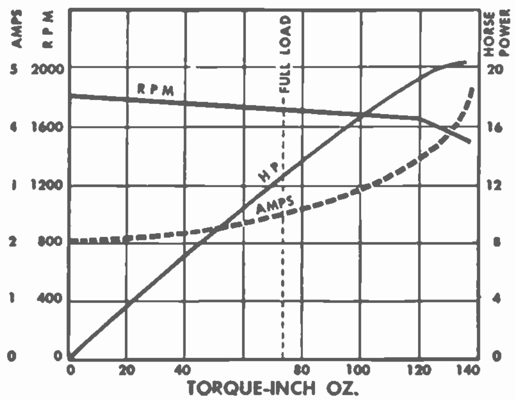




COYNE ELECTRICAL SCHOOL.

How General Purpose Motors are Rated

While there are a number of different ways in which an electric motor can be rated, the usual practice is to rate a motor in terms of horsepower output. For example, a certain motor may have a rating of 1/10 hp.



Typical characteristic curves of a fractional horsepower motor, showing horsepower output, speed, and motor current.

First of all, let us define our unit. One horsepower is a unit of power about equal to the rate at which a strong horse can work for a short period. It was first used by inventor James Watt, who applied it to his steam engine in order to be able to compete directly with the horses being used for power in the mines of his day. Numerically, it is equal to 33,000 foot-pounds of work per minute. Thus, a motor's horsepower is a measure of the work it is capable of doing over a period of time.

A motor's horsepower rating depends upon two things: the torque (turning effort) of the motor and its speed. If torque is expressed in lb-ft, the formula is:

Horsepower — .00019 x torque x rpm

Now, we know that any motor is capable of carrying a load, for a short time at least, far in excess of its rated capacity. A 1/4-hp motor will not stall if we force it to do slightly more than 1/4 hp of work. What is to prevent a motor manufacturer from putting a 1/15-hp rating on what should be a 1/20-hp motor?

To prevent arbitrary ratings being assigned, certain standards have been set up for the National Electrical Manufacturers Association. General purpose motors must be so designed that the temperature rise of a ventilated motor carrying its rated load will not exceed 40 C.* This temperature rise is based on ambient (air) temperature being not more than 40 C,** and voltage and frequency must also be uniform.

Even without the NEMA standard, temperature rise would still be an automatic limiting factor. If the motor windings exceed certain temperature limits, the insulation deteriorates or burns out. Thus, the main effect of the NEMA rule is to standardize motor ratings so that the purchaser of a motor will know what to expect from it.

Constant-duty motors—that is, motors which operate continuously—reach their maximum temperature in two or three hours. The same motor operating intermittently, on the other hand, will cool off between runs and never reach this maximum temperature. Intermittent-duty motors, therefore, can be given a higher rating than constant-duty motors. They are limited by the same temperature rise, but reach this temperature in a shorter time. When it is known, for example, that a motor will not be used more than 30 minutes at a time, with sufficient idle time for cooling, it can be rated higher than if it were used in constant duty.

The type of frame also affects the rating of a motor. Totally enclosed frames are used to prevent dirt, dust, or harmful gases from entering. In such motors, the heat developed is not carried away as quickly as in open type frames. Therefore, NEMA permits a temperature rise of 55 C† in totally enclosed motors.

In order that general purpose motors made by different manufacturers may be easily compared, NEMA publishes standard horsepower ratings to which most manufacturers conform. Some of these are: 1/20, 1/15, 1/12, 1/8, 1/6, and 1/4 horsepower. Standard speeds are also recommended by NEMA. For constant-speed motors, these are: 1140, 1725, and 3450 rpm. For very small motors, 1725 rpm is sometimes preferable. Standard voltages in use today are 115 and 230 volts single-phase, and 220 volts three-phase. Standard frequencies are 25 and 60 cycles per second, with the latter in almost universal use.

Even though two motors have similar ratings, the torques they develop at starting, during acceleration, or during the running period may differ greatly. To prevent wide differences, certain minimum values of torque have been recommended by NEMA for a given type of general purpose motor of a given horsepower.

Another important limitation is the locked-rotor current rating. To prevent undue fluctuations in distribution line voltages, most power companies will not tolerate motors of 1/6 hp or smaller which draw more than 20 amperes locked current on 115 volts. This is in accordance with NEMA standards.

In addition to such limitations, NEMA sets a definite minimum value for the efficiency and power factor of different types of motors at 1/2, 3/4, and full load.

Sometimes manufacturers build motors for which no standards exist, especially in the lower horsepower ratings. In these cases, reputable manufacturers make a practice of paralleling as closely as possible the standards for ratings listed.

*40 C rise is equivalent to 72 F rise.
**40 C ambient temperature is equivalent to 104 F.
†55 C rise is equivalent to 99 F rise.

How Special Purpose Motors are Rated

On the preceding page of the Motorgram there is a brief discussion on rating general purpose motors. In that article it is brought out that the National Electrical Manufacturers Association have set up certain limiting requirements of temperature rise, speed, torque, efficiency, and power factor for general purpose fractional horsepower motors, with which all NEMA manufacturers comply. Bodine general purpose motors meet or exceed these NEMA standards.

What do NEMA standards mean to the purchaser of motors? They are a guarantee of performance and an aid in comparing competitive equipment. When a user purchases a motor made by a NEMA manufacturer, he is assured that it will do certain things. It will have a given *minimum* rating, torque, efficiency, etc., and will not exceed the standard temperature rise. But, while the minimum requirements are guaranteed, NEMA does not limit the maximum characteristics. A manufacturer can, if he believes it desirable, give the buyer extra benefits in increased operating characteristics. NEMA standards cannot be used, therefore, as a measure of the value of a motor.

Then too, just because a standard general purpose motor will meet NEMA requirements is no guarantee that it will suit the individual requirements of a job. For example, a motor may develop the necessary power for a specific application and remain within the NEMA limits on temperature rise, but the presence of a noticeable magnetic hum may be objectionable. Under these conditions, a larger frame size may be used so that the saturation of the iron is cut down and the motor operates more quietly.

For some applications, the standard 40 C temperature rise is too high for proper lubrication of the ball bearings. In order to get maximum life out of ball bearings, they should operate at temperatures below 72 C (160 F). If the room temperature is high, the operating bearing temperature may be excessive. Special ball bearings or a motor with a large frame may be necessary.

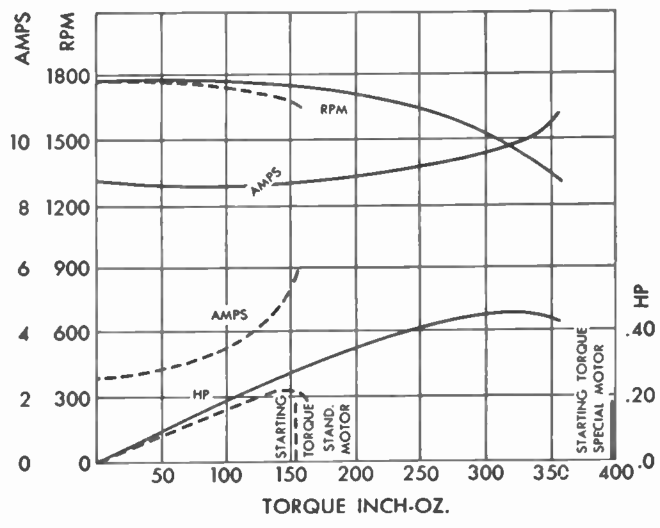
There are many other applications in which high motor temperatures are not permissible. If the motor is to be located close to a person, the comfort of that individual may be the limiting factor. Heat-sensitive instruments mounted nearby may be affected by high motor temperatures. In such cases, a motor with a larger frame is needed.

The speed regulation of a general purpose NEMA motor may not be satisfactory, or the starting torque requirements may be so severe that a standard motor will not do. Likewise, the starting current, breakdown torque, or some other characteristic of a NEMA general purpose motor may not be suitable.

To fit such needs, "special purpose" motors must sometimes be built. NEMA defines a special purpose motor as one "specifically designed and listed for a particular power application, where load requirements and duty cycle are definitely known." Special purpose motors are usually built to order. By meeting the exact requirements of the load, they provide satisfactory performance without excessive bulk or weight, although cost must be higher.

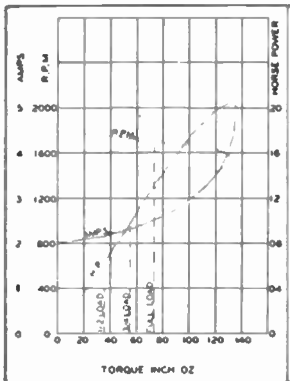
It is possible to do many things with special purpose motors that are beyond the capacity of general purpose motors. Yet, it must be understood that getting one special characteristic usually means sacrificing another. For example, high starting torque can be built into a motor at the expense of efficiency, or vice versa. Unusually high speeds will step up the horsepower of a motor for a given torque and a given frame size, but the life of the bearings may be decreased. In a fan motor it is important to have a high breakdown torque. Yet the locked-rotor torque necessary in a fan motor is practically negligible. Special purpose motors for fans, therefore, are built to give a high breakdown torque at the expense of locked-rotor torque.

In general, it can be said that general purpose motors are built to meet most of the ordinary requirements and are so balanced that no one characteristic is sacrificed in order to gain another. Only by knowing the exact requirements of the job is it possible for a motor manufacturer to design a motor to do exactly what is wanted. Unless the manufacturer has this complete information, he hesitates to design for special characteristics in fear of encountering trouble at other points.



Performance curves of a typical general purpose motor (dotted line) and special purpose motor (solid line) of the same frame size. In the special purpose motor, higher starting torque and greater output were necessary. Because the motor was to be used for intermittent duty, a higher temperature rise than NEMA standard could be tolerated. The special purpose motor, therefore, was designed to give higher starting torque and greater horsepower output.

CHARACTERISTIC CHART

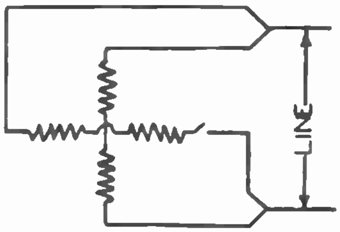


	SPLIT-PHASE	SHUNT or COMPOUND	SERIES	POLYPHASE	SYNCHRONOUS	SYNCHRONOUS POLYPHASE	SYNCHRONOUS CAPACITOR	SHADED POLE	SERIES GOVERNOR	CAPACITOR	CAPACITOR START
CURRENT SUPPLY											
A.C.	✓			✓	✓	✓	✓	✓		✓	✓
D.C.		✓									
A.C. or D.C.			✓						✓		
DUTY											
CONTINUOUS	✓	✓		✓	✓	✓	✓	✓		✓	✓
INTERMITTENT			✓						✓		
ROTATION											
UNIDIRECTIONAL			✓					✓	✓		
REVERSIBLE AT REST ONLY	✓				✓		✓				✓
REVERSIBLE AT REST or DURING ROTATION		✓		✓		✓				✓	
SPEED											
CONSTANT FIXED	✓			✓	✓	✓	✓	✓		✓	✓
CONSTANT ADJUST.		✓							✓		
VARIABLE			✓								
STARTING TORQUE											
LOW							✓	✓		✓	
NORMAL	✓	✓	* ✓		✓						
HIGH				✓		✓			✓		✓
STARTING CURRENT											
LOW							✓	✓		✓	
NORMAL	✓	✓	✓	✓	✓	✓			✓		† ✓

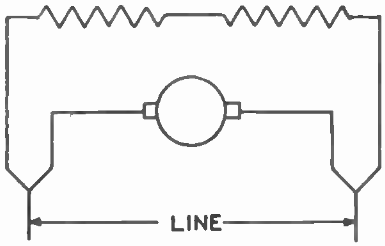
*Starting torque high for series motors with normal speed ratings of 7500 R.P.M. or more.
†Starting current appreciably lower than for split-phase motors.
Special characteristics available at additional charge.

WIRING DIAGRAMS

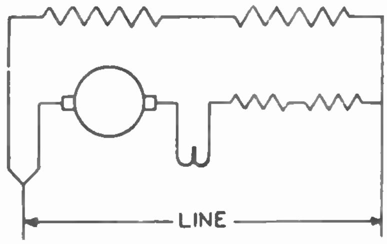
The following connection diagrams are those used with standard windings of the types indicated. Special connections are available with special windings. Consult Bodine engineers for windings tailored to your requirements.



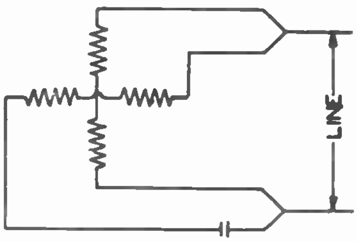
SPLIT PHASE AND SYNCHRONOUS
SPLIT PHASE 4 LEAD REVERSIBLE



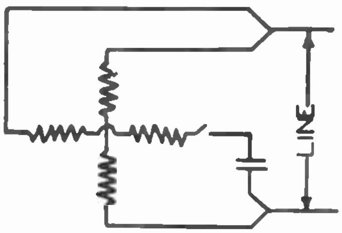
SHUNT WOUND 4 LEAD REVERSIBLE



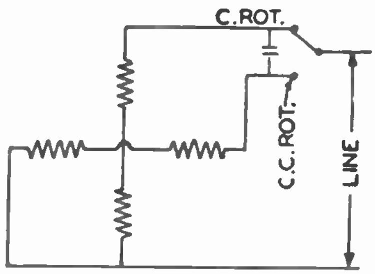
COMPOUND WOUND 5 LEAD
REVERSIBLE



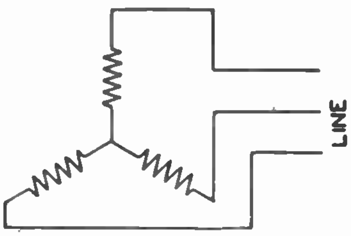
CAPACITOR AND SYNCHRONOUS
CAPACITOR 4 LEAD REVERSIBLE



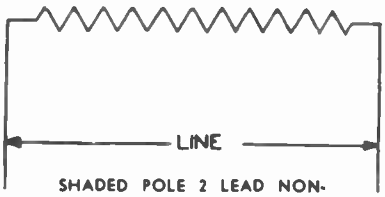
CAPACITOR START 4 LEAD
REVERSIBLE



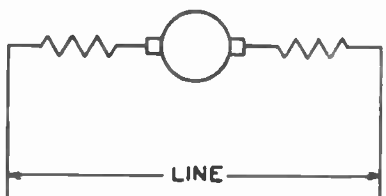
CAPACITOR AND SYNCHRONOUS
CAPACITOR 3 LEAD REVERSIBLE



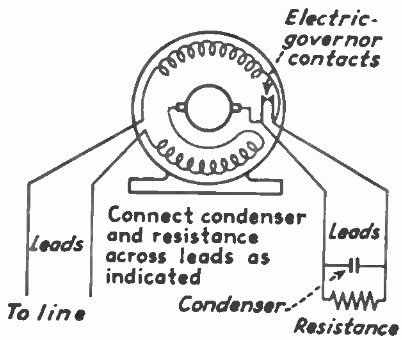
THREE PHASE AND SYNCHRONOUS
THREE PHASE



SHADED POLE 2 LEAD NON-
REVERSIBLE



SERIES 2 LEAD NON-REVERSIBLE



GOVERNOR CONTROLLED SERIES
WOUND 4 LEAD NON-REVERSIBLE

WESTINGHOUSE *Electric*

Select THIS ➡ TYPE OF

THREE major requirements must be met in selecting your motor:

1. **SIZE**—The motor must be big enough. The rating must be sufficient to start the driven machine and handle its running load.
2. **POWER SUPPLY**—The motor must fit your power supply. You must know whether your current is AC or DC; number of phases and cycles; voltage.
3. **OPERATING CONOITIONS**—Location of motor must be considered, as to the presence of dust, explosive and corrosive gases and normal of abnormal moisture. Consider whether conditions call for special splash-proof, dust-tight or explosion-proof enclosures.

Requirements which must be met in selecting your control are:

1. Manual or magnetic starter.
2. Reversing or non-reversing starter.
3. The motor specifications—voltage, frequency, horsepower, speed, phases.
4. Starting only or speed control.

This drive selector table is offered as a ready, approximate guide to the selection of Westinghouse motors and control. Naturally, the most efficient installations result from careful engineering study of all factors. Westinghouse engineers will insist on any application problems.

POLYPHASE

LINESTART CLASS 1 (CS AND CSP) (NEMA Class B) FOR 80% OF INDUSTRY'S DRIVES	Linestart Class II (CS) (NEMA CLASS C)


The All Around Motor (suitable for the large majority of polyphase alternating current applications). Meets Low Starting Current Requirements

TYPICAL INDUSTRIAL

Linestart Class I:

Blowers	Drill Presses	Lathes	Saws
Bottling Machines	Fans	Lineshafts	Screw Machines
Bottle Washers	Feed Grinders	Machine Tools	Shapers
Buffers	Feed Mixers	Metal Grinders	Spinning Machines
Capping Machines	Grain Separators	Milking Machines	Stokers
Compressors (unloaded start)	Grinders	Planers	Woodworking Machines
Concrete Mixers	Hammer Mills	Polishers	Weaving Machines
Crushers	Hay Balers	Pulp Grinders	
Dish Washers	Irrigation Pumps	Pumps (centrifugal)	
	Jordans	Roll Grinders	

Linestart Class II: For Heavy Starting Duty Drives such as: Compressors (without unloaders) Heavy Conveyors Reciprocating Pumps or other applications requiring high starting duty.

GENERAL

Linestart Class I:

Normal starting (effort) torque up to 150% of full load (effort).

3 HP., 1800 rpm. and smaller, high starting effort—200-250% of full load effort.

Low starting current, no more than 5 to times full-load current.

Full voltage starting sizes 1-200 HP.

Standard open frame.

Standard voltages 208, 220, 440, 550, 2200.

Standard frequencies 25, 50 and 60 cycles.

Two or three phase 40°C rise continuous open-frame, 50°C rise continuous splash-proof frame, 55°C rise continuous totally enclosed fan-cooled.

Constant Speed.

All standard speeds available.

Available with sealed sleeve or ball bearings.

Lowest operating cost.

No wearing parts except shaft and bearings.

Requires simplest and least expensive control and circuit protective device.

Can operate continuously at full rated load without undue heating.

Standard 220 volt motors operate satisfactorily on 199 or 208 network voltages for normal starting effort.

Linestart Class II:

High Starting Torque—up to 250% of full-load.

Low starting current.

All standard speeds available 3 to 150 HP.

Standard frequencies—25, 50 and 60 cycles.

Standard voltages—208, 220, 440, 550 and 2200.

2 and 3 phase.

40°C rise continuous, open frame types.

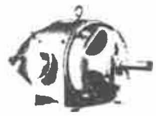
Other features similar to General Purpose Class I Motors.

With THIS ➡ TYPE OF

	Linestart Class I	Linestart Class II
FOR MANUAL CONTROL *Non-Reversing:* —Across-the-Line Starting (Overload Protection)	Manual Starters: Type DnW "De-ion": Motor Watchman; up to 7½ HP. Class 10-103	Same as Class I
—Reduced Voltage Starting (Low Voltage Protection)	Autostarter (overload protection). Class 10-700	No
—Speed Adjustment (Low Voltage Protection)	No	No
Reversing: —Across-the-Line Starting	Drum Switch, Class 10-300; to 15 HP.	Same as Class I
—Speed Adjustment	No	No
FOR MAGNETIC CONTROL *Non-Reversing:* —Across-the-Line Starting	Linestarter, Class 11-200; Combination Linestarter Class 11-206	Same as Class I
—Reduced Voltage Starting	Class 11-400 Resistance Type Starter to 50 HP.; Class 11-600 Autotransformer Type above 50 HP.	No
Reversing: —Across-the-Line Starting	Linestarter, Class 11-200; Combination 11-216	Same as Class I
—Reduced Voltage Starting	Class 11-410 Resistance Type Starter to 50 HP.; above 50 HP. special	No
CIRCUIT PROTECTION	Nofuze "De-ion" Circuit Breaker or Safety Switch	Same as Class I

Drive SELECTOR . . . .

MOTOR

A-C			REPULSION-INDUCTION	DIRECT CURRENT	
HIGH SLIP (CS) (NEMA CLASS D)	WOUND ROTOR (CW)	WOUND ROTOR (CI)	CRP & CU Single ф	Constant or Variable Speed (SK)	ADJUSTABLE SPEED (SK)
					

SERVICE APPLICATIONS

HIGH SLIP (CS)	WOUND ROTOR (CW)	WOUND ROTOR (CI)	REPULSION-INDUCTION	DC Constant or Variable Speed	DC Adjustable Speed
For High Peak Load or Fly-wheel Drives such as: Cranes Elevators Hoists Punch Presses Shears	For Adjustable Varying Speed Drives (continuous duty) such as: Blowers Conveyors Fans Crushers Pumps or for any alternating current application where variable speed is needed.	For Intermittent Service. Variable Speed, Heavy-Duty Drives such as: Cranes Hoists Bending Rolls Lift Bridges Bascule Bridges RR Turntables Transfer Tables, etc.	Heavy Starting Duty for Drives such as: Blowers; Compressors Fans Farm Machinery Household Appliances Pumps; Shop Tools Stokers, etc. For use in home, shop or store sizes up to 7½ HP	For Constant or Variable Speed Drives such as: Blowers Compressors Fans Pumps Lineshafting, etc.	For Drives Requiring Wide Speed Range or Accurate Speed Adjustment such as. Machine Tools Planers Paper Machines, etc.

DESCRIPTION

HIGH SLIP (CS)	WOUND ROTOR (CW)	WOUND ROTOR (CI)	REPULSION-INDUCTION	DC Constant or Variable Speed	DC Adjustable Speed
Motor speed drops off as load increases, permitting use of stored energy of a flywheel. Heavy starting torque—up to 300% of full-load. Other features same as General Purpose Line-start Class I.	Adjustable-varying speed. Heavy starting effort. Extremely low starting current with high starting effort for either constant or variable speed. ½ to 200 HP., 2 to 3 phase, 25, 50 or 60 cycles, all standard speeds available.	¾ to 200 HP. 2 or 3 phase. 25, 50 and 60 cycles. 208, 220, 440, 550 volts. For plugging reversing service and heavy intermittent duty. Develops high starting torque with low starting current. 50°C open, 55°C enclosed.	Type FH Split Phase, 1/6 – 1/3 HP. Type FJ Capacitor start (simple and foolproof) 1/40 – 1/4 HP. Type CR Repulsion Start – Induction Run 1/4 – 3 HP. Type CU Repulsion Induction 5 – 7½ HP. Available for 110 or 220 volts, 25, 50 or 60 cycles.	SHUNT-WOUND: for constant or variable speed drives; good starting torque. COMPOUND-WOUND: for varying speed; high-starting torque. SERIES-WOUND: varying speed; very high starting torque of full-load. All Types 1/4 to 200 HP.; 115, 230 or 550 volts; continuous or intermittent service; 580 to 1750 rpm. 40°C continuous.	Speed adjustable over a wide range by means of field control. ½ to 200 HP. 115 or 230 volts.

CONTROL

HIGH SLIP (CS)	WOUND ROTOR (CW)	WOUND ROTOR (CI)	REPULSION-INDUCTION	DC Constant or Variable Speed	DC Adjustable Speed
Same as Class I	No	Motor Watchman	SENTINEL BREAKER Up to 1 HP. Class 10-023 Manual Starters Type DnW "De-ion"	Manual Starters Type DnW "De-ion" Motor Watchman Up to 2 HP.	No
No	Rheostat Class 12-012 up to 25 HP. Drum Controller Class 12-3000 Linestarter Class 11-200 for primary control		Rheostat Class 10-030	Rheostat Class 7010	No
No	Rheostat Class 12-016 up to 25 HP. Drum Controller Class 12-300 Linestarter Class 11-200 for primary control		No	Rheostat Class 7310	Rheostat Class 7210
Same as Class I	No		No	Drum Switch Class 10-300 Up to 2 HP.	No
No	Drum Controller Class 12-700		No	Drum Controller Class 8300	Drum Controller Class 8110
Same as Class I	Combination Linestarter Class 11-206 in combination with Secondary Controller		Linestarter, Class 11-200	No	No
Special	Resistance Type Starter Class 13-100		Special	Timestarters Classes 8512, 8513, 8522	Timestarter Classes 8512, 8513, 8522 and Field Rheostat
Same as Class I	No		Linestarter, Class 11-210	Linestarter Class 8503	No
Special	Special		No	Timestarters Classes 9013, 9022	Timestarter Classes 9013, 9022 and Field Rheostat
Same as Class I	Same as Class I		Nofuze Flipon or Safety Switch	Same as Class I	Same as Class I

SELECTING THE CORRECT MOTOR

HORSEPOWER REQUIREMENTS—The horsepower requirements of the driven machine can usually be determined from one or more of several sources as listed below:

1. **By Test**—Actually load the machine, duplicating conditions under which it will normally operate. The watts can then be measured with an industrial analyzer or other instruments.

2. **By Careful Comparison**—By comparing the machine to be driven with known power requirements of similar apparatus. This method should only be used when tests are not practical.

3. **By Accurate Calculations**—Use factual information or power requirements for specific operations (such as the horsepower per cubic inch required at the tool to remove metal of specified analysis in specified time).

4. **By Nameplate Information**—On some machines, the manufacturer stamps the motor horsepower required on the nameplate of the machine.

5. **Determination of Root-Mean-Square Horsepower**—Many machines work on a definite duty cycle that repeats at regular intervals. Often this horsepower value occurs during the cycle when the values of power required and the length of their duration are known, and the rating of the motor required can be calculated by the RMS method.

Multiply the square of the horsepower required for each part of the cycle by the time in seconds necessary to complete that part of the cycle. Divide the sum of these results by the effective time in seconds to complete the whole cycle. Extract the square root of this last result. This gives the RMS horsepower. If the motor is stopped for part of the cycle, only ⅓ of the rest period should be used in determining the effective time for open motors (enclosed motors use ½ of the rest period). This is due to the reduction in cooling effect when the motor is at rest.

Example: Assume a machining operation where an open motor operates at 8 Hp. load for 4 minutes, 6 Hp. load for 50 seconds, 10 Hp. load for 3 minutes and the motor is at rest for 6 minutes, after which the cycle is repeated.

$$\text{RMS Hp.} = \sqrt{\frac{(8^2 \times 240) + (6^2 \times 50) + (10^2 \times 180)}{240 + 50 + 180 + \frac{360}{3}}} = \sqrt{59.5} = 7.7 \text{ Hp.}$$

Use 7.5 Hp. Motor.

Note: For fast repeating cycles involving reversals and deceleration by plugging, the additional heating due to reversing and external WR^2 loads must be taken into consideration, and a more elaborate duty cycle analysis than shown above is required.

In addition to determining the horsepower rating with regard to heat capacity, a check should also be made to assure that the peak loads, even though of short duration, imposed by the driven machine do not exceed the maximum power the motor will develop without stalling. From table under "Locked Rotor and Maximum Running Torque Values", determine the maximum torque in terms of full load torque. This value should always exceed peak torque imposed by the duty cycle. Preferably, this should be at least 25% greater in order to compensate for unusual conditions, such as low voltage, high friction, etc.

STARTING CURRENT (Locked Rotor)—The table below shows representative starting (locked rotor) currents for Linestart Class I Type CS Motors. When exact values are needed, refer to the nearest Westinghouse District Sales Office.

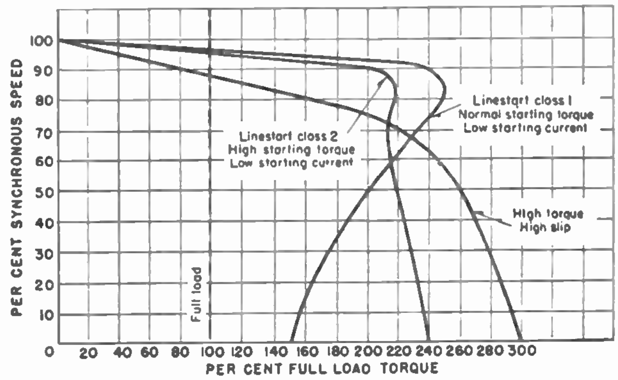
HORSE-POWER	LOCKED ROTOR AMPS. AT 220 VOLTS	HORSE-POWER	LOCKED ROTOR AMPS. AT 220 VOLTS
1	25	15	225
1.5	35	20	285
2	43	25	250
3	60	30	420
5	88	40	585
7.5	120	50	735
10	150		

SLIP—At no load, the induction motor runs at practically synchronous speed. With a load, the motor is below synchronous speed by a percentage known as the slip. For example; if the synchronous speed is 1800 Rpm. and the full load speed 1700 Rpm., the slip at full load is 5½% (slip is synchronous speed minus full load speed divided by synchronous speed).

The slip of any induction motor depends on the voltage drop in the secondary circuit, i.e. on the rotor resistance times the current. The greater the rotor resistance, the higher is the starting torque with a given current. The greater the slip, the greater the losses and the lower the efficiency.

Comparison of the average performance of the 3 most commonly used types of squirrel cage induction motors, Type CS, 30 Hp. and smaller.

TORQUE—The selection of the correct motor type should also be based on torque requirements. There are two kinds of torque that must be considered in a motor—the starting torque and the pull-out torque. Motor torque must be balanced against efficiency and power factor. Excessive starting torque results in low efficiency, low power factor, and poor speed regulation.



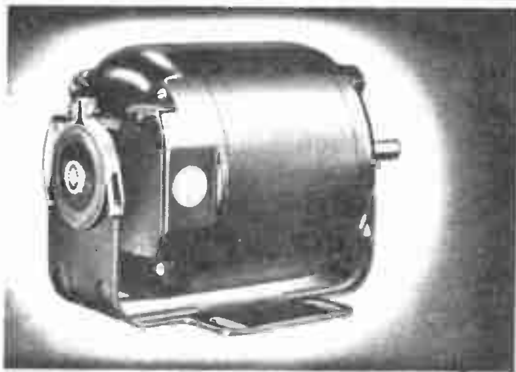
Comparative Speed—Torque Curve

GEARMOTORS
APPLICATION DATA
AGMA CLASSES I, II, III

APPLICATION	8 TO 10 HR. SERVICE	24 HR. SERVICE
AGITATORS		
Pure liquid	I	II
Variable density	II	II
BLOWERS		
Centrifugal	I	II
Lobe	II	II
BREWING & DISTILLING		
Bottling machinery	I	II
Brew kettles, continuous duty	II	II
Cookers, continuous duty	II	II
Mash tubs, continuous duty	II	II
Scale hopper (frequent starting peaks)	II	II
CAR DUMPERS	II	III
CAR PULLERS	II	III
CLARIFIERS	I	II
CLASSIFIERS	II	II
CLAY WORKING MACHINERY		
Brick press	III	III
Briquette machine	III	III
Clay working machinery	II	II
Pug mill	II	II
COMPRESSORS		
Centrifugal	I	II
Lobe	II	II
Reciprocating — Multi-Cylinder — Adequately fly-wheeled (within 3% cyclic variation)	II	III
Reciprocating—Single cylinder	Refer to Factory	
CONVEYORS		
(Uniformly loaded or fed)		
Apron	I	II
Assembly	I	II
Belt	I	II
Flight	I	II
Oven	I	II
Screw	I	II
CONVEYORS		
(Heavy duty or dual drive—not uniformly fed)		
Apron	II	II
Assembly	II	II
Belt	II	II
Flight	II	II
Oven	II	II
Screw	II	II
Reciprocating	III	III
Shaker	III	III
CRANES & HOISTS		
Main hoists—medium duty	II	II
Main hoists—heavy duty	III	III
Skip hoists	II	II
Travel motion	II	II
Trolley motion	II	II
DREDGES		
Cable reels	II	II
Conveyors	II	II
Cutter head drives	III	III
Jig drive	III	III

APPLICATION	8 TO 10 HR. SERVICE	24 HR. SERVICE
DREDGES—Continued		
Screen drive	III	III
Stackers	II	II
Utility winches	II	II
ELEVATORS		
(Conveyor Type—same as conveyors)		
Freight	II	II
Passenger	III	III
FANS		
Centrifugal	I	II
Cooling towers	II	II
Large (mine, etc.)	II	III
Light, small diameter	I	II
FOOD INDUSTRY		
Beet slicers	II	II
Cereal cookers	I	II
Dough mixers	II	II
Meat grinders	II	II
HOISTS—See CRANES		
LAUNDRY WASHERS	II	II
LAUNDRY TUMBLERS	II	II
LINE SHAFTS		
Driving processing equipment	II	II
Other line shafts	I	II
MACHINE TOOLS		
Punch press (gear connected to load) and shears	III	III
Notching press (belt driven)	I	II
Plate planers	III	III
Other machine tools—main drives	II	II
Auxiliary drives (Feed-Traverse, etc.)	I	II
METAL MILLS		
Draw bench carriage and main drives	III	III
Forming machines	III	III
Pinch, dryer and scrubber rolls (reversing)	Refer to Factory	
Slitters	III	III
Small rolling mill drives	III	III
Table conveyors (non reversing)	II	II
Table conveyors (reversing)	Refer to Factory	
Wire drawing and flattening machines	III	III
MILLS (ROTARY TYPE)		
Ball	III	III
Cement kilns		III
Dryers and coolers		II
Hammer	III	III
Kilns	II	III
Pebble	II	III
Rod	III	III
Tumbling barrels	III	III
MIXERS		
Concrete mixers—continuous duty	II	II
Concrete mixers — intermittent duty	I	
Constant density	I	II
Irregular density	II	II

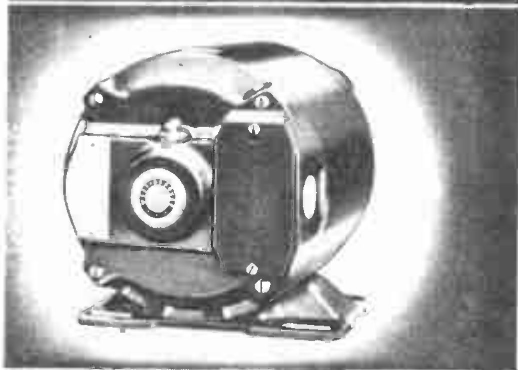
APPLICATION	8 TO 10 HR. SERVICE	24 HR. SERVICE
OIL INDUSTRY		
Oil well pumping (not over 150% peak torque)	III	III
Refineries		
Chillers	II	II
Paraffin filter press	II	II
Rotary Kiln	II	II
PAPER MILLS		
Agitators (mixers)		II
Bleachers		II
Beaters and pulpers		III
Calenders		III
Conveyors		II
Couch		III
Cylinders		II
Dryers		III
Felt stretchers		II
Jordans		III
Presses		III
Stock chests		III
Suction rolls		III
Winders		II
RUBBER INDUSTRY		
Mixer	III	III
Calenders	II	III
Mills	III	III
Sheeters	III	III
Tire building machines	II	II
Tire and tube press openers	I	I
Tubers or strainers	II	II
PUMPS		
Centrifugal — with surge tanks or equivalent	I	II
Centrifugal—without surge tanks	II	II
Gear and rotary—constant density fluid	I	II
Gear and rotary—variable density fluid	II	II
Proportioning pumps	II	III
Reciprocating—with open discharge	I	II
Reciprocating — multi-cylinder, double acting	II	II
Reciprocating — single-cylinders	Refer to Factory	
SEWAGE DISPOSAL EQUIPMENT		
Inside service	I	II
SCREENS		
Rotary—stone or gravel	II	II
Traveling water intake	I	I
TEXTILE INDUSTRY		
Batchers	II	II
Calenders	II	II
Card Machines	II	III
Dry cans	II	II
Dyeing machinery	II	II
Looms	Refer to Factory	
Mangles	II	II
Nappers	II	II
Soapers	II	II
Spinners	II	II
Tenter frames	II	II



SPLIT PHASE MOTORS • GENERAL PURPOSE—TYPE FH

For Single-Phase applications where medium starting and breakdown torques are sufficient. Low starting current minimizes light flicker, making motors very suitable for such frequent starting applications as oil burners, office appliances, fans and blowers. Available with rigid or resilient mounting. Reversed by changing terminal block connections.

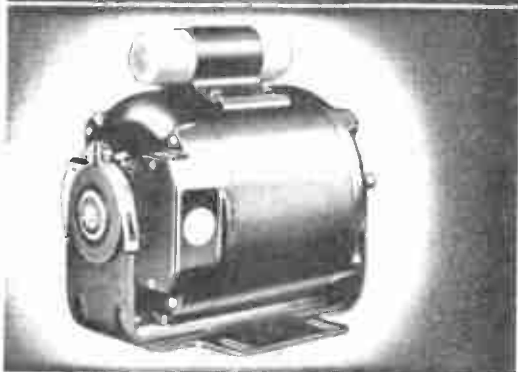
HORSEPOWER—1/20 to 1/3
PHASE—Single
CYCLES—60, 50, 25
VOLTS—115 or 230
SPEEDS—Approximate Full Load Rpm.
60 Cycles—3450, 1725, 1140, 860
50 Cycles—2850, 1425, 960
25 Cycles—1425



SPLIT PHASE MOTORS • HIGH TORQUE—TYPE FHT

For Single-Phase applications where high starting and breakdown torques are needed, where starting is infrequent and where starting current in excess of NEMA values is not objectional. Ideal for washing machines, ironers and home workshop machines. Available with rigid or resilient mounting. Reversed by changing terminal block connections.

HORSEPOWER—1/6, 1/4, 1/3
PHASE—Single
CYCLES—60, 50, 25
VOLTS—110 or 220
SPEEDS—Approximate Full Load Rpm.
60 Cycles—1725
50 Cycles—1425
25 Cycles—1425



CAPACITOR-START MOTORS • TYPE FJ

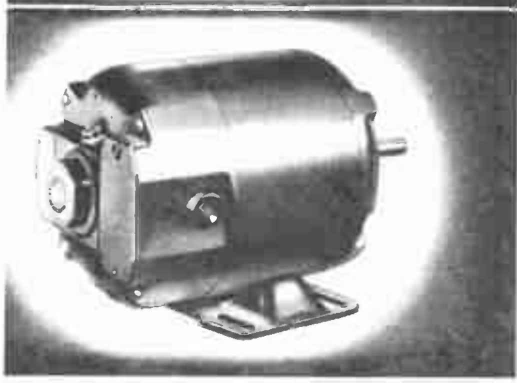
All-purpose Single-Phase Motors for extra high starting torque, low starting current, quietness and economy. High efficiency and power factor. Ideal for compressors, pumps, stokers, refrigerators and air conditioning equipment. Dual voltage in all but 1/6 and 1/4 Hp. 4-pole sizes. Available with rigid or resilient mounting. Reversed by changing terminal block connections.

HORSEPOWER—1/6 to 3/4
PHASE—Single
CYCLES—60, 50, 25
VOLTS—115 or 230 for 1/4 Hp. 4-pole and smaller; larger sizes are 115/230 Dual Voltage.
SPEEDS—Approximate Full Load Rpm.
60 Cycles—3450, 1725, 1140, 860
50 Cycles—2850, 1425, 960
25 Cycles—1425

POLYPHASE MOTORS—TYPE FS

For all applications where polyphase circuits are available. Squirrel-Cage induction type motor with high starting torque and extra high break-down torque. Dual frequency, 60/50 cycles, 2 or 3-phase. Motors can be reversed while in motion by use of proper starting switch.

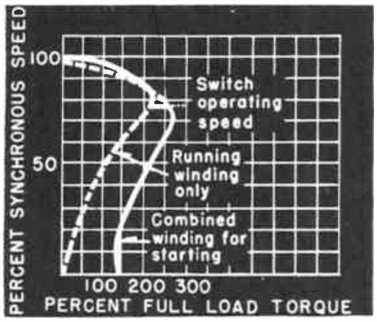
HORSEPOWER—1/6 to 3/4
PHASE—2 or 3
CYCLES—60/50 (Dual Frequency) or 25
VOLTS—110, 220, 440, 550
SPEEDS—Approximate Full Load Rpm.
60 Cycles—3450, 1725, 1140, 860
50 Cycles—2850, 1425, 960
25 Cycles—1425

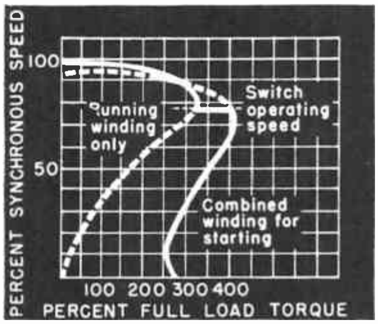


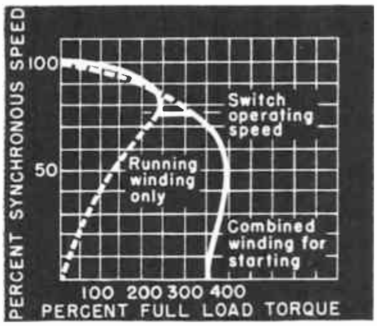
DIRECT-CURRENT MOTORS—TYPE FK

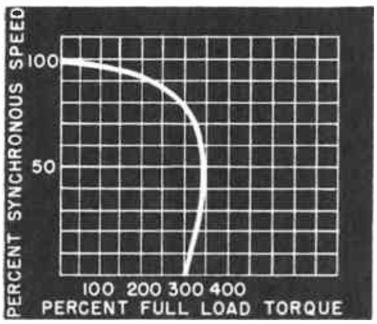
For all applications on direct-current circuits. When compound winding is used, starting torque is extra high. Speed may be increased up to 15% by means of a field rheostat. Starting rheostat is recommended for ratings 1/2 hp. and larger.

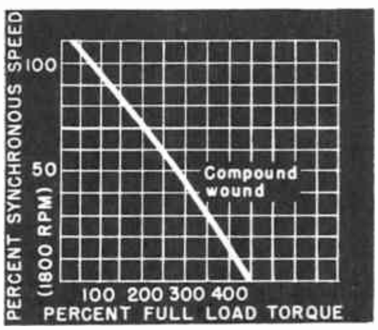
Reversed by changing connections.
HORSEPOWER—1/20 to 3/4
VOLTS—32, 115, 230
SPEEDS—Approximate Full Load Rpm.
3450, 1725, 1140











APPLICATION AND PERFORMANCE

The "F" Line of Fractional Horsepower Motors is adaptable to a wide range of applications on all types of equipment. The brief instructions below will help to simplify selection. Speed-Torque Curves at the left compare the performance of the various motors available.

SELECTING THE RIGHT MOTOR

To select the right motor for a given application, the following factors must be considered:

1. **CHARACTERISTICS OF POWER SUPPLY**—Motor must fit available power supply. Therefore, it is necessary to know voltage, frequency and number of phases if A-C; voltage if D-C.

2. **HORSEPOWER REQUIRED**—The motor must not only be able to start and run the appliance, but also to handle any momentary overload imposed. In case of doubt, application tests should be conducted. Duty cycle and frequency of starting may also affect size.

3. **TORQUE REQUIRED**—Motor torque characteristics must match those of the load. Therefore, consider load requirements in terms of starting and breakdown torque. Refer to the curves at the left for a comparison between motor types available.

4. **STARTING CURRENT LIMITATIONS**—Many power companies restrict the use of motors with high starting current because of the possibilities of light flicker. For this reason, Type FHT Split-Phase Motors occasionally meet with objections except where operated infrequently. All other "F" Line Motors have locked rotor currents within the following NEMA standards for 115-volt motors.

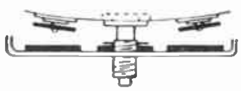
   ⅙ Hp. and Below.......... 20-Amperes   ⅓ Hp.................... 31-Amperes
   ¼ Hp.................... 23-Amperes   ½ Hp.................... 45-Amperes
   ¾ Hp............. 61-Amperes

5. **THERMOGUARD BURN-OUT PROTECTION** (Single-Phase Motors Only)—When a motor is subject to overload or abnormal heat, built-in Thermoguard protection should be used, see below. Particularly essential on devices for automatic operation such as Domestic Refrigerators or Stokers where severe overloads may be encountered.

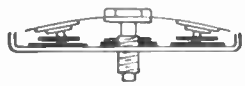
THERMOGUARD BURN-OUT PROTECTION (Optional Extra)

Thermoguard bi-metallic disc type device protects single-phase motors against failure caused by:

- Continuous or frequent overloads
- Jamming of motor drive
- Failure of ventilation
- Excessive Temperatures
- Inability to start or run due to low voltage

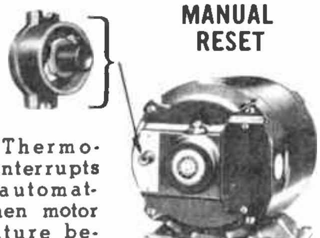


CLICK! IT'S OFF—The simple bi-metallic Thermoguard disc opens with rifle-bullet speed when heat endangers motor. Prevents damage to insulation.



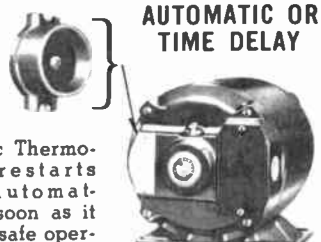
CLICK! IT'S ON—When motor cools to safe temperature, automatic type Thermoguard restores motor to service automatically. Manual type must be hand reset.

MANUAL RESET



Manual Thermoguard interrupts circuit automatically when motor temperature becomes abnormally high. Does not reset until button is pushed. Fool-proof—pressing button will not open circuit. Trip-free—cannot be reset until motor cools to a safe temperature.

AUTOMATIC OR TIME DELAY



Automatic Thermoguard restarts motor automatically as soon as it cools to a safe operating temperature. Time delay—for such applications as oil burners with intermittent ignition—recloses automatically, but not for at least three minutes.

SPEED CLASSIFICATION	POWER SUPPLY	N.E.M.A. CLASS	L.A. TYPE	TYPE OF MOTOR	✱✱ RANGE OF HORSEPOWER RATINGS	STARTING TORQUE PER CENT OF FULL LOAD	MAXIMUM TORQUE PER CENT OF FULL LOAD	SPEED REGULATION PER CENT SLIP	GENERAL REMARKS	AGITATORS - MIXERS	BALL - ROD - PUG MILLS	BALING PRESSES	BENDING ROLLS	BLOWERS - POSITIVE PR.	BORING MILLS	BUCKET ELEVATORS
CONSTANT SPEED	ALTERNATING CURRENT 3 & 2 PHASE	A	S	STANDARD SQUIRREL CAGE NORMAL TORQUE - NORMAL STARTING CURRENT	½ TO 300 HP	150	200 TO 250	2 TO 5	GENERAL PURPOSE WIDE APPLICATION	◉				◉	◉	
		B	X	SQUIRREL CAGE NORMAL TORQUE - LOW STARTING CURRENT	7½ TO 200 HP	125 TO 150	200 TO 225	2 TO 5	SIMPLE CONTROL	◉				◉	◉	
		C	A	SQUIRREL CAGE HIGH TORQUE - LOW STARTING CURRENT	3 TO 100 HP	200 TO 250	175 TO 225	4 TO 5	HEAVY STARTING SIMPLE CONTROL		◉					◉
		D	K	SQUIRREL CAGE HIGH TORQUE - HIGH SLIP	½ TO 100 HP	200 TO 300	200 TO 300	8 TO 15	HEAVY STARTING - INTERMITTENT AND FLUCTUATING LOAD		◉	◉	◉			◉
		F	W	SQUIRREL CAGE LOW TORQUE - LOW STARTING CURRENT	40 TO 100 HP	50 TO 80	125 TO 150	4 TO 5	SPECIAL PURPOSE CONSTANT LOAD LIGHT STARTING					◉		
		-	WX	SQUIRREL CAGE LOW TORQUE	½ TO 10 HP	100 TO 125	175 TO 200	4 TO 5	SPECIAL SERVICE SMOOTH REVERSAL							
		-	H	WOUND ROTOR	½ TO 300 HP	200 TO 250	200 TO 250	✱	FREQUENT & HEAVY STARTING		◉		◉			◉
	SING PHASE	-	C	CAPACITOR - INDUCTION LOW TORQUE	½ TO 10 HP	50 TO 75	175 TO 200	4 TO 6	LIGHT STARTING DIRECT CONN. LOAD							
		-	CN CU	CAPACITOR - INDUCTION NORMAL TORQUE	½ TO 10 HP	150 TO 200	175 TO 200	4 TO 6	GENERAL PURPOSE INFREQUENT STARTING	◉				◉		
	DIRECT CURRENT	-	NA	SHUNT WOUND	½ TO 75 HP	150	†	5 TO 10	GENERAL PURPOSE STEADY LOADS	◉				◉	◉	
		-	NA	COMPOUND WOUND	½ TO 75 HP	175 TO 200	†	10 TO 25	HEAVY STARTING FLUCTUATING LOAD		◉	◉				◉
		-	NA	SERIES WOUND	½ TO 75 HP	300 TO 400	†	✱	HEAVY AND FREQUENT STARTING				◉			
AJUSTABLE SPEED	A.C. 3 & 2 PHASE	-	M	CONSTANT HORSEPOWER 2 - 3 - 4 SPEEDS	¼ TO 150 HP	125 TO 150	175 TO 200	4 TO 6	SPEED INDEPENDENT OF LOAD						◉	
		-	M	CONSTANT TORQUE 2 - 3 - 4 SPEEDS	¼ TO 200 HP	125 TO 150	175 TO 200	4 TO 6	SPEED INDEPENDENT OF LOAD	◉	◉			◉		◉
		-	M	VARIABLE TORQUE 2 - 3 - 4 SPEEDS	¼ TO 200 HP	125 TO 150	175 TO 200	4 TO 6	SPEED INDEPENDENT OF LOAD							
	DIRECT CURRENT	-	NW	FIELD CONTROL	¼ TO 50 HP	150	†	5 TO 10	WIDE RANGE FLEXIBLE CONTROL						◉	
		-	NA	VARIABLE VOLTAGE CONTROL	¼ TO 30 HP	150	†	✱	EXTREME WIDE RANGE FLEXIBLE CONTROL							
VARIABLE SPEED	A.C.	-	H	WOUND ROTOR	½ TO 300 HP	200 TO 250	200 TO 250	✱	LIMITED RANGE HEAVY STARTING	◉	◉		◉	◉		◉
	DIRECT CURRENT SHUNT	-	NA	ARMATURE CONTROL	½ TO 75 HP	150	†	✱	LIMITED RANGE DEPENDENT ON LOAD	◉				◉		
		-	NA	FIELD AND ARMATURE CONTROL	½ TO 50 HP	150	†	✱	WIDE RANGE LIMITED APPLICATION							
		-	NA	VARIABLE VOLTAGE CONTROL	¼ TO 30 HP	150	†	✱	WIDE RANGE LOW EFFICIENCY							
	DIRECT CURRENT COMPOUND	-	NA	ARMATURE CONTROL	½ TO 75 HP	175 TO 200	†	✱	LIMITED RANGE DEPENDENT ON LOAD		◉					◉
		-	NA	FIELD AND ARMATURE CONTROL	½ TO 50 HP	175 TO 200	†	✱	WIDE RANGE LIMITED APPLICATION							
		-	NA	VARIABLE VOLTAGE CONTROL	¼ TO 30 HP	175 TO 200	†	✱	WIDE RANGE LOW EFFICIENCY							
	DIRECT CURRENT SER.	-	NA	ARMATURE CONTROL	½ TO 75 HP	300 TO 400	†	✱	LIMITED RANGE HEAVY STARTING				◉			

✱ DEPENDENT UPON LOAD AT NORMAL SPEED.
✱✱ HORSEPOWER RATINGS, TORQUE AND REGULATION DATA IS FOR 4 POLE (1800 R.P.M.) 60 CYCLE A.C. MOTO
† MAXIMUM TORQUE IS LIMITED BY COMMUTATION. UNDER NORMAL CONDITIONS D.C. MOTOR DEVELOPS 200 T

RS AND 1750 R.P.M. D.C. MOTORS.
O 400% MAXIMUM TORQUE MOMENTARILY.

																									TYPICAL APPLICATION
			●				●							●				●			●				BULLDOZERS
●													●					●			●				CAPSTANS - CAR PULLERS
														●		●		●				●			COMPRESSORS
			●				●							●				●			●	●			CONVEYORS - LOADED START
	●	●					●	●			●		●	●				●			●				CRANES - HOISTS - ELEVATORS
														●				●			●	●			CRUSHERS - GRINDERS - WITH FLY-WHEEL
															●	●							●	●	CRUSHERS - GRINDERS - NO FLY-WHEEL
									●		●				●								●	●	DOUGH MIXERS
									●			●			●	●							●	●	DRILLING MACHINES
														●					●						DRYING TUMBLERS - CYL.
											●			●				●			●				EXTRACTORS - LDRY. & CHEM.
						●	●			●					●		●			●			●	●	FANS - CENTRIFUGAL
						●	●			●					●		●			●			●	●	FANS - PROPELLER
									●			●			●	●							●	●	GRINDERS - BUFFERS
														●				●			●	●			HAMMER MILLS
									●		●			●									●	●	IRONERS - FLATWORK
									●			●			●	●							●	●	LATHES
															●	●							●	●	LINE SHAFTS
									●			●			●	●							●	●	MILLING MACHINES
																●				●			●	●	MOTOR - GEN. AC - D.C.
															●										MOTOR - GEN. D.C. - AC.
															●								●	●	MOULDERS - TENONERS
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		●					●				●			●		●							●	●	PRINTING PRESS - JOB
		●		●	●		●				●			●											PRINTING PRESS - FLAT BED
	●	●		●	●		●				●			●											PRINTING PRESS - ROTARY & OFFSET
						●	●				●				●	●				●			●	●	PUMPS - CENTRIFUGAL - TURBINE
			●				●				●			●		●		●				●			PUMPS - DISPLACEMENT
														●				●			●				PUNCHES - SHEARS - HAMMERS
											●				●	●							●	●	SANDERS
															●	●							●	●	SAWS - CIRCULAR
														●				●				●			SAWS - BAND
									●			●			●	●							●	●	SHAPERS
							●		●		●					●							●	●	STOKERS
													●								●				VALVES
														●					●						WASHERS - REV. MOTOR

GENERAL-PURPOSE, D-C MOTORS

Where To Use Them

These are quiet operating motors for general-purpose applications. They are often used in conjunction with a-c and d-c conversion equipment where speed variation over a considerable range is necessary.

Description

You can choose from a wide range in horsepower ratings and speeds at 115 and 230 volts. The listed standard motors come in either dripproof, sleeve-bearing, or totally-enclosed, ball-bearing constructions. Both have welded-on bases. Designed for quiet operation, smooth and easy acceleration. Mounting dimensions are interchangeable with a-c motors of equal rating.

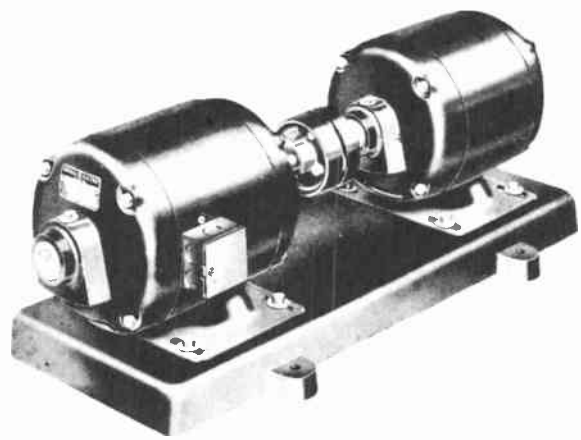
D-C GENERATORS AND MOTOR-GENERATOR SETS

Where To Use Them

This equipment is well suited as a d-c power unit for industrial devices such as magnetic chucks, battery charging equipments, variable speed drives, etc. Highly recommended as exciters for large equipment and a variety of similar applications.

Description

You can obtain d-c generators as a single unit for separate drives, or assembled on a common base with an a-c drive motor to form a motor-generator set. They are available in output ratings of 125, 250, and 500 watt continuous duty, and at voltages of 125 and 250 d-c volts. Drive motors are single phase, a-c for the 125 watt rating, and three phase for the 250 and 500 watt sized when furnished as a motor-generator.



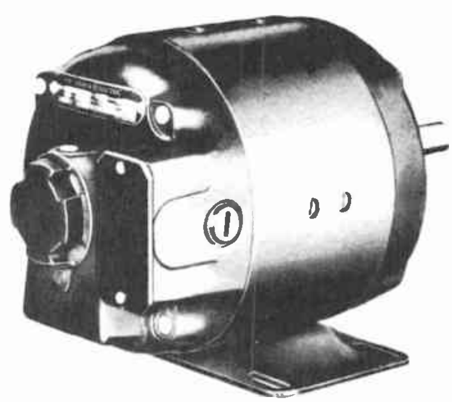
LOW-VOLTAGE SPECIAL D-C MOTORS

Where To Use Them

Fans and blowers, car-door operators, crossing gates, compressors, water circulators, drive and lifting motors on battery-operated industrial trucks are some typical applications for these motors. They are designed to operate on such sources of d-c power as commonly used on busses and transport trucks, railroad equipment, and battery-operated industrial trucks.

Description

These motors usually can be made up from general-purpose motor parts, but utilizing low-voltage commutators and brush mechanisms where required.



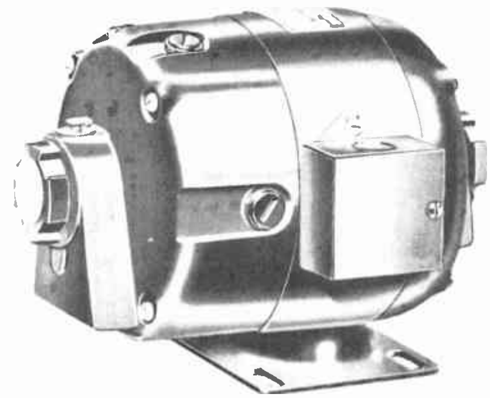
DYNAMOTORS

Where To Use Them

G-E dynamotors provide a convenient and reliable means of converting d-c power to 60-cycle, a-c power at commercial voltages. Used effectively on such applications as neon signs, fluorescent lighting in districts served by d-c current, communication equipment, locomotive headlights, transportation fluorescent lighting, a-c power for many auxiliary devices.

Description

Standard dynamotors are available in ratings of 200- and 500-volt-amperes for 60-cycle, continuous duty. They are lightweight but sturdy enough to withstand long periods of extremely rigorous work.



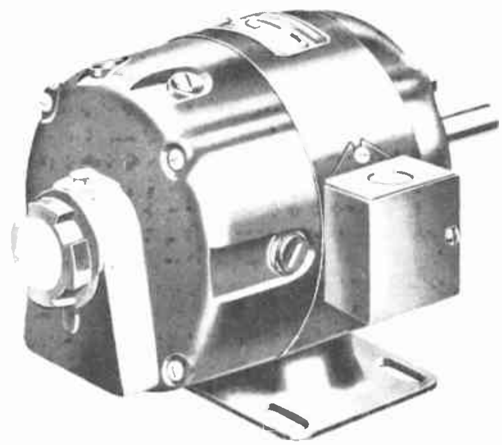
A-C GENERATORS

Where To Use Them

These generators furnish the most effective sources of alternating current to operate all kinds of devices where no a-c power is obtainable. Suitable for belted or direct-coupled drives.

Description

Available in standard ratings of 200- and 500-volt-amperes, 115 volts, 60 cycle, single phase, for operation at 3600 rpm. The 60-cycle generators are self-excited.



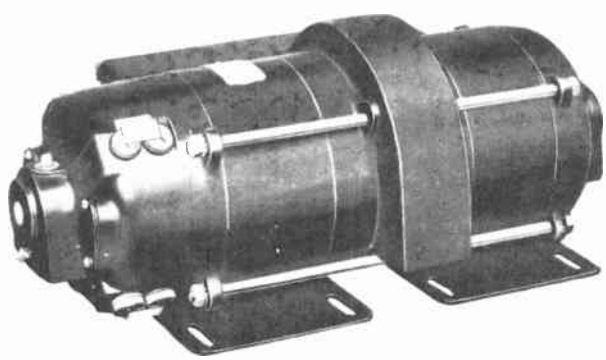
MOTOR AMPLIDYNE-GENERATOR SETS AND AMPLIDYNE GENERATORS

Where To Use Them

Because of its unusually quick response over a wide range of operating loads, the amplidyne generator has found wide application in such fields as steel mills, paper mills, and printing, where they have been used for variable-speed drives, current control, and voltage control. Also, recommended for many special applications such as voltage buck-boost control for railway cars.

Description

Amplidyne generators are available as a single unit for separate drive, or assembled with a drive motor to form a motor amplidyne-generator set. In either combination, the uses are similar. Standard amplidyne generators are listed in ratings from 500 watts to 1500 watts, continuous duty.



MOTOR CHARACTERISTICS

Type of Driven Machinery	Motor Type Designation	Speed R.P.M.	Approx. Starting Torque in % of Full Load Torque	Approx. Maximum Torque in % of Full Load Torque	Approx. Starting Current in % of Full Load Current	Approx. Speed Regulation % Slip	Starting Equipment	Load Conditions
Pumps (Centrifugal, Rotary and Turbine); Cotton Gins; Fans (Centrifugal and Propeller); Line Shafts; Motor Generator Sets; Shapers; Screw Machines; Planers; Milling Machines; Keyseating Machines; Lathes; Buffers; Drill Presses; Metal Grinders; Joiners; Molders; Sanders; Circular Saws (Small and Medium); Positive Pressure Blowers; Job Printing Presses; Brine Agitators; Pulp Grinders; Jordans; Laundry Washers; Small Stokers.	Type QZK	1800	125 To 180	200 To 250	450 To 550	2 To 4	Type QZK motors may be started across the line at full voltage with comparative low starting current. Starters may be reduced voltage or full voltage types. Manual or magnetic, non-reversing or reversing.	Require normal starting torque for continuous duty. Infrequent load fluctuations. Motor provides service factor for overload conditions. Constant speed. No special conditions.
		1200	125 To 180	200 To 250	450 To 550	2 To 4		
		900	115 To 140	200 To 225	450 To 550	2 To 4		
Pumps (Reciprocating and Displacement); Air Compressors; Refrigerating Compressors; Conveyors; Stokers; Crushers (without flywheels); Dough Mixers; Grinders, Hammer Mills; Ball Mills; Turn Tables; Car Pullers; Large Band Saws; Pug Mills; Dry Pans; Brick Presses; Gear Plungers; Brick and Tile Machines; Foundry Tumbling Barrels; Centrifugal Sand Mixers; Grain Elevator Legs; Bending and Straightening Rolls; Bucket-type Elevators; Conveyors starting loaded.	Type QOZK Ratings 3 H.P.& Larger	1800	225 To 275	200 To 250	450 To 550	3 To 5	Across the line, full-voltage manual or magnetic, non-reversing or reversing.	Compressors and pumps requiring less than 7½ Hp. under certain conditions may be successfully handled by type QZK Motors. Heavy starting, continuous or intermittent duty; service factor for overload conditions.
		1200	200 To 250	200 To 225	450 To 550	3 To 5		
		900	190 To 225	190 To 200	450 To 550	3 To 5		
Passenger and Freight Elevators.	Type QRZK	1800	300-400	300-400	300-350	15-20	Across the line, full-voltage reversing elevator control with master switches or drives.	Require high starting torque intermittent duty single speed reversing service.
		1200	300-400	300-400	300-350	15-20		
Hoists, Lifts, Small Cranes, Valves.	Type QLZK	1800	300-400	300-400	325-375	15-20	Same as for Type QRZK.	Intermittent duty single speed reversing.
		1200	300-400	300-400	325-375	15-20		
Punch Presses, Laundry Extractor, Shears, Power Hammers, Crushers with Flywheels, Bending Rolls with Flywheels.	Type QFZK	1800	300-350	300-350	375-450	Range 5-8 8-13	Across the line, full-voltage, manual or automatic reversing or non-reversing.	High starting torque. Heavy fluctuating loads, usually with flywheels or high inertia to accelerate; continuous duty.
		1200	300-350	300-350	375-450			
		900	300-350	300-350	375-450			
Pumps, Centrifugal and Turbine Blowers and Fans, Centrifugal and Propeller.	Type QBZK 40 H.P. & Larger	1800	75-100	150-160	350-400	3-5	Across the line, full-voltage, manual or automatic reversing or non-reversing.	Low starting and maximum torque. Low starting current. Continuous duty, service factor 1.0 and no overload capacity.
		1200	75-100	150-160	350-400	3-5		
		900	75-100	150-160	350-400	3-5		
Compressors; Conveyors; Elevators; Grinding Machinery; Hoists; Laundry Machinery; Machine Tools; Mills; Mixing Machines; Positive Displacement Blowers; Positive Displacement Pumps; Printing Presses; Pulverizing Machines; Woodworking Machines.	QXZK Multi-Speed Constant Torque	1800/900	125-180	200-250	450-550	2-4	Type QXZK motors may be started across the line at full voltage with comparative low starting current. Starters may be reduced voltage or full voltage types. Manual or magnetic, non-reversing or reversing.	Require normal starting torque for continuous duty. Infrequent load fluctuations. Motor provides service factor for overload conditions. Constant speed. No special conditions.
		1800/1200/900/600	125-180	200-250	450-550	2-4		
Machine Tools; Production Equipment; Punch Presses; Winches, Bending Rolls, etc.	QMZK Multi-Speed Constant Horse-power	1800/900	125-180	200-250	450-550	2-4	Type QMZK motors may be started across the line at full voltage with comparative low starting current. Starters may be reduced voltage or full voltage types. Manual or magnetic, non-reversing or reversing.	Require normal starting torque for continuous duty. Infrequent load fluctuations. Motor provides service factor for overload conditions. Constant speed. No special conditions.
		1800/1200/900/600	125-180	200-250	450-550	2-4		
Blowers, Fans and Pumps.	QNZK Multi-Speed Variable Torque	1800/900	125-180	200-250	450-550	2-4	Type QNZK motors may be started across the line at full voltage with comparative low starting current. Starters may be reduced voltage or full voltage types. Manual or magnetic, non-reversing or reversing.	Require normal starting torque for continuous duty. Infrequent load fluctuations. Motor provides service factor overload conditions. Constant speed. No special conditions.
		1800/1200/900/600	125-180	200-250	450-550	2-4		

FARM MOTORS

Application and Operating Data

FRACTIONAL HORSEPOWER MOTORS

Satisfactory performance from a small general purpose motor will be assured by use of a repulsion-induction motor or a "capacitor" motor as described in the following table. These types are slightly higher in price than a split-phase motor, but provide higher starting power without imposing heavy current demands that may reduce voltage in the line and cause lights to flicker, or cause a fuse to blow because of starting overload. On the other hand, the split-phase motor will give satisfactory service for the lighter jobs such as running the washing machine, churn, small tool grinders, etc.

1. REPULSION-START INDUCTION MOTORS

Similar in performance to the larger 3, 5, 7½ horsepower motors. Sizes from ½ to ¾ horsepower, high starting power, low starting current. For use on 110–220 volt, single phase, 60-cycle circuits.

2. CAPACITOR MOTORS

For use on 110 or 220-volt single-phase service. High starting power, low starting current, high efficiency. Highly satisfactory for general purpose use. Sizes range from ⅙ to ¾ horsepower.

3. SPLIT-PHASE MOTORS

Inexpensive type of small motor, but requires high starting current. Suitable for washing machine, ventilating fan, small tool grinder or other uses where starting load is not heavy. Sizes, 1/30 to ⅓ horsepower for 110 or 220-volt service.

Machine	Hp. Most Used	Recommended Motor Type: Repulsion Induction	Split Phase	Capacitor	Recommended Control
Washing Machine	⅙ or ¼		x		Sentinel Breaker
Cream Separator	⅙ or ¼	x		x	Sentinel Breaker
Churn	¼		x		Sentinel Breaker
Concrete Mixer (small)	¼ or ⅓	x		x	Sentinel Breaker
Farm Shop Equipment	¼	x		x	Sentinel Breaker
Fanning Mill	¼		x		Sentinel Breaker
Corn Sheller (single hole)	¼	x		x	Sentinel Breaker
Fruit Grader	¼	x		x	Sentinel Breaker
Grindstone	¼		x		Sentinel Breaker
Shearing Tool	¼		x		Sentinel Breaker
Sausage Grinder	¼	x		x	Sentinel Breaker
Potato Grader	½	x		x	Sentinel Breaker
Pump Jack	½	x		x	Sentinel Breaker
Root Cutter	¼ and 1	x		x	Sentinel Breaker
Small Feed Grinder (Burr)	½ and 1	x		x	Sentinel Breaker

MINIMUM RECOMMENDED SPEEDS OF CUTTER FANS TO ELEVATE ENSILAGE INTO SILOS OF DIFFERENT HEIGHTS USING 5-HP. MOTOR*

Diameter of Cutter Fan Inches (Wing Tip to Wing Tip)	Height of Silo in Feet: 25′	30′	35′	40′	45′	50′	55′	60′	75′
	Recommended Fan Speed, Revolutions per Minute								
30	500	530	575	610	650	690	720	750	835
32	465	495	540	575	610	645	675	705	735
34	440	465	510	540	570	610	635	660	780
36	415	440	480	510	540	575	600	625	695
38	390	415	450	480	510	545	570	595	660
40	370	395	430	460	485	515	540	565	625
42	355	380	410	435	465	490	515	535	595
44	340	360	390	415	440	470	490	510	570
46	325	345	375	400	425	450	470	490	545
48	310	330	360	380	405	430	450	470	520

For silos higher than 40 feet, the 7½ h.p. motor is recommended.

*From Wisconsin Rural Electrification Handbook. (Published by University of Wisconsin)

FARM WORK MOTORS AND CONTROL

INFORMATION SHOWING THE TYPE OF MOTOR AND CONTROL FOR VARIOUS TYPES OF MACHINERY USED ON THE FARM

FARM JOB			MOTOR			CONTROL	
Name	Speed Recommended Rpm.	Pulley Recommended Dia. Inches	Hp. Most Used	Pulley Recommended Inches Dia.	Face	Preferred Westinghouse Pushbutton Class No.	Alternate Westinghouse Manual Class No.
Milking Machine† (Pipe Line Type)	800	6	1	3	2½	Sentinel Breaker††	WK-18
Refrigerator (Dairy)†	See mfrs. specification	Determine by formula	¾ or 1	3	2½	Sentinel Breaker††	WK-18
Hay Hoist	Rope speed 100–200 ft./min	Determine by formula to give correct rope speed	3 or 5	5½	6¾	WK-16†† or 11–200	10–030
Grain Elevator (Inside or outside)	See mfrs. specification	Determine by formula	3 or 5	5½	6¾	WK-16†† or 11–200	10–030
Bone Grinder	See mfrs. specification	Determine by formula	5	4½	6¾	11–200	10–030
Cider Mill (large)	See mfrs. specification	Determine by formula	5	4½	6¾	11–200	10–030
Feed Grinder							
Hammer Type*	3500	4	5	8	6¾	11–200	10–030
Burr Type	800	12	5	5½	6¾	11–200	10–030
Feed Mixer	See mfrs. specification	Determine by formula	5	5½	6¾	11–200	10–030
Grain Blower Elevator*	3500	4	5	8	6¾	11–200	10–030
Wood Saw	1300	6	5	4½	6¾	11–200	10–030
Ensilage Cutter	SEE PRINT No. 843	Determine by formula	5 or 7½	4½	6¾	11–200	10–030
Hay Baler	600	16	5 or 7½	5½	6¾	11–200	10–030
Spraying Plant (Stationary)	600	13	5 or 7½	4½	6¾	11–200	10–030
Husking and Shredding Corn	See mfrs. specification	Determine by formula	5 or 7½	4½	6¾	11–200	10–030
Irrigation	Depends on conditions and capacity of pump. See manufacturers requirements.						

* If an individual motor is justified for these machines, it may be desired to use a 3450-Rpm. motor direct connected to eliminate pulleys and belts. † Would generally be permanently installed. †† These are manual starters.

MOTOR PULLEY DIAMETER

Dia. of Pulley on Driven Machine	3½"	4½"	5½"	7"	8"	9"
	Approx. Rpm. of Driven Machine with Full Load Motor Speed of 1750 Rpm					
3"	2040	2580	3140	4000	....	....
4"	1530	1930	2360	3000	3500	3950
5"	1225	1540	1880	2400	2800	3150
6"	1020	1290	1570	2000	2340	2620
8"	765	965	1175	1500	1750	1970
10"	612	770	940	1200	1400	1575
12"	510	640	785	1000	1170	1310
14"	437	550	670	860	1000	1120
16"	383	480	580	750	880	990
18"	340	430	520	670	780	880
20"	306	385	470	600	700	790
22"	278	350	430	550	640	720
24"	255	320	390	500	580	660

FORMULA FOR FIGURING PULLEY SIZES AND SPEEDS

For machine speeds and pulley sizes not covered in the tables, the following simple formula may be used.

$$\text{Machine Pulley Diameter} = \frac{\text{Motor Pulley diameter} \times \text{Motor Rpm.}}{\text{Machine Rpm.}}$$

(Pulley diameters should be figured in inches)

For example, the motor pulley is 8 inches in diameter. The motor speed is 1750 revolutions per minute. It is desired to operate a hammer mill at 3500 rpm. What size pulley should be used on the mill?

Using the formula, we get:

$$\text{Hammer Mill Pulley Diameter} = \frac{8 \times 1750}{3500} = 4 \text{ inches}$$

NEMA STANDARDS AND DEFINITIONS

(From NEMA Publication 38-49)

MG3-10 Proper Selection of Apparatus

Extreme care should be used in the proper selection of apparatus in order that successful operation and good service will result. Where the apparatus is subjected to unusual risk, the manufacturer should be consulted; especially where the apparatus is used under the following conditions.

(1) Exposed to chemical fumes.

(2) Operated in damp places.

(3) Operated at speeds in excess of specified overspeed.

(4) Exposed to combustible or explosive dust.

(5) Exposed to gritty or conducting dust.

(6) Exposed to lint.

(7) Exposed to steam.

(8) Operated in poorly ventilated rooms.

(9) Operated in pits, or where entirely enclosed in boxes.

(10) Exposed to inflammable or explosive gases.

(11) Exposed to temperatures below 10 C.

(12) Exposed to oil vapor.

(13) Exposed to salt air.

(14) Exposed to abnormal shock or vibration from external sources.

(15) Where the departure from rated voltage is excessive.

(16) Where parallel operation of generators is required.

(17) Where the alternating-current supply voltage is unbalanced.

Adopted Standard 10-29-1937.

MG3-12 Speed Limitations—Belt Drive

(a) The following limitations represent good practice in belting motors under normal conditions to relatively high-speed drives:

(1) The use of 1700 to 1800 rpm motors should be limited to a maximum of 40 hp.

(2) The use of 1440 to 1500 rpm motors should be limited to a maximum of 40 hp.

(3) The use of 1150 to 1200 rpm motors should be limited to a maximum of 75 hp.

(4) The use of 850 to 900 rpm motors should be limited to a maximum of 125 hp.

(5) The use of 680 to 720 rpm motors should be limited to a maximum of 150 hp.

(6) The use of 560 to 600 rpm motors should be limited to a maximum of 200 hp.

(b) The above limitations are based on the use of pulleys as standardized by The National Electrical Manufacturers Association. The limitations will be less than those given when motors are belted to slow-speed drives, such as counter-shafts.

(c) The use of outboard bearings is approved and recommended for belted motors in frame sizes of 250 hp, 575 to 600 rpm and larger.

NOTE I—It is not the intention to establish a definite dividing line below which the use of outboard bearings is not standard, but rather to establish a dividing line which will indicate to the motor user what the manufacturers consider to be good practice in general service.
NOTE II—Where an outboard bearing is specified, it is assumed that the necessary three-bearing type base plate and slide rails, if required, are included with the motor.

Recommended Practice 7-16-1931.

MG3-12.5 Speed Limitations—V-Belt Drive

The following limitations represent good practice in using V-belts on motors under normal conditions on relatively high-speed drives:

(1) The use of 1700 to 1800 rpm motors should be limited to a maximum of 75 hp.

(2) The use of 1440 to 1500 rpm motors should be limited to a maximum of 75 hp.

(3) The use of 1150 to 1200 rpm motors should be limited to a maximum of 125 hp.

(4) The use of 850 to 900 rpm motors should be limited to a maximum of 150 hp.

(5) The use of 680 to 720 rpm motors should be limited to a maximum of 200 hp.

Recommended Practice 7-21-1937.

MG3-13 Speed Limitations—Gear or Chain Drive

(a) The following limitations represent good practice in gearing motors, (based on the use of steel pinions) and for chain drives:

(1) The use of 1700 to 1800 rpm motors should be limited to a maximum ot 5 hp.

(2) The use of 1440 to 1500 rpm motors should be limited to a maximum of 10 hp.

(3) The use of 1150 to 1200 rpm motors should be limited to a maximum of 25 hp.

(4) The use of 850 to 900 rpm motors should be limited to a maximum of 50 hp.

(5) The use of 720 to 750 rpm motors should be limited to a maximum of 75 hp.

(b) The use of outboard bearings should be specified for general-purpose motors with gear or chain drive in frame sizes 75 hp, 850 to 900 rpm and larger.

(c) For quiet operation and freedom from severe vibration when using gear drive, the speed of the motor should be selected such that with the pinion or gear used the peripheral speed at the pitch diameter will not exceed 1300 feet per minute when using cut steel spur gearings.

Recommended Practice 8-5-1930.

MG50-10 Protected Machine

(Formerly called semi-enclosed machine)

A protected machine is one in which all ventilating openings in the frame are protected with wire screen, expanded metal or perforated covers, the openings in which do not exceed ½ sq. in. (323 sq mm) in area and are of such shape as not to permit the passage of a rod larger than ½ in. (12.7 mm) in diameter, except where the distance of exposed live parts from the guard is more than 4 in. (101.7 mm) the openings may be ¾ sq. in. (484 sq mm) in area and must be of such shape as not to permit the passage of a rod larger than ¾ in. (19 mm) in diameter.

Adopted Standard 8-1-1935.

MG50-12 Semi-Protected Machine

A semi-protected machine is one in which part of the ventilating openings in the frame, usually in the top half are protected as in the case of a "protected machine" but the others are left open.

Adopted Standard 8-1-1935.

MG50-14 Drip-Proof Machine

A drip-proof machine is one in which the ventilating openings are so constructed that drops of liquid or solid particles falling on the machine at any angle not greater than 15 deg from the vertical, cannot enter the machine either directly or by striking and running along a horizontal or inwardly inclinded surface.

Adopted Standard 8-1-1935

MG50-16 Splash-Proof Machine

A splash-proof machine is one in which the ventilating openings are so constructed that drops of liquid or solid particles falling on the machine or coming towards it in a straight line at any angle not greater than 100 deg from the vertical cannot enter the machine either directly or by striking and running along a surface.

Adopted Standard 8-1-1935.

MG50-18 Explosion-Proof Machine

An explosion-proof machine is one in an enclosing case which is designed and constructed to withstand an explosion of a specified gas or dust which may occur within it, and to prevent the ignition of the specified gas or dust surrounding the motor by sparks, flashes, or explosions of the specified gas or dust, which may occur within the machine casing.

Adopted Standard 8-1-1935.

MG50-20 Water-Proof Machine

1. A water-proof machine is a totally enclosed machine so constructed that it will exclude water applied in the form of a stream from a hose.

2. A water-proof machine is a totally enclosed machine so constructed that a stream of water from a hose (not less than 1 inch in diam) under a head of 35 ft and from a distance of about 10 ft can be played on the machine without leakage, except that leakage which may occur around the shaft may be considered permissible, provided it is prevented from entering the oil reservoir and provision is made for automatically draining the machine.

NOTE—The machine should be provided with a check valve for drainage or a tapped hole at the lowest part of the frame which will serve for application of drain or drain plug.

Adopted Standard 8-1-1935.

MG50-22 Dust-Tight Machine

A dust-tight machine is one so constructed that the enclosing case will exclude dust.

Adopted Standard 8-1-1935.

MG50-24 Resistant (As a suffix)

A machine is designated as moisture-resistant, fume-resistant, etc., when so constructed, protected or treated that it will not be readily injured when subjected to the specified material as follows:

1. Moisture (very damp or humid atmosphere such as occurs in dye houses, evaporating rooms, certain tropical localities and in some mines.)
2. Fumes (as may be specified).
3. Gas (as may be specified).

4. Acid (as may be specified).

5. Alkali (as may be specified).

Adopted Standard 8-1-1935.

MG50-26 Submersible Machine

A submersible machine is one so constructed that it will operate successfully when submerged in water under specified conditions of pressure and time.

Adopted Standard 8-1-1935.

MG50-54 Printing Press Duty

The duty on rotary web printing presses is of an intermittent nature, but the cycle on which they operate does not permit of using main driving motors with a short-time rating. Printing press duty for these presses is, therefore, defined as 40 C rise, open continuous operation, constant torque or 50 C rise, semi-enclosed, continuous operation, constant torque, the horsepower rating being specified at the maximum speed. This rating applies to both direct-current and alternating-current drives.

Adopted Standard 11-5-1929

MG50-60 Ambient Temperature

Ambient temperature is the temperature of the air or water which, coming into contact with the heated parts of a machine, carries off their heat. (See MG50-64.)

NOTE—Ambient temperature is commonly known as "room temperature" in connection with air cooled apparatus not provided with artificial ventilation.

Adopted Standard 5-1-1916.

MG-50-62 Rating

A rating of a machine is a designated operating limit based on definite conditions.

Adopted Standard 10-29-1937.

MG50-63 Service Factor—General-Purpose Motors

A service factor of a general-purpose motor is a multiplier which, applied to the normal horsepower rating, indicates a permissible loading which may be carried under the conditions specified for the service factor.

Adopted Standard 10-29-1937.

MG50-64 Rated Load

Rated load shall mean horsepower output for motors, kilowatt output for direct-current generators, and kilovolt-ampere output for alternating-current generators.

Adopted Standard 10-29-1937.

MG50-65 Time Ratings and DurationTests of

(a) Many machines are operated on a cycle of duty which repeats itself with more or less regularity. The heating of machines operating under such conditions is equivalent to a continuous run for a certain specified time. The standard duration of load tests, or time ratings, for machines operating on such ratings shall be as follows:

5 min, to and including 30 hp
15 min, to and including 50 hp
30 min, to and including 60 hp
60 min
Continuous

(b) Of the foregoing rating, the first four are commonly known as short-time ratings. In every case the short-time load test shall commence only when the windings and other parts of the machine are within 5 C of the room temperature at the time of starting the test.

Adopted Standard 12-8-1932.

MG50-66 Time Rating

Time rating is the period of a test run within which the specified conditions of load and temperature rise shall not be exceeded.

Adopted Standard 11-10-1915.

MG50-67 Locked-Rotor or Static Torque—A-c Motor

The locked-rotor torque of a motor is the minimum torque which it will develop at rest for all angular positions of the rotor, with rated voltage applied at rated frequency.

Adopted Standard 10-29-1937.

MG50-68 Pull-Up Torque—A-c Motor

The pull-up torque of a motor is the minimum torque developed by the motor during the period of acceleration from rest to full speed with rated voltage applied at rated frequency.

Adopted Standard 10-29-1937.

MG50-69 Break-Down Torque—A-c Motor

The break-down torque of a motor is the maximum torque which it will develop with rated voltage applied at rated frequency, without an abrupt drop in speed.

Adopted Standard 10-29-1937.

MG50-72 Locked-Rotor Current—A-c Motor

The locked-rotor current of a squirrel-cage induction or other internally short-circuited motor is the current taken from the line with the rotor locked and with rated voltage and frequency applied to the motor.

Adopted Standard 5-27-1926

MG50-75 Secondary Voltage of Wound-Rotor Motors

The secondary voltage of wound-rotor motors is the open-circuit voltage at standstill, measured across the slip rings.

Adopted Standard 6-7-1922.

MG50-76 Dielectric Test

Dielectric tests are tests which consist of the application of a voltage higher than the rated voltage for a specified time and are designed to determine the adequacy of insulating material and spacing.

Adopted Standard 6-13-1923

MG50-78 Voltage Regulation of D-c Generators

The regulation of a d-c generator is usually stated by giving the numerical values of the voltage at no-load and rated load, and in some cases it is advisable to state regulation at intermediate loads. The regulation of d-c generators refers to changes in voltage corresponding to gradual changes in load, and does not relate to the comparatively large momentary fluctuations in voltage that frequently accompany instantaneous changes in load.

Adopted Standard 1-26-1934.

MG50-140 Rated Speed

The rated speed of an alternating-current general-purpose motor is defined as the full load speed stamped on the nameplate.

Adopted Standard 5-27-1926.

MG50-141 Constant-Speed Motor

A constant-speed motor is one the speed of which at normal operation is constant or practically constant. For example, a synchronous motor, an induction motor with small slip, or an ordinary direct-current shunt-wound motor.

Adopted Standard 10-29-1937

MG50-142 Varying-Speed Motor

A varying-speed motor is one the speed of which varies with the load, ordinarily decreasing when the load increases; such as a series motor, or an induction motor with large slip.

Adopted Standard 10-29-1937

MG50-143 Adjustable-Speed Motor

An adjustable-speed motor is one the speed of which can be varied gradually over a considerable range, but when once adjusted remains practically unaffected by the load, such as a shunt motor with field-resistance control designed for a considerable range of speed adjustment.

Adopted Standard 10-29-1937.

MG50-144 Adjustable Varying-Speed Motor

An adjustable varying-speed motor is one the speed of which can be adjusted gradually, but when once adjusted for a given load will vary in considerable degree with change in load; such as a compound-wound direct-current motor adjusted by field control or a slip-ring induction motor with rheostatic speed control.

Adopted Standard 10-29-1937.

MG50-145 Multi-Speed Motor

A multi-speed motor is one which can be operated at any one of two or more definite speeds, each being practically independent of the load. For example a direct-current motor with two armature windings, or an induction motor with windings capable of various pole groupings.

Adopted Standard 10-29-1937.

MG50-160 Front

The front of a normal motor or generator is the end opposite the coupling or driving pulley.

Adopted Standard 10-29-1937.

MG50-161 Back

The back of a normal motor or generator is the end which carries the coupling or driving pulley.

Adopted Standard 10-29-1937.

MG50-163 D-c Generator—Complete

(a) Belt Type.

A belt type generator consists of a generator, sliding base or rails, and field rheostat. Standard field rheostats for generators above 10 kw capacity are of the back-of-board type, and for generators of 10 kw and smaller, rheostats are of the front-of-board type.

(b) Engine Type.

An engine type generator consists of a generator without base, shaft, bearings, shaft keys or foundation bolts, but with back-of-board field rheostat and with cap plates when required.

Adopted Standard 5-20-1937.

MG50-165 Large Power Motor—Complete

A complete large power motor is an open large power motor ready to run, including standard pulley, belt-tightening base or slide rails, and hand-operated, no-voltage release starter for front-of-board mounting. (See also MG50-114.)

Adopted Standard 5-20-1912.

MG50-166 Bare Motor

A bare motor is an open type motor ready to run, without pulley, belt-tightening base, slide rails or starter.

Adopted Standard 10-30-1911.

MG50-167 Motor-Reduction Unit

A motor-reduction unit is a motor with an integral mechanical means of obtaining a speed differing from the speed of the motor.

NOTE—Motor-reduction units are usually desired to obtain a speed lower than that of the motor, but may also be built to obtain a speed higher than that of the motor.

Adopted Standard 7-21-1932.

MG50-168 Frame

A frame is the supporting structure for the stator parts.

In a direct-current machine the frame usually forms a part of the magnetic circuit; it includes the poles only when they form an integral part of it.

Adopted Standard 10-29-1937.

MG50-169 Assembled Field Frame

An assembled field frame is a field frame with necessary complement of poles, pole shoes and field coils assembled thereon.

Adopted Standard 10-30-1911.

MG50-170 Field Pole

A field pole is a structure of magnetic material on which a field coil may be mounted.

Adopted Standard 10-29-1937.

MG50-171 Pole Shoe

A pole shoe is the portion of a field pole facing the armature of the machine. It may be separable from the body of the pole.

Adopted Standard 10-29-1937.

MG50-172 Field Coil

A field coil is a suitably insulated winding to be mounted on a field pole to magnetize it.

Adopted Standard 10-29-1937.

MG50-180 Rotor

A rotor is the rotating member of a machine.

Adopted Standard 10-29-1937.

MG50-181 Squirrel-Cage Rotor

A squirrel-cage rotor is the rotor of a squirrel-cage induction motor. Its circuits consist of conductors suitably disposed in the slots in a core and permanently connected together at the two ends of the core. The conductors may or may not be insulated.

Adopted Standard 11-5-1929.

MG50-182 Wound Rotor

A wound rotor is the rotor of a wound-rotor induction motor. Its circuits consist of a polyphase winding of insulated conductors suitably disposed in slots in a core, and with terminals brought out to collector rings.

Adopted Standard 11-5-1929.

MG50-183 Armature

The armature is the part of a machine which includes the main current-carrying winding.

In direct-current machines and in alternating-current commutator machines, the armature winding is connected to the commutator and the armature is the rotating member.

In alternating-current machines without commutators, the armature may be either the rotating member or the stationary member.

NOTE—in some types of alternating-current machines the use of the term 'armature' is apt to be misleading and should be avoided.

Adopted Standard 10-29-1937.

MG50-184 Armature—Complete

A complete armature is an armature ready to place in a machine.

Adopted Standard 10-30-1911.

MG50-185 Armature Core

An armature core consists of the assembled armature laminations without the slot insulation or windings.

Adopted Standard 10-29-1937.

MG50-186 Armature Quill

An armature quill is a ventilated or unventilated structure upon which an armature and commutator are assembled and which in turn may be mounted on the armature shaft.

NOTE—A quill may be an integral part of the armature and commutator, one or both; or the armature and commutator, having been assembled separately, may be mounted together on the quill.

Adopted Standard 11-18-1916.

MG50-187 Armature Sleeve

An armature sleeve is an unventilated support on which armature laminations are or may be mounted and which in turn is mounted on the armature shaft.

Adopted Standard 10-30-1911.

MG50-188 Armature Spider

An armature spider is a ventilated support upon which armature laminations are mounted, and which in turn is mounted on the armature shaft.

Adopted Standard 10-30-1911.

MG50-189 Commutator—Complete

A commutator is an assembly of commutator bars suitably insulated in a shell or on a hub, ready for mounting on an armature shaft, sleeve or spider.

Adopted Standard 10-30-1911.

MG50-190 Commutator Bars

Commutator bars are the metal current-carrying members of a commutator which make contact with the brushes.

Adopted Standard 10-29-1937.

MG50-191 Commutator Insulating Rings

Commutator insulating rings are rings which constitute all the insulation between the ends of the assembled commutator bars and the supporting structure.

Adopted Standard 10-29-1937.

MG50-192 Commutator Insulator Strips

Commutator insulating strips are the insulating members between adjacent commutator bars.

Adopted Standard 10-29-1937.

MG50-193 Commutator-Bar Assembly

A commutator-bar assembly consists of the complete set of commutator bars assembled with the commutator insulating strips bound and ready for installation on the commutator shell, but this term does not include the commutator insulating rings or the commutator shell insulation.

Adopted Standard 10-29-1937.

MG50-194 Commutator Shell

A commutator shell is the support on which the commutator bar assembly, commutator insulating rings and the commutator shell insulation are mounted.

Adopted Standard 10-29-1937.

MG50-195 Commutator-Shell Insulation

Commutator-shell insulation is the insulation between the under (or in the case of a disk commutator, the back) side of the assembled commutator bars and the adjacent supporting structure.

Adopted Standard 10-29-1937.

MG50-196 Brush Yoke

A brush yoke is a rocker arm, ring, quadrant or other adjustable support for maintaining the brush holders or brush-holder studs in their relative positions.

Adopted Standard 10-29-1937.

MG50-198 Brush Holder

A brush holder is a device which holds the brush in position.

Adopted Standard 10-30-1911.

MG50-200 Brush-Holder Stud

A brush-holder stud is an intermediate support between the brush holder and the brush yoke.

Adopted Standard 10-29-1937.

MG50-201 Collector Rings (Slip Rings)

Collector rings are metal rings suitably mounted on an electrical machine serving, through stationary brushes bearing thereon, to conduct current into or out of the rotating member.

Adopted Standard 10-29-1937.

MG50-202 End Shield

An end shield assembly is an end shield together with its bearing sleeve and all parts associated therewith.

Adopted Standard 10-29-1937.

MG50-203 Bearing Bracket

A bearing bracket is a bracket secured to the frame to support the bearing but including no part thereof, and not designed specifically to protect the windings.

Adopted Standard 10-29-1937.

MG50-204 Bearing Bracket Assembly or End-Shield Assembly

A bearing-bracket or end-shield assembly is a bearing bracket or end shield with its bearing sleeve and all parts associated therewith.

Adopted Standard 10-29-1937.

MG50-205 Bearing Sleeve

A bearing sleeve is a bushing, sleeve, box or shell within which the shaft rotates.

Adopted Standard 10-30-1911.

MG50-206 Bearing Pedestal

A bearing pedestal is a bearing support, mounted on or constructed as a part of the base plate, but not including the bearing or any part thereof.

Adopted Standard 10-29-1937.

MG50-207 Bearing-Pedestal Assembly

A bearing-pedestal assembly is a bearing pedestal together with its bearing and all parts associated therewith.

Adopted Standard 10-29-1937.

MG50-208 Oil Rings

The oil rings are usually of metal, loosely hung on the journal of an armature shaft, free to revolve thereon and therewith, located within the oil space of the bearing sleeve support and adapted to raise a lubricant from the oil cellar into which they dip and to distribute it on the journal of the shaft.

Adopted Standard 11-18-1916.

Selection of Proper Brushes—I

The performance of a brush-type motor is dependent to a large degree upon the brushes used. The selection of the right grade and size of brush is, therefore, of great importance.

The main factors governing the proper choice of brushes are:

1. Applied voltage
2. Carrying capacity of brush and peripheral speed of commutator
3. General characteristics of the motor (type of service, etc.)
4. Atmospheric conditions

End shield from Bodine d-c motor.

The following discussion of these four points is intended to be a general guide in selecting brushes for fractional horsepower motors. Thus, some of these statements will not hold true for larger motors.

Applied voltage. The applied or operating voltage of a motor is the first consideration in choosing the proper brush. Voltage is generally termed *normal* voltage when it lies between 100 and 130 volts, *low* when it is between 6 and 32 volts, and *high* when it is 200 to 250 volts. Voltage ranges in between these are seldom used, while voltages above 250 volts are not ordinarily recommended for small motors.

For best all-around performance at normal voltages, Electro-Graphitic or Graphite grades (see definitions below) are usually selected. Their low friction characteristics and good lubricating qualities make them suitable for high peripheral speed and difficult commutation conditions.

Low-voltage motors with their correspondingly higher input currents require brush grades known as Metal-Graphite, with the metal content increasing inversely with the voltage. This type of brush is used almost exclusively for low-voltage motors. The copper content of these brushes gives them the highest current-carrying capacity of any grade of brush. This is necessary because these low-voltage motors require relatively high currents.

High-voltage motors need brushes which limit the current surge into the armature coils when starting and during commutation. For this purpose the higher resistance brushes — those known as Graphite, Electro-Graphitic, or Carbon grades — are used. Carbon brushes in particular have high contact voltage drop and low current-carrying capacity. Because of their hardness, they are able to withstand considerable shock, vibration, and reversal of motor rotation. This type of brush will keep the commutator clean even under extremely dirty conditions.

Carrying Capacity of Brush and Peripheral Speed of Commutator. These two qualities are closely related because they are determined by mechanical considerations in designing the brushes. Carrying capacity depends upon size, area of fully seated brush surface, temperature rise, and brush pressure. Peripheral speed also affects the current-carrying capacity of the brush. Brush pressure is governed by peripheral speed, and higher speeds mean greater wear and higher surge currents.

In choosing a brush to meet these various conditions, it is difficult to make general rules. For example, since higher peripheral speed generally results in increased wear, higher surge current, and increased friction losses, it may be desirable to counteract these disadvantages by using a harder brush to cut down wear on brushes and one with lower abrasiveness to cut down wear on the commutator. (Hardness is not related to abrasiveness — a soft brush may be very abrasive.) At the same time a higher contact drop must be had to limit surge current, and a lower coefficient of friction will be necessary to cut down friction loss. Whether this type of brush will be proper for the motor can only be determined by considering the particular case.

CARBON BRUSHES

Hard carbon brushes have high abrasiveness, specific resistance, and contact drop; comparatively low current-carrying capacity; are able to withstand considerable shock, vibration and reversal. They tend to keep the commutator clean.

ELECTRO-GRAPHITIC BRUSHES

Carbon brushes specially treated to produce high graphite content. Specific resistance, hardness, and current-carrying capacity medium to high; abrasiveness low; contact drop high. Low friction characteristics and good lubricating qualities for high peripheral speeds and difficult commutation conditions.

GRAPHITE BRUSHES

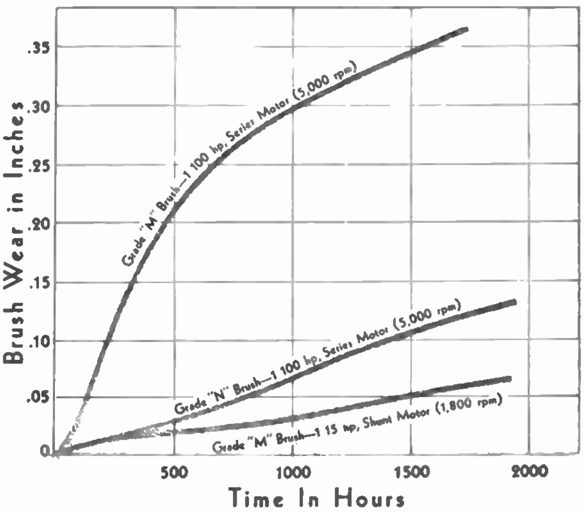
Specific resistance generally low (with some exceptions); hardness low to very low; abrasiveness medium; contact drop medium; current-carrying capacity high. Extreme softness and high lubricating properties. Useful for high peripheral speeds.

METAL-GRAPHITE BRUSHES

Specific resistance, hardness, and contact drop low; abrasiveness varies directly with the copper content; current-carrying capacity highest of any grade. Used for low-voltage motors.

Selection of Proper Brushes—II

General Motor Characteristics. In the first article, in the November Motorgram, the factors of applied voltage, brush capacity, and peripheral speed were discussed as they relate to selection of the proper grade brush for a given motor. In addition, this selection depends on inherent design data like type of winding, kind of current, the ampere-turns ratio, and commutator lead. The kind of service required of the motor brings additional conditions that influence the selection of the brush. Frequent starting or reversing, necessity for high efficiency, overload capacity, presence of vibration, required absence of brush noise, etc., are various factors that must be considered. Sometimes the various points influencing the brush selection contradict each other and a compromise must be found.



This graph shows how the same brush wears differently in different motors, and how wear is greatly reduced when the proper brush is chosen. Grade "M" is suitable for the 1/15 hp shunt motor, but wears too rapidly in the 1/100 hp series motor. Grade "N" is better suited for use in the series motor, showing greatly reduced wear.

Series motors, for example, often gain higher efficiency with a low ampere-turns ratio, but sparking then becomes more pronounced and the commutator is blackened or burned. If efficiency is more important than brush life in this case, a hard brush grade with a slight "cleaning action" would be the answer. To cite another example, shunt motors, which generally show better brush life than series motors, have poor commutation when motor speed is increased by inserting resistance in the field. Of course the brush grade must be chosen with this in mind.

All d-c motors show the phenomenon of "electrolytic action," with the negative brush wearing down faster. Not all grades of brushes are equally affected, and sometimes the use of different grades for positive and negative brushes is resorted to. Of course, the ill effects of electrolytic action can best be overcome by reversing the motor leads at regular intervals.

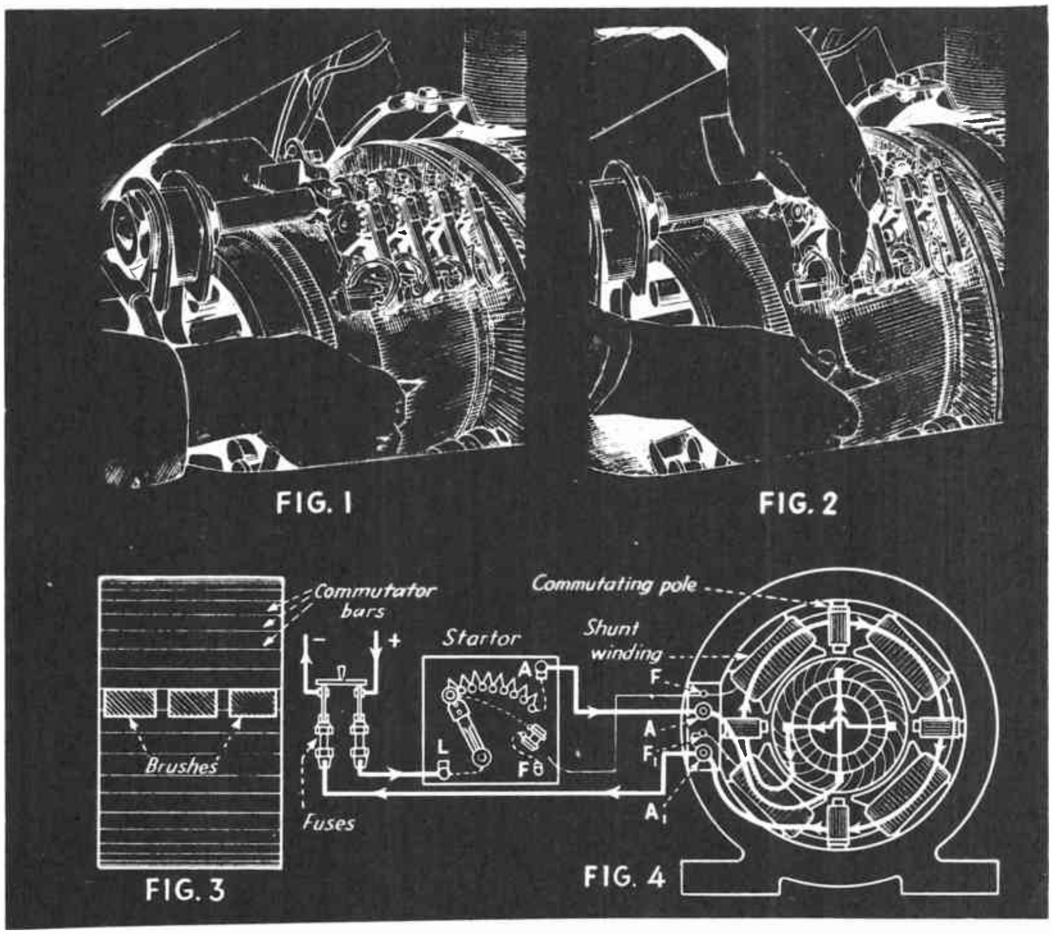
Frequent starting and stopping imposes a heavy load on brushes. This has a particularly pronounced effect with high voltage shunt motors. A high contact drop brush (one with a voltage drop of one volt or more) may help. On the other hand, low voltage motors are sometimes required to start on fifty percent or less of rated voltage; then a brush with a very low contact drop (less than one-half volt) must be used with comparatively low spring pressure. This will improve the starting ability of the motor, but will adversely affect the brush life at full load under the rated motor voltage.

Where quietness is of prime importance, a softer brush grade can be used than would otherwise be chosen, with enough spring pressure to maintain an uninterrupted contact. Thus, chatter is eliminated. Although commutators are usually undercut, a commutator with flush mica is sometimes used to avoid noise. In this case, a brush must be used that is abrasive enough to wear the mica down evenly with the copper bar of the commutator. The presence of vibration and shock also require a different grade of brush, usually a harder brush of the carbon type.

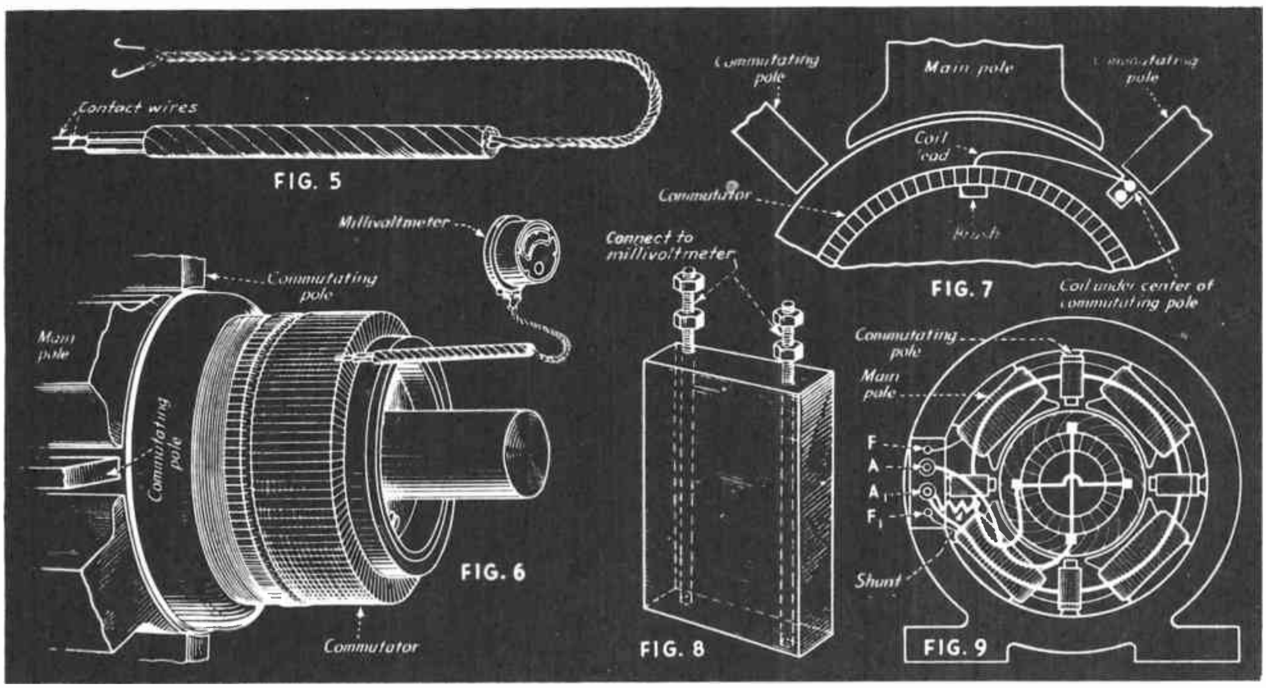
Atmospheric conditions. Temperature and humidity have a definite effect on brush wear. High humidity may increase electrolytic action while extremely low humidity, such as that encountered at high altitudes, increases brush friction and causes dusting and rapid wearing away of the brushes. A brush with a certain amount of abrasiveness will frequently improve commutation at high humidity; on the other hand, brushes must be treated with some kind of lubricant for extremely low humidity such as that found at high altitudes. The presence of chemical fumes, dirt, or dust may also become a deciding factor in determining the grade of brush. Under such conditions, brush grades with some cleaning action are usually preferred.

Conclusion. From the foregoing discussion the selection of a suitable set of brushes may seem like a very difficult job involving a large amount of guesswork. Actually, when a decision on a particular motor has to be reached, the task is fairly simple for experienced Bodine engineers. On one hand, the electrical data of the motor, the brush size with its required current carrying capacity, and frequently the past commutation performance of the motor are known. On the other hand, the brush manufacturer's table lists all pertinent brush data. Therefore, it is usually possible to select the brush which will give greatest efficiency and satisfaction in the service required by giving due thought to the various elements involved and considering these in light of past experience.

Brushes and Brush Setting



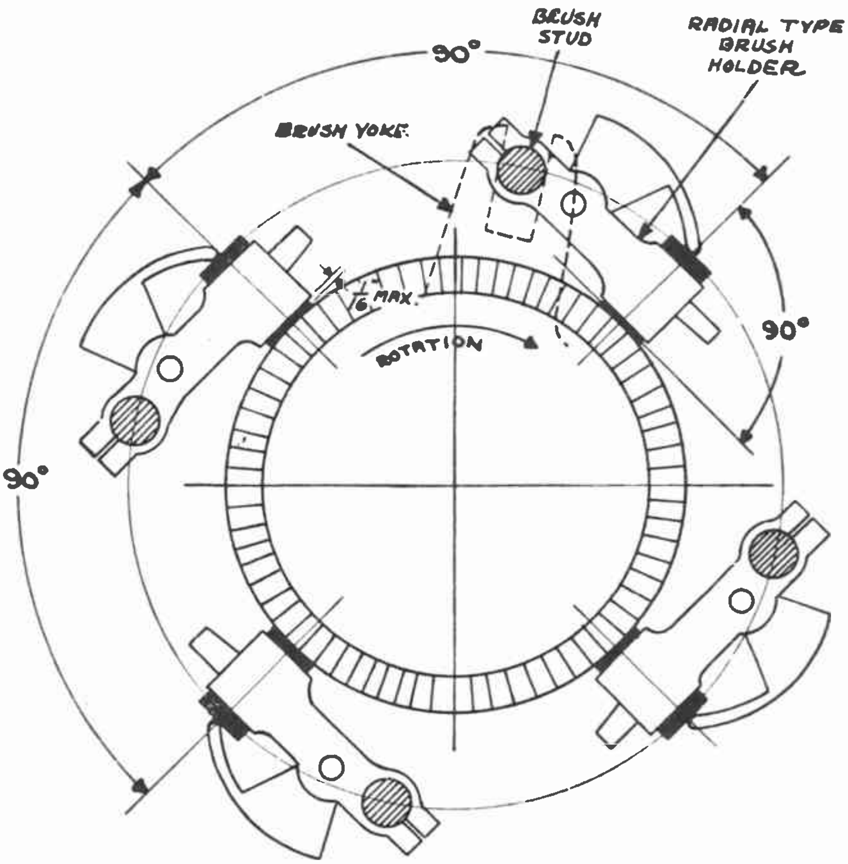
Figs. 1 and 2—Fitting brushes to commutator with sand paper. Fig. 3—Brushes in each group should be in line. Fig. 4—Field circuit open to test brush location on commutator



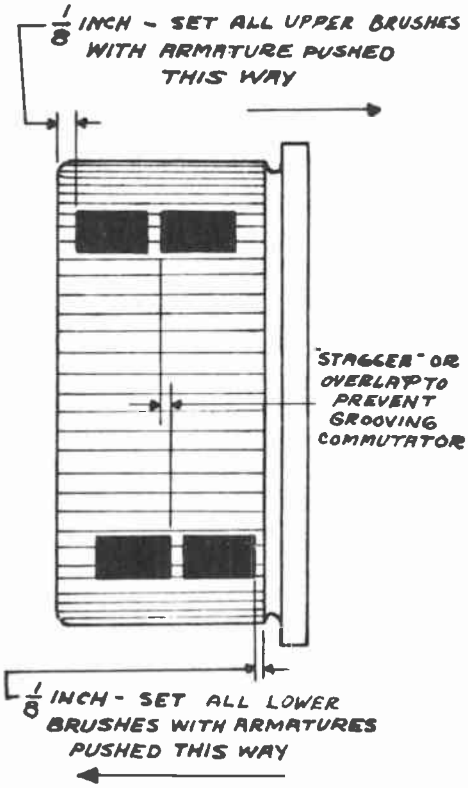
Figs. 5 and 6—Locating neutral on commutator with millivoltmeter. Fig. 7—Armature-coil lead locates neutral. Fig. 8—Fibre brush used with millivoltmeter. Fig. 9—Shunt across commutating-pole coil leads to adjust field-pole strength.

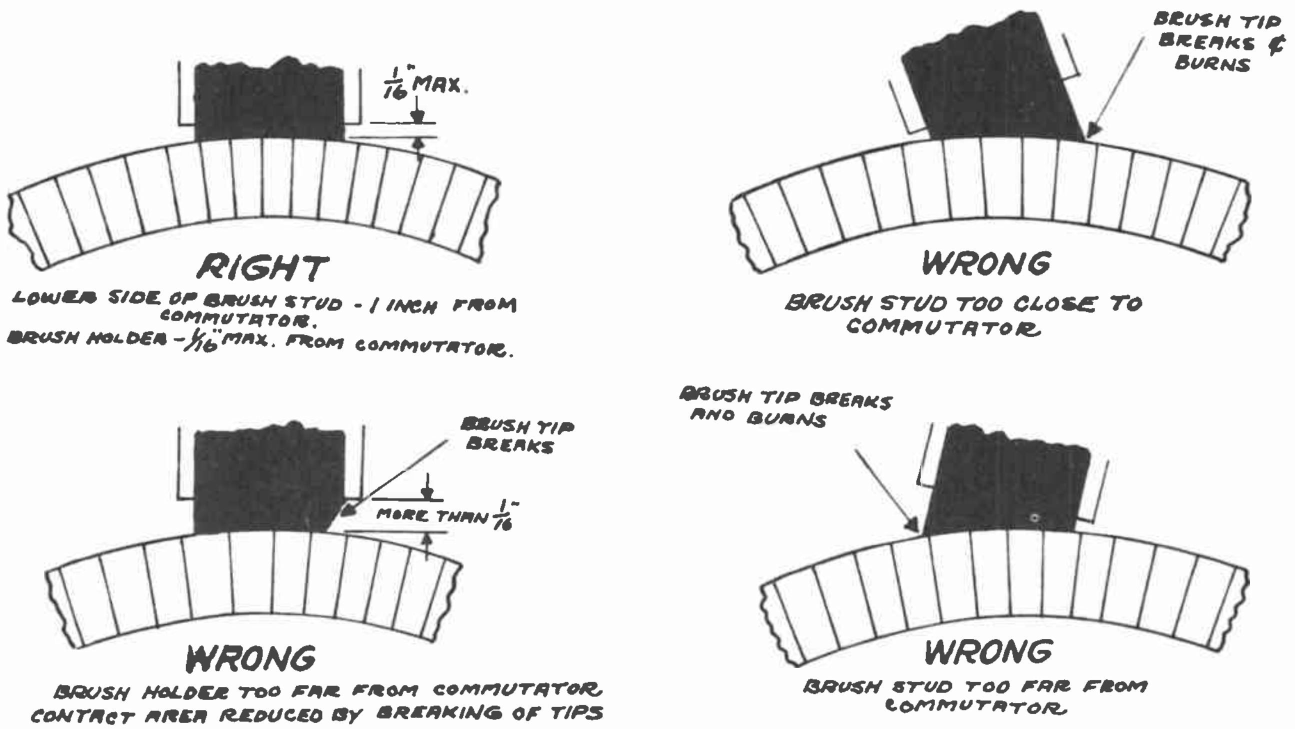
INSTRUCTIONS FOR SETTING BRUSH HOLDERS (RADIAL TYPE) TO PREVENT INJURY TO BRUSHES AND COMMUTATOR

JANETTE MANUFACTURING COMPANY



VIEW FACING COMMUTATOR



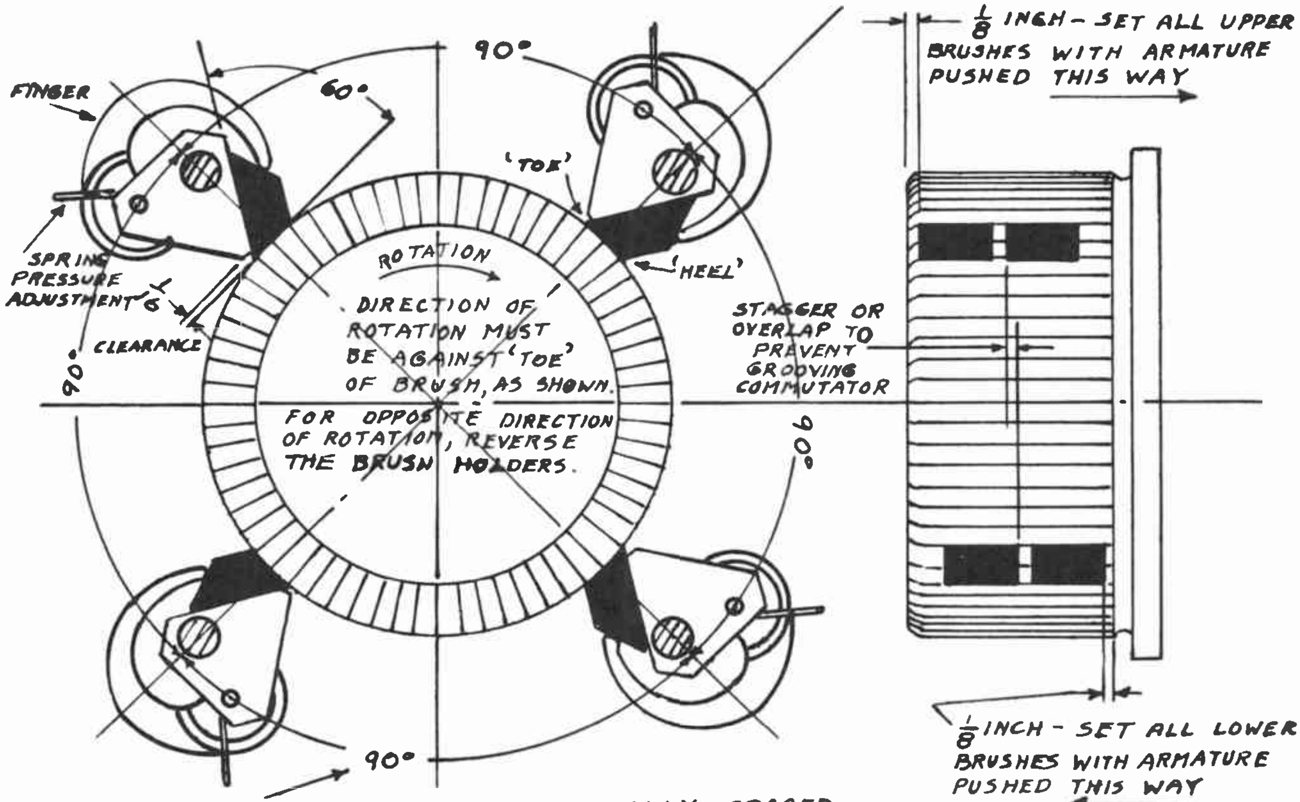


SET MACHINE LEVEL TO ALLOW FREE END PLAY

INSTRUCTIONS FOR SETTING REACTION TYPE BRUSH HOLDERS AND FOR INSTALLING BRUSHES

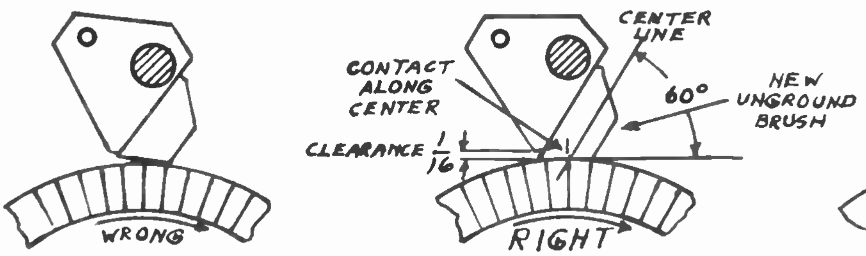
TO OBTAIN CORRECT ANGLE (60°)

ADJUST ONE STUD AND HOLDER TO PROPER CLEARANCE AND SO THAT A NEW UNGROUND BEVELED BRUSH BEARS ON COMMUTATOR ALONG ITS CENTER. (SEE RIGHT AND WRONG SKETCHES BELOW.) SEAT THIS BRUSH WITH SANDPAPER TO FIT COMMUTATOR SURFACE. THEN USE THIS BRUSH AS AN ANGLE GAGE TO SET ALL THE OTHER HOLDERS.

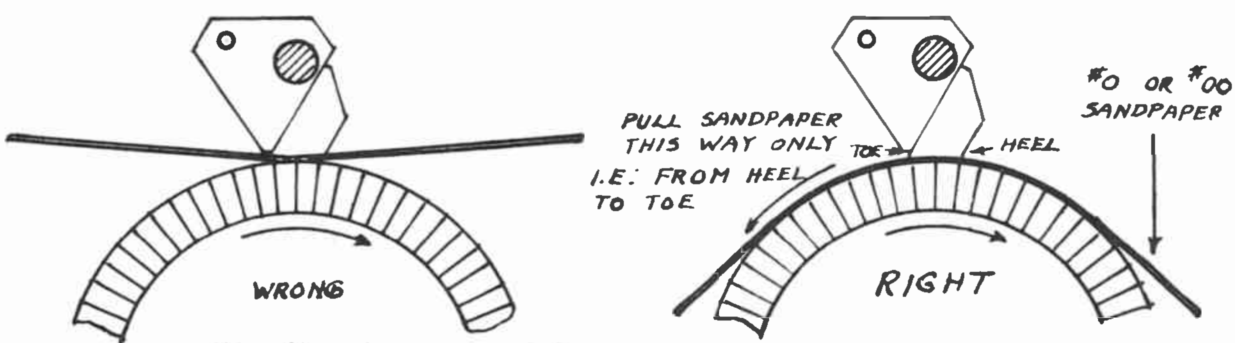


BRUSH HOLDERS MUST BE EQUALLY SPACED AROUND COMMUTATOR. TO CHECK SPACING:

1. COUNT NUMBER OF COMMUTATOR BARS BETWEEN BRUSHES
OR
2. WRAP EQUALLY SPACED PAPER AROUND COMMUTATOR AND SEE THAT 'TOES' OF BRUSHES LINE UP ON SPACING MARKS.



HOW TO SET BRUSH HOLDER FOR CORRECT ANGLE



HOW TO HOLD SANDPAPER WHEN SEATING BRUSHES

Measuring brush spring pressure. Take reading when pressure between spring and brush is reduced sufficiently to free piece of paper previously inserted. (Peerless Electric Company)

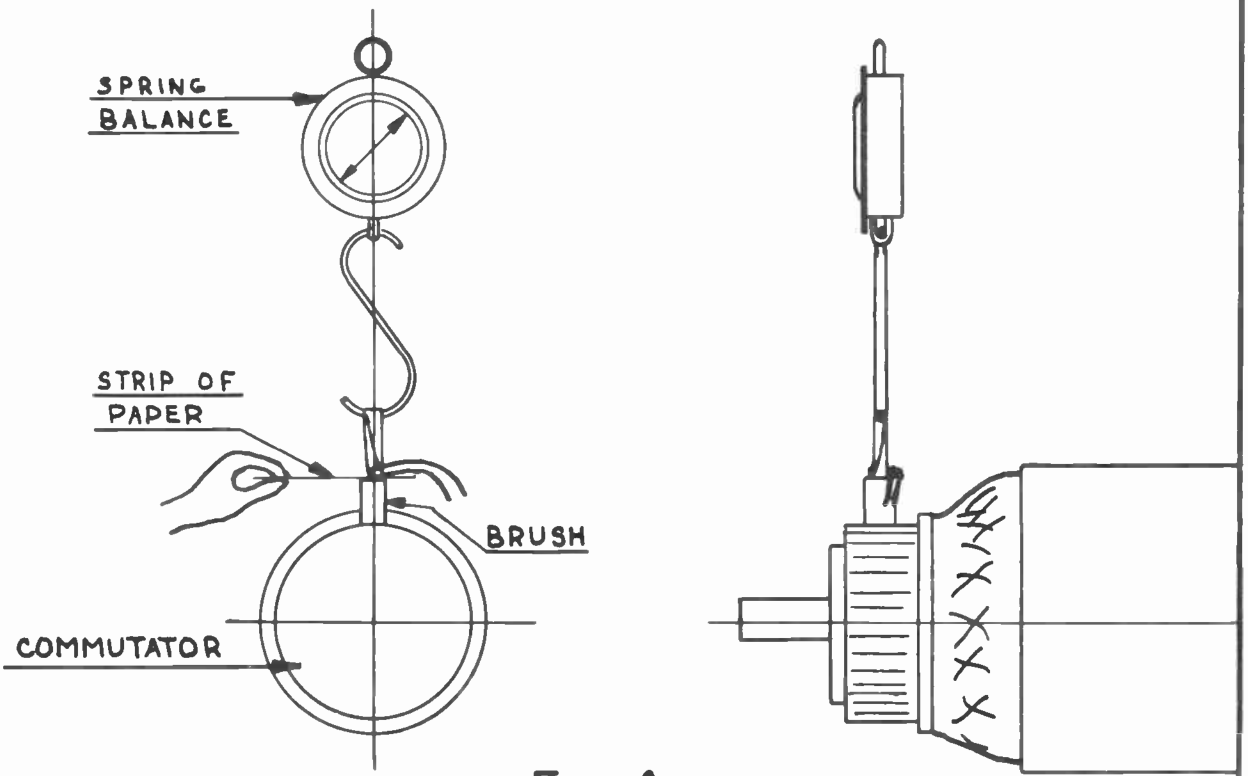


FIG. A.

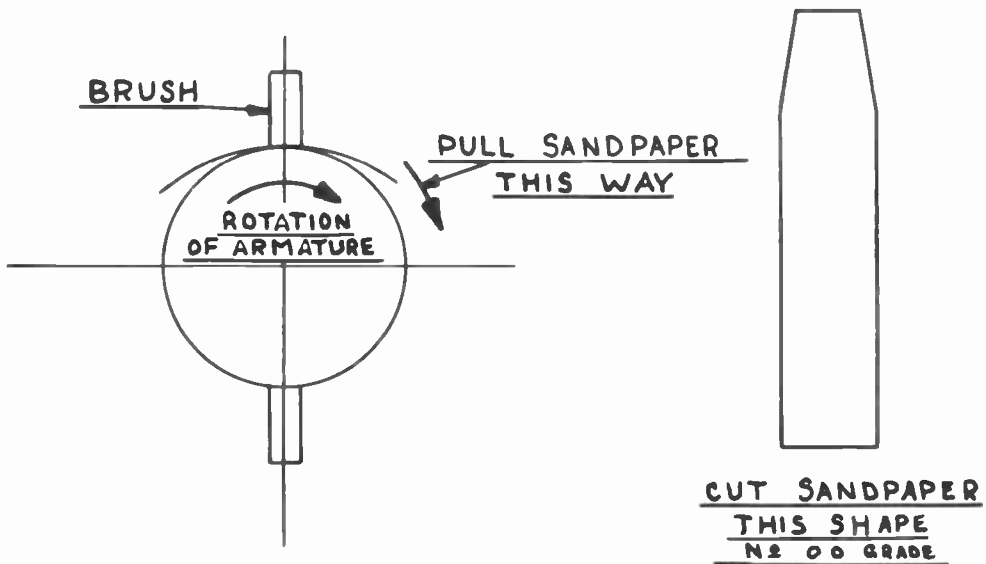


FIG B.

METHOD OF SANDING AND OBTAINING BRUSH PRESSURE.

CARE OF THE COMMUTATOR

GENERAL ELECTRIC

1. Commutator eccentric. A dial-indicator reading of .001 in. on high-speed machines to several thousandths on low-speed machines can be considered normal.
2. High and low bars. Season the commutator by substituting maple blocks for the brushes in the brush holders with the commutator turning.
3. High mica. Where conditions of high mica occur, the mica must be undercut by one of the methods described below.

Example of a set of brushes fractured as a result of brush chatter caused by high mica and rough commutator surface.

4. Pitted mica—usually caused by the presence of oil, grease, minute particles of carbon and copper, or unclean commutator.
5. Grooving of commutator—caused by the use of brushes having a too high abrasive quality or by incorrect staggering of brushes. This condition can also be helped by providing a small amount of end play in the rotor wherever possible.

Cleaning the Commutator

To properly clean a commutator, use a piece of dry canvas or other hard nonlinting material which is wound around and securely fastened to a wooden stick, and held against the commutator. Do not use a lubricant on the commutator, either during or after the polishing period. If the commutator is clean and polished, and the brushes have a perfect fit, the unit may be loaded at once, provided the insulation resistance is satisfactory. If the commutator is not polished, the machine should be run with a light load for several hours in order to establish a high and uniform polish on the commutator surface, and a good fit on the brush faces. Brushes can be fitted more quickly if the machine is carrying a load in proportion to the percentage of contact surface of the brushes. As the brush fit improves, the load can be increased depending on the amount of sparking and heating.

To properly clean a commutator, use a piece of dry canvas or other hard nonlinting material which is wound around and securely fastened to a wooden stick, and held against the commutator.

Truing the Commutator

1. Undercut the mica. A square slot is preferable, if slots are accessible to easy cleaning. Where slots are likely to collect dirt, as in low-speed machines or in a dirty atmosphere, the V-shaped slot may be more satisfactory. It is well to slightly bevel the segment corners.

   Various types of undercutting tools are available. See drawings on next page.
2. Polish the commutator with one of the varieties of dressing stones, several varieties of which are available on the market (see drawings on next page). These stones may be held in the hands or mounted in adjustable rests.

   When stoning, the brushes should be lifted away from the commutator, and the machine, if a generator, should be driven at normal speed by the prime mover; if a motor, by mechanical power from external source, if possible.

Before stoning a commutator, all traces of oil or grease should be removed from the commutator and stone. The stone should be worked from end to end of the commutator, and the surface ground down evenly. After stoning, the commutator should be smoothed with a very fine grade of sandpaper, and then polished by using the back of the paper.

3. After the commutator has been conditioned, make sure that it is completely cleaned out with every trace of copper, carbon, or other dust removed, preferably by suction.

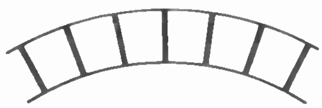
4. Reinstall the brushes and seat them by applying a small amount of seating compound, if available, to the commutator. After seating, clean the commutator thoroughly again.

Grinding the Commutator

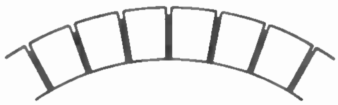
When the commutator is too rough or eccentric to be stoned down successfully by hand, the stone can be held by a pair of clamps in a tool post. However better results can be obtained by the use of a revolving-wheel grinder, or it may be advisable to turn the commutator in a lathe. When extreme roughness exists, it is probably better to send the armature to a reputable service shop.

Turning the Commutator

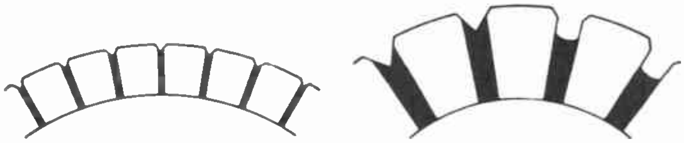
For extreme commutator roughness, turning of the commutator in a lathe is suggested.



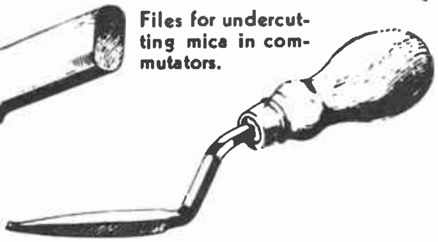
Flush mica.



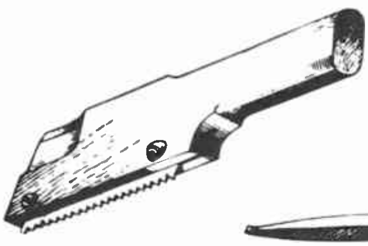
Undercut mica in commutators.



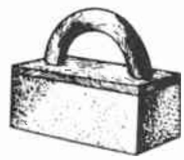
Undercut mica in commutators.



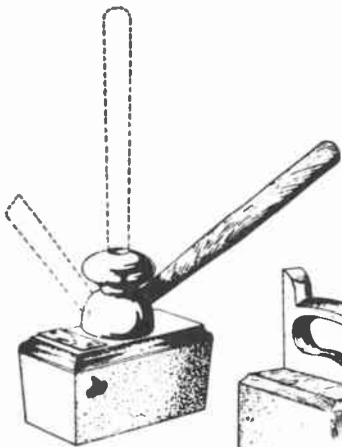
Files for undercutting mica in commutators.

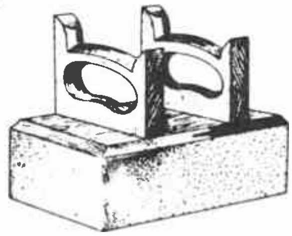


Hacksaw mica undercutter.

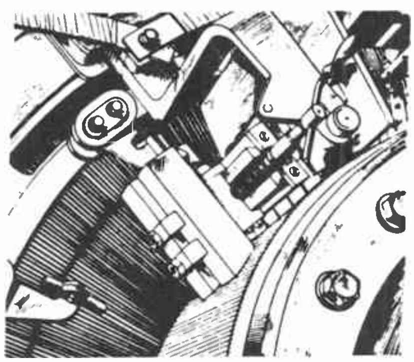


Hand stones for grinding commutators.

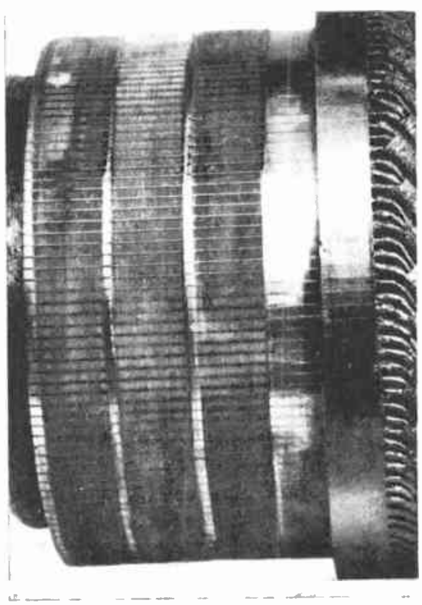




Commutator showing high mica and burning of the surface because of the attendant sparking; also, ridges between the brushes, caused by improper brush staggering.



Hand stones for grinding commutators and commutator stones mounted on a special rest on a brush-holder stud.



Sleeve Bearing Lubrication

Proper lubrication will make motors run better and last longer.

With antifriction bearings, such as ball or roller types, the lubricant is primarily concerned with rust prevention and cooling, but when sleeve bearings are used, the lubricant actually becomes a part of the motor, as it must sustain the load imposed by the rotating shaft. The bearing itself should nowhere contact the shaft. If it does, it is not being properly lubricated and wear will result.

A pure mineral oil is the only type of fluid lubricant that should ever be used for sleeve bearings. The ideal oil is one which will give most efficient motor performance and not require frequent renewal. These two characteristics will be obtained by choosing the oil carefully according to the ambient and operating temperatures required.

The viscosity of the oil to be used is determined by two things. First of all, the lowest ambient temperature at which the motor must operate is of prime importance. High temperatures will be taken care of by using only better grade oils, which are fluid at low temperatures and still hold their body at high temperatures. Heavier oils will give longer life at the higher temperatures, but the oil must not be so heavy that it will not provide proper lubrication when the motor is started.

A second consideration in choosing an oil of proper viscosity is the power of the motor. Internal friction of a heavy oil takes away some motor power, and this becomes important when the oil is used in small horsepower motors. For example, some Bodine motors are rated as low as 1/2000 horsepower. A heavy oil cannot be used in such a motor as it would tend to reduce efficiency.

SLEEVE BEARING MOTORS			
Bodine Motor Size	−40°C Ambient to 55°C total	0°C Ambient to 100°C total	−40°C Ambient to 100°C total
V-1 (up to ⅝′ shaft diameter)	Univis J-43 (Penola Inc.)	Univis P-48 (Penola Inc.)	Univis J-43 (Penola Inc.)
N-1 (up to ⅝′ shaft diameter)	Univis J-43 (Penola Inc.)	Stanoil #18 (Stand. Oil-Ind.)	Univis J-43 (Penola Inc.)
N-3 & N-5 (up to ⅝′ diameter)	Univis J-43 (Penola Inc.)	Stanoil #35 (Stand. Oil-Ind.)	Univis J-43 (Penola Inc.)

A mechanical consideration sometimes involved in choosing oil is bearing clearance. The difference between the shaft O. D. (outside diameter) and the bearing I. D. (inside diameter) is commonly between .00020 and .00100 inches, giving a clearance on each side of the rotating shaft of from .00010 to .00050 inches. When temperatures below 0°F are involved, these clearances must be made greater. This is due to the fact that the bronze bearings contract more than the steel shaft under chilling, and too small a clearance will result in literal "freezing" of the shaft.

For motors used in low temperatures, the difference between the shaft O. D. and bearing I. D. may run from .0010 to .0025 inches. This thicker oil film is more easily sheared, and special care must be taken to select an oil which is fluid at the lowest temperature encountered.

The table at the bottom of the first column lists lubricants which are suitable for sleeve bearings. These oils are satisfactory over the temperature ranges indicated at the top of each column in the table.

Some speed reducer motors are designed so that the grease in the gear housing also lubricates the motor bearing. A grease chosen for this purpose must have a definite tendency to "bleed oil" slightly at room temperature, and still not melt completely at high temperature. A list of greases which satisfy this requirement is given below. The first temperature given is the ambient temperature; the second temperature is the highest motor temperature at which the grease is still suitable.

Temperature Range	Grease	Manufacturer
−20°F to +240°F	Beacon Lubricant M-285	Penola Inc.
0°F to +200°F	Alemite #33*	Alemite Corp.
−10°F to +250°F	#100 Absorbed Oil	E. F. Houghton & Co.
−5°F to +250°F	H.M.P. #3*	D. A. Stuart

* Also suitable for moist atmospheres.

The greases listed in the above table are suitable for most applications, but in some cases it is necessary to use "custom built" lubricants. Many weak motors, such as K-type, (1/2000 hp) require a special lubricant, as do speed reducer motors used in aircraft.

Ball Bearing Lubrication

End shield from Bodine ball-bearing motor showing grease-packed bearing.

Motors which are in special service or operating under special atmospheric conditions must have specially selected lubricants in order to allow the motor to operate at highest efficiency.

Like most products of industry, lubricants have been vastly improved in the past few years. The increased use of ball bearings in small motors has lent impetus to research into providing suitable greases which are stable and noncorrosive, and which may be used over wide temperature ranges or for special operating conditions.

For applications where shaft speeds are less than 5000 rpm, where the ambient operating temperatures are from 40F to 90F, and where the motor temperature rise is less than 70F, the usual lubricants serve very well indeed. The surrounding air must also be free from corrosive gases and dust and must be reasonably humid but not unusually moist.. Two lubricants in common use under these normal operating conditions are STARFAK M (Texas Company) and SUPERLA No. 2X (Standard of Indiana). These lubricants are satisfactory for a temperature range of +30F to +200F.

When operating temperatures and conditions vary from normal, the use of the correct modern lubricants becomes of the utmost importance. For example, temperatures met by motors in aircraft service may vary over a wide range. In northern winter or high altitudes −40F may be encountered. Planes serving in the Canal Zone may encounter temperatures as high as 120F. In addition, confined air space and heat from adjacent equipment might raise the operating temperatures beyond 200F. Sudden variations are also involved, as the plane which descends from the cold air of high altitude to a field in the tropics undergoes a great temperature charge in a short time and makes possible moisture condensation on metal parts.

Another difficulty that must be considered is the fact that such motors may be only occasionally operated. Long periods of inactivity demand a grease of great stability. It must also be a low-torque grease because of the small horsepower of the motor in which it is used. Therefore, a number of requirements must be met in specifying a grease of this type, as indicated in the list below:

1 — Low pour point (oil in grease must pour at low temperatures)

2 — High melting point (grease must hold its body at high temperatures)

3 — Oxidation resistance

4 — Stable in the presence of moisture

5 — Must adhere well to the entire steel surface of the bearing

6 — Must enable the bearing to turn freely — not a "sticky grease"

One of the few greases which approximate these special requirements is the lubricant Andok "C" (Standard of New Jersey).

Under certain conditions (such as in motors with low starting torque) it is desirable to use external lubricants which will gradually seep into the bearing. Thus solidifying of the grease will not prevent the shaft from turning. In such cases a grease that has a tendency to bleed is used.

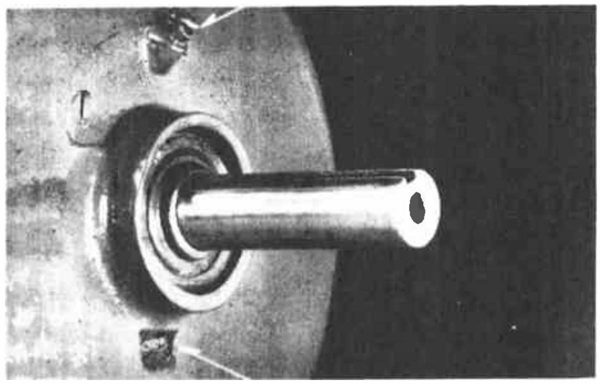
There are several greases which might be satisfactory for general service, but which have some one limiting characteristic which makes them more specialized in application. Some makes of grease may be used only where steel retainers are used, as they will corrode when used with brass. Others cannot be used in sealed ball bearings. Grease for motors used in submarines or under other high moisture conditions must be very water repellent. Under such conditions it is often desirable to use an external felt oil reservoir where the design of the motor and available space allow this construction.

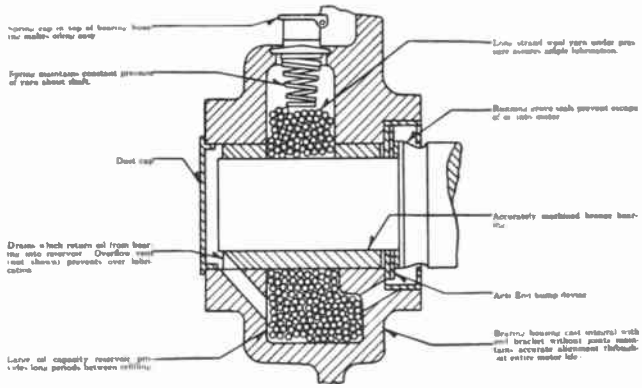
The following table lists some greases which have been found satisfactory for use in ball bearings within the given temperature ranges. These lubricants are satisfactory for most, but not all, fractional horsepower motors.

Temperature Range	*Grease*	*Manufacturer*
−30F to +250F	Andok "C"	Standard Oil, N.J.
−20F to +200F	Starfak M	Texas Company
+30F to +250F	Superla No. 2X	Standard Oil, Ind.
+10F to +250F	Gargoyle BRB No.3	Socony Vacuum
+40F to +300F	Massed No. 177	Borne & Scrymser

LUBRICATION — SLEEVE BEARINGS

Wool Packed Type of Sleeve Bearing





If the motor is equipped with sleeve bearings, always use a small oil can, which has a spout small enough to go down into the oiling cup or filler. Never use a can and pour the oil into the motor. This procedure may result in oil getting inside the motor. This oil will collect dirt and finally trouble will result. All motors have an oiling system which is easily accessible and on the outside. Never attempt to oil around the shaft on the inside of the motor as this is not necessary. Never get even one drop of oil on the commutator or brushes. Under normal conditions a sleeve bearing motor should hold enough oil to last from 3 to 6 months.

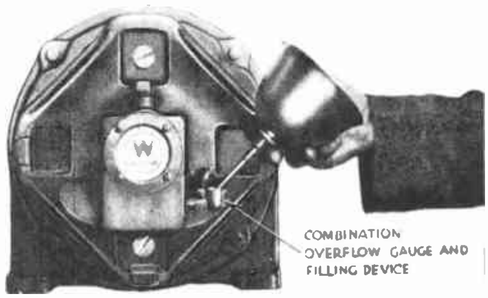
Over-oiling of the bearings should be avoided. It is a good plan to inspect the wool packed type every 4 months and add oil. Add only a small amount and wait for it to run down into the wool packing before adding any more. When oil begins to flow out of the overflow hole on the bottom, the bearing is full. Wipe off the excessive oil from around the overflow hole with a clean, dry rag or piece of waste.

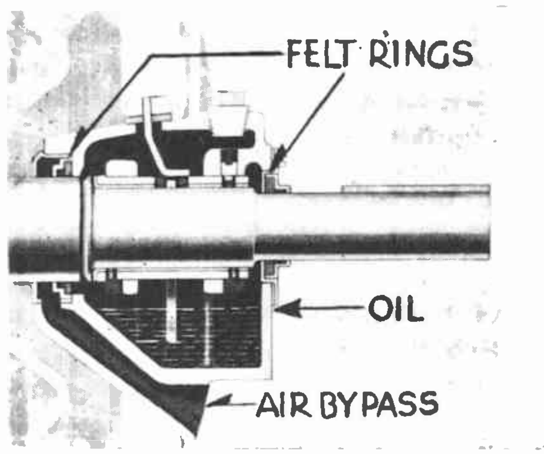
Under normal temperature conditions, such as the central part of the U.S.A., a good grade of engine oil having a viscosity of SAE 10 should be used in waste or wool packed bearings. When oiling the bearing on the commutator end, do not get even one drop of oil on the commutator or brushes.

Oil Ring Type of Sleeve Bearing

The oil ring type of motor sleeve bearing should be inspected every 2 or 3 months, and no oil need be added until the oil level is ⅛" or more below the top of the gage or filling device. Wipe any oil from motor surface with a clean, dry rag or piece of waste.

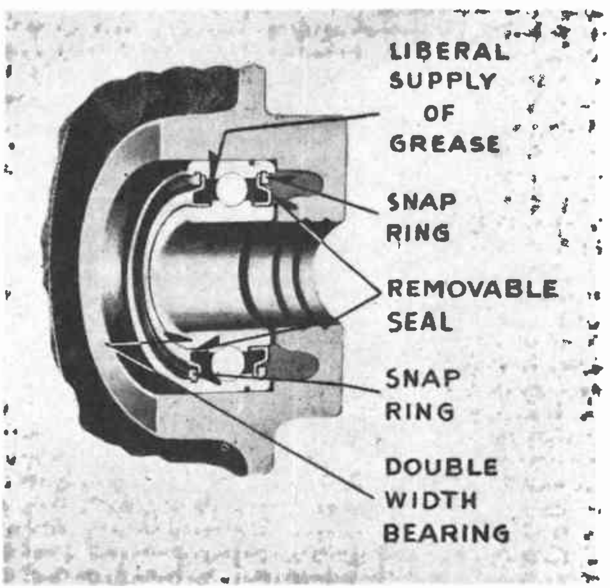
Use a good grade of engine oil having a viscosity of SAE 20. Make sure that no oil gets on the commutator or brushes.





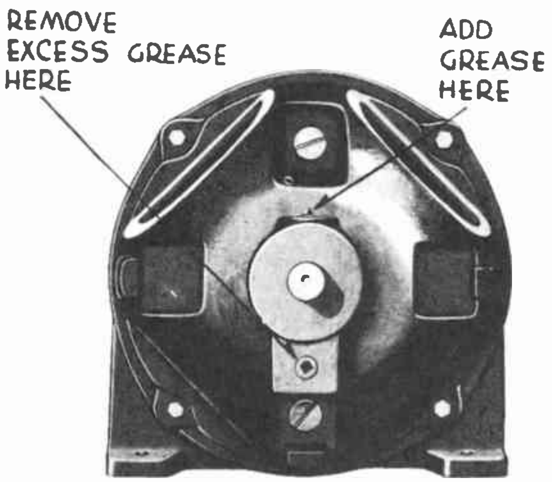
LUBRICATION — BALL BEARINGS

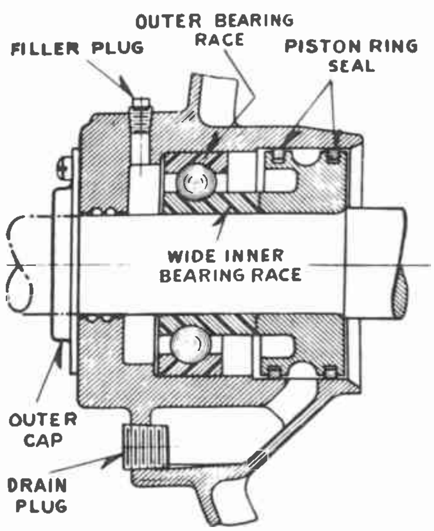
Sealed Cartridge Type



If no greasing plugs or fittings are on the outside of the end bell, the bearing is the sealed cartridge type. This type has the retaining grease seal built into the bearing itself. The grease provided in this bearing will be sufficient for at least three years. No grease need be added within this time. It is recommended at the end of three years the end bells of the motor be removed exposing the bearings on the shaft. Remove the snap ring and removable seal from the outer end of the bearing and examine the grease. If the grease is discolored and has a bad odor, the bearings should be cleaned with carbon tetrachloride or an equivalent solution. Repack with a good grade of grease especially made for ball bearing electric motors. Do not pack tight. Only about one half of the grease space should be used. Tightly packed bearings will overheat. If the grease on examination shows no discoloration and has no offensive odor, the shield may be replaced and the bearing put into service for several years more, after which it should be again examined.

Standard or Greaseable Type





If the end bells have a grease plug or fitting, the bearing is the standard or greasable type. This type should have sufficient grease to last at least one year. After this period, grease should be added in the top plug or fitting. Do not use a high pressure grease gun. Only a small amount of good grades of grease especially made for ball bearing electric motors should be used. Some motors are equipped with an overflow sump in the end bell and a removable plug in this sump. When too much grease has been added to the bearing, the excess will run into the sump. When the sump is full, it will be carried out the plug hole. Therefore, on this type of motor, the bottom or overflow sump plug should always be removed while greasing the bearings. When this sump is overflowing, it is a good practice to remove the end bell and wash out the bearing and sump. Repack the bearing by filling only about one half of the grease space around the balls of the bearing and then reassemble the end bells.

Some motors are equipped with a cast iron housing or cartridge which will be around the bearing when the end bell is removed. In this case, it will be necessary to remove the cap from the cartridge so the bearing is accessible for cleaning and repacking. The same procedure as for the greasable bearings should be followed.

All ball bearing motors should have only a small amount of grease added at each greasing. If the end bell has no grease sump, greater care must be taken or else the grease may be forced inside the motor. In any case, when the end bell on the commutator end is removed, it should be marked and same precautions as under cleaning should be followed when replacing it.

GENERAL ELECTRIC

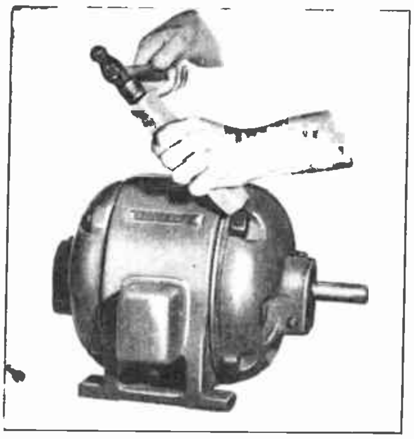
Motors and Generators

DISASSEMBLING AND ASSEMBLING

Check air gap for bearing information before taking down the motor or generator. It will be useful after bearings and journals have been reassembled. Bearings that contain oil should be drained at the start to avoid spillage and waste. It is preferable to move a motor to the shop for overhauling, where the parts can be kept clean and in good order. Coupling-halves, pulleys, pinions, and fans should be removed by a puller. Serviceable pullers can be made largely from existing parts in the shop. Severe hammering or wedging is likely to injure other parts, as well as those being removed.

Clean each part immediately; put them all in a clean place under paper or cloth cover.

If it is necessary to remove a ball bearing, use a puller, maintaining a uniform pull all around so as not to distort the bore of the race, and to avoid shaving the shaft.



End shields (bells or bearing housings) usually are provided with ledges or wedging recesses, so that reasonable tapping or wedging will separate the rabbet fit without upsetting or bruising the keen edges.

Rotors or armatures may be lifted slightly by rope slings when moving out of stator. Dragging over punchings should be avoided.

Smaller parts that are disconnected, such as field connections, yokes, brush holders, collector rings and the like, should be cleaned, tagged, and put aside in order, where they will not get mixed up with similar parts from other units. Field coils, armatures, and wound rotors should be carefully handled and placed in a suitable support to avoid bruising or cracking the exposed insulation. Rehandle as little as possible.

When the motor is being reassembled, parts should not be forced together; it is better to find the trouble and bring things into position without marring or distortion. Start with parts clean, and keep them so during assembly operations.

Check air gap again, and compare with previous check. Line up motor carefully when it is put back into service. If a coupling is used, check to make sure the faces are parallel, and that the shafts are in line before setting up the coupling. A flexible coupling calls for equally good alignment.

Make sure that fans have been replaced, and that lubrication has been provided.

Restore all enclosing features and replace broken or missing fastenings. Explosion-proof motors call for great caution in maintaining exact fit at all joints.

Reconnect ground wire. Check connections with diagram, especially on two-voltage motors. Turn motor by hand, or if connected to a machine, use a lever if possible. Note any binding, noises, or uneven torque and make corrections if needed. Apply voltage, and operate motor unloaded for a little while, noting ventilation, lubrication, speed, and noises.

Remove all dirt and rubbish around the machine.

Make a special inspection within a few days after putting motor into service; regular inspection time may be far off.

Motors and Generators

GENERAL ELECTRIC

CLEANING WINDINGS

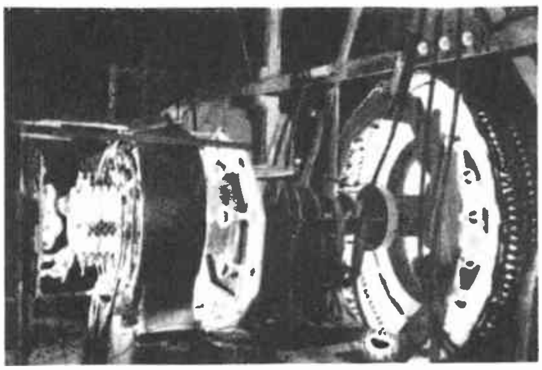
Many motors are located where dust accumulates on windings and in ventilating ducts. Oily vapor and paper or textile dusts build up, and block off, ventilation, leading to overheating of windings. Conducting dusts shorten creepage distances and penetrate windings, causing short circuits and grounds. Hard, sharp dusts abraid insulation, and shorten its useful life as they are driven past vulnerable surfaces by ventilation air. Cast-iron dust is a vicious enemy of insulation, because it is magnetic and is agitated by stray fields. Light, comparatively harmless dusts can be blown out with low-pressure, dry air. Grit, iron dust, carbon, and copper dusts should be removed by suction. Hose tips for either pressure or suction should not be of metal.

Grease and oil can be removed by the conservative use of a solvent like carbon-tetrachloride, which evaporates quickly. After cleaning, dirt can be blown out. If dirt is excessive, this process must be repeated several times. Excessive applications of solvent will soak into inaccessible places, where it may soften and harm insulation. Vapor of the solvent mentioned does not present a fire or explosion hazard, but has toxic effects, therefore, making good ventilation essential wherever this solvent is used.

If motor windings require very frequent cleaning, consider substituting an enclosed motor, or take steps to keep dirt away from the motor.

DRYING WINDINGS

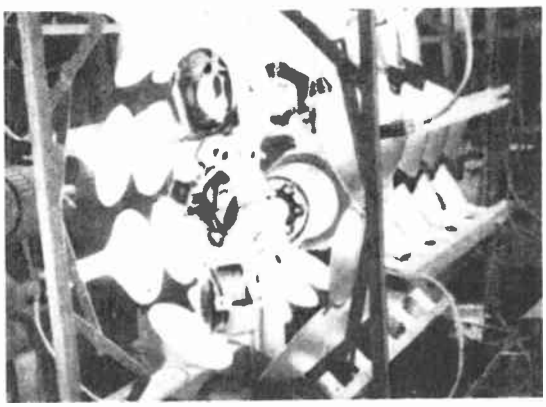
Motors in continuous operation will stay at a temperature sufficiently above room air to prevent condensation of moisture on and about the windings, even if the location is very steamy. Cold motors, however, accumulate moisture readily, which causes gradual deterioration of insulation. Where motors have to be idle for a long time, lamps or small space heaters should be installed, to keep the windings a few degrees higher than the surrounding temperature.



After a flood, G-E R-40 infrared-ray lamps were used to dry out the generator and exciter without moving any of the equipment.

Dampness will be indicated by low insulation resistance. Deep penetration of dampness calls for special treatment. External heat can be applied under a canvas cover, well vented. Heating should not go beyond 90 C, as water must not be boiled in the insulation. If this is not successful, consult the nearest G-E service shop. Current can be circulated through the windings by applying a low voltage to the windings. Current should be only a fraction of full-load current, and the temperature limitation of 90 C, should be observed. Resistance tests should be taken at intervals to note the trend. The motor can be put into load service somewhat below the recommended reading in megohms, because load heating will continue the drying-out process.

If the motor has been submerged for a long time, it must be carefully checked to see if rewinding is necessary. In the case of d-c machines, water between the commutator bars and the shell may be the source of low ground resistance instead of the windings. Rewinding is almost certain to be required sooner or later, if the motor has been "drowned" in salt water. After cleaning, some salt may remain, and if so, it will combine with moisture from the air. Totally enclosed motors, if idle in a damp place, should be examined periodically, as the insulation may gradually absorb moisture from the entrapped air. Presence of water in enclosed motors almost invariably indicates leakage at shield joints, handhole covers, lead entrances, etc. Such leakage may be avoided by use of sealing greases or compounds.



Infrared-ray lamps can also be used for drying small motors.

PEERLESS ELECTRIC COMPANY
CARE AND OPERATION OF MOTOR OR GENERATOR

To Disassemble Motor or Generator

Disconnect and move motor or generator that is to be serviced to a convenient bench. In disassembling motor or generator, it is best to start at the commutator end, remove the following parts in sequence named, the four small screws holding the end cap, the bearing lock nut, the four hood bolt screws, open cover on commutator hood, loosen rocker arm set screw, rotate rocker arm, raise all brushes off the commutator and lock brushes in raised position with brush springs. Remove these two rocker arm set screws, slide complete rocker arm toward inside of motor so as to clear hood; do not remove leads, See Drawing B-4681. Fasten Puller Cap to hood with hood cap screws. Then with Pulley Puller in position as shown on this drawing, remove Commutator Hood. To remove bearings from this hood, get a round piece of wood that will go in shaft hole on inside of hood. With hood held bearing down, push wood against bearing. It will drop out. Have a clean piece of paper for bearing to fall on and immediately wrap bearing in this clean paper to keep any more dirt from getting on bearing.

(Caution) DO NOT TRY TO REMOVE ARMATURE UNTIL PULLEY HOOD IS OFF, AS FAN WILL INJURE WINDINGS.

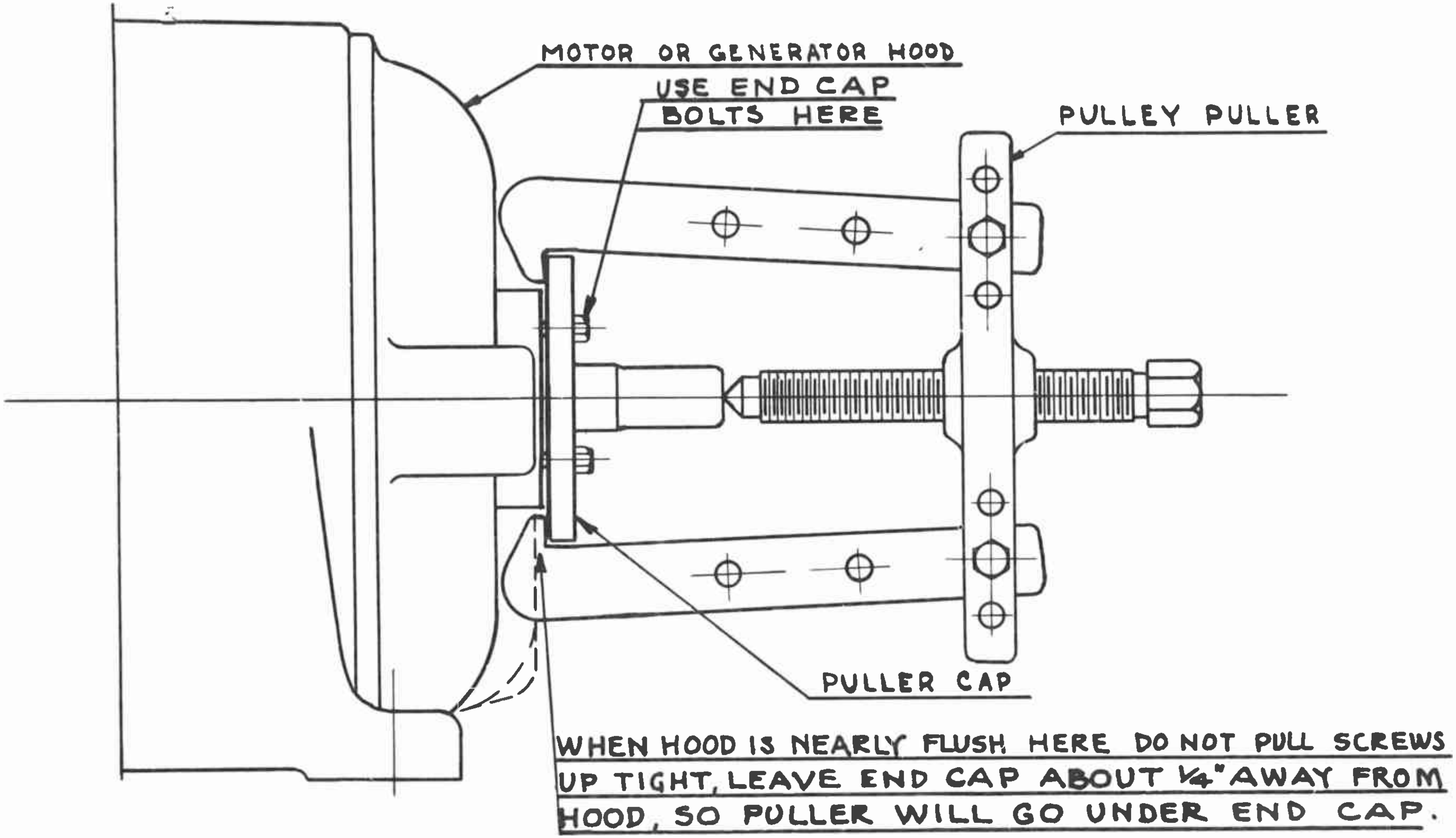
Remove pulley hood and bearing in same manner as the commutator hood. Then armature can be removed out pulley or fan end. Wash bearings in cleaner to remove old grease and dirt, blow out with an air hose. While bearings are out, check to see if they run free and are fairly quiet. If not, replace with new bearings.

Clean brushes, brushholders, and brushholder insulation of all grease and dirt. Use a clean cloth dipped in cleaner, wipe dirt and grease off both ends of coils on armature and field; in other words, remove all dirt and grease from your motor or generator.

If a single phase, Repulsion-Induction motor is being serviced, while armature is out, remove split ring, governor weight guide, governor weights, short-circuit weight assembly, and spring. Clean these parts and wipe under side of commutator. If there are any signs of pitting better put armature in a lathe and true up, finish with No. 00 sandpaper, wipe clean before reassembling.

To Reassemble Motor or Generator

Place armature in field from pulley end commutator first, then assemble parts as follows: rocker arm on commutator hood, commutator hood on shell, fasten hood with the four hood bolt screws, assemble ball bearing, and lock washer and nut. Then return to pulley end, assemble pulley hood, fasten with hood bolt screws, assemble ball bearing, lock washer and nut. In assembling these ball bearings on shaft, use a piece of steel tubing that will fit over the shaft, and not larger on outside diameter than the inner race of the ball bearing, a piece of pipe will be good if the ends are square, so that all the driving force will be on the inner race of the bearing. You are now ready to grease bearings. (See Sheet on Bearings, Care and Lubrication)



METHOD OF REMOVING HOODS

R.B.

B-4681

ALTERNATING-CURRENT MOTOR TROUBLES

A.C. MOTOR FAILING TO START

1-CAUSES OUTSIDE OF THE MOTOR: Since Peerless motors are fully tested and inspected before shipment, any trouble which appears to lie within the motor, may, in the majority of cases, be due to causes outside of the motor. Therefore, in case of trouble, the driven apparatus should be carefully inspected for overloads, binding, lack of oil, etc.

2-NO VOLTAGE: Check the voltage in all phases at the motor terminals with test lamp or voltmeter. Check for blown fuses or open overload device in the starter. Be sure to check all phases separately to detect single phasing.

3-LOW VOLTAGE: Measure the voltage at the motor terminals with the switch closed. Voltage should read within 10 per cent of the voltage stamped on the motor nameplate. Overloaded transformers or circuits can be found by comparing the voltage at the motor terminals with the voltage at the power source with the switch closed.

4-GROUNDED FIELD: If the motor gets very hot, produces shock when touched, or if the idle watts are excessive, test for field ground with test lamp across field leads and frame. If grounded, remove the motor to shop for repairs.

5-OPEN CIRCUITED FIELD: Apply current to each winding separately with a test lamp. Do not leave the windings connected too long while the rotor is stationary. If any winding is open remove the motor to a shop for repairs.

6-SHORT CIRCUITED FIELD: If the motor draws excessive watts and at the same time lacks torque, gets hot or hums, a shorted field is indicated. Remove to shop for repairs.

7-EXCESSIVE LOAD: May be approximately determined by checking the ampere input with the nameplate marking. Excessive load may prevent the motor from starting or accelerating to full speed. (See Paragraph 4 and 8 sheet #d)

8-TIGHT SLEEVE BEARINGS: Test by turning the armature by hand. If adding oil does not help, check the bearing alignment. If the bearing has been hot and is still tight, it may be necessary to disassemble the motor, polish the shaft and bearing and clean out the oil groove in the bearing.

9-BELT TOO TIGHT: (See Paragraph 11, Sheet D)

10-IF MOTOR HAS BURNED OUT: Have motor rewound. Before reinstalling, ascertain the cause of the burnout.

NOISY OPERATION

11-WORN BEARINGS: A heavy rumbling, especially noticeable at starting, may be due to worn bearings permitting the rotating element to rub on the field. Replace the bearings. Ascertain the cause of the wear. (See Paragraph 11, sheet d)

12-INSUFFICIENT LUBRICATION: See that the bearings always have sufficient lubrication. Wool yarn bearings, when once properly oiled, rarely require additional oil. Ball bearings, the housing should be about one half full of ball bearing grease and such grease should be added when necessary to bring the level up to this point before the motor is started.

ALTERNATING CURRENT MOTOR TROUBLES - Continued

HOT OR RAPID WEARING BEARINGS

13-CHECK OIL: The oil may be too light, or too heavy, or in insufficient quantity. (See the tag furnished with the motor.) On wool yarn bearing motors be sure the yarn touches the shaft. If bearings have become clogged with dirt, clean thoroughly and add new oil or grease. Worn bearings should be replaced.

14-DIRTY BEARINGS: Dirty bearings may cause heating. If yarn packed, remove and wash the yarn in kerosene. If ball bearing remove old grease entirely, replace with fresh grease. Use extreme care not to allow dirt or grit to enter bearing housings.

15-TIGHT BELT: The belt may be too tight. (See Paragraph 11, Sheet d)

16-PULLEY RUBBING: The pulley may be rubbing against the bearing housing or the shaft may be sprung. Look for excessive thrust.

17-ALIGNMENT OF MOTOR ASSEMBLY: The bearing could be too tight. Make sure the end brackets fit snugly against the frame and that there is no dirt in the joint between them. Make sure that the rotor is properly centered in the stator. Check air gap.

18-ALIGNMENT OF DRIVE: Check the alignment of driven machine. Be sure the belts or coupling do not put heavy thrust or strain on the bearings.

IF OPERATION OF MOTOR IS UNSATISFACTORY

19-IF MOTOR RUNS HOT: Do not judge temperature by hand. A thermometer is necessary. Motor insulation will successfully withstand a maximum observable temperature of 95°C (200°F)

Check for grounded field. (Paragraph 4, Sheet # f)
Check for short circuited field. (Paragraph 6, Sheet # f)
Check for tight bearing. (Paragraph 8, Sheet # f)
Check for wrong line current. (Paragraph 3, Sheet d and Paragraph 3, Sheet f)
Check for excessive load. (Paragraph 7, Sheet # f)
Check for loose parts on the motor, loose hold-down bolts, loose pulley, bad alignment, bad belts, sprung shafts.
Check for unbalanced rotor or burrs on the shaft shoulders.
Check for uneven air gap.
Check for low voltage. (Paragraph 3, Sheet # f)
Check for single phasing. (Paragraph 2, Sheet # d and Paragraph 2, Sheet # f)
Check for broken or burned rotor bars.

20-IF MOTOR DOES NOT COME UP TO SPEED: Make the same checks as in Paragraph 19, Sheet # g. In addition to above, make sure the air gap is free of any foreign residue such as dust, dirt or paint spray. If air gap fills up, this will over load motor and cause undue heating.
If motor is operating in dirty surroundings, the motor ventilating fan will suck in dirt which fills up the air gap. So keep air gap clean.

(Peerless Electric Company)

CARE AND OPERATION OF DC MOTOR OR GENERATOR

Motor or Generator Overheating

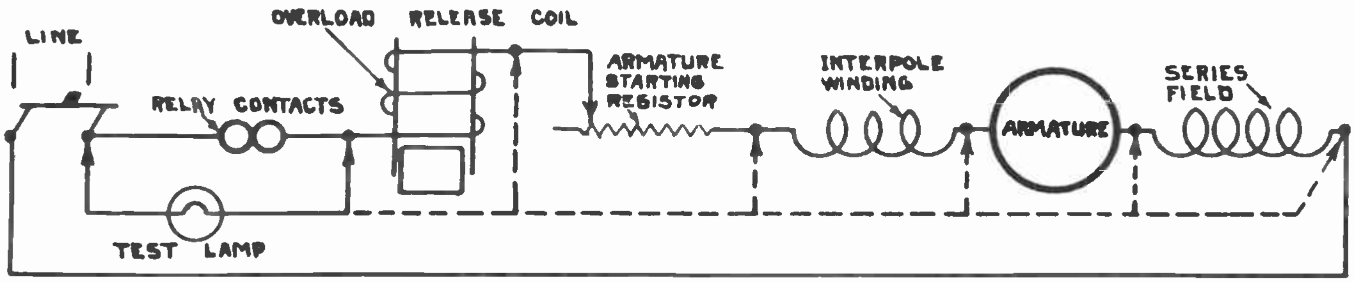
1. Entire Motor or Generator
   a. Insufficient ventilation due to blocking of ventilating holes, this would result in a uniform overheating of the generator.
   b. The motor or generator should be thoroughly cleaned internally by blowing out foreign matter with clean, dry, compressed air. This should be done with the armature turning slowly and with it stationary. With the armature stationary insert the hose in the fan openings and thoroughly blow out the rear armature windings and field coils. Extreme care must be taken to be sure the insulation is not damaged during this operation. Clean the commutator end of the fields by blowing air directly on them.
   c. Overloading the motor or generator will result in excessive heat in the armature and field coils. In extreme cases an odor of hot insulating varnish may be noticed.
   d. See if fan is tight on shaft.
2. Armature Overheating
   a. Excessive overloads would probably produce a noticeable odor of overheated varnish or charred insulation in the exhaust air from motor or generator. The commutator would eventually become blackened and pitted, and the brushes burned. In extreme cases there is a possibility of melting the solder out of the commutator bars. The overheating would be general and uniform. The remedy is to remove the overload.
   b. An open circuited armature coil would cause flashing at the commutator. Two adjacent bars will show severe burning, and overheated armature will result. The remedy is to repair or replace armature.
   c. Short-circuited coils or commutator bar would cause local heating which would destroy the insulation locally and would probably result in the burning of the armature coils, banding wire, or commutator bars. Solder may be thrown out of the commutator bars. The remedy is to replace the armature.
   d. Grounds in the armature circuit may be detected by using a 110 volt or 220 volt circuit with a lamp of corresponding voltage in series with test points, and with the brushes lifted off the commutator. Place one terminal against the commutator and the other terminal against the motor frame. The lighting of the lamp indicates the presence of one or more grounds in the armature.
3. Field Coil Overheating
   a. The most common cause of overheated field coils is a short in one of the shunt coils. Any turns of wire that might become shorted will increase the field current and cause excessive heating.
   b. To check for a shorted coil, apply line voltage to shunt coils only. A voltmeter should read one half of line voltage across either coil. If shorted, the defective coil will show less than one half of line voltage. New coil should be installed.
   c. A grounded coil may cause overheating. This defect may be indicated with test points as described under ground test for armatures. With brushes lifted, place one test point on either motor lead, the other on the motor frame. If Lamp lights, a ground is indicated. Field coil must be re-insulated or replaced.
   d. An open field coil will prevent a generator from "building up" voltage, while on a motor it will cause the armature to rotate at a very high speed and cause flashing at the commutator. To locate open coil, apply line voltage to shunt coils (brushes lifted). A voltmeter will indicate no reading across the good coil, but will show approximate line voltage across the open coil. A new coil must be substituted for the open one.

(Peerless Electric Company)

MAINTENANCE & TROUBLE SHOOTING

A MACHINE MAY FAIL TO START OR IMPROPERLY OPERATE DUE TO-

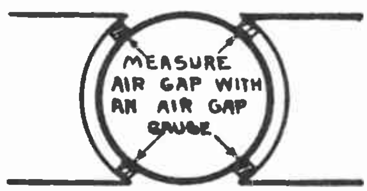
1. Opens, loose connections or high resistance contacts in the motor, line or starter. Use a test lamp or a voltmeter and make a continuity test as shown by sketch.



2. Worn bearings, on small machines and bearings can be tested by moving the shaft. If bearings are worn there will be a noticeable clearance between the bearing and shaft. For a more accurate test measure the air gap with an air gap or thickness gauge. For best condition the surface of all field poles should be the same distance from the armature core. Use the same position on the armature for all tests.

BEARINGS NOT WORN

UPPER	LEFT	MEASUREMENT	.026"
UPPER	RIGHT	"	.026"
LOWER	"	"	.026"
LOWER	LEFT	"	.026"

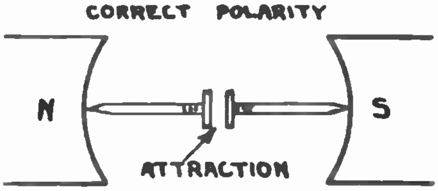


WORN BEARINGS

UPPER	LEFT	MEASUREMENT	.044"
UPPER	RIGHT	"	.044"
LOWER	"	"	.008"
LOWER	LEFT	"	.008"

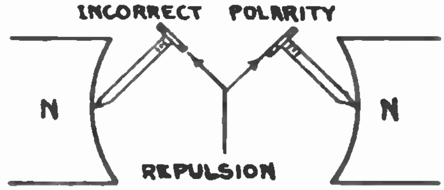
3. Incorrect field pole polarity. Field pole polarity will not reverse itself. This trouble occurs when field connections are being made between coils. Adjacent poles should produce opposite polarity otherwise maximum field strength will not be produced. A weakened field will cause a motor to run at a speed higher than normal and decrease the amount of torque it will produce.

CORRECT POLARITY



A magentic compass or large nails can be used to determine if adjacent poles are opposite polarity.

INCORRECT POLARITY

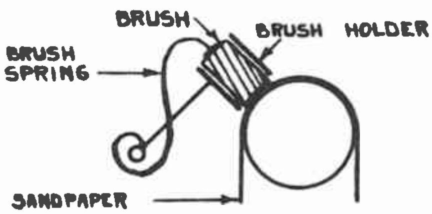


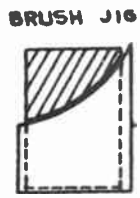
4. High or low line voltage. The armature of a shunt or compound motor will overheat if the line voltage is lower than normal if the motor is carrying its full load. High line voltage will cause the shunt field to overheat. Series motors will not be affected except the speed will vary with the voltage applied to the motor.

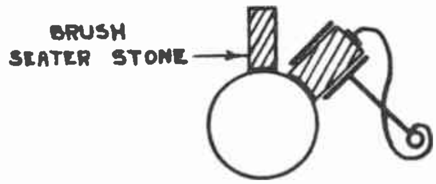
5. Operating temperatures. The temperature rating on the name plate is the amount of heat the machine will produce when operating with full load. The maximum operating temperature for any machine is the name plate temperature plus normal room temperature. Example - Name plate temperature 40 degrees centigrade - Normal room temperature is always considered to be 40 degrees centigrade. This machine will operate at a temperature of 40° plus 40° or 80° centigrade which is equal to 176 degrees fahrenheit. The following formulas are used to change fahrenheit to centigrade or vise versa. F equals (C times 1.8) plus 32 C equals (F minus 32) divided by 1.8.

MAINTENANCE & TROUBLE SHOOTING (continued)

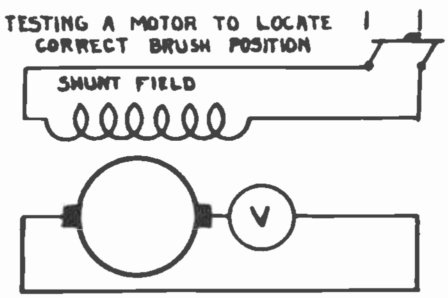
6. Brushes not properly fitted to the commutator. Use sandpaper, brush jig or brush seater stone to fit or seat brushes.

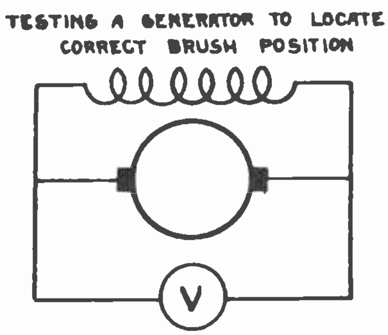


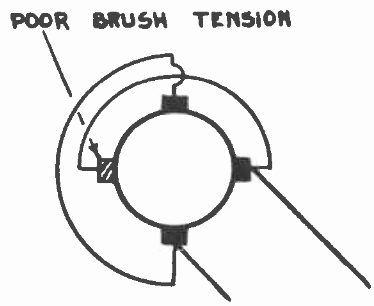




7. Brushes off neutral position. This condition will cause brush sparking and cause a motor to operate at a speed higher than name plate speed. The correct position can be located by using one of the following methods. 1. If the machine is operating with load shift the brushes to a position of sparkless commutation. 2. Connect a voltmeter across the brushes of a motor and the shunt field circuit. The brush position giving the lowest voltmeter reading will be the correct position. The motor must not rotate while the test is being made. For a generator the brush position giving the highest voltage will be the correct position. The generator should be operating without load when the test is made.







8. Poor or unequal brush tension. Apply equal tension of 1 to 3 lbs. per square inch of brush surface on the commutator. Measure brush tension by using a small spring scale.

9. High mica. Use hack saw blade or undercutting machine and undercut the mica about 1/16 inch.

10. Wet or oily windings. All damaged windings must be properly cleaned and repaired before drying. Use carbon tetra chloride or other agents for cleaning. Dry windings by baking at 180 F. until dry. Motors can be dried out by operating them with an ammeter and a regulating resistor connected in series with the machine windings. Adjust the regulating resistor so the current through the chine windings will not exceed name plate value. After machine has been dried out make an insulation test to determine the condition of the insulation.

11. Rough or dirty commutator. Smooth commutator with sandpaper or commutator stone. True commutator by turning it in a lathe or using tools made for that purpose. After trueing a commutator in a lathe use #000 or #0000 sandpaper to smooth commutator. Clean commutator with fine sandpaper or use a cleaning agent such as carbon tetra chloride. It is best not to use a cutting agent for cleaning. Never use emery cloth or a lubricant of any kind on a commutator.

12. Incorrect grade of carbon brush. Carbon brushes vary in capacity from 40 I to 125 I per square inch of brush surface in the commutator. When renewing brushes always be certain that the brush used has sufficient capacity to carry the load without overheating.

A.C. Motor ....Name ....Number ....

1. Clean any dust, dirt or oil from frame and metal parts ....
2. If ventilating ducts in winding are clogged, clean carefully ....
Do not damage insulation.
3. Check shaft, duct seal at both sides of bearing, Good.....Bad.....
4. Oil leaks at bearings, Leaky.....No Leaks.....
5. Oil Well Covers O.K......Defective.....Missing.....
6. Oil Well Drain O.K......Leaky.....Oil Good.....Poor.....
7. Oil level as shown by indicator Full.....low.....
8. With motor running does wither bearing heat Pulley end.....Opposite end.....
9. Bearing retaining screw (See bearing diagram) Tight.....Loose.....
10. Shaft end play Measure and state amount................
11. Oil Rings Turn freely.....Sticking.....
12. If pulley or gear Tight.....Loose..... Motor vibrates Yes.....No.....
13. Key way Good.....Worn.....Key Good.....Worn.....
14. With motor running note any unusual noise Quiet.....Noisy.....
15. Run motor single phase and note sound and behavior.
16. Connections and Lugs Loose.....Tight.....Unsoldered.....
17. Bare wires touching frame.....none.....one or more.....
18. Condition of stator winding.....(A) Condition of insulation Good.....Bad..... (B) Oily.....Dry..... (C) Caked Grease Yes.....No..... (D) Bare conductors Yes.....No..... (E) Poor taping Yes.....No..... (F) Loose connections Yes.....No..... (G) Clearance between rotor and stator or poles, (pulley end) check with air gap gauge and mark measurements Top.........Bottom.......... Right side.........Left side.........
19. If machine has wound rotor check for: (A) Condition of insulation Good...... Bad..... (B) Oily.....Dry..... (C) Caked grease and dirt on windings Yes..... No..... (D) Bare conductors Yes.....No.... (G) Solder thrown from connections Yes.....No..... (H) If machine has commutator, is brush setting correct Yes.... No..... (I) Brush pig tails Loose.....Tight..... (J) Brush gear, Mechanical condition of holders Good.....Bad..... (K) Brushes, Poor Contact Yes..... No..... (L) Brush sticks in holder Yes.....No..... (M) Brushes too loose in holders Yes.....No..... (N) Brushes too long Yes.....No..... Too short Yes.....No..... (O) Slip rings pitted or worn.....Out of Round.....Dirty..... Poor insulation..... (P) Brush Spring tension Even:....uneven.....too much.... O.K......Too little..... (Q) Slip rings to rotor connections O.K......Poor..... (R) If machine has commutator is it O.K......Dirty.....High Mica..... (S) Band wires tight.....Loose..... (T) Squirrel cage rotor bars Tight.....Loose or thrown solder.....

STARTING EQUIPMENT

20. (A) Loose connections Yes.....No..... (B) Contactors clean and well fitted.... Pitted.....Dirty.....Worn..... (C) Spring tension on contactors Equal..... Unequal.... (D) Do all contactors make contact at the same time Yes....No.... (E) Does magnet holding arm, line up squarely with magnet poles Yes.....No..... (F) What type of overload relay is used Thermo....Magnetic.... (G) Condition of trip contacts Good....Bad.... (H) If time relay is used is it mechanical.... or magnetic..... (I) If time relay is used is its condition Good.....Bad..... (J) Are interlocking contact switches in Good....or Bad....condition (K) Does starter use a mechanical interlock Yes....No....(L) Are any mechanical parts loose Yes....No.... (M) Are starting or holding magnets Noisy....Excessive Magnetic hum,...Quiet.... (N) are shading coils used on magnets Yes....No.... (O) Make a note of anything unusual in starter operation.

INSTALLATION AND OPERATION OF A.C. OR D.C. MOTORS

SOME THINGS TO DO BEFORE STARTING YOUR MOTOR

1-UNPACKING: When unpacking the motor look for signs of damage in transportation and report any damage at once. Save the connection diagrams and instruction tags shipped with the motor.

2-CHECK LINE VOLTAGE: Make certain that the line voltage, phase or frequency agree with the nameplate marking of the motor. If the motor is dual voltage A.C. motor, see that the leads are connected for the voltage on which it is to operate.

3-OVERLOAD PROTECTION: See that the proper size fuses or overload protective devices are installed in the line. (See the latest edition of National Electric Code.)

4-MOTOR AND LOAD SHOULD TURN FREE: With the belt removed, or on a direct connected unit, with the minimum load, see that the rotor turns freely and that the driven machine can be turned easily by hand.

5-SLEEVE BEARING LUBRICATION: Make sure that the bearings are lubricated in accordance with the instruction card attached to the motor. If wool packing is used, see that sufficient oil is supplied to thoroughly saturate the yarn before the motor is put in operation. (This will require about one minute.).

6-BALL BEARING LUBRICATION: Ball bearing motors are shipped packed with sufficient grease in the bearings to last for a limited period. Normally about one year.

7-SECURE FOUNDATION: See that the motor is securely fastened to its base or foundation.

8-CHECK MOTOR AND CONTROL DIAGRAMS: See that all connections have been made in accordance with the instruction card or connection diagram furnished with the motor--also the diagram furnished with switch or starter.Do not throw these instruction cards or diagrams away--they may be useful at some future date.

9-GROUNDING THE FRAME:Except on portable units, the motor frame should be grounded. A wire of the same size as the largest lead of the motor should be used,and this wire connected permanently under one of the screws that holds the terminal box to the motor.

10-CHECK ROTATION: Run the motor for a short time without load to check starting and the direction of rotation. If the rotation must be changed, consult the card or the wiring diagram furnished with the motor. If standard three phase motor, interchange any two leads.

11-PROPER BELT TENSION: The belt should be only tight enough to prevent slipping. Check the alignment of the driving and the driven shaft, couplings or pulleys. Too great a belt tension or misalignment may prevent the motor from starting with load or cause rapid bearing wear. If the pulley ratio is such as to require excessive belt tension, the ratio must be changed. If possible, the lower side of the belt should be the tension side.

12-EXPOSED TO DIRT, GRIT, OR MOISTURE: If the motor has been exposed to dirt,grit, or moisture, as in damp locations, new or unoccupied buildings, clean and dry thoroughly. If the windings have been exposed to moisture, remove motor to the shop for drying. Never start a motor which has been wet without having it thoroughly dried, either by baking in an oven at not more than 95°C. (200°F), or by passing a low voltage current through the windings until it is dry.

PERIODIC INSPECTION OF ELECTRIC MOTORS

A systematic and periodic inspection of motors is necessary to insure best operation. Of course, some machines are installed where conditions are ideal, where dust, dirt, and moisture are not present to an appreciable degree; but most motors are located where some sort of dirt accumulates in the windings, lowering the insulation resistance and cutting down creepage distances. Some dusts are highly abrasive and actually cut the insulation in being carried through by the ventilating air. Fine cast-iron dust quickly penetrates most insulating materials. Hence the desirability of cleaning the motors periodically. If conditions are extremely severe,open motors might require a certain amount of cleaning each day. For less severe conditions, weekly inspection and partial cleaning are desirable. Most machines require a complete overhauling and thorough cleaning about once a year. For the weekly cleaning the motors should be blown out., see following paragraph.

CLEANING ELECTRIC MOTORS

About once a year, motors should be taken apart and cleaned as follows:

First, the heavy dirt and grease should be removed with a heavy, stiff brush, wooden or fiber scrapers, and clothe. Dry dust and dirt may be blown off, using dry compressed air at moderate pressure, for example, 25-to 30-lb pressure at the point of application, taking care to blow the dirt out from the winding. If the dirt and dust are metallic, conducting, or abrasive, air pressure may drive the material into the insulation and damage it. Hence, for such conditions, pressure is not so satisfactory as a suction system. If compressed air at low pressure is used, care must be taken to direct it properly so that the dust will not cause damage and will not be pocketed in the various corners.

Grease, oil, and sticky dirt are easily removed by applying cleaning liquids like carbon tetrachloride, gasoline, or naphtha. All of these liquids evaporate quickly and, if not applied too generously, will not soak or injure the insulation. Carbon tetrachloride is best and is recommended because it is non-inflammable.

In case one of the other liquids must be used, it should be applied in the open or in a well-ventilated room. It must be remembered that gasoline or naphtha vapor is heavier than air and will flow into pits, basements, etc., and may remain there for hours or even days.

Proper ventilation of the room is essential. In using carbon tetrachloride the explosion hazard is obviated, but some ventilation is required to remove the vapor.

There are several good methods of applying the cleaning liquid. A cloth, saturated in the liquid, may be used to wipe the coils. A paint brush, is handy to get into corners and crevices, and between small coils. Care should be taken not to soak the insulation as would be the case if coils were dipped into the liquid. While the insulation will dry quickly at ordinary room temperature after such cleansing methods, it is highly desirable to heat it to drive off all moisture before applying varnish.

The insulation should be dried out by heating to from 90° to 100°C. While the motor is warm, air drying insulating varnish should be applied. For severe acid, alkali, or moisture conditions, a black plastic baking varnish is best, while, for conditions where oil or dusts are present, a clear or yellow varnish should be used.

The varnish should be sprayed or brushed on. It is best to dip the windings into the varnish, cleaning off the adjacent metal parts afterwards by using a solvent of the varnish. After applying the varnish, the best results are obtained by baking for 6 to 7 hours at about 100°C. Experience with particular conditions of operation, or the condition of the insulation, may indicate the desirability of applying a second coat of the same varnish. followed again by 6 to 7 hours of baking at 100°C.

If the machine must be put back in service quickly, or if facilities are not available for baking, fairly good results will be obtained by applying one of the quick-drying black or clear varnishes which dry in a few hours at ordinary room temperatures.

(Peerless Electric Company)

Reversing Fractional Horsepower Motors -I

In order to eliminate complicated mechanical reversing mechanisms and provide more reliable, efficient drives, many devices are now built to be driven with reversible motors. Voltage regulators, grinding wheel dressers, variable ratio drives, field rheostats, door operators, scale devices, and telescope drives are some of the places where reversing fractional horsepower motors are found. Some applications require fast reversing, in others speed regulation is critical, while in still other applications a wide range of speed control may be required. Therefore, the type of motor chosen depends upon the reversing characteristics that will be needed.

Some fractional horsepower motors are nonreversible because they are built to start and run in a certain direction only. For example, most shaded pole motors are constructed to run in only one direction and would have to be completely rebuilt to change the direction of rotation. Other motors may be reversed, either at rest or while running, by changing the direction of flow of current through either the armature or field of brush-type motors, or by changing the direction of rotation of the magnetic field in induction-type motors.

Reversing motors are divided into two groups. One includes motors which can be reversed only while at rest. These motors cannot be reversed during rotation because the starting winding, which gives direction to the rotor, has been disconnected from the line by an internal centrifugal switch. The other group comprises those which can be reversed during rotation. This is done by changing the relative polarity between the windings, so that the motor goes from full speed in one direction to full speed in the other when a reversing switch is thrown.

Motors are often specially constructed so that they will have the best reversing characteristics available. However, such construction changes also alter the normal running characteristics of the motor. Motors which are reversible only while at rest do not have their running characteristics affected by their reversing characteristics. All motors reversible during rotation, however, have their running characteristics affected by their reversing characteristics.

For example, skewed-slot armatures improve the reversing torque of shunt-wound motors. The greater the angle of skew, the quicker the reversal, but the poorer the speed regulation. The use of a strong field and relatively large air gap are also helpful in reversing, but running efficiency is lowered. Series-wound motors made for one direction of rotation have armature windings connected to the commutator with a definite lead. For reversible operation to give equal power in each direction, the windings must be connected neutral (without lead in either direction of rotation). Efficiency and commutation are not as good with a neutral lead.

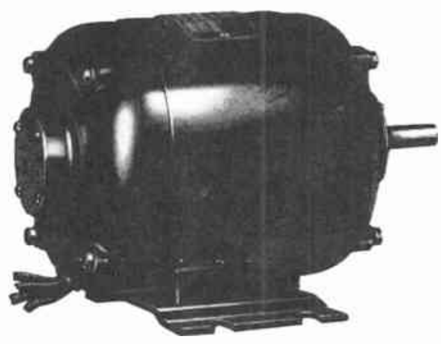
Inertia-type loads adversely affect the reversing operation of a motor which is reversed while in motion. If a motor has sufficient reversing torque to quickly reverse a high-inertia load to which it is connected, excessive strain may be placed upon the driven machine and upon the medium through which the torque is transmitted. Capacitor start and run motors which have insufficient torque to reverse a given load may continue to run in the original direction at a very low efficiency.

Features of Fractional Horsepower Reversing Motors

	Induction Type Reversing Motor								Brush Type Reversing Motor				
			Capacitor Start & Run								Compound Motor		
	Split Phase		Non-Synch.		Synch.		Multiphase		Shunt Motor			Series Motor	
Fractional Horsepower Motors From 1/2000 Hp to ¼ Hp	Non-Synch.	Synch.	4-Lead Rev.	3-Lead Rev.	4-Lead Rev.	3-Lead Rev.	Non-Synch.	Synch.	Full Field	Split-Field	5-Lead Reversible	4-Lead Rev.	3-Lead Rev.
Suitable for reversing at rest only	X	X											
Suitable for reversing during rotation or at rest			X	X	X	X	X	X	X	X	X	X	X
Double-pole double-throw switch required	X	X	X		X		X	X	X		X	X	
Single-pole double-throw switch sufficient				X		X				X			X
Running characteristics slightly affected by best obtainable instantaneous reversing characteristics			X	X	X		X	X	X		X	X	
Running characteristics greatly affected by best obtainable instantaneous reversing characteristics						X				X			X

Reversing Fractional Horsepower Motors-II

Motors designed for quick reversal and good reversing characteristics may be especially wound for this purpose. For example, a split field may be used, with the two sections of the field wound so that changing the line connection from one section of the field to the other will result in a reversal of torque. Likewise, in a shunt motor a strong field aids reversing and quick acceleration. This reduces running speed; therefore, these specially designed motors generally run at speeds not exceeding 2000 revolutions per minute.



Bodine polyphase motor is easily reversible

Of the reversible motors, split-phase motors with the conventional type of starting switch are reversible at rest only. Other types of motors may be reversed as follows.

SHUNT WOUND MOTORS. Reversed by reversing the current to either the shunt field or the armature (see diagram "a" below). The armature current is usually reversed because this reverses the flow of current through the brushes and prolongs their life. Rate of brush wear is affected by electrolytic action, and reversing the current at regular intervals equalizes the rate of wear between the two brushes.

COMPOUND WOUND MOTORS. Reversed by reversing the current through the armature (see diagram "b" below). A compound wound motor generally has better reversing characteristics than a shunt wound motor, because the series part of the field winding increases the field strength during the reversing period. Increasing the proportion of series to shunt-field ampere-turns increases the reversing torque but impairs speed regulation.

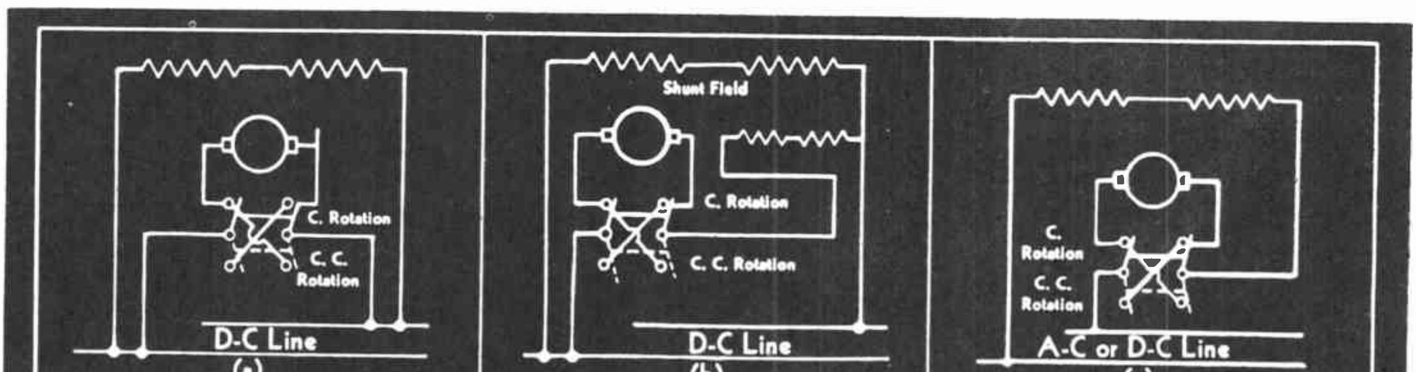
SERIES WOUND MOTORS. Reversed by reversing the current through either the field or the armature. (See diagram "c" below. In this case, the armature current is reversed.)

CAPACITOR START-AND-RUN INDUCTION MOTORS. Windings for this type of motor resemble those of a two-phase motor. There are two independent windings, each displaced ninety electrical degrees from the other. Rotation is reversed by reversing the current through either winding, but it is usually more desirable to reverse the connection of the main winding.

Capacitor induction motors can be made synchronous by the use of different rotors and can be reversed in the same manner. However, changing an induction motor to a synchronous type reduces the available power output.

POLYPHASE INDUCTION MOTORS. Two-or three-phase induction motors have their windings — one for each phase — evenly divided by the same number of electrical degrees. Reversal of the 2-phase motor is accomplished by reversing the current through either winding. Reversal of a 3-phase motor is accomplished by interchanging any two of its connections to the line.

Starting and reversing torque characteristics of polyphase motors are exceptionally good. This is due to the fact that the different windings are identical and, unlike the capacitor motor, the currents are balanced. They have an ideal phase relation which results in a true rotating field over the full range of operation from locked rotor to full speed. Polyphase synchronous motors also have good reversing characteristics.



(a) Shunt Motor 4-Wire Reversible

(b) Compound Motor 5-Wire Reversible

(c) Series Motor 4-Wire Reversible

Full-Load Currents of Motors

The following data are approximate full-load currents for motors of various types, frequencies, and speeds. They have been compiled from average values for representative motors of their respective classes. Variations of 10 per cent above or below the values given may be expected.

Hp. of Motor	Amoeres—Full-load Current																								
	Direct-current Motors			Alternating-current Motors																					
				Single-phase Motors		Squirrel-cage Induction Motors										Slip-ring Induction Motors									
						Two-phase					Three-phase					Two-phase					Three-phase				
	115-volt	230-volt	550-volt	110-volt	220-volt	110-volt	220-volt	440-volt	550-volt	2200-volt	110-volt	220-volt	440-volt	550-volt	2200-volt	110-volt	220-volt	440-volt	550-volt	2200-volt	110-volt	220-volt	440-volt	550-volt	2200-volt
¼	....	....	....	4.8	2.4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
½	4.5	2.3	....	7	3.5	4.3	2.2	1.1	.9	....	5.0	2.5	1.3	1.0	....	....	....	....	....	....	....	....	....	....	....
¾	6.5	3.3	1.4	9.4	4.7	4.7	2.4	1.2	1.0	....	5.4	2.8	1.4	1.1	....	6.2	3.1	1.6	1.3	....	7.2	3.6	1.8	1.5	....
1	8.4	4.2	1.7	11	5.5	5.7	2.9	1.4	1.2	....	6.6	3.3	1.7	1.3	....	6.7	3.4	1.7	1.4	....	7.8	3.9	2.0	1.6	....
1½	12.5	6.3	2.6	15.2	7.6	7.7	4.0	2	1.6	....	9.4	4.7	2.4	2.0	....	11.7	5.9	3.0	2.3	....	....	....	....	....	....
2	16.1	8.3	3.4	20	10	10.4	5	3	2.0	....	12.0	6	3.0	2.4	....	12.5	6.3	3.1	2.5	....	14.4	7.2	3.6	2.9	....
3	23	12.3	5.0	28	14	....	8	4	3.0	....	....	9	4.5	4.0	....	....	8.7	4.3	3.5	....	20.2	10	5.0	4	....
5	40	19.8	8.2	46	23	....	13	7	6	....	....	15	7.5	6.0	....	....	13.0	6.5	5.2	....	....	15	7.5	6	....
7½	58	28.7	12	68	34	....	19	9	7	....	....	22	11	9.0	....	....	20.0	10.0	7.6	....	....	25	13	10	....
10	75	38	16	86	43	....	24	12	10	....	....	27	14	11	....	....	24.3	12.1	10.0	....	....	28	14	11	....
15	112	56	23	....	....	....	33	16	13	....	....	38	19	15	....	....	39	19.5	15.6	....	....	45	23	18	....
20	140	74	30	....	....	....	45	23	19		....	52	26	21	5.7	....	49	24.7	19.8	....	....	56	28	22	....
25	185	92	38	....	....	....	55	28	22	6	....	64	32	26	7	....	60	30.0	24.0	6.4	....	67	34	27	7.5
30	220	110	45	....	....	....	67	34	27	7	....	77	39	31	8	....	72	36.0	28.8	7.8	....	82	41	33	9
40	294	146	61	....	....	....	88	44	35	9	....	101	51	40	10	....	93	46.5	37.3	9.5	....	106	53	42	11
50	364	180	75	....	....	....	108	54	43	11	....	125	63	50	13	....	113	57	45	12.1	....	128	64	51	14
60	436	215	90	....	....	....	129	65	52	13	....	149	75	60	15	....	135	68	54	14.0	....	150	75	60	16
75	540	268	111	....	....	....	156	78	62	16	....	180	90	72	19	....	164	82	65	17.3	....	188	94	75	19
100	....	357	146	....	....	....	212	106	85	22	....	246	123	98	25	....	214	108	87	21.7	....	246	123	99	25
125	....	443	184	....	....	....	268	134	108	27	....	310	155	124	32	....	267	134	108	27	....	310	155	124	31
150	....	....	220	....	....	....	311	155	124	31	....	360	180	144	36	....	315	158	127	32	....	364	182	145	37
175	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
200	....	....	295	....	....	....	415	208	166	43	....	480	240	195	49	....	430	216	173	44	....	490	245	196	52

FAIRBANKS-MORSE ELECTRIC MACHINERY CATECHISM

CENTIGRADE AND FAHRENHEIT TEMPERATURE SCALES

Centigrade	Fahrenheit	Centigrade	Fahrenheit	Centigrade	Fahrenheit	Centigrade	Fahrenheit
−15	5	15	59	45	113	75	167
−10	14	20	68	50	122	80	176
−5	23	25	77	55	131	85	185
0	32	30	86	60	140	90	194
5	41	35	95	65	149	95	203
10	50	40	104	70	158	100	212

Temp. F = 9/5 (Temp.C) + 32.
Temp. C = 5/9 (Temp.F − 32.)

INDUCTION MOTOR DATA

Effects of Variation of Voltage or Frequency on Induction Motor Performance

Condition	Power Factor	Torque	Slip	Full Load Eff.
High Volt.	Decreased	Increased	Decreased	Slightly Higher
Low Volt.	Increased	Decreased	Increased	Slightly Lower
High Freq.	Increased	Decreased	Same	Approx. same
Low Freq.	Decreased	Increased	Same	Approx. same

APPROXIMATE FULL-LOAD CURRENTS OF MOTORS

The table below gives values that are approximate, and typical only of motors of usual speeds and frequencies. For low speed and special motors the full load currents are somewhat higher than shown here. For this reason, the values shown here are mainly used for estimating purposes and the selection of cable and should not be used in the selection of overload relays.

HP OF MOTOR	FULL-LOAD CURRENT—AMPERES											
	Direct-Current Motors		ALTERNATING-CURRENT INDUCTION MOTORS									
			Single-Phase Motors		THREE-PHASE (Full load currents for 2-phase motors are 0.87 times the 3-phase values)							
					Squirrel-Cage				Wound-Rotor			
	115-VOLT	230-VOLT	110-VOLT	220-VOLT	220-VOLT	440-VOLT	550-VOLT	2200-VOLT	220-VOLT	440-VOLT	550-VOLT	2200-VOLT
1/6	2.0	1.0	....	....	0.90	0.45	0.36	....	.....	.....	.....	.....
1/4	2.6	1.3	....	....	1.16	.58	.48	....	.....	.....	.....	.....
1/3	3.2	1.6	....	....	1.4	.70	.56	....	.....	.....	.....	.....
1/2	4.6	2.3	8.0	4.0	1.9	.95	.76	....	.....	.....	.....	.....
3/4	6.4	3.2	10.6	5.3	2.6	1.3	1.04	....	.....	.....	.....	.....
1	8.2	4.1	12.8	6.4	3.4	1.7	1.36	....	5.4	2.7	2.2	.....
1½	12.4	6.2	17.6	8.8	5.0	2.5	2.0	....	6.8	3.4	2.7	.....
2	16.2	8.1	22	11	6.2	3.1	2.5	....	8.0	4.0	3.2	.....
3	24	12	31	15.5	9.0	4.5	3.6	....	10.5	5.3	4.2	.....
5	40	20	48	24	14.5	7.2	5.7	....	16	8.0	6.4	.....
7½	60	30	68	34	21	10.5	7.3	....	23	11.5	9.2	.....
10	78	39	90	45	26	13.5	11	....	29	14.5	10.5	....
15	114	57	....	....	40	20	16	....	42	21	17	.....
20	150	75	....	....	52	26	21	....	54	27	23	.....
25	186	93	....	....	65	32	26	7.0	68	34	27	7.7
30	225	112	....	....	78	39	31	8.1	80	40	32	8.8
40	295	147	....	....	102	51	41	10.5	104	52	42	11
50	365	182	....	....	126	63	51	12.5	128	64	51	13.5
60	.....	218	....	....	152	76	60	15	154	77	62	15.5
75	.....	270	....	....	188	94	75	18.5	188	94	75	19
100	.....	355	....	....	250	125	100	24.5	250	125	100	25
125	.....	445	....	....	310	155	125	30	310	155	125	31
150	.....	530	....	....	370	185	145	36	370	185	145	37
200	.....	700	....	....	490	245	195	49	490	245	195	49

NOTE: On 2-phase, 3-wire motors, the current carried by the common conductor is 1.23 times the 3-phase value.

NEMA STANDARD RESISTOR CLASSIFICATION

The values given in this table are based on continued performance for one hour—also on the assumption that the steps of resistance will be cut out at equal intervals in the "time-on" period of the cycle specified, and that the average accelerating current will not exceed 125% full load.

APPROX. PER CENT OF FULL-LOAD CURRENT ON FIRST POINT	30 SECONDS ON OUT OF EACH 15 MINUTES	5 SECONDS ON OUT OF EACH 80 SECONDS	10 SECONDS ON OUT OF EACH 80 SECONDS	15 SECONDS ON OUT OF EACH 90 SECONDS	15 SECONDS ON OUT OF EACH 60 SECONDS	15 SECONDS ON OUT OF EACH 45 SECONDS	15 SECONDS ON OUT OF EACH 30 SECONDS	CONTINUOUS
25	No. 101	No. 111	No. 131	No. 141	No. 151	No. 161	No. 171	No. 91
50	No. 102	No. 112	No. 132	No. 142	No. 152	No. 162	No. 172	No. 92
70	No. 103	No. 113	No. 133	No. 143	No. 153	No. 163	No. 173	No. 93
100	No. 104	No. 114	No. 134	No. 144	No. 154	No. 164	No. 174	No. 94
150	No. 105	No. 115	No. 135	No. 145	No. 155	No. 165	No. 175	No. 95
200 or over	No. 106	No. 116	No. 136	No. 146	No. 156	No. 166	No. 176	No. 96

FULL-LOAD CURRENT*

Direct-Current Motors†

(Amperes at Full Load)

HP	115V	230V	550V
½	4.6	2.3	.....
¾	6.6	3.3	1.4
1	8.6	4.3	1.8
1½	12.6	6.3	2.6
2	16.4	8.2	3.4
3	24	12.	5.0
5	40	20	8.3
7½	58	29	12.0
10	76	38	16.0
15	112	56	23.0
20	148	74	31.
25	184	92	38.
30	220	110	46
40	292	146	61
50	360	180	75
60	430	215	90
75	536	268	111
100		355	148
125		443	148
150		534	220
200		712	295

* These values for full-load current are average for all speeds.
† 1947 N. E. Code, Table 21.

Two-Phase A.C. Motors (4-wire)

	Induction Type Squirrel-Cage and Wound Rotor Amperes					Synchronous Type † Unity Power Factor Amperes			
HP	110V	220V	440V	550V	2300V	220V	440V	550V	2300V
½	4	2	1	.8	—	—	—	—	—
¾	4.8	2.4	1.2	1.0	—	—	—	—	—
1	6.4	3.2	1.6	1.3	—	—	—	—	—
1½	8.8	4.4	2.2	1.8	—	—	—	—	—
2	11.2	5.6	2.8	2.2	—	—	—	—	—
3	—	8	4	3.2	—	—	—	—	—
5	—	13	7	6	—	—	—	—	—
7½	—	19	9	8	—	—	—	—	—
10	—	24	12	10	—	—	—	—	—
15	—	34	17	14	—	—	—	—	—
20	—	45	23	18	—	—	—	—	—
25	—	55	28	22	6	47	24	19	4.7
30	—	67	34	27	7.5	56	29	23	5.7
40	—	88	44	35	9	75	37	31	7
50	—	108	54	43	11	94	47	38	9
60	—	129	65	52	13	111	56	44	11
75	—	158	79	63	16	140	70	57	13
100	—	212	106	85	21	182	93	74	17
125	—	268	134	108	26	228	114	93	22
150	—	311	155	124	31	—	137	110	26
200	—	415	208	166	41	—	182	145	35

* These values of full-load current are for motors running at speeds usual for belted motors and motors with normal torque characteristics. Motors built for especially low speeds or high torques may require more running current, in which case the nameplate current ratings should be used. Current in common conductor of 2-phase, 3-wire system will be 1.41 times value given.

† For 90 and 80 per cent P. F. the above figures should be multiplied by 1.1 and 1.25 respectively.

(1947 N. E. Code, Table 23.)

FULL-LOAD CURRENT* (Continued)

Three-Phase A.C. Motors

	Induction Type Squirrel-Cage and Wound Rotor Amperes					Synchronous Type † Unity Power Factor Amperes			
HP	110V	220V	440V	550V	2300V	220V	440V	550V	2300V
½	4	2	1	.8	—	—	—	—	—
¾	5.6	2.8	1.4	1.1	—	—	—	—	—
1	7	3.5	1.8	1.4	—	—	—	—	—
1½	10	5	2.5	2.0	—	—	—	—	—
2	13	6.5	3.3	2.6	—	—	—	—	—
3	—	9	4.5	4	—	—	—	—	—
5	—	15	7.5	6	—	—	—	—	—
7½	—	22	11	9	—	—	—	—	—
10	—	27	14	11	—	—	—	—	—
15	—	40	20	16	—	—	—	—	—
20	—	52	26	21	—	—	—	—	—
25	—	64	32	26	7	54	27	22	5.4
30	—	78	39	31	8.5	65	33	26	6.5
40	—	104	52	41	10.5	86	43	35	8
50	—	125	63	50	13	108	54	44	10
60	—	150	75	60	16	128	64	51	12
75	—	185	93	74	19	161	81	65	15
100	—	246	123	98	25	211	106	85	20
125	—	310	155	124	31	264	132	106	25
150	—	360	180	144	37	—	158	127	30
200	—	480	240	192	49	—	210	168	40

For full-load currents of 208 and 200 volt motors, increase the corresponding 220-volt motor full-load current by 6 and 10 per cent, respectively.

* These values of full-load current are for motors running at speeds usual for belted motors and motors with normal torque characteristics. Motors built for especially low speeds or high torques may require more running current, in which case the nameplate current rating should be used.

† For 90 and 80 per cent P. F. the above figures should be multiplied by 1.1 and 1.25 respectively.

(1947 N. E. Code, Table 24.)

Single-Phase A.C. Motors†

(Amperes at Full Load)*

HP	115V	230V	440V
1/6	3.2	1.6	
¼	4.6	2.3	
⅓	7.4	3.7	
½	10.2	5.1	
1	13.	6.5	
1½	18.4	9.2	
2	24.	12.	
3	34.	17.	
5	56.	28.	
7½	80.	40.	21.
10	100.	50.	26.

For full-load currents of 208 and 200-volt motors, increase corresponding 230-volt motor full-load current by 10 and 15 per cent-respectively.

* These values of full-load current are for motors running at speeds usual for belted motors and motors with normal torque characteristics. Motors built for expecially low speeds or high torques may require more running current, in which case the nameplate current rating should be used.

(† 1947 N. E. Code, Table 22.)

APPROX. AMPERES FOR INDUCTION MOTORS

Hp. of Motor	220 Volts 2-Ph.	220 Volts 3-Ph.	Hp. of Motor	220 Volts 2-Ph.	220 Volts 3-Ph.
.5	1.7	2.0	50.	108.	125.
1.0	3.0	3.5	60.	130.	150.
2.0	5.5	6.4	75.	160.	185.
3.0	8.0	9.2	100.	215.	250.
5.0	13.	15.	125.	260.	300.
7.5	19.	22.	150.	320.	370.
10.	24.	28.	175.	360.	420.
15.	35.	40.	200.	415.	480.
20.	45.	52.	225.	460.	530.
25.	56.	65.	250.	520.	600.
30.	66.	75.	275.	570.	660.
40.	87.	100.	300.	620.	720.

For 110 volts, use 2; for 440, use ½; for 550, use ⅖; for 1100, use ⅕; and for 2200, use 1/10 of the above values. For single phase motors use twice the value for two phase motors.

CONDUCTOR SIZES AND OVERCURRENT PROTECTION FOR MOTORS

These values are in accordance with sections 4309, 4312, 4322, 4324, 4342, and 4349, except as follows: The current values in Column 1 are to be taken from Tables 21 to 24, including footnotes, but the values shown for running protection in Columns 5 and 6 must be modified if nameplate full load current values are different, as provided in section 4309. Conductor sizes shown in Columns 2 and 3 may be smaller for certain motors as provided in section 4312. The current values shown in Columns 5 and 6 must be reduced by 8 per cent for all motors other than open type motors marked to have a temperature rise not over 40 degrees C as required by section 4322. For certain exceptions to the values in Columns 7, 8, 9, and 10, see sections 4342 and 4343 of 1947 N. E. Code. See section 4343 of 1947 N. E. Code for values to be used for several motors on one branch circuit.

Full load current rating of motor amperes	Minimum size conductor in raceways. For conductors in air or for other insulations see tables 1 and 2 AWG and MCM		For Running Protection of Motors****		Maximum Allowable Rating or Setting of Branch Circuit Protective Devices			
	Type R Type T	Type RH	Maximum rating of non-adjustable protective devices Amperes	Maximum setting of adjustable protective devices Amperes	With Code Letters Single-phase and squirrel cage and synchronous. Full voltage, resistor and reactor starting, Code letters F to R inc. **Without Code Letters** Same as above.	**With Code Letters** Single-phase and squirrel cage and synchronous. Full voltage, resistor or reactor starting, Code letters B to E inc. Auto-transformer starting, Code letters F to R inc. **Without Code Letters** Squirrel cage and synchronous, auto-transformer starting, High reactance squirrel cage.*** Both not more than 30 amperes	**With Code Letters** Squirrel cage and synchronous Auto-transformer starting, Code letters B to E inc. **Without Code Letters** Squirrel cage and synchronous, auto-transformer starting, High reactance squirrel cage.*** Both more than 30 amperes.	**With Code Letters** All motors. Code letter A. **Without Code Letters** DC and wound-rotor motors.
Col. No. 1	2	3	5	6	7	8	9	10
1**	14	14	2*	1.25*	15	15	15	15
2**	14	14	3*	2.50*	15	15	15	15
3**	14	14	4*	3.75*	15	15	15	15
4**	14	14	6*	5.0 *	15	15	15	15
5**	14	14	8*	6.25*	15	15	15	15
6**	14	14	8*	7.50*	20	15	15	15
7	14	14	10*	8.75*	25	20	15	15
8	14	14	10*	10.0 *	25	20	20	15
9	14	14	12*	11.25*	30	25	20	15
10	14	14	15*	12.50*	30	25	20	15
11	14	14	15*	13.75*	35	30	25	20
12	14	14	15	15.00	40	30	25	20
13	12	12	20	16.25	40	35	30	20
14	12	12	20	17.50	45	35	30	25
15	12	12	20	18.75	45	40	30	25
16	12	12	20	20.00	50	40	35	25
17	10	10	25	21.25	60	45	35	30
18	10	10	25	22.50	60	45	40	30
19	10	10	25	23.75	60	50	40	30
20	10	10	25	25.0	60	50	40	30
22	10	10	30	27.50	70	60	45	35
24	10	10	30	30.00	80	60	50	40
26	8	10	35	32.50	80	70	60	40
28	8	10	35	35.00	90	70	60	45
30	8	8	40	37.50	90	70	60	45
32	8	8	40	40.00	100	80	70	50
34	6	8	45	42.50	110	90	70	60
36	6	8	45	45.00	110	90	80	60
38	6	6	50	47.50	125	100	80	60
40	6	6	50	50.00	125	100	80	60
42	6	6	50	52.50	125	110	90	70
44	6	6	60	55.0	125	110	90	70
46	4	6	60	57.50	150	125	100	70
48	4	6	60	60.0	150	125	100	80
50	4	6	60	62.50	150	125	100	80
52	4	6	70	65.0	175	150	110	80
54	4	4	70	67.50	175	150	110	90
56	4	4	70	70.00	175	150	120	90
58	3	4	70	72.50	175	150	120	90
60	3	4	80	75.00	200	150	120	90
62	3	4	80	77.50	200	175	125	100
64	3	4	80	80.00	200	175	150	100
66	2	4	80	82.50	200	175	150	100
68	2	4	90	85.00	225	175	150	110
70	2	3	90	87.50	225	175	150	110
72	2	3	90	90.00	225	200	150	110
74	2	3	90	92.50	225	200	150	125
76	2	3	100	95.00	250	200	175	125
78	1	3	100	97.50	250	200	175	125
80	1	3	100	100.00	250	200	175	125
82	1	2	110	102.50	250	225	175	125
84	1	2	110	105.00	250	225	175	150
86	1	2	110	107.50	300	225	175	150

CONDUCTOR SIZES AND OVERCURRENT PROTECTION FOR MOTORS

These values are in accordance with sections 4309, 4312, 4322, 4324, 4342, and 4349, except as follows: The current values in Column 1 are to be taken from Tables 21 to 24, including footnotes, but the values shown for running protection in Columns 5 and 6 must be modified if nameplate full load current values are different, as provided in section 4309. Conductor sizes shown in Columns 2 and 3 may be smaller for certain motors as provided in section 4312. The current values shown in Columns 5 and 6 must be reduced by 8 per cent for all motors other than open type motors marked to have a temperature rise not over 40 degrees C as required by section 4322. For certain exceptions to the values in Columns 7, 8, 9, and 10, see sections 4342 and 4343 of 1947 N. E. Code. See section 4343 of 1947 N. E. Code for values to be used for several motors on one branch circuit.

Full load current rating of motor amperes	Minimum size conductor in raceways. For conductors in air or for other insulations see tables 1 and 2 AWG and MCM: Type R Type T	Minimum size conductor in raceways: Type RH	For Running Protection of Motors****: Maximum rating of non-adjustable protective devices, Amperes	For Running Protection of Motors****: Maximum setting of adjustable protective devices, Amperes	Maximum Allowable Rating or Setting of Branch Circuit Protective Devices: With Code Letters *Single-phase and squirrel cage and synchronous. Full voltage, resistor and reactor starting, Code letters F to R inc. Without Code Letters Same as above.	With Code Letters Single-phase and squirrel cage and synchronous. Full voltage, resistor or reactor starting, Code letters B to E inc. Auto-transformer starting, Code letters F to R inc. Without Code Letters Squirrel cage and synchronous, auto-transformer starting, High reactance squirrel cage.*** Both not more than 30 amperes	With Code Letters Squirrel cage and synchronous Auto-transformer starting, Code letters B to E inc. Without Code Letters Squirrel cage and synchronous, auto-transformer starting, High reactance squirrel cage.*** Both more than 30 amperes.	With Code Letters All motors. Code letter A. Without Code Letters DC and wound-rotor motors.
Col. No. 1	2	3	5	6	7	8	9	10
88	1	2	110	110.00	300	225	200	150
90	0	2	110	112.50	300	225	200	150
92	0	2	125	115.00	300	250	200	150
94	0	1	125	117.50	300	250	200	150
96	0	1	125	120.00	300	250	200	150
98	0	1	125	122.50	300	250	200	150
100	0	1	125	125.00	300	250	200	150
105	00	1	150	131.5	350	300	225	175
100	00	0	150	137.5	350	300	225	175
115	00	0	150	144.0	350	300	250	175
120	000	0	150	150.0	400	300	250	200
125	000	00	175	156.5	400	350	250	200
130	000	00	175	162.5	400	350	300	200
135	0000	00	175	169.0	450	350	300	225
140	0000	00	175	175.0	450	350	300	225
145	0000	000	200	181.5	450	400	300	225
150	0000	000	200	187.5	450	400	300	225
155	0000	000	200	194.0	500	400	350	250
160	250	000	200	200.0	500	400	350	250
165	250	0000	225	206.	500	450	350	250
170	250	0000	225	213.	500	450	350	300
175	300	0000	225	219.	600	450	350	300
180	300	0000	225	225.	600	450	400	300
185	300	0000	250	231.	600	500	400	300
190	300	250	250	238.	600	500	400	300
195	350	250	250	244.	600	500	400	300
200	350	250	250	250.	600	500	400	300
210	400	300	250	263.	...	600	450	350
220	400	300	300	275.	...	600	450	350
230	500	300	300	288.	...	600	500	350
240	500	350	300	300.	...	600	500	400
250	500	350	300	313.	...	...	500	400
260	600	400	350	325.	...	...	600	400
270	600	400	350	338.	...	...	600	450
280	600	500	350	350.	...	...	600	450
290	700	500	350	363.	...	...	600	450
300	700	500	400	375.	...	...	600	450
320	750	600	400	400.	...	...	...	500
340	900	600	450	425.	...	...	...	600
360	1000	700	450	450.	...	...	...	600
380	1250	750	500	475.	...	...	...	600
400	1500	900	500	500.	...	...	...	600
420	1750	1000	600	525.	...	...	...	...
440	2000	1250	600	550.	...	...	...	...
460	....	1250	600	575.	...	...	...	...
480	....	1500	600	600.	...	...	...	...
500	....	1500	...	625.	...	...	...	...

* For running protection of motors of 1 horsepower or less, see section 4322.

** For the grouping of small motors under the protection of a single set of fuses, see section 4343.

*** High-reactance squirrel-cage motors are those designed to limit the starting current by means of deep-slot secondaries or double-wound secondaries and are generally started on full voltage.

**** For running protection of motors see section 4322. (1947 N. E. Code, Table 20)

CONDUCTOR SIZES • BRANCH CIRCUIT BREAKER AND FUSE RATINGS FOR MOTOR APPLICATIONS

Table for selecting switch, circuit breaker, wire and fuse sizes for motor branch circuits adapted from 1937 N. E. Code Chapter 9. Obtain proper terminal ampere rating of motor from table on page 1. All switches and circuit-breakers have lugs in accordance with 1937 Code Requirements.

FULL LOAD CURRENT RATING OF MOTOR	NON-FUSIBLE SWITCH SIZE	TO SELECT PROPER SIZE FUSE, SAFETY SWITCH OR CIRCUIT BREAKER FOR MOTOR CIRCUIT — Fusible Switch or ABI Breaker Size for Circuit Protection Columns 4, 6 and 8. Recommended Rating of Branch Circuit Breaker Amperes Based on 20 Seconds Accelerating Time†									WIRE SIZE (From 1940 Code, Chapter 10) — Minimum Size Conductor in Raceways — AWG AND MCM		
		SINGLE PHASE, SQUIRREL-CAGE AND SYNCHRONOUS FULL-VOLTAGE, REACTOR AND RESISTOR STARTING			SQUIRREL-CAGE AND SYNCHRONOUS AUTO-TRANSFORMER STARTING. HIGH REACTANCE SQUIRREL-CAGE			WOUND ROTOR AC AND DC					
1	2	3	4		5	6		7	8		9	10	11
AMP.	AMP.	Max. Allowable Rating of Branch Circuit Fuses AMP.	Fusible Switch AMP.	Circuit Breaker AMP.	Max. Allowable Rating of Branch Circuit Fuses AMP.	Fusible Switch AMP.	Circuit Breaker AMP.	Max. Allowable Rating of Branch Circuit Fuses AMP.	Fusible Switch AMP.	Circuit Breaker AMP.	TYPE R	TYPE RP	TYPE RH
1	Non-fusible Safety Switches for Motor Circuits should be applied according to the 1937 National Electrical Code, Sections 4401 to 4410 inclusive, or to a later edition.	15	30	15	15	30	15	15	30	15	14	14	14
2		15	30	15	15	30	15	15	30	15	14	14	14
3		15	30	15	15	30	15	15	30	15	14	14	14
4		15	30	15	15	30	15	15	30	15	14	14	14
5		15	30	15	15	30	15	15	30	15	14	14	14
6		20	30	15	15	30	15	15	30	15	14	14	14
7		25	30	15	20	30	15	15	30	15	14	14	14
8		25	30	20	20	30	20	15	30	15	14	14	14
9		30	30	20	25	30	20	15	30	15	14	14	14
10		30	30	25	25	30	20	15	30	20	14	14	14
11		35	60	25	30	30	25	20	30	20	14	14	14
12		40	60	25	30	30	25	20	30	20	14	14	14
13		40	60	35	35	60	35	20	30	25	12	14	14
14		45	60	35	35	60	35	25	30	25	12	14	14
15		45	60	35	40	60	35	25	30	25	12	12	14
16		50	60	35	40	60	35	25	30	25	12	12	14
17		60	60	50	45	60	35	30	30	35	10	12	14
18		60	60	50	45	60	35	30	30	35	10	12	12
19		60	60	50	50	60	35	30	30	35	10	10	12
20		60	60	50	50	60	35	30	30	35	10	10	12
22		70	100	50	60	60	50	35	60	35	8	10	10
24		80	100	50	60	60	50	40	60	50	8	10	10
26		80	100	50	70	100	50	40	60	50	8	8	10
28		90	100	50‡	70	100	50	45	60	50	8	8	10
30		90	100	50‡	70	100	50	45	60	50	6	8	8
32		100	100	70	70	100	50	50	60	50	6	8	8
34		110	200	70	70	100	70	60	60	70	6	6	8
36		110	200	70	80	100	70	60	60	70	6	6	8
38		125	200	70	80	100	70	60	60	70	5	6	8
40		125	200	70	80	100	70	60	60	70	5	6	6
42		125	200	70	90	100	70	70	100	70	5	6	6
44		125	200	70	90	100	70	70	100	70	4	5	6
46		150	200	70	100	100	70	70	100	70	4	5	6
48		150	200	90	100	100	90	80	100	90	4	5	6
50		150	200	90	100	100	90	80	100	90	3	5	6
52		175	200	90	110	200	90	80	100	90	3	4	6
54		175	200	90	110	200	90	90	100	90	3	4	5
56		175	200	90	120	200	90	90	100	90	2	4	5
58		175	200	90	120	200	90	90	100	90	2	3	5
60		200	200	90	120	200	90	90	100	90	2	3	5
62		200	200	100	125	200	100	100	100	100	2	3	4
64		200	200	100	150	200	100	100	100	100	2	3	4
66		200	200	100	150	200	100	100	100	100	1	3	4
68		225	400	125	150	200	125	110	200	125	1	2	4
70		225	400	125	150	200	125	110	200	125	1	2	3
72		225	400	125	150	200	125	110	200	125	1	2	3
74		225	400	125	150	200	125	125	200	125	0	2	3
76		250	400	125	175	200	125	125	200	125	0	2	3
78		250	400	125	175	200	125	125	200	125	0	1	3
80		250	400	125	175	200	125	125	200	125	0	1	2
82		250	400	125	175	200	125	125	200	125	0	1	2
84		250	400	150	175	200	150	150	200	150	0	1	2
86		300	400	150	175	200	150	150	200	150	00	1	2

† Applications having unusually long starting period or frequent starting refer to works for proper size breaker. High ambients affect rating of breakers (ambients over 75°F. use a breaker rated one % higher for each 5°F. For ambients under 75°F. use a breaker rated one % lower for each 5° change. This rule applies over a range of 40°F. either way.) ‡ Does not allow more than 8 seconds starting time.

CONDUCTOR SIZES • BRANCH CIRCUIT BREAKER AND FUSE RATINGS FOR MOTOR APPLICATIONS—(Cont'd)

Table for selecting switch, circuit breaker, wire and fuse sizes for motor branch circuits adapted from 1937 N. E. Code Chapter 9. Obtain proper terminal ampere rating of motor from table on page 1. All switches and circuit-breakers have lugs in accordance with 1937 Code Requirements.

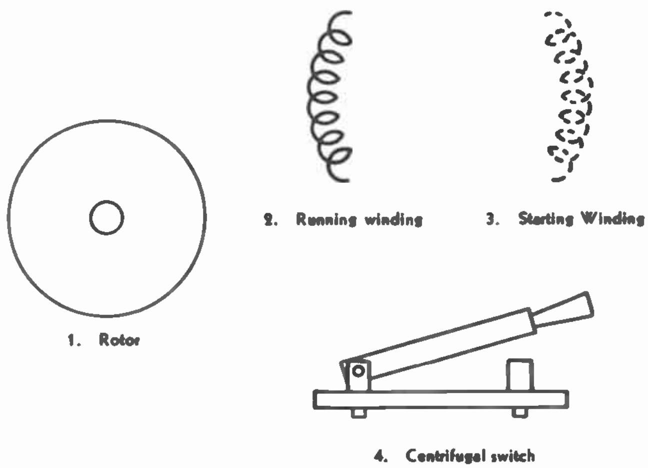
FULL LOAD CURRENT RATING OF MOTOR	NON-FUSIBLE SWITCH SIZE	TO SELECT PROPER SIZE FUSE, SAFETY SWITCH OR CIRCUIT BREAKER FOR MOTOR CIRCUIT — Fusible Switch or ABI Breaker Size for Circuit Protection Columns 4, 6 and 8 Recommended Rating of Branch Circuit Breaker Amperes Based on 20 Seconds Accelerating Time† — SINGLE PHASE, SQUIRREL-CAGE AND SYNCHRONOUS FULL-VOLTAGE, REACTOR AND RESISTOR STARTING			SQUIRREL-CAGE AND SYNCHRONOUS AUTO-TRANSFORMER STARTING. HIGH-REACTANCE SQUIRREL-CAGE			WOUND ROTOR AC AND DC			WIRE SIZE (From 1940 Code, Chapter 10) — Minimum Size Conductor In Raceways — AWG AND MCM		
1	2	3	4		5	6		7	8		9	10	11
AMP.	AMP.	Max. Allowable Rating of Branch Circuit Fuses AMP.	Fusible Switch AMP.	Circuit Breaker AMP.	Max. Allowable Rating of Branch Circuit Fuses AMP.	Fusible Switch AMP.	Circuit Breaker AMP.	Max. Allowable Rating of Branch Circuit Fuses AMP.	Fusible Switch AMP.	Circuit Breaker AMP.	TYPE R	TYPE RP	TYPE RH
88	Non-fusible Safety Switches for Motor Circuits should be applied according to the 1937 National Electrical Code, Sections 4401 to 4410 inclusive, or to a later edition.	300	400	150	200	200	150	150	200	150	00	1	2
90		300	400	150	200	200	150	150	200	150	00	0	2
92		300	400	150	200	200	150	150	200	150	00	0	2
94		300	400	150	200	200	150	150	200	150	00	0	1
96		300	400	150	200	200	150	150	200	150	00	0	1
98		300	400	150	200	200	150	150	200	150	000	0	1
100		300	400	150	200	200	150	150	200	150	000	0	1
105		350	400	175	225	400	175	175	200	175	000	00	1
110		350	400	175	225	400	175	175	200	175	000	00	0
115		350	400	175	250	400	175	175	200	175	0000	00	0
120		400	400	200	250	400	200	200	200	200	0000	000	0
125		400	400	200	250	400	200	200	200	200	0000	000	00
130		400	400	200	300	400	200	200	200	200	250	000	00
135		450	600	200	300	400	200	225	400	200	250	0000	00
140		450	600	225	300	400	225	225	400	225	250	0000	000
145		450	600	225	300	400	225	225	400	225	300	0000	000
150		450	600	225	300	400	225	225	400	225	300	0000	000
155		500	600	275	350	400	275	250	400	275	300	0000	000
160		500	600	275	350	400	275	250	400	275	350	250	000
165		500	600	275	350	400	275	250	400	275	350	250	0000
170		500	600	275	350	400	275	300	400	275	350	250	0000
175		600	600	275	350	400	275	300	400	275	400	300	0000
180		600	600	275	400	400	275	300	400	275	400	300	0000
185		600	600	300	400	400	300	300	400	300	400	300	0000
190		600	600	300	400	400	300	300	400	300	500	300	250
195		600	600	300	400	400	300	300	400	300	500	350	250
200		600	600	300	400	400	300	300	400	300	500	350	250
210		...	...	...	450	600	325	350	400	325	500	400	300
220		...	...	...	450	600	325	350	400	325	600	400	300
230		...	...	...	500	600	400	350	400	400	600	500	300
240		...	...	...	500	600	400	400	400	400	700	500	350
250		...	...	...	500	600	400	400	400	400	700	500	350
260		...	...	...	600	600	400	400	400	400	750	600	400
270		...	...	...	600	600	450	450	600	450	800	600	400
280		...	...	...	600	600	450	450	600	450	900	600	500
290		...	...	...	600	600	450	450	600	450	900	700	500
300		...	...	...	600	600	450	450	600	450	1000	700	500
320		...	...	...	...	...	...	500	600	500	1250	750	600
340		...	...	...	...	...	...	600	600	525	1500	900	600
360		...	...	...	...	...	...	600	600	550	1750	1000	700
380		...	...	...	...	...	...	600	600	600	...	1250	750
400		...	...	...	...	...	...	600	600	600	...	1500	900
420		...	...	...	...	...	...	...	...	...	...	1500	1000
440		...	...	...	...	...	...	...	...	...	...	1750	1250
460		...	...	...	...	...	...	...	...	...	...	...	1250
480		...	...	...	...	...	...	...	...	...	...	...	1500
500		...	...	...	...	...	...	...	...	...	...	...	1500

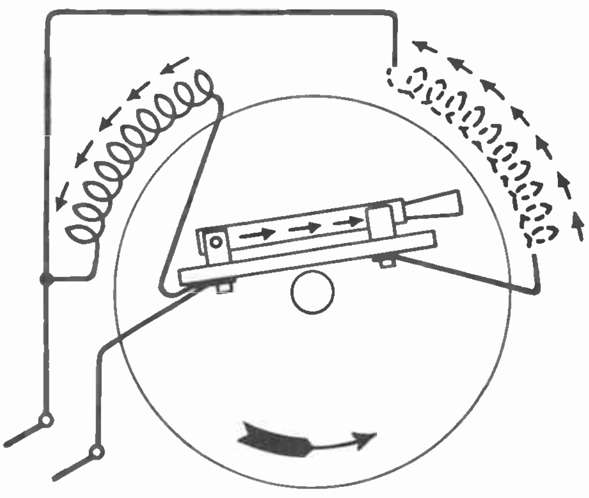
† Applications having unusually long starting period or frequent starting refer to works for proper size breaker. High ambients affect rating of breakers (ambients over 75°F. use a breaker rated one % higher for each 5°F. For ambients under 75°F. use a breaker rated one % lower for each 5° change. This rule applies over a range of 40°F. either way.)

What Is a Split-phase Motor?

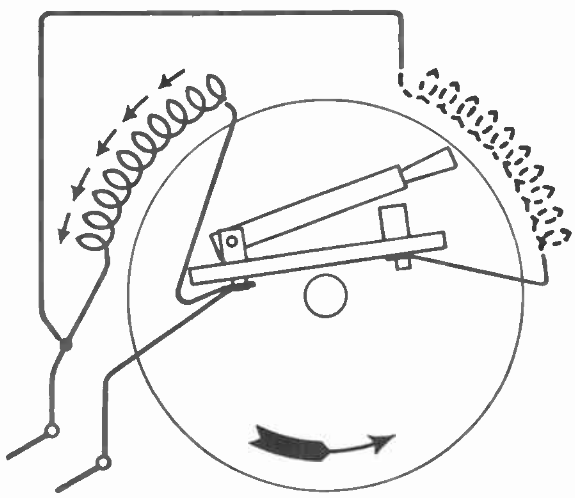
A SPLIT-PHASE motor is a single-phase motor that obtains its starting torque from two stator windings of different impedance values which in effect convert the single-phase current to an equivalent two-phase current. The few and simple parts of this motor are shown schematically at the right.

The arrangement and operation of these parts are shown below. The windings are located in different sectors around the stator, and the starting winding is in series with the starting switch. A switch-actuating mechanism is mounted on the rotor and is set to open the switch and open-circuit the starting winding when the motor reaches a predetermined speed.





The phase displacement of the currents in the starting and running windings, together with their physical displacement on the stator, produces a rotating magnetic field that starts the rotor revolving

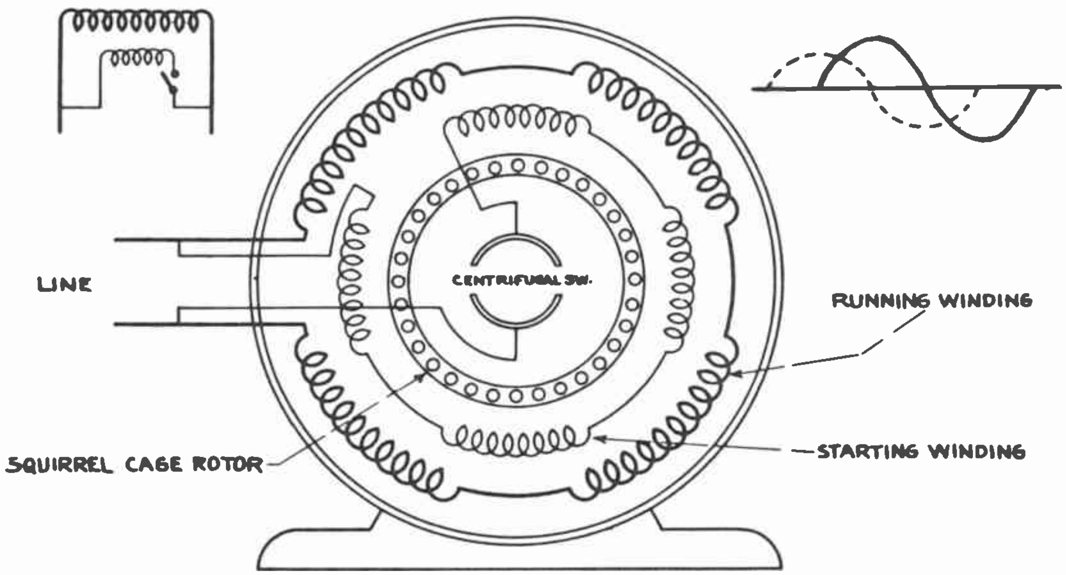


When the rotor reaches a predetermined speed, the centrifugal switch opens the starting winding. Current flows only in the running winding, and the motor operates the same as an ordinary induction motor.

Why Split-phase Motors Are Used

Split-phase motors are admirably suited to applications that require an inexpensive, reliable motor with moderate torque. Inherently simple in construction and operation, the split-phase motor will give many years of satisfactory operation without attention except occasional oiling. Split-phase motors do not interfere with radio reception — they have no brushes or commutators. Split-phase motors have become the accepted drive for domestic washing machines, ironers, fans, and similar devices where long periods of operation without attention are so desirable.

SINGLE-PHASE SPLIT-PHASE INDUCTION MOTOR



OPERATION

To be self-starting, the stator winding of a squirrel-cage induction motor must be capable of setting up a rotating magnetic field. Since such a field cannot be produced by a single winding energized by a single-phase current, some method of splitting this current into two currents approximately 90 degrees out of phase with with other must be provided. This is accomplished by having the single-phase current flow through two parallel paths having different electrical characteristics. One path, being highly inductive, causes the current flowing through it to lag almost 90 degrees behind the current through the other path. By this method, a revolving magnetic field is produced with single-phase current. Starting as a two-phase machine, this motor accelerates to about 75% of normal full load speed when a centrifugally-operated switch disconnects the starting winding and converts the unit to a straight single-phase type.

CHARACTERISTICS

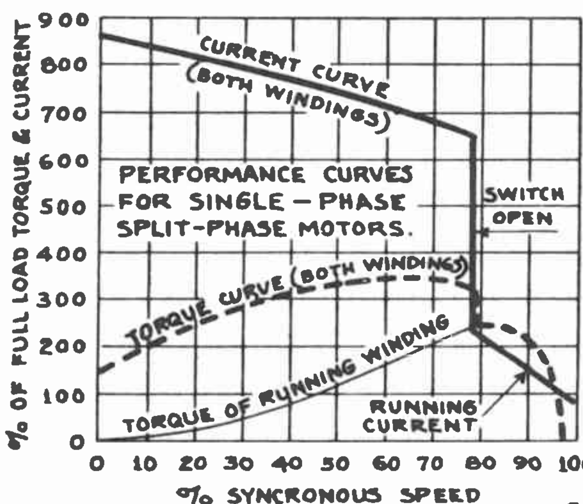
This motor will develop from 1 to 1.5 times normal full load torque, and will draw as high as 9 times normal full load current when full line voltage is applied at starting. The speed variation from no load to full load will not exceed 5% of the normal full load speed. For complete data on current, torque, etc., see curves given below.

APPLICATION

Washing machines, ventilating fans, sign flashers, bottling machinery, oil burners, dairy machinery, garage equipment, stokers, coffee mills, shoe machinery, exercisers, dish washers, oil pumps, etc. In general, this motor - which is usually built in fraction h.p. sizes only - may be used for any small load that does not require a high starting torque and can be operated at constant speed.

TROUBLES

Centrifugal switch, starting winding, bearings, loose connections, oil-soaked insulation, opens, shorts and grounds, improper connections.



COYNE

Split Phase MOTORS

for Alternating Current

APPLICATION AND PERFORMANCE DATA

Application—The split-phase motor is perhaps the most widely used constant speed motor of appreciable power, employed for driving domestic appliances. It is also used on many different types of industrial equipment. The Bodine split-phase motor has been especially designed for those applications where continuous service may be required.

Bodine split-phase alternating current motors are regularly manufactured with ratings from 1/70 to 1/6 hp at 1725 rpm. Other ratings at standard 60 cycle speeds of 1125, and 3450 rpm are also available. Split-phase motors can also be furnished for odd frequency operation, the usual speed for 25 and 50 cycles being 1425 rpm.

Characteristics — The following features are characteristic of split-phase motors:

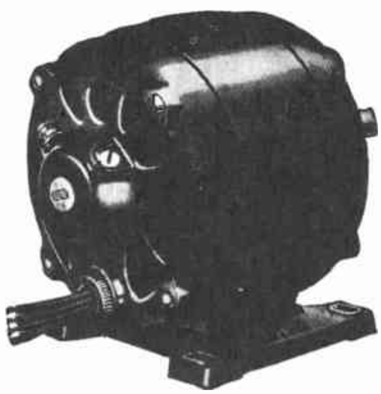


Fig. 1—The Type NSI-54 split phase motor. One of the larger Bodine motors of this type.

1. **Practically constant speed.**
   The speed varies from about 1780 rpm at no load to 1725 rpm at full load for 4 pole, 60 cycle, motors.

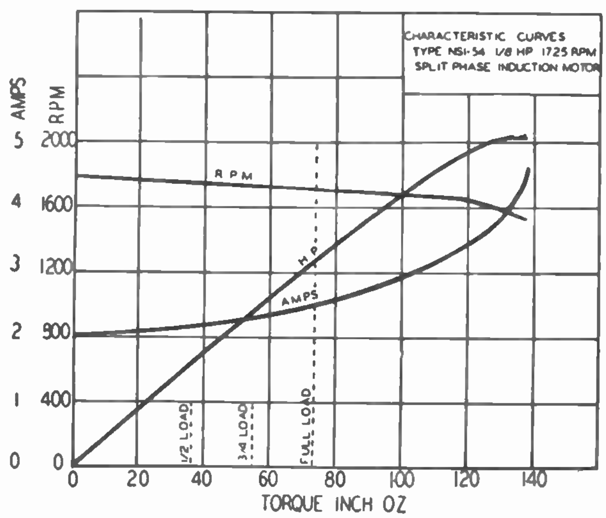
2. **Reliable performance with little maintenance.**
   No brushes to replace. After the motor attains normal speed, the only physical connection between stator and rotor is at the bearings.

3. **Reversible at standstill.**
   The motor connections may be interchanged at standstill for reverse rotation, but the motor cannot be reversed while rotating.

4. **Definitely fixed speeds.**
   The speeds of split-phase motors depend upon the frequency and the number of poles, and are therefore limited in number for any one frequency. Usual 60 cycle speeds are 1125, 1725, and 3450 rpm. Rheostat control is not practical, so effective speed variations cannot be secured.

Motors of this type are relatively simple in construction with no brushes or slip rings. Their first cost is therefore lower than that of many other types. They have good efficiency, a rather good output for a given frame size, and good starting torque. For these reasons, the split-phase motor has become today's general purpose motor.

The characteristic curves at the bottom of the page show the speed, current, and horsepower values of an average fractional horsepower split-phase motor for various torque loads. The speed is fairly constant over the entire range from no load to stalling point, dropping off as the load increases. The efficiency is approximately at its peak at full load, falling at



overloads. The starting torque varies with the motor temperature, being greatest at lowest temperature. Rapidly repeated motor starting heats the windings and results in a loss of torque. In general, the split-phase motor should be used only where the torque required for starting does not exceed about 150% of full load torque.

Split-phase motors have a rather high starting current which ranges from 5 to 10 times the current drawn while running. On lighting circuits this high current at the instant of starting causes a voltage drop which may produce dimming of lights on the same circuit. For this reason some power companies have limited the starting current of motors on lighting circuits to 20 amperes. Split-phase motors are only furnished in sizes of 1/6 hp and less. If the starting load is heavy, the wiring between motor and outlet should be of adequate size to prevent excessive voltage drop. The low voltage conditions resulting from inadequate wiring will also decrease the motor starting torque.

Many applications require a fixed speed motor or one which changes speed but little with changes in load. A split-phase winding is admirably suited for such drives provided that the accuracy of a synchronous motor is not required. Where wide speed variation is needed, some other type of motor must be considered.

The rate at which a motor can be accelerated is often of importance to the designer. Split-phase motors pick up speed quite rapidly, reaching their full running speed in a very few seconds. The acceleration may be somewhat retarded through the use of reactors, or of special rotors, but the split-phase motor does not lend itself well to those applications where a very gradual increase in speed is desired. Such applications are rather limited in number, however.

Construction — By definition, a split-phase motor is a simple, single-phase induction motor equipped with an auxiliary winding displaced in magnetic position from, and connected in parallel with the main winding. The single-phase motor without this auxiliary starting winding has no starting torque, but once it has been brought to a speed approaching its synchronous speed, will develop a good running torque. The purpose of the auxiliary or split-phase winding. therefore, is to start the motor. Once this has been done, it has served its purpose and can be disconnected from the circuit.

The auxiliary winding is wound in the same slots as the main winding but is displaced in space from the main winding. Generally, the auxiliary winding is made of a finer wire that has a high resistance, so that current flowing through it is substantially in phase with the line voltage. The current in the main winding, because of the lower resistance and greater reactance, lags behind the voltage by a greater angle. This magnetic displacement sets up a revolving field in the stator, similar to that encountered in a polyphase induction motor, which starts the motor. Once the motor has been brought up to speed, it will develop a running torque, and the auxiliary winding is disconnected by means of a centrifugal cutout switch.

Modern cutouts are practically trouble free and will give satisfactory service for hundreds of thousands of starts and stops. Some few applications require exceptionally rapid starting, and for these, other types of motors should be considered.

Because the starting winding must be of rather fine wire, to secure the desired starting torque, it can only be momentarily left on the line. The centrifugal switch disconnects the winding normally, but care should be taken to avoid having the motor stalled with the current on.

There are many important details of construction which are described at length, and fully illustrated in Bulletins which explain just how each frame type is built. The machine designer will find these Bulletins of considerable assistance in selecting his motor.

Bodine split-phase motors are regularly built in a number of different frame sizes, to meet almost any application. All are long annual service motors, designed to give years of service.

Constant speed motors may also be provided with integral worm gear speed reducers to simplify drive problems.

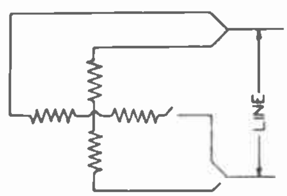


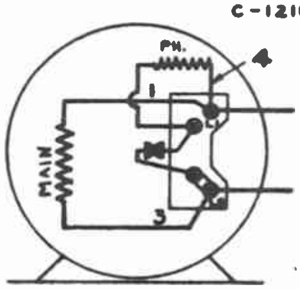
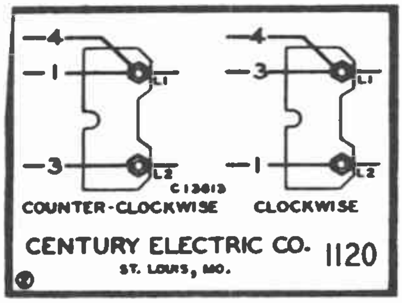
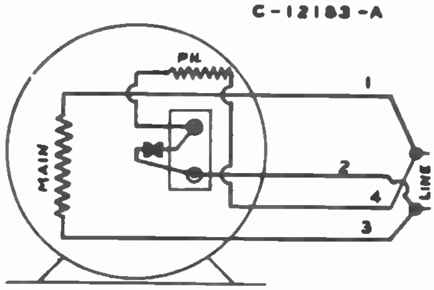
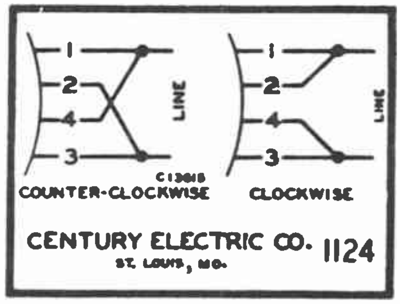
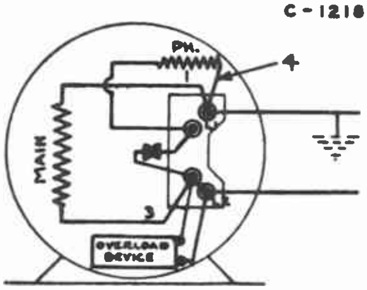
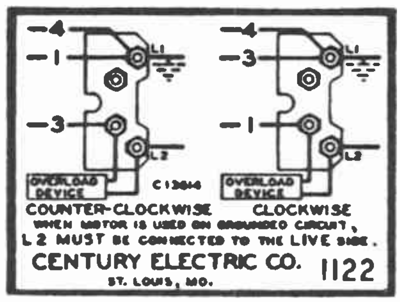
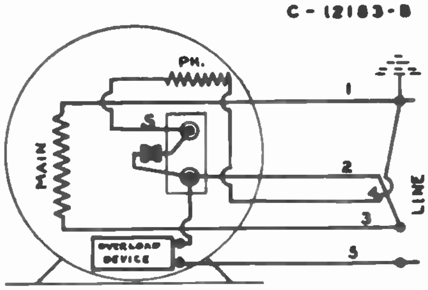
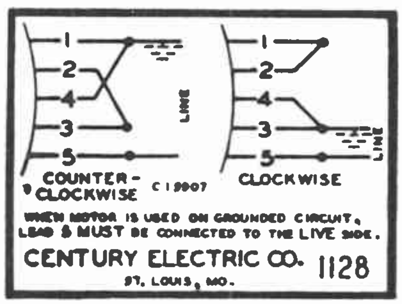
Fig. 3—Diagram of connections for a split phase four lead reversible motor. Note cutout switch.

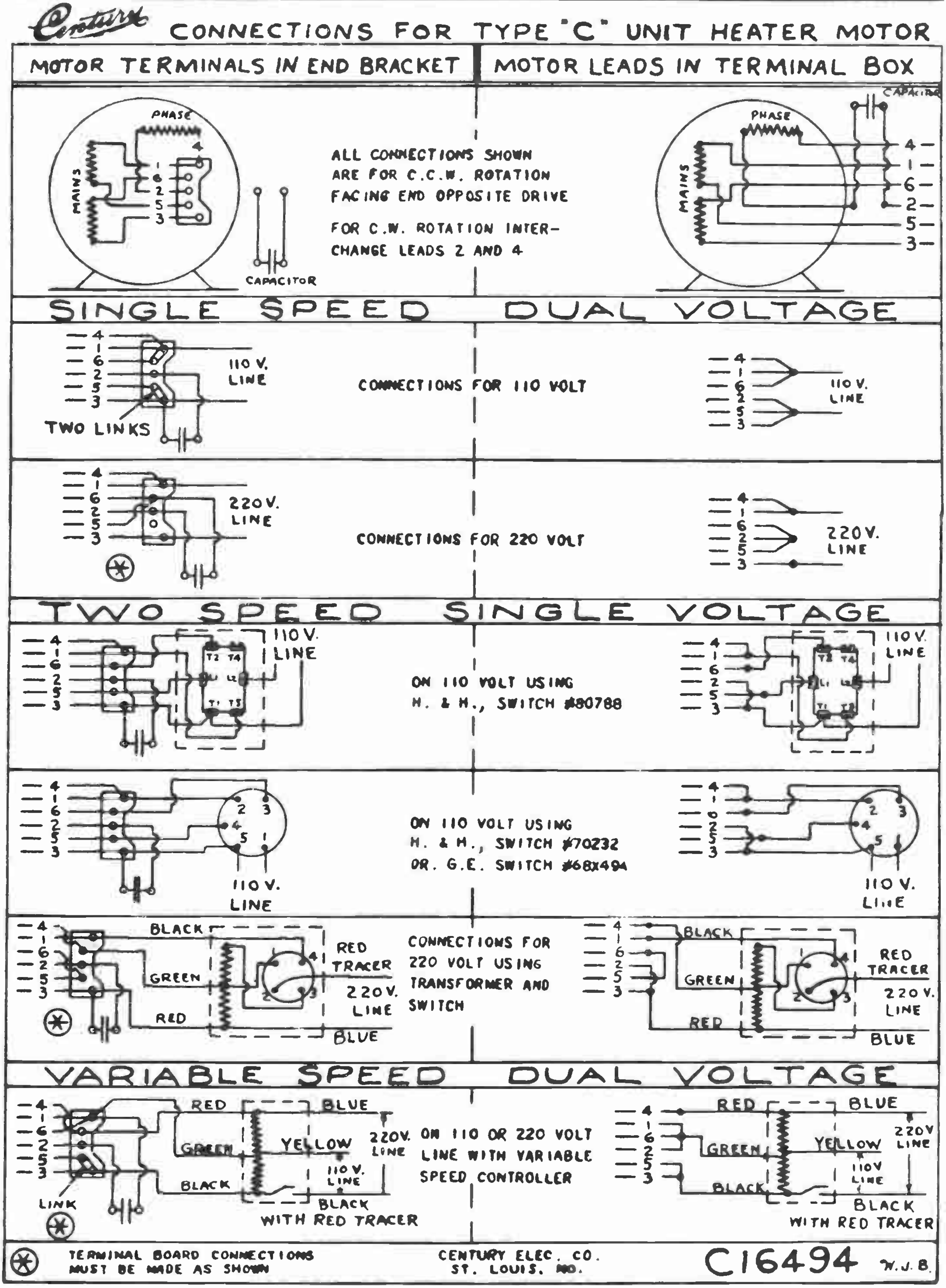
Century

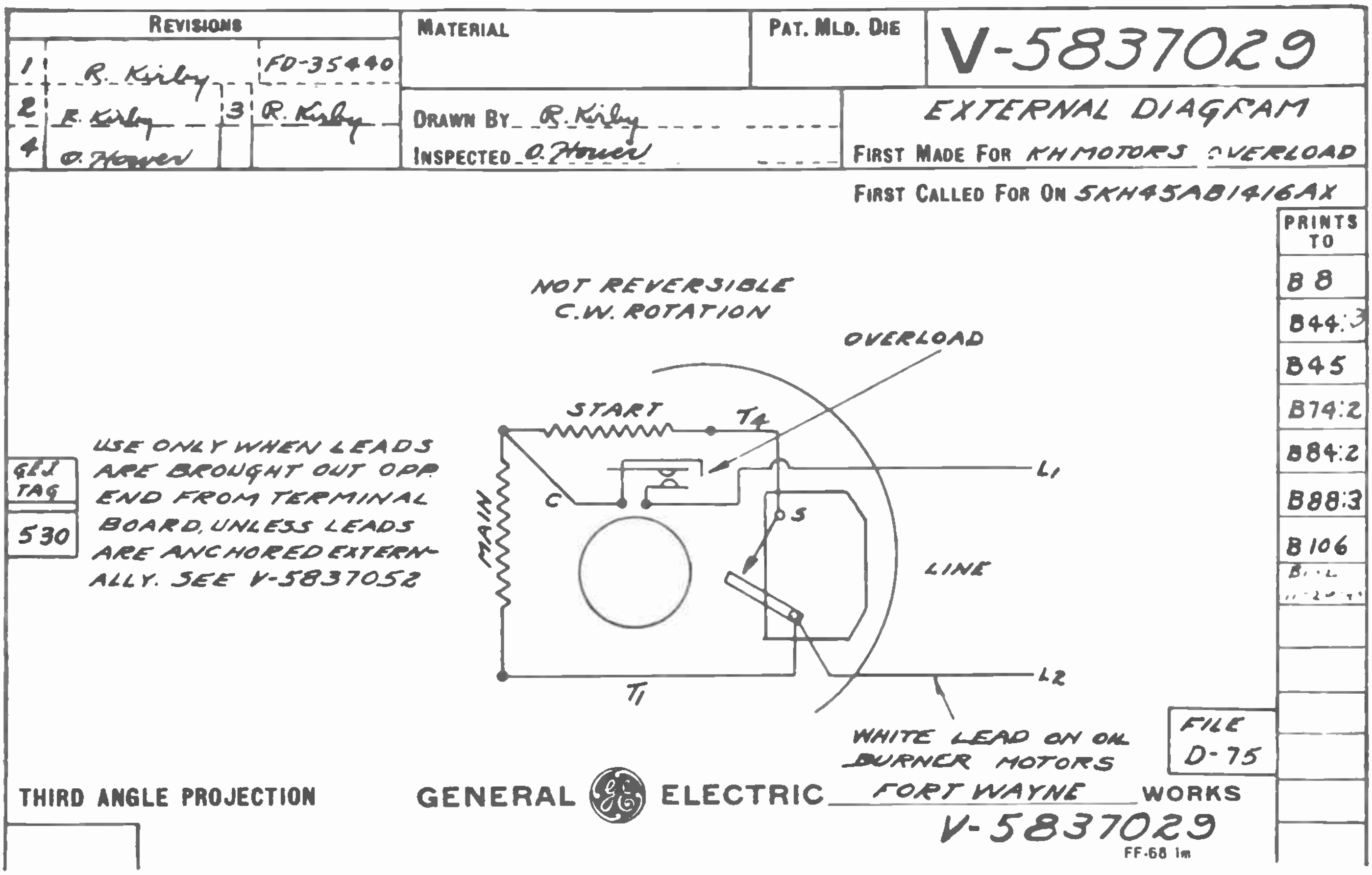
ENGINEERING INFORMATION

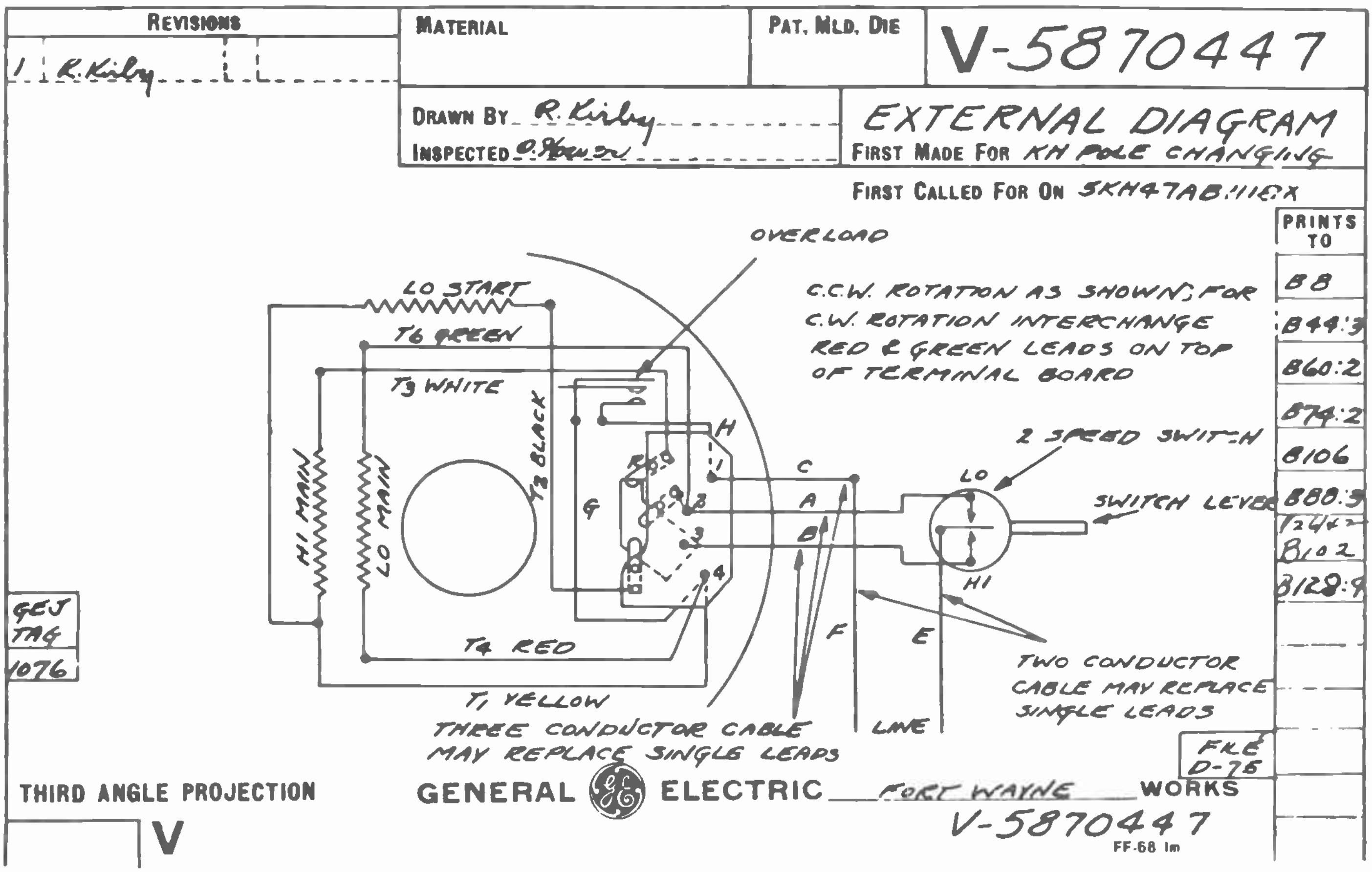
SPLIT PHASE INDUCTION MOTORS

TYPE SP; 110 OR 220 VOLTS; REVERSIBLE

Location of Terminals	Frames	Internal Connection Diagrams (Counter Clockwise Rotation)	Label (Attached To Cover Over Terminals
WITHOUT OVERLOAD PROTECTION			
In Front Bracket	63G, 65G, 67G, 65L, 67L	C-12184-A 	
In Frame	43, 45, 53, 71, 73	C-12183-A 	
WITH OVERLOAD PROTECTION			
In Front Bracket	63G, 65G, 67G, 65L, 67L	C-12184-B 	
In Frame	53, 71, 73	C-12183-B 	


Century
CONNECTIONS FOR TYPE "C" UNIT HEATER MOTOR
MOTOR TERMINALS IN END BRACKET
MOTOR LEADS IN TERMINAL BOX
PHASE
MAINS
CAPACITOR
ALL CONNECTIONS SHOWN ARE FOR C.C.W. ROTATION FACING END OPPOSITE DRIVE
FOR C.W. ROTATION INTERCHANGE LEADS 2 AND 4
SINGLE SPEED DUAL VOLTAGE
110 V. LINE
TWO LINKS
CONNECTIONS FOR 110 VOLT
220 V. LINE
CONNECTIONS FOR 220 VOLT
TWO SPEED SINGLE VOLTAGE
110 V. LINE
ON 110 VOLT USING H. & H., SWITCH #80788
ON 110 VOLT USING H. & H., SWITCH #70232 OR. G.E. SWITCH #68X494
BLACK
GREEN
RED
RED TRACER
220 V. LINE
BLUE
CONNECTIONS FOR 220 VOLT USING TRANSFORMER AND SWITCH
VARIABLE SPEED DUAL VOLTAGE
YELLOW
220V. LINE
110 V. LINE
LINK
BLACK WITH RED TRACER
ON 110 OR 220 VOLT LINE WITH VARIABLE SPEED CONTROLLER
TERMINAL BOARD CONNECTIONS MUST BE MADE AS SHOWN
CENTURY ELEC. CO. ST. LOUIS, MO.
C16494 W.J.B.


REVISIONS
1 R. Kirby FD-35440
2 R. Kirby 3 R. Kirby
4 O. Hower
MATERIAL
PAT. MLD. DIE
V-5837029
DRAWN BY R. Kirby
INSPECTED O. Hower
EXTERNAL DIAGRAM
FIRST MADE FOR KH MOTORS OVERLOAD
FIRST CALLED FOR ON 5KH45AB1416AX
PRINTS TO
B8
B44:3
B45
B74:2
B84:2
B88:3
B106
NOT REVERSIBLE
C.W. ROTATION
OVERLOAD
START
T4
L1
C
S
MAIN
LINE
T1
L2
USE ONLY WHEN LEADS ARE BROUGHT OUT OPP. END FROM TERMINAL BOARD, UNLESS LEADS ARE ANCHORED EXTERNALLY. SEE V-5837052
GEJ TAG
530
WHITE LEAD ON OIL BURNER MOTORS
FILE D-75
THIRD ANGLE PROJECTION
GENERAL ELECTRIC FORT WAYNE WORKS
V-5837029
FF-68 1m


REVISIONS
1 R. Kirby
MATERIAL
PAT. MLD. DIE
V-5870447
DRAWN BY R. Kirby
INSPECTED O. Hower
EXTERNAL DIAGRAM
FIRST MADE FOR KH POLE CHANGING
FIRST CALLED FOR ON 5KH47AB111EX
PRINTS TO
B8
B44:3
B60:2
B74:2
B106
B88:3
B102
B128:4
OVERLOAD
LO START
T6 GREEN
T3 WHITE
T8 BLACK
H
C.C.W. ROTATION AS SHOWN; FOR C.W. ROTATION INTERCHANGE RED & GREEN LEADS ON TOP OF TERMINAL BOARD
2 SPEED SWITCH
LO
SWITCH LEVER
HI MAIN
LO MAIN
G
C
A
B
1
2
3
4
HI
F
E
T4 RED
T1 YELLOW
GEJ TAG
1076
TWO CONDUCTOR CABLE MAY REPLACE SINGLE LEADS
THREE CONDUCTOR CABLE MAY REPLACE SINGLE LEADS
LINE
FILE D-75
THIRD ANGLE PROJECTION
V
GENERAL ELECTRIC FORT WAYNE WORKS
V-5870447
FF-68 1m

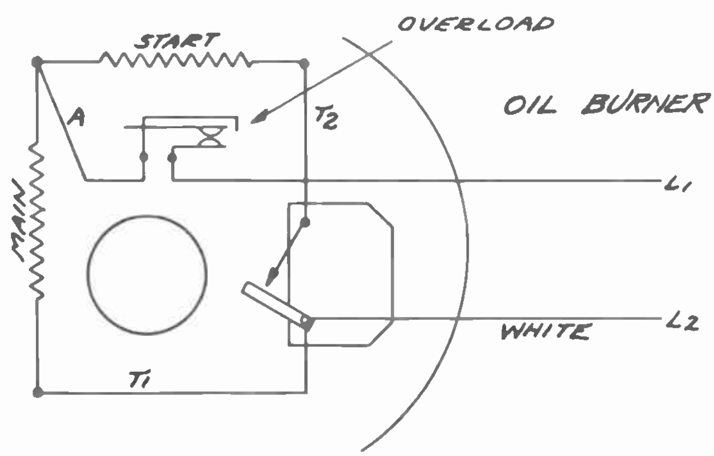
REVISIONS	MATERIAL	PAT. MLD. DIE	V-5837494
	DRAWN BY R. Kirby INSPECTED W.A.Hahn		EXTERNAL DIAGRAM FIRST MADE FOR KH MOTORS - OVERLOAD -

FIRST CALLED FOR ON 5KH49BB688Y

PRINTS TO: B8, B44:3, B74:2, B84:2, B88:3, B106

GEJ TAG 530

OIL BURNER MOTORS



NOT REVERSIBLE
C.C.W. ROTATION

FILE D-75

THIRD ANGLE PROJECTION V

GENERAL ELECTRIC FORT WAYNE WORKS

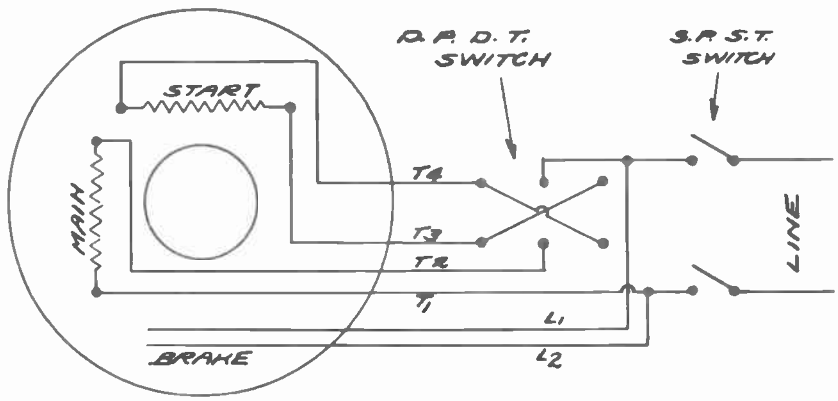
V-5837494

FF-68 Im

REVISIONS	MATERIAL	PAT. MLD. DIE	V-5834076
	DRAWN BY O. Howey INSPECTED		EXTERNAL DIAGRAM FIRST MADE FOR SCA REV. WITH BRAKE

FIRST CALLED FOR ON B-18596

PRINTS TO: B8, B44:2, B45, B14(4), B74:2

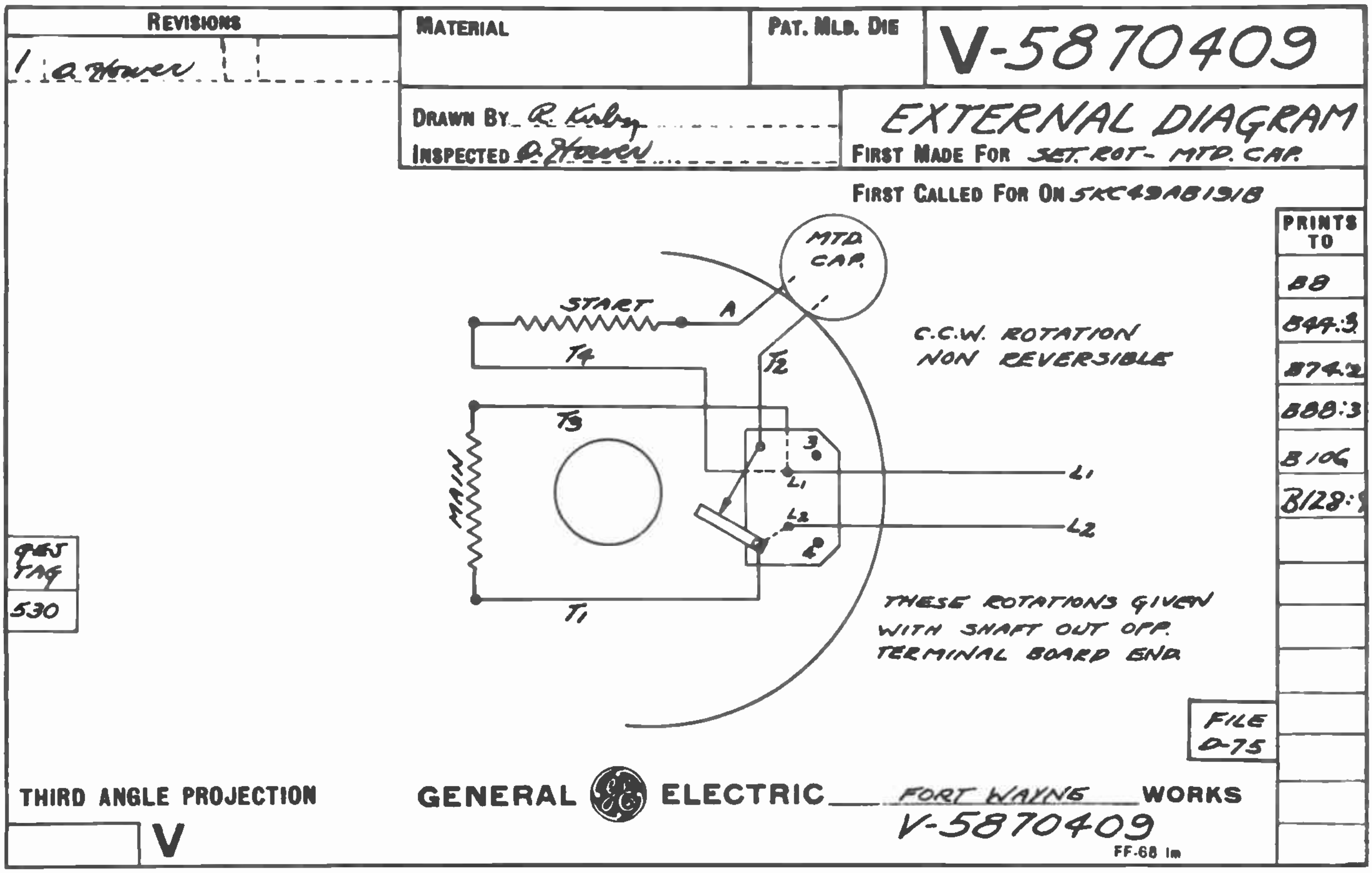


THIRD ANGLE PROJECTION V

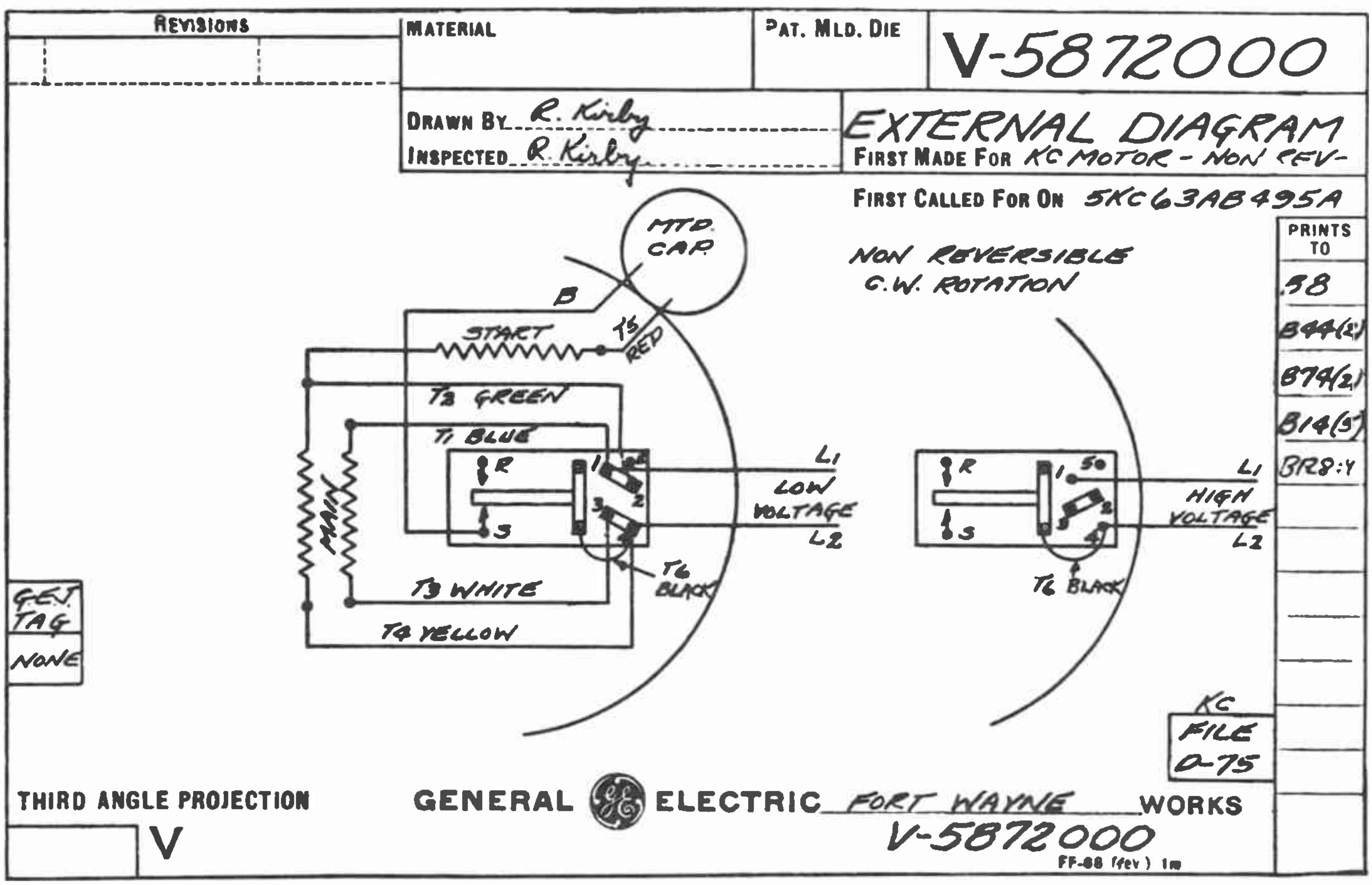
GENERAL ELECTRIC FORT WAYNE WORKS

V-5834076

FF-68 Im



REVISIONS
MATERIAL
PAT. MLD. DIE
V-5870409
DRAWN BY R. Kirby
INSPECTED
EXTERNAL DIAGRAM
FIRST MADE FOR SET. ROT- MTD. CAP.
FIRST CALLED FOR ON 5KC49AB1318
MTD. CAP.
START
A
T4
T2
T3
MAIN
T1
3
L1
L2
C.C.W. ROTATION
NON REVERSIBLE
THESE ROTATIONS GIVEN
WITH SHAFT OUT OPP.
TERMINAL BOARD END
PRINTS TO
88
844:3
874:2
888:3
8106
8128:
G.E.T. TAG
530
FILE
D-75
THIRD ANGLE PROJECTION
V
GENERAL ELECTRIC FORT WAYNE WORKS
V-5870409
FF-68 Im

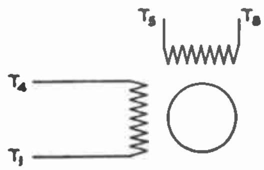


REVISIONS
MATERIAL
PAT. MLD. DIE
V-5872000
DRAWN BY R. Kirby
INSPECTED R. Kirby
EXTERNAL DIAGRAM
FIRST MADE FOR KC MOTOR - NON REV-
FIRST CALLED FOR ON 5KC63AB495A
MTD. CAP.
B
START
T5 RED
T2 GREEN
T1 BLUE
MAIN
T3 WHITE
T4 YELLOW
T6 BLACK
R
S
L1
LOW VOLTAGE
L2
NON REVERSIBLE
C.W. ROTATION
HIGH VOLTAGE
PRINTS TO
88
844(2)
874(2)
814(5)
8128:4
G.E.T. TAG
NONE
KC
FILE
D-75
THIRD ANGLE PROJECTION
V
GENERAL ELECTRIC FORT WAYNE WORKS
V-5872000

AMERICAN STANDARD

3.5 SINGLE-PHASE MOTORS

3.505 Connections and Terminal Markings—Single-Phase Motors



		L_1	L_2
One direction rotation	Start	T_1T_5	T_4T_8
	Run	T_1	T_4
Other direction rotation	Start	T_4T_5	T_1T_8
	Run	T_4	T_1

FIG. 1 Split-Phase with Automatic Cutout Reversible Motor

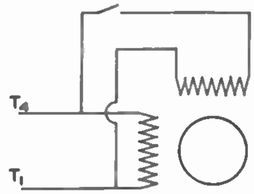
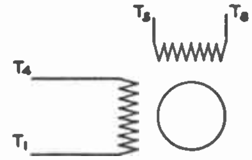


FIG. 2. Split-Phase with Automatic Cutout Non-Reversible Motor



		L_1	L_2	Open
One direction rotation	Start	T_1T_5	T_4T_8	—
	Run	T_1	T_4	T_5T_8
Other direction rotation	Start	T_4T_5	T_1T_8	—
	Run	T_4	T_1	T_5T_8

FIG. 3. Split-Phase Manual Cutout Reversible Motor

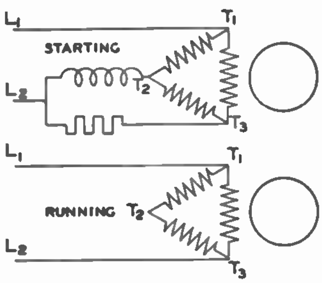


FIG. 4. Induction Motor with Starting Box Non-Reversible

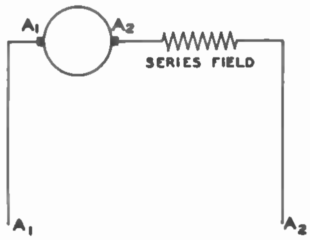
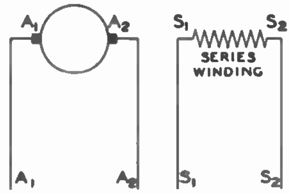


FIG. 5. Series Universal Non-Reversing Motor not Compensated



	L_1	L_2	Tie Together
One direction rotation	A_1	S_2	A_2S_1
Other direction rotation	A_1	S_1	A_2S_2

FIG. 6. Series Universal Reversing Motor not Compensated

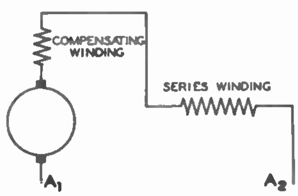


FIG. 7 Series Motor Conductively Compensated Separate Stator Windings*

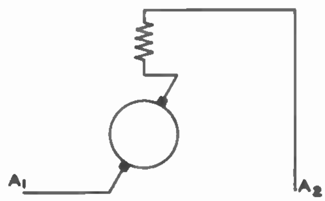


FIG. 8. Series Motor Conductively Compensated Common Stator Windings†

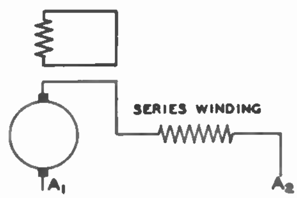


FIG. 9. Series Motor Inductively Compensated Separate Stator Windings*

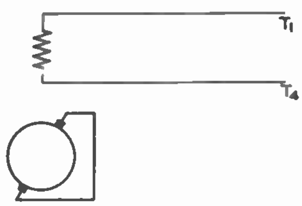
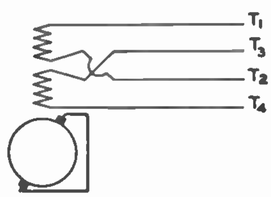
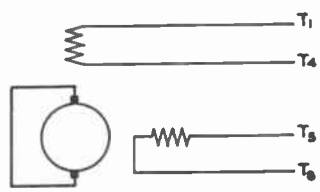


FIG. 10. 1. Repulsion Motor Single Voltage not Compensated†
2. Repulsion-Start Induction-Run Motor Single Voltage not Compensated†



	L_1	L_2	Tie Together
Low Voltage	T_1T_3	T_2T_4	—
High Voltage	T_1	T_4	T_2T_3

FIG. 11. 1. Repulsion Motor Double Voltage not Compensated†
2. Repulsion-Start Induction-Run Motor Double Voltage not Compensated†



	L_1	L_2	Tie Together
One direction rotation	T_1	T_8	T_4T_5
Other direction rotation	T_1	T_5	T_4T_8

FIG. 12. 1. Repulsion Motor Single Voltage Reversible
2. Repulsion-Start Induction-Run Motor Single Voltage Reversible

* Motor may be reversed by reversing the series field only.
† Motor may be reversed by shifting brushes as per manufacturer's instructions.

AMERICAN STANDARD

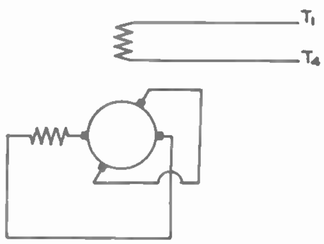
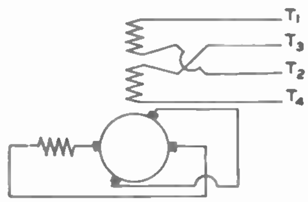
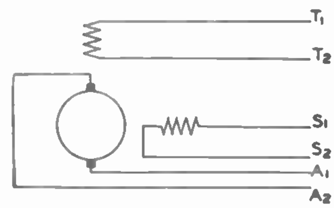


FIG. 13. Repulsion Motor Single Voltage Inductively Compensated†



	L_1	L_2	Tie Together
Low Voltage	T_1T_3	T_2T_4	——
High Voltage	T_1	T_4	T_2T_3

FIG. 14. Repulsion Motor Double Voltage Inductively Compensated†



	L_1	L_2	Tie Together
One direction rotation	A_1	S_1	S_2 to T_1 & A_2 to T_2
Other direction rotation	A_1	S_2	S_1 to T_1 & A_2 to T_2

FIG. 15. Series Motor Conductively Compensated Reversible, Separate Stator Windings

† Motor may be reversed by shifting brushes, as per manufacturer's instructions.

NOTE I—See 1.510 for terminal letters assigned to different types of windings, and 1.130 for significance of the subscript numerals.

NOTE II—The markings for single-phase motors are based on the following principles:

1st Principle

Designate the running winding of a single voltage single-phase motor by T_1T_4 and the starting winding by T_5T_8. This distinguishes it from a quarter-phase motor which uses odd subscript numbers in one phase and even subscript numbers in the other phase.

2nd Principle

The first principle permits a dual voltage motor to have markings which follow the general practice now used of connecting odd to odd and even to even for parallel (low voltage) connection and connecting odd to even for series (high voltage) connection.

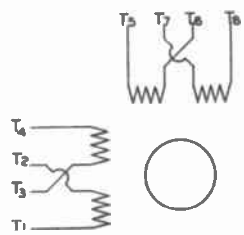
3rd Principle

Always represent the rotor by a circle on schematic diagrams of single-phase motors, even though it has no external connections. This indicates definitely whether it has any connections (short circuits or external) and further distinguishes the diagram and markings from a quarter-phase schematic which never shows the rotor as a circle. (See rules under Section 3.7.)

3.510 Connections and Terminal Markings—Single-Phase, Dual-Voltage Motors

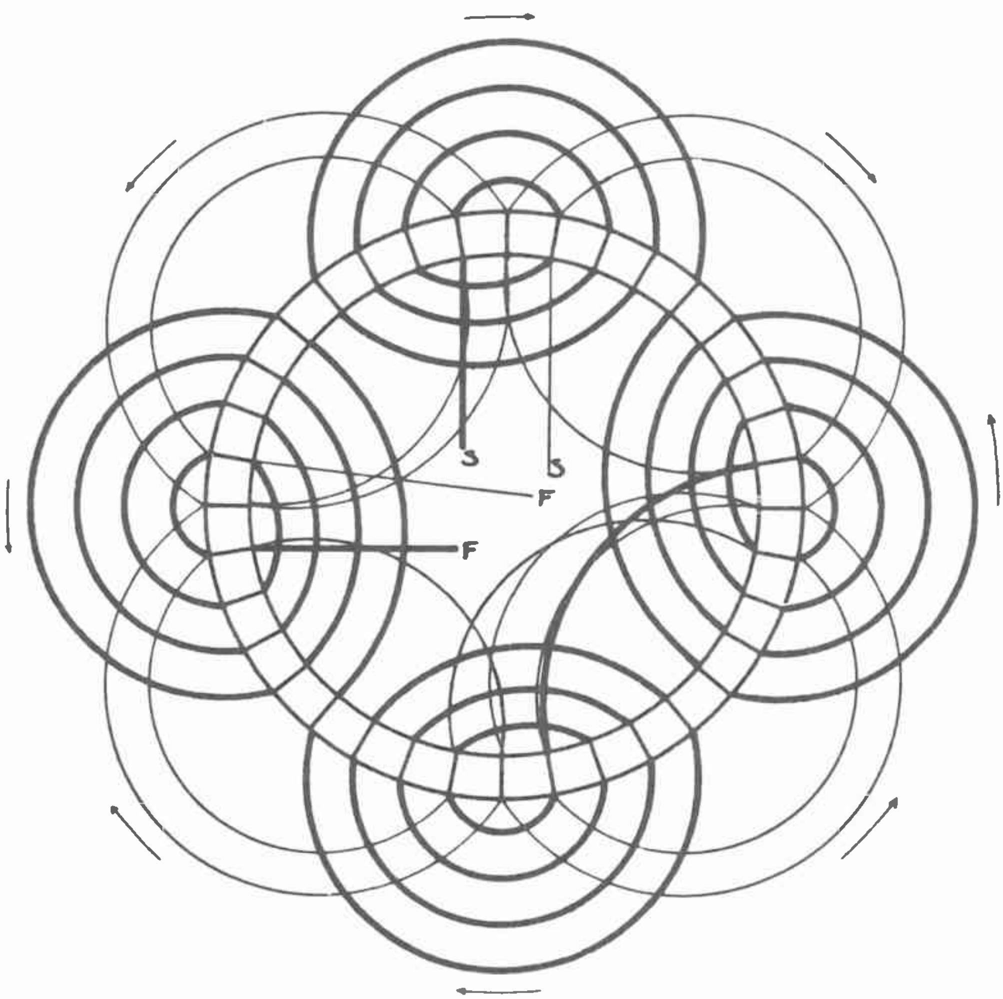
Regardless of the type of single-phase motor, when a series or parallel connection of any winding is necessary, proceed as follows:

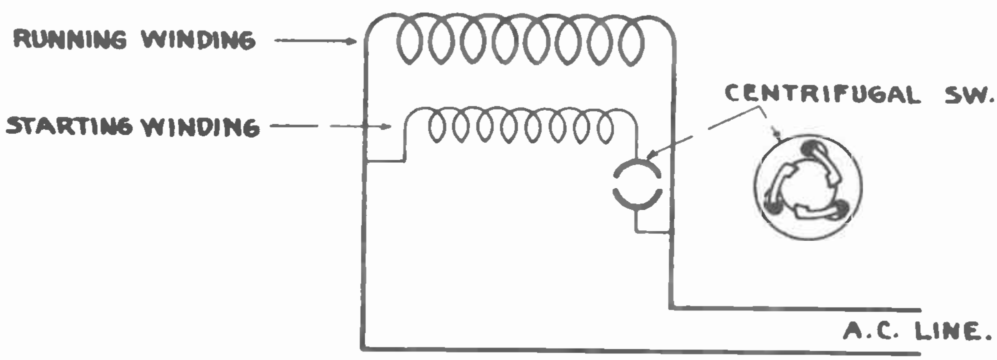
Divide single winding into two halves and assign T_1T_2 to one half and T_3T_4 to other half of running winding. Assign T_5T_6 to one half and T_7T_8 to other half of starting or reversing winding. This is shown diagrammatically in the opposite column.



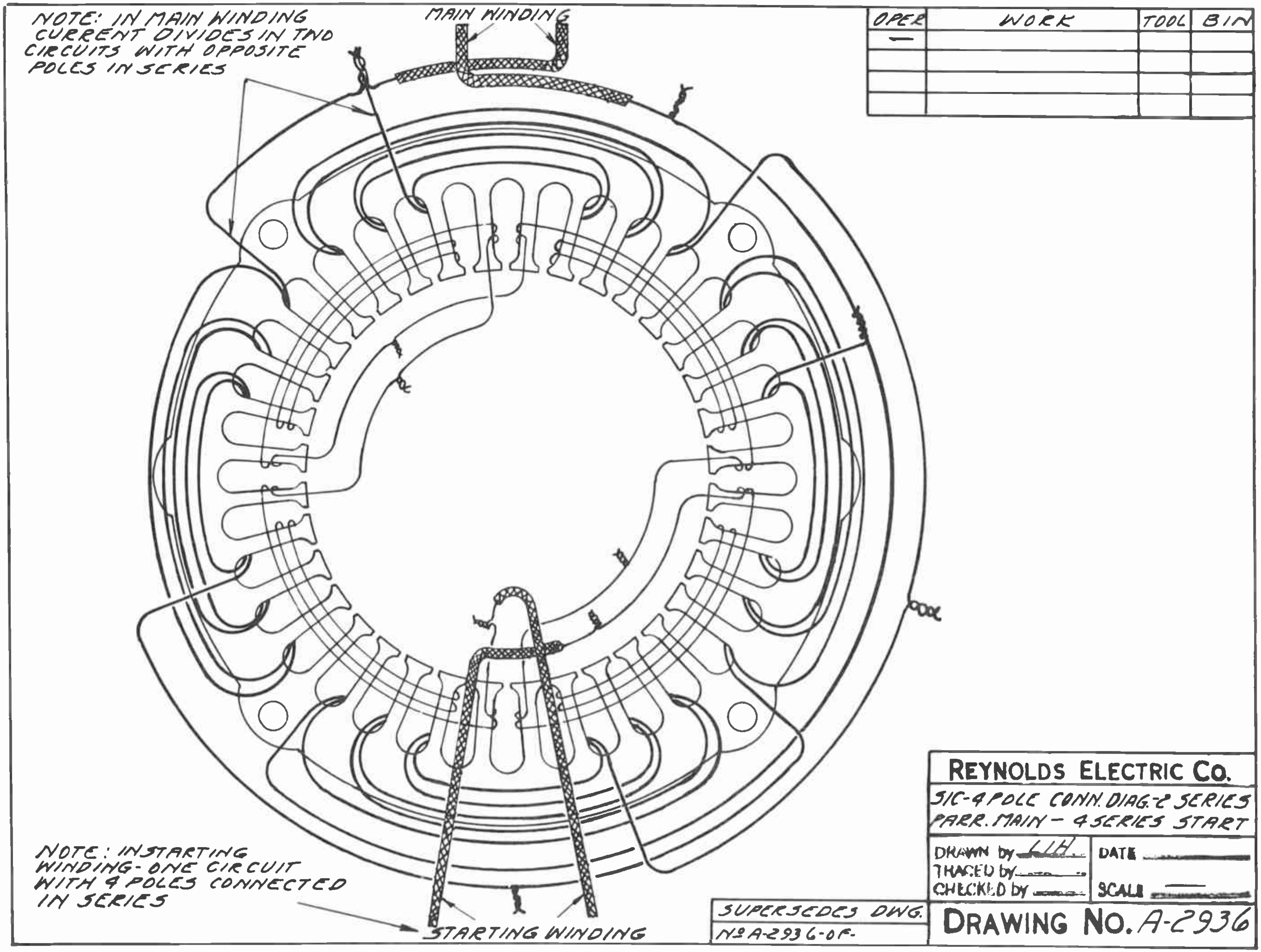
SPIRAL TYPE WINDING USED IN SINGLE PHASE SPLIT PHASE MOTORS

SLOTS = 36 POLES = 4





COYNE.

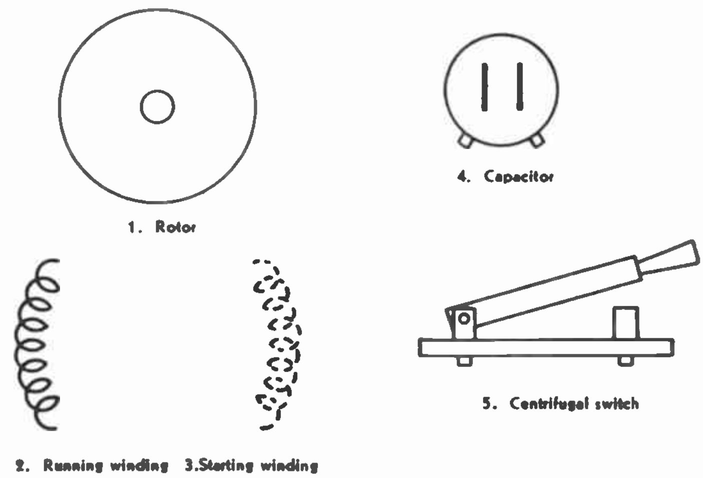

NOTE: IN MAIN WINDING CURRENT DIVIDES IN TWO CIRCUITS WITH OPPOSITE POLES IN SERIES
MAIN WINDING
OPER
WORK
TOOL
BIN
NOTE: IN STARTING WINDING - ONE CIRCUIT WITH 4 POLES CONNECTED IN SERIES
STARTING WINDING
SUPERSEDES DWG. Nº A-2936-OF-
REYNOLDS ELECTRIC CO.
SIC-4 POLE CONN. DIAG. 2 SERIES PARR. MAIN - 4 SERIES START
DRAWN by LIH.
TRACED by
CHECKED by
DATE
SCALE
DRAWING NO. A-2936

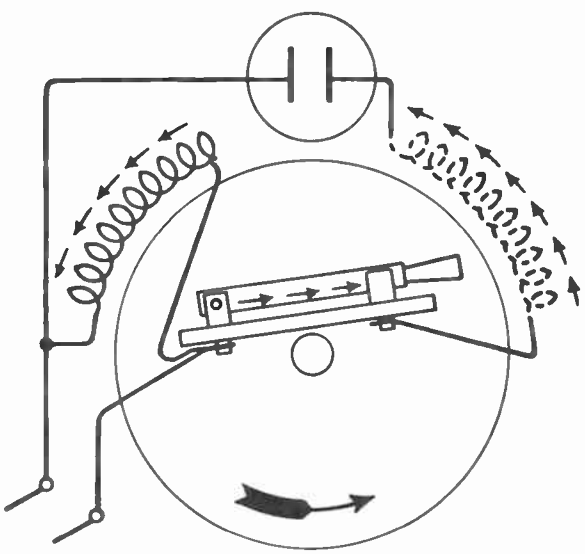
What Is a Capacitor-motor?

A CAPACITOR-MOTOR is a single-phase motor that has a capacitor (condenser) connected in one of its windings. The few and simple parts of this motor are shown schematically at the right.

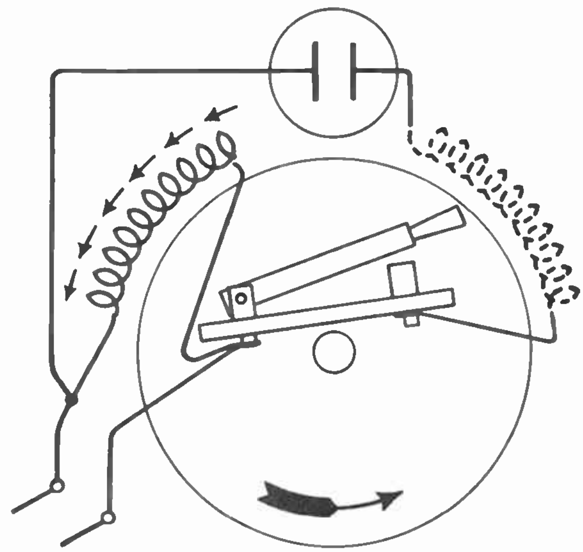
The arrangement of these parts is shown below. The two windings are in different sectors around the stator. The starting winding, the capacitor, and the centrifugal switch are connected in series. The centrifugal switch is mounted on the rotor and is set to open at a predetermined speed.

When power is applied, current flows in the direction shown by the red lines and arrows.





The phase displacement, set up by the capacitor, of the currents in the starting and running windings, together with their physical displacement on the stator, produces a rotating magnetic field that starts the rotor revolving

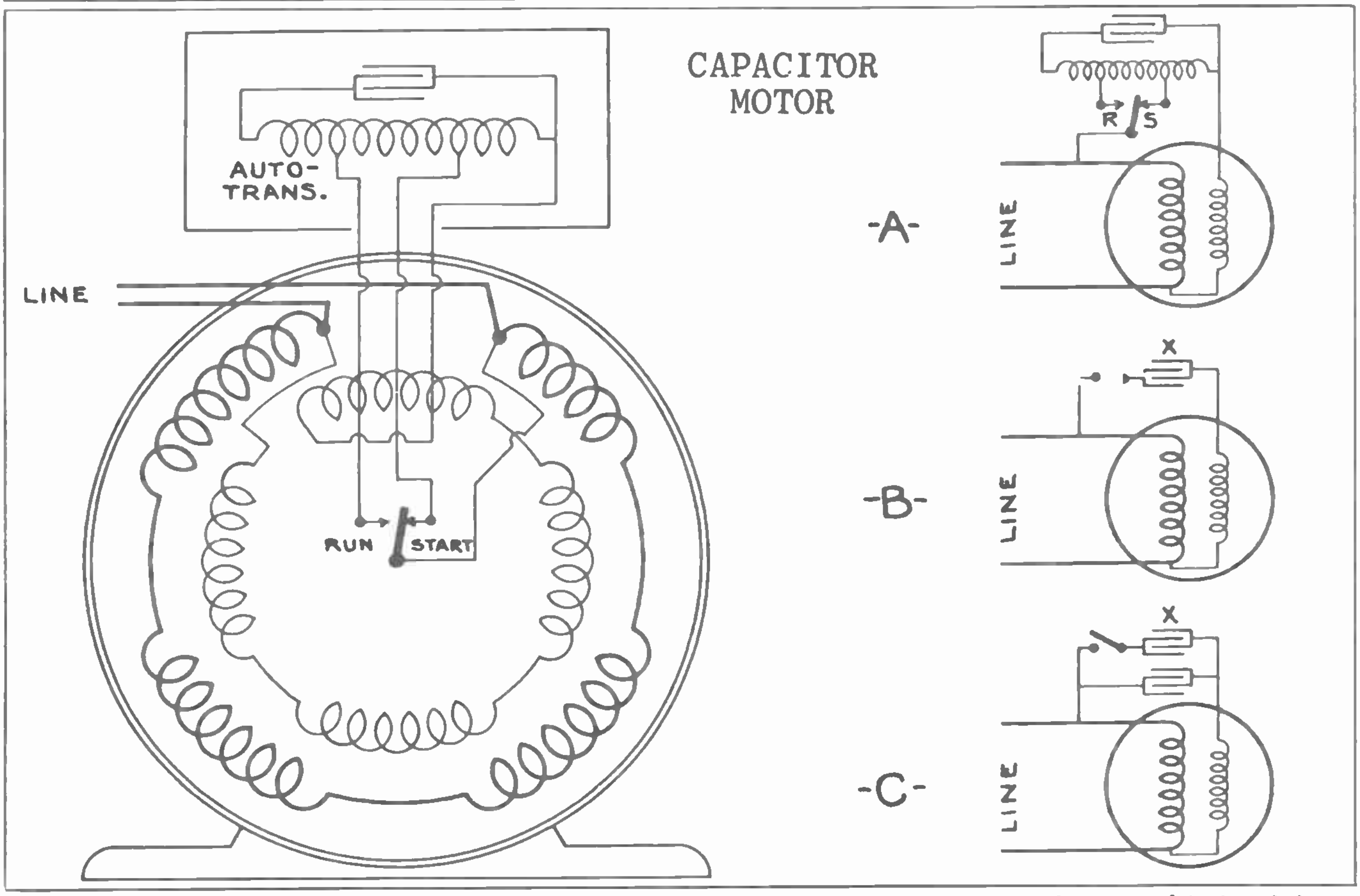


When the rotor reaches a predetermined speed, the centrifugal switch opens the starting-winding circuit. Current flows only in the running winding, and the motor operates the same as an ordinary induction motor

Why Capacitor-motors Are Used

Some machines require more torque (effort) to start them than the resistance split-phase motor can provide. The capacitor-motor is designed for these applications and differs from the resistance split-phase motor chiefly in that it has a capacitor connected in series with the starting winding.

The use of the capacitor gives the motor a high starting torque with low starting current without sacrifice of the advantages of the resistance split-phase motor. Occasional oiling depending upon conditions of motor service, is the only attention required. Motor operation does not interfere with radio reception. Capacitor-motors have become the accepted drive for domestic refrigerators, and for stokers and similar devices in which long life, minimum servicing, and quiet operation are of paramount importance.



The above motor is a split-phase type, the phase-splitting action being obtained by the insertion of a condenser in series with the starting winding. This motor starts and runs as a two-phase motor. The auto transformer connected across the condenser applies a comparatively high voltage to the condenser, thereby giving a higher capacity effect, and making possible the use of a smaller condenser than would otherwise be necessary.

During starting the centrifugally-operated switch is in the "start" position. This applies about 500 volts to the condenser, giving a high capacity effect and producing a comparatively high starting torque. When the motor has reached about 75% of normal full speed, the switch is thrown over to the "run" position, applying about 350 volts to the condenser, thereby reducing its capacity effect to a value which will maintain a high power factor during operation.

This motor will develop approximately 4 times normal full load torque with 7 times normal full load current. Compared with the repulsion-start-induction motor, the capacitor motor has a lower starting torque and a much higher starting current, about the same full load efficiency and a higher full load power factor. For equal rating, capacitor motors cannot stand as long a starting period as the repulsion type. Capacitor motors are widely used in household refrigeration and may be used where repulsion-start-induction motors are applicable, except where very high starting torque and long starting periods are involved in which case the repulsion-start-induction motor is used.

The small diagrams, A, B and C, on the right are schematic diagrams of capacitor motors. "A" is the circuit for the large diagram, (capacitor start, capacitor run motor) while "B" and "C" represent two other types which do not use an auto transformer. "B" uses a condenser on starting only, while "C" uses two condensers on starting, while only one remains in the circuit when running.

The electrolytic type of condenser is used on condenser-start motors only. This type of condenser must not be left in the circuit for more than 3 or 4 seconds, if condenser breakdown is to be avoided. Condensers marked "X" may be electrolytic, but the others shown must be the metal foil and paper type.

Capacitor MOTORS

for Alternating Current Only

APPLICATION AND PERFORMANCE DATA

Application—Although it has not yet challenged the supremacy of the split-phase motor, the capacitor motor is rapidly gaining in popularity as a general purpose single-phase fractional horsepower motor. It is used for applications similar to those in which split-phase motors are used and because of several important advantages is often preferred despite its small additional cost.

Fig. 1—The Type NCI-34 Capacitor motor, one of a number of different sizes, built by Bodine. Capacitor unit mounted on top of motor.

Capacitor motors are particularly well adapted to household appliances where public utilities limitations covering low starting current and freedom from radio interference must be met. They are especially desirable where low noise level is required and are finding increased use wherever a general purpose motor, capable of smooth quiet operation, good efficiency, and low starting current, is required.

There are several types of capacitor motors, each having characteristics which make it particularly favorable for a given type of application. Capacitor motors are frequently used where absolute reliability is required, as for example on control apparatus and airways beacons. Another type, the capacitor start motor, is particularly advantageous where high starting torques must be obtained, yet where the starting current must be kept quite low.

Characteristics—The principal characteristics of these two types of motors are tabulated below:

CAPACITOR MOTOR

1. **Extreme reliability.**
   No brushes or starting switches to give trouble under adverse service conditions.
2. **Quiet operation.**
   Favorable magnetic distribution minimizes vibrations of electrical origin.
3. **High power factor.**
   The power factor of capacitor motors, even at very light loads, is exceptionally good.
4. **Low starting torque.**
   Starting torque is generally somewhat less than 100% of full load torque.

CAPACITOR START MOTOR

1. **High starting torque.**
   An internal switch is used permitting the employment of a large capacitor of the electrolytic type during the starting period.

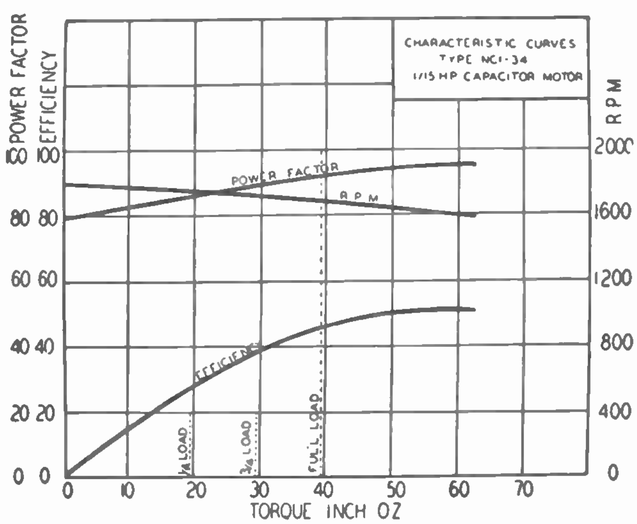


Fig. 2—Curves showing the performance of the Type NCI-34 Capacitor motor.

CAPACITOR MOTORS - Continued

2. Low starting current.

These motors are always preferable to split-phase motors where starting current limitations are made.

The capacitor motor, the first listed above, is sometimes known as a capacitor start and run motor, and has a capacitor permanently connected in series with one of the two windings. This acts to displace the current in one winding producing a revolving field which provides the motor with an initial starting torque and drives the unit much like a two-phase motor.

Since the capacitor motor has no centrifugal cutout switch it is preferred for installations where frequent starting is necessary. While cutout switches have been made as nearly trouble free as is mechanically possible, they still represent a potential source of trouble. By eliminating them, as in the capacitor motor, this source of trouble is removed.

Capacitor motors with capacitors in the circuit during the running period operate very quietly and without vibration. The pulsations which occur in a single-phase motor are eliminated by the smoother two-phase operation. Capacitor motors have a high power factor, especially at light loads, as compared with split-phase motors, and their efficiency is usually equally good.

Unfortunately, although these motors draw a small starting current they also have a low starting torque, generally no more than 75% of their full load torque. It is sometimes possible to modify the rotor construction in order to increase this starting torque, but in no case can it be made to equal that of the split-phase motor.

The starting torque can also be increased without an appreciable rise in the starting current by increasing the capacitance in the circuit, but this also results in a higher temperature rise which may not be permissible.

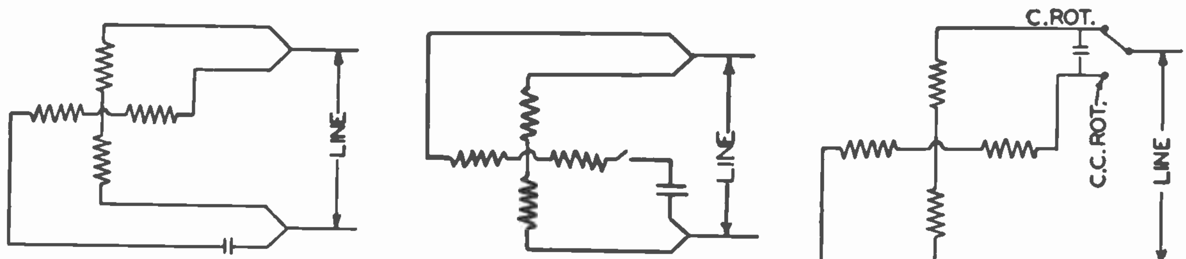
Where high starting torque is required, the capacitor start motor is frequently used. It has an internal starting switch to disconnect the capacitor from the circuit as normal running speed is approached. Since the capacitor is in the circuit only momentarily, high capacity electrolytic type condensers which are compact and inexpensive may be used. These cannot, however, be operated continuously as can the oil-filled type, and consequently are applicable only to motors with the internal starting switch.

Construction—Capacitor motors have frames and internal construction quite similar to that of all alternating current induction motors. Where electrolytic capacitors are employed, an internal cutout switch is utilized.

The rotor is of the usual squirrel cage type, except for capacitor synchronous motors which run at synchronous speeds. Information concerning motors of this type is given in another Bulletin.

The capacitor may be mounted directly on the motor as in the illustration, or at some distance from the motor. This latter arrangement is particularly desirable where space is limited, or where the capacitor does not require the use of a heavy metal protecting case.

Complete details on the internal construction of capacitor motors will be found in Bulletins describing the several motor frame types.



(a) 4 LEAD REVERSIBLE CAPACITOR (b) 4 LEAD REVERSIBLE CAPACITOR START (c) 3 LEAD REVERSIBLE CAPACITOR

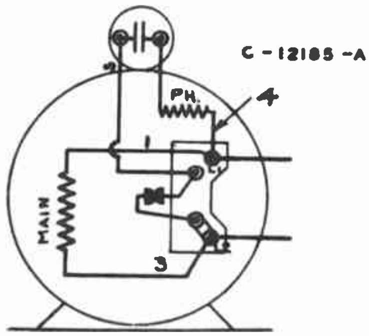
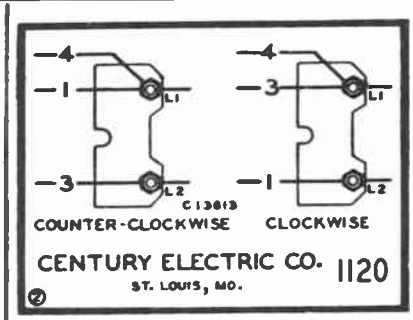
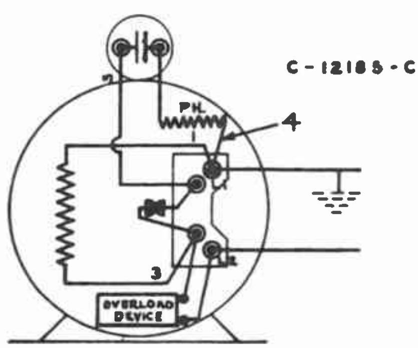
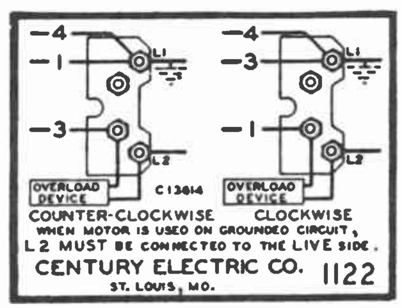
Fig. 3—Three frequently used arrangements for the internal connection of Capacitor motors. A number of others, for use on special applications may be provided.

Century

ENGINEERING INFORMATION

CAPACITOR START INDUCTION MOTORS

TYPES CSH & CSX; * 110 VOLTS; REVERSIBLE

<table>
<tr><th>Location of Terminals</th><th>* Frames</th><th>Internal Connection Diagrams (Counter Clockwise Rotation)</th><th>Label (Attached To Cover Over Terminals)</th></tr>
<tr><td colspan="4">WITHOUT OVERLOAD PROTECTION</td></tr>
<tr><td>In Front Bracket</td><td>63G, 65G, 67G, 65L 67L</td><td></td><td></td></tr>
<tr><td>In Frame</td><td>71, 73, 81, 83, 91, 93</td><td>Standard Construction is Dual Voltage (See Page 7)</td><td></td></tr>
<tr><td colspan="4">WITH OVERLOAD PROTECTION</td></tr>
<tr><td>In Front Bracket</td><td>63G, 65G, 67G, 65L, 67L</td><td></td><td></td></tr>
<tr><td>In Frame</td><td>71, 73, 81, 83, 91, 93</td><td>Standard Construction is Dual Voltage (See Page 7)</td><td></td></tr>
</table>

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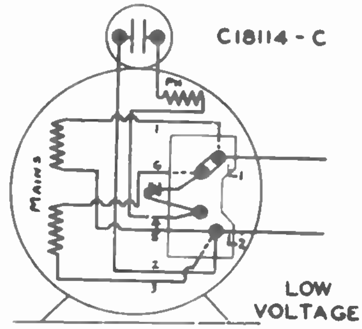
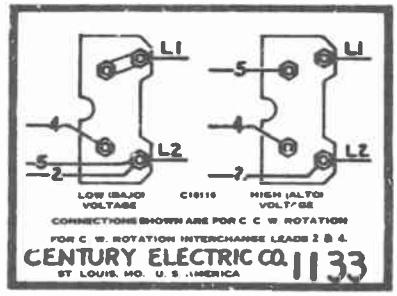
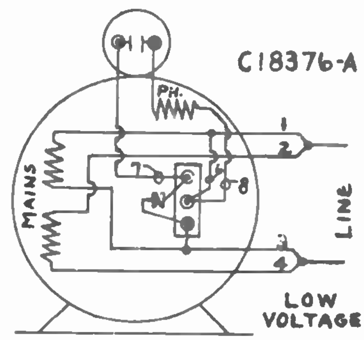
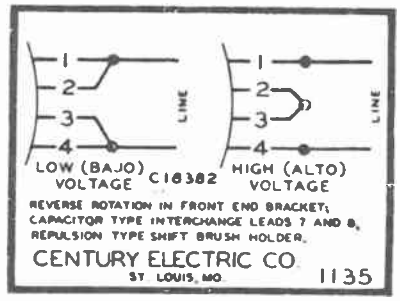
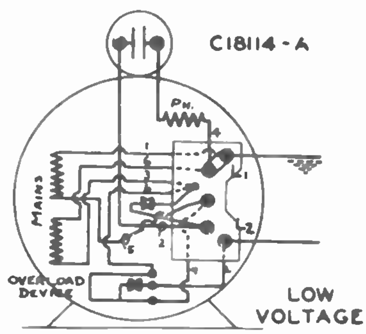
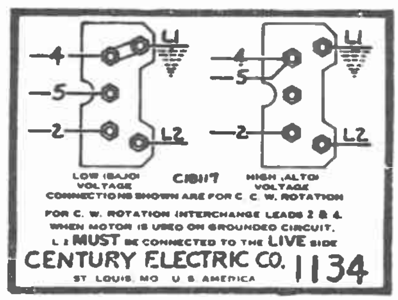
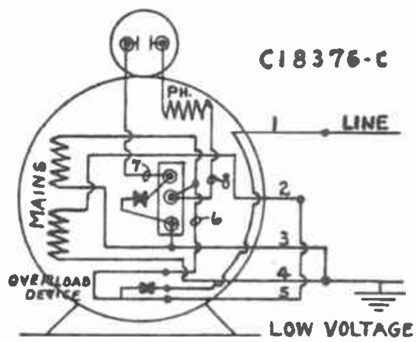
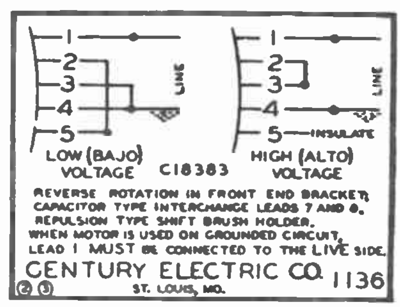
ENGINEERING INFORMATION

CAPACITOR START INDUCTION MOTORS

TYPES CSH & CSX; * 110/220 VOLTS; REVERSIBLE

Location of Terminals	* Frame	Internal Connection Diagrams (Counter Clockwise Rotation)	Label (Attached To Cover Over Terminals)
WITHOUT OVERLOAD PROTECTION			
In Front Bracket	63G, 65G, 67G, 65L, 67L		
In Frame	71, 73, 81, 83, 91, 93		
WITH OVERLOAD PROTECTION			
In Front Bracket	63G, 65G, 67G, 65L 67L		
In Frame	71, 73, 81, 83, 91, 93		

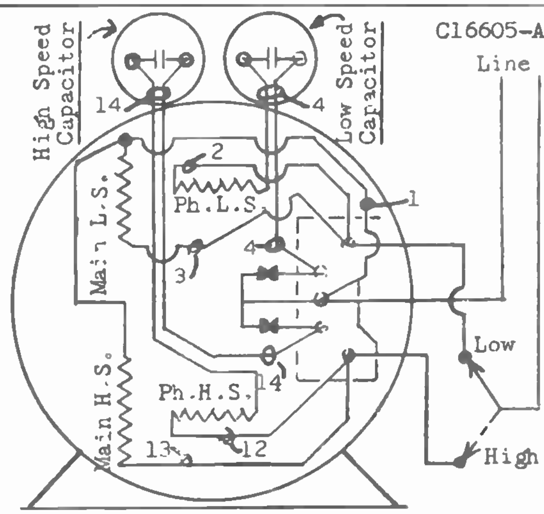
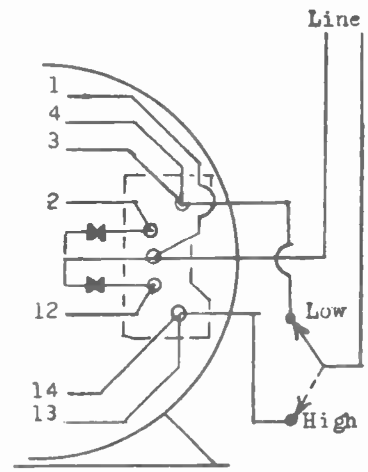
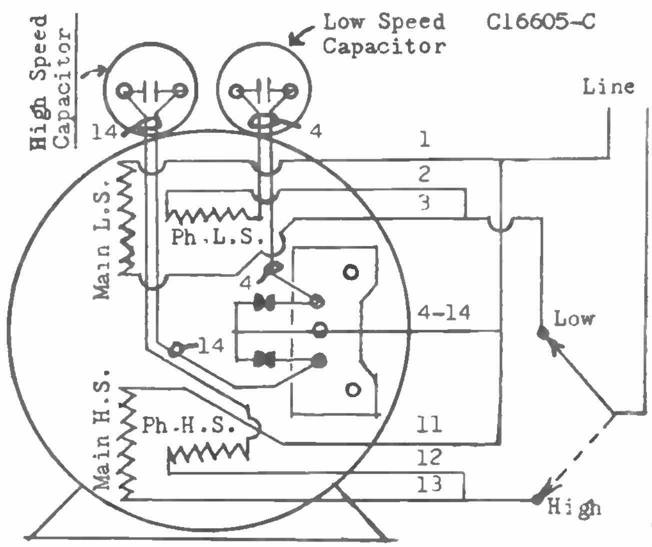
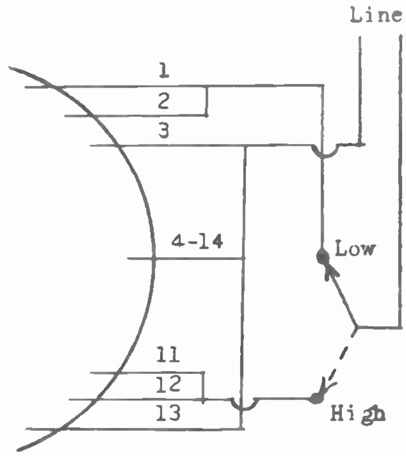
ENGINEERING INFORMATION

SPLIT PHASE AND CAPACITOR START INDUCTION MOTORS

"3 LEAD" TWO SPEED - REVERSIBLE - TWO WINDING

CONSTANT OR VARIABLE TORQUE

TYPES CSXM - 110 V; SPM▲ 110 OR 220 V*

LOCATION OF TERMINALS	FRAME	INTERNAL CONNECTION DIAGRAMS — COUNTER CLOCKWISE ROTATION	INTERNAL CONNECTION DIAGRAMS — CLOCKWISE ROTATION
		WITHOUT OVERLOAD PROTECTION	
Bracket	63G 65G 67G 65L 67L		
Frame	71 73 81 88 91 93 204		

▲ - SPM do not have Capacitor; otherwise same diagram applies

* - See price sheets for standard voltage and horsepower for individual frames.

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ENGINEERING INFORMATION

CONNECTION PLATES FOR MULTI-SPEED MOTORS

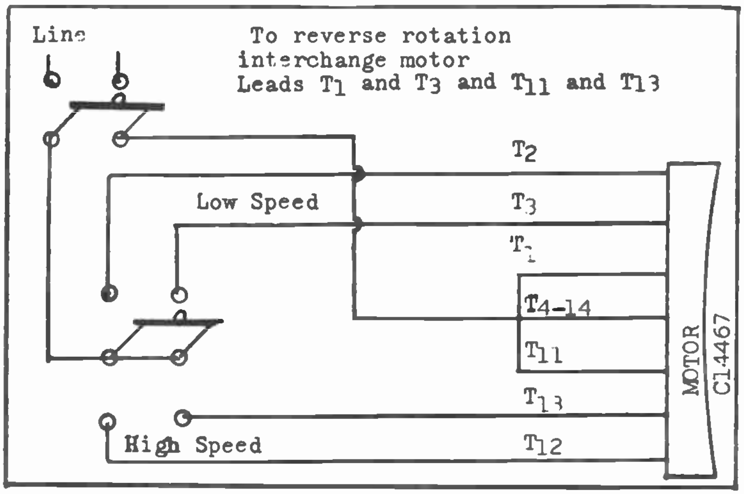
2 SPEED 2 WINDING

CONSTANT OR VARIABLE TORQUE

TYPES CPXM - CPHM

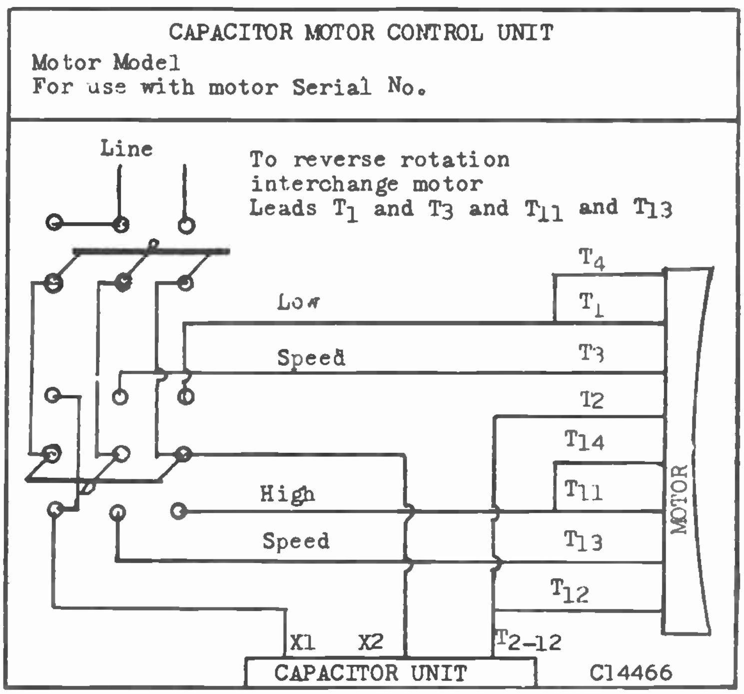
1 PHASE

Capacitor unit mounted on motor.



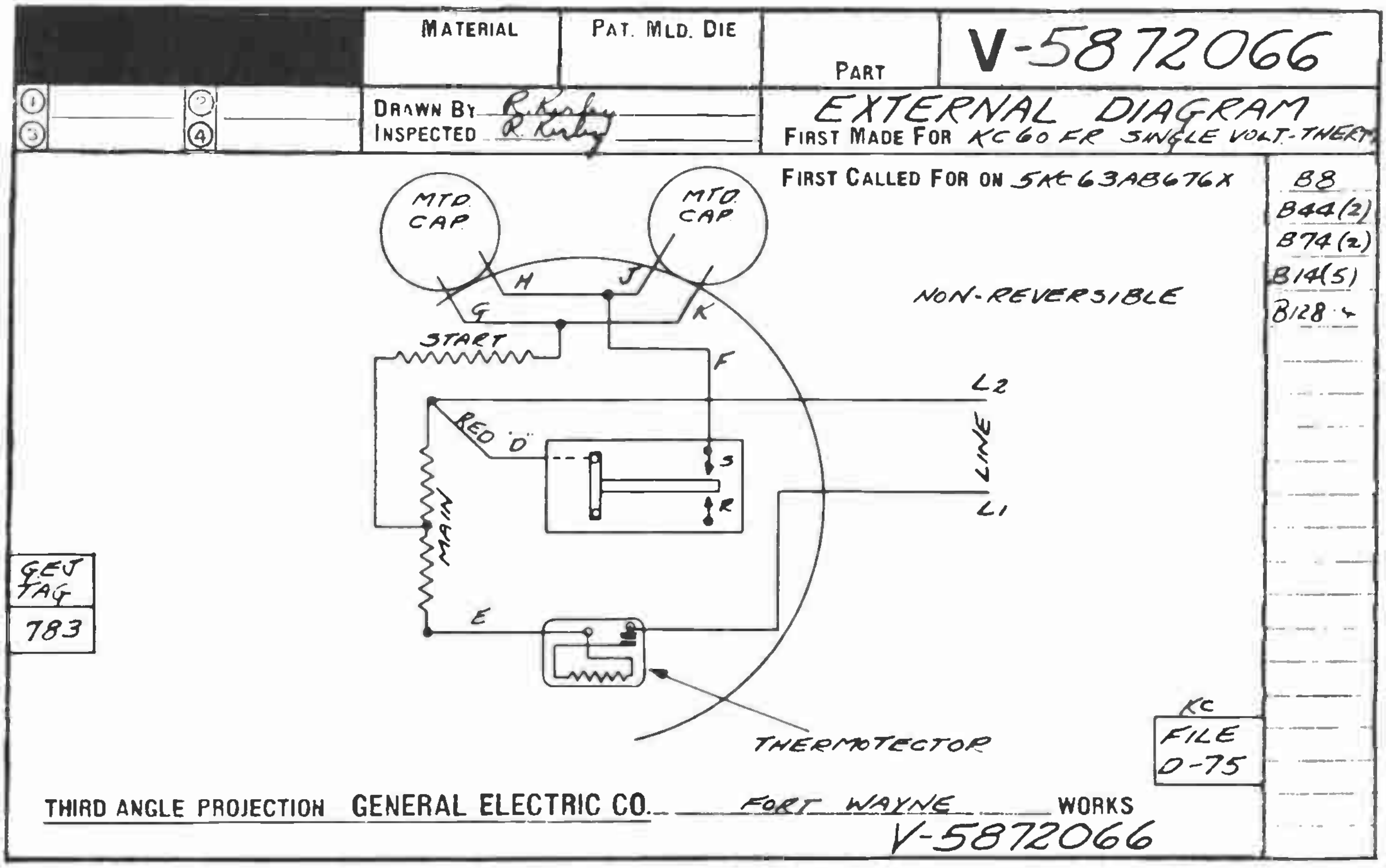
Similar to C14467

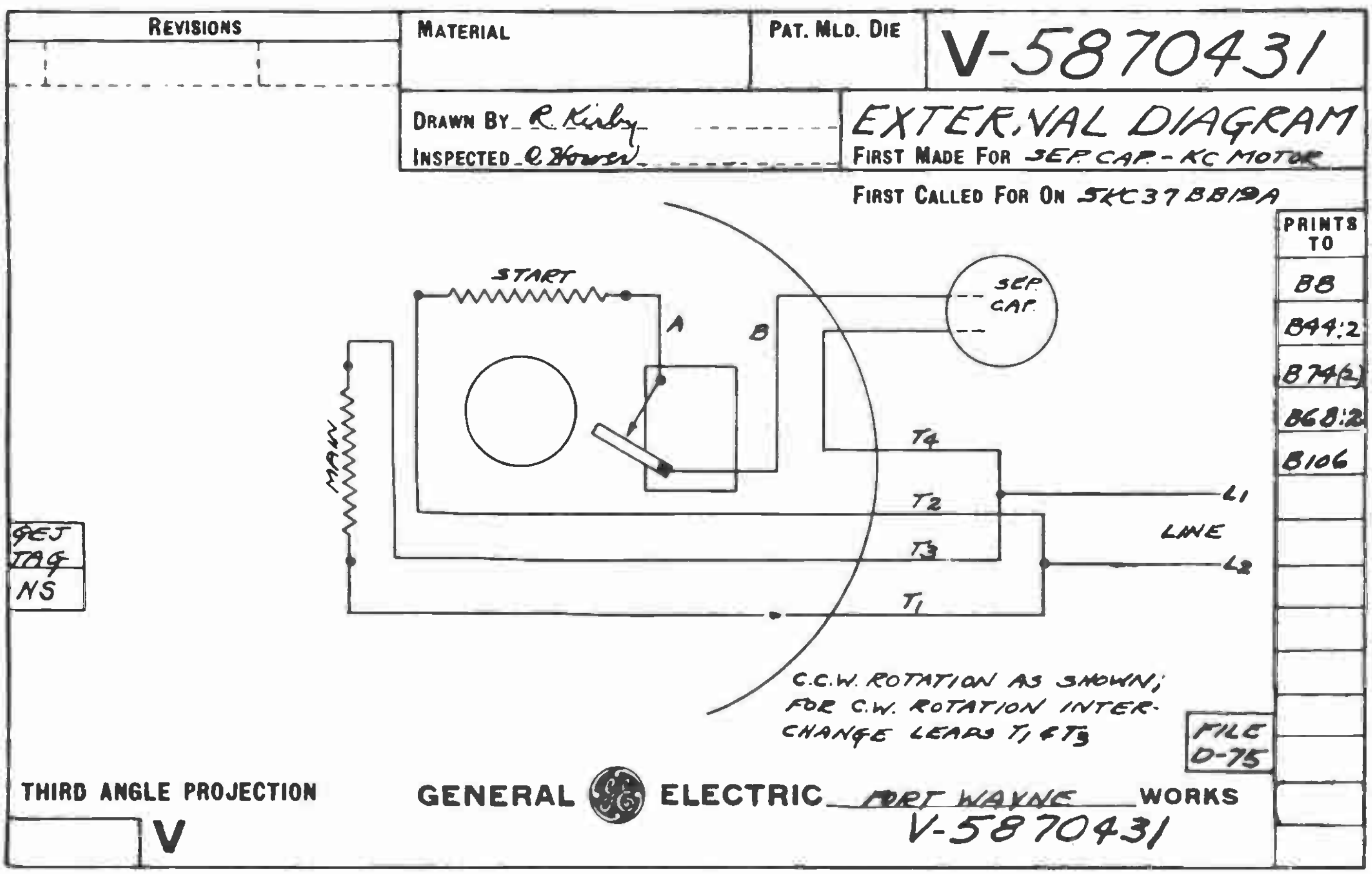
Motor with separate Capacitor unit and relay.

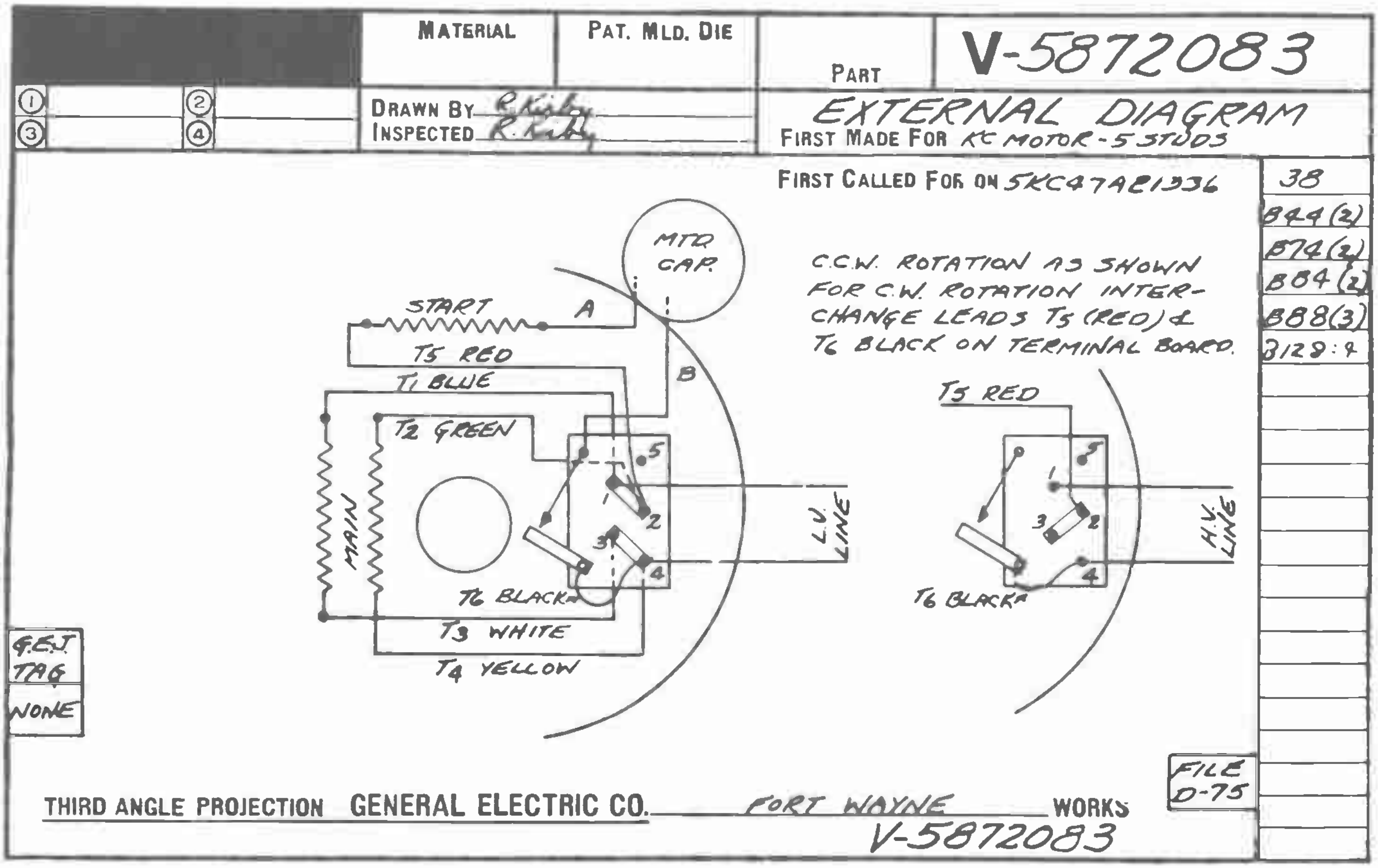


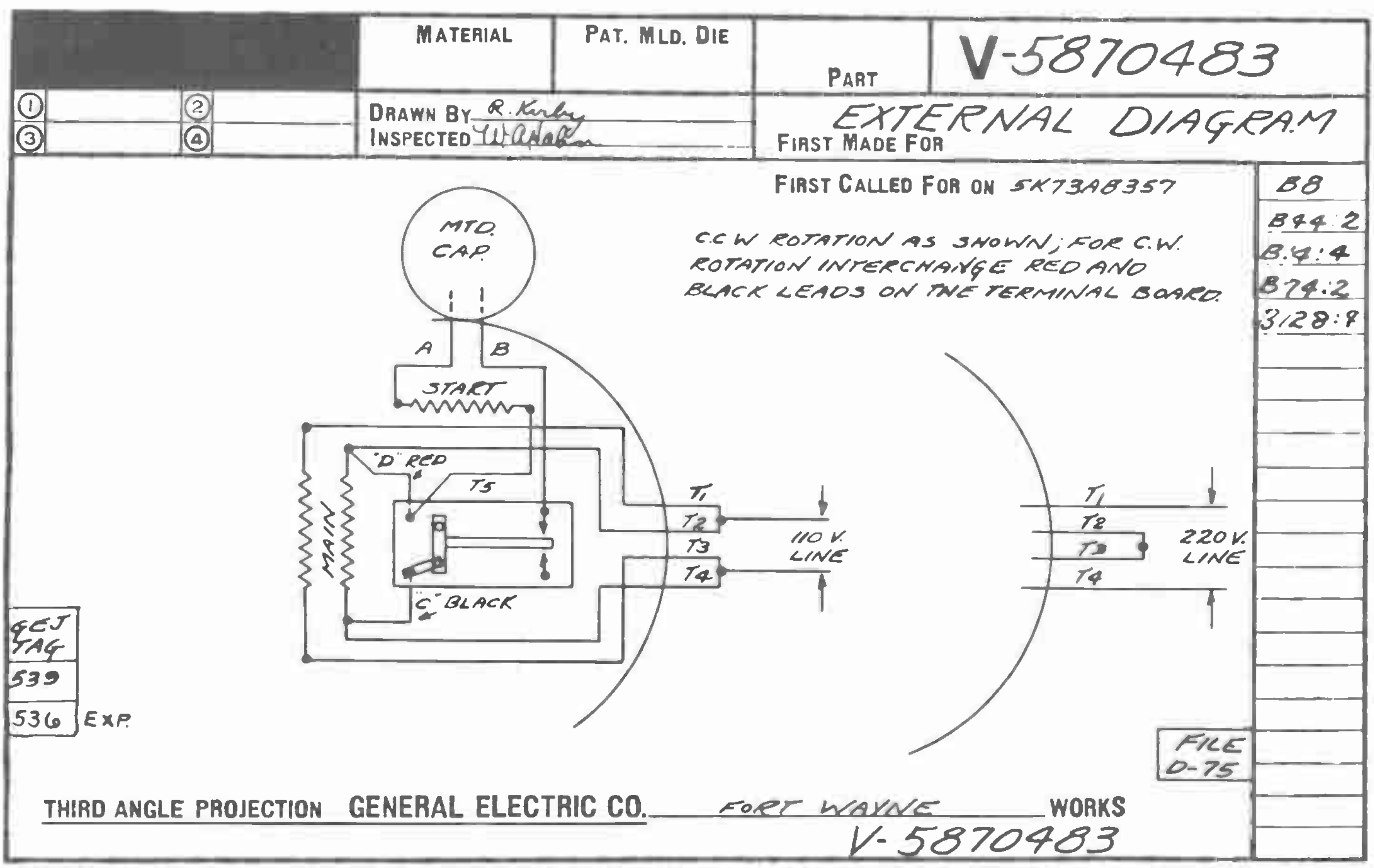
Similar to C14466

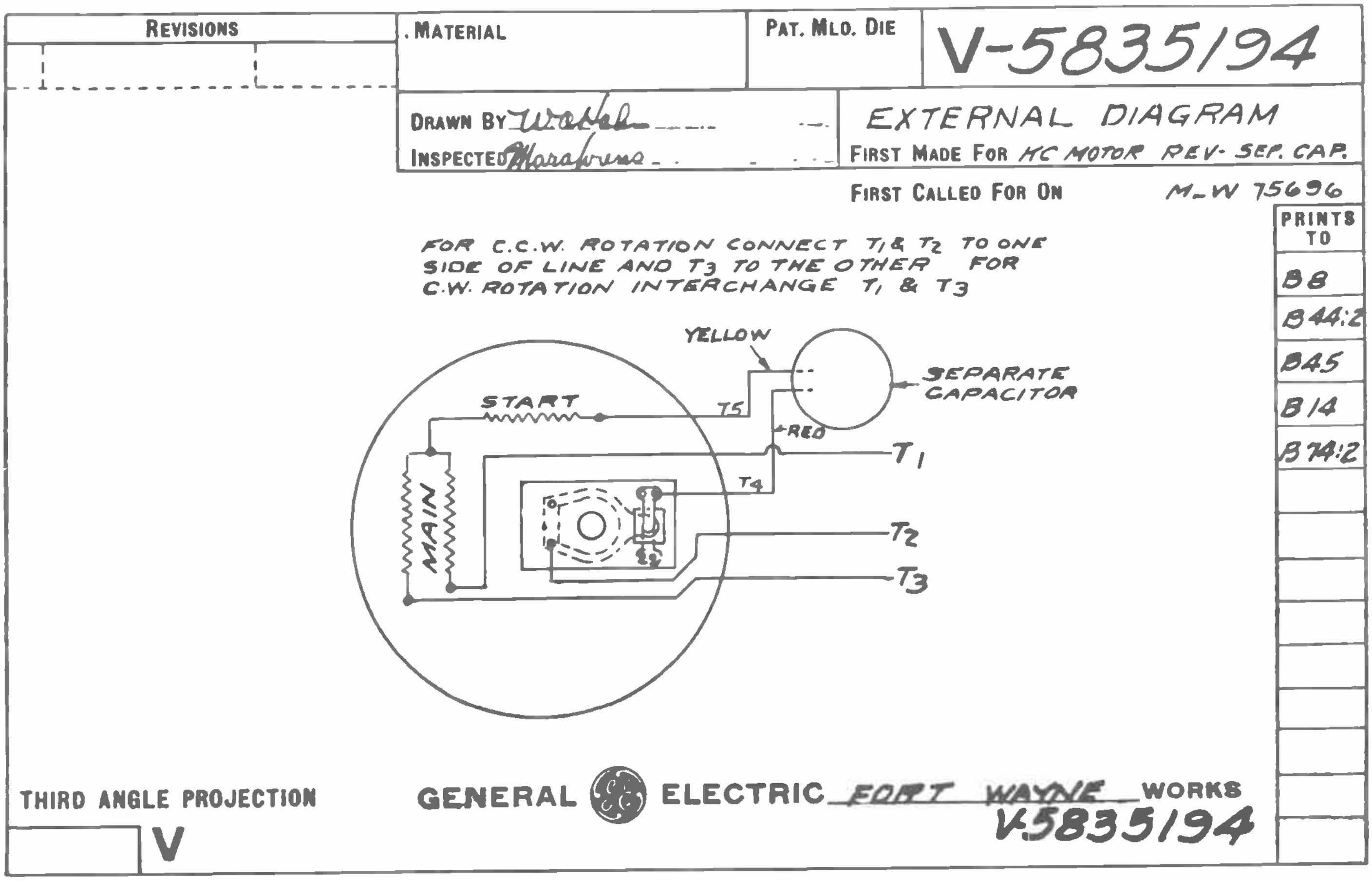
These diagrams are similar to the plates attached to motors when they leave the factory.

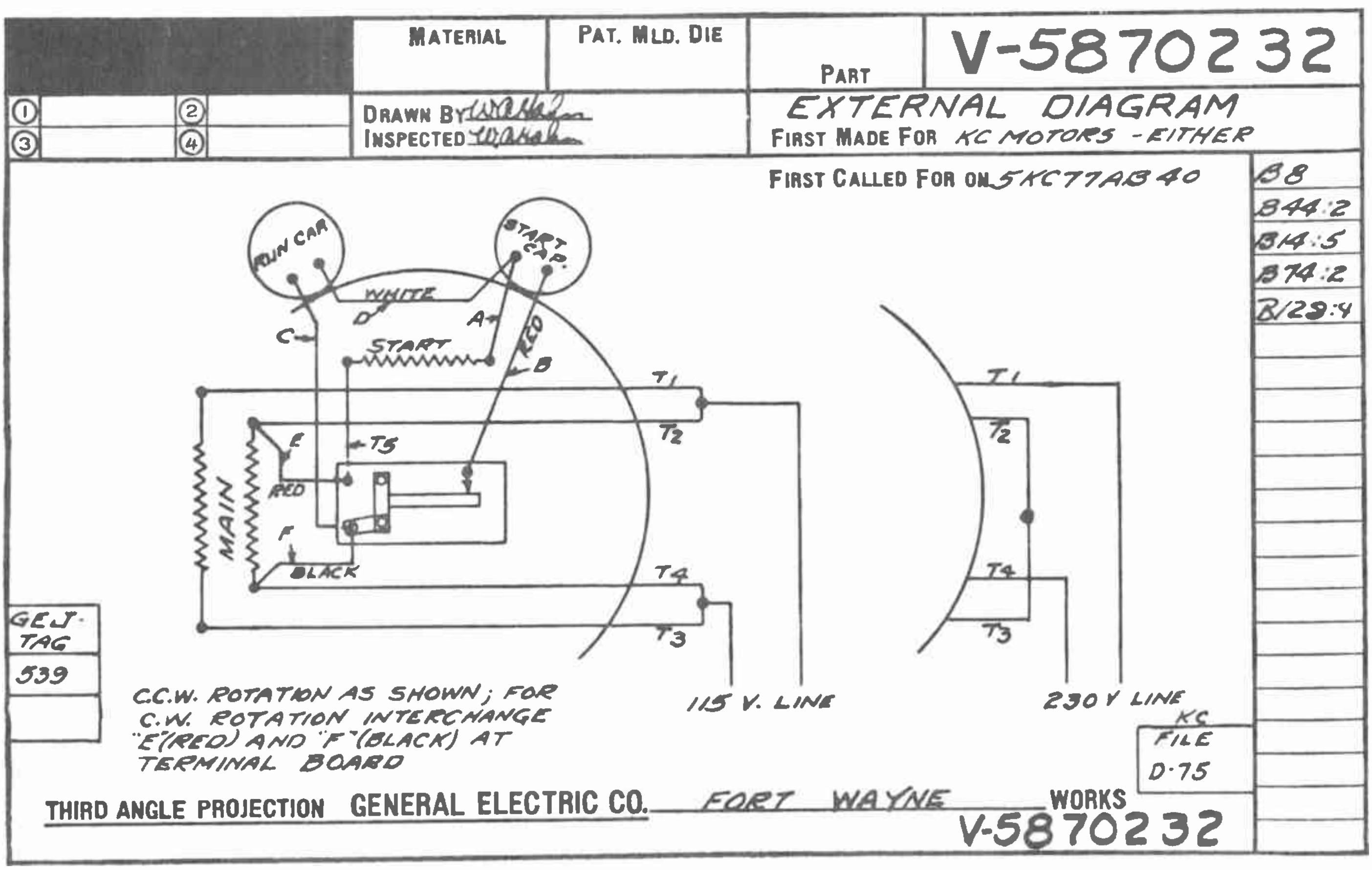

MATERIAL
PAT. MLD. DIE
PART
V-5872066
DRAWN BY R. Kirby
INSPECTED R. Kirby
EXTERNAL DIAGRAM
FIRST MADE FOR KC 60 FR SINGLE VOLT-THERM.
FIRST CALLED FOR ON 5KC63AB676X
B8
B44(2)
B74(2)
B14(5)
B128
MTD. CAP
MTD. CAP
G
H
J
K
START
F
NON-REVERSIBLE
L2
LINE
L1
RED 'D'
S
R
MAIN
E
GEJ TAG
783
THERMOTECTOR
KC FILE D-75
THIRD ANGLE PROJECTION
GENERAL ELECTRIC CO.
FORT WAYNE
WORKS
V-5872066

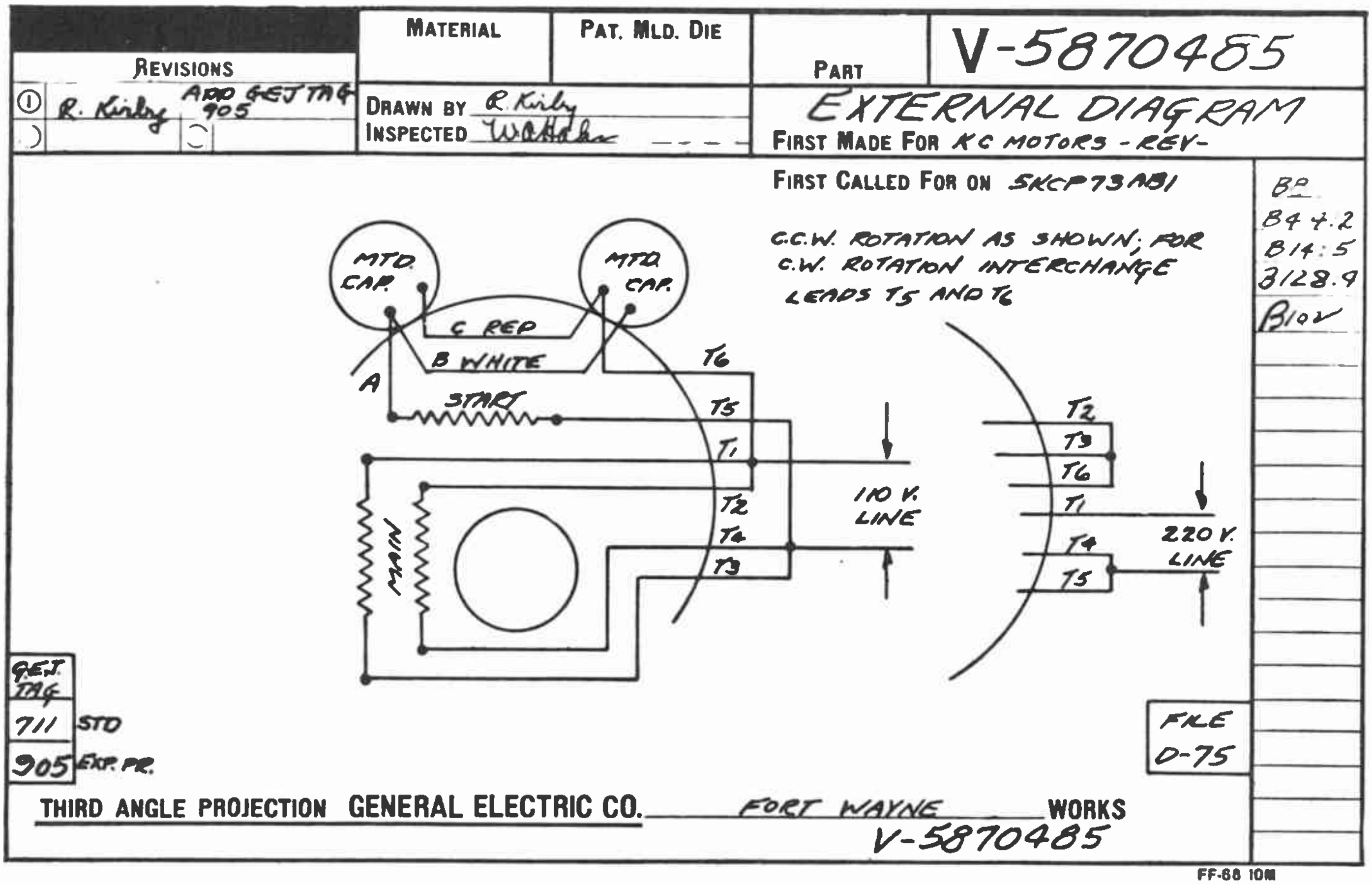

REVISIONS
MATERIAL
PAT. MLD. DIE
V-5870431
DRAWN BY R. Kirby
INSPECTED C. Shower
EXTERNAL DIAGRAM
FIRST MADE FOR SEP. CAP. - KC MOTOR
FIRST CALLED FOR ON 5KC37BB19A
PRINTS TO
B8
B44:2
B74(2)
B68:2
B106
START
SEP. CAP.
A
B
MAIN
T4
T2
T3
T1
L1
LINE
L2
GEJ TAG
NS
C.C.W. ROTATION AS SHOWN;
FOR C.W. ROTATION INTER-
CHANGE LEADS T1 & T3
FILE D-75
THIRD ANGLE PROJECTION
GENERAL ELECTRIC
FORT WAYNE
WORKS
V
V-5870431


MATERIAL
PAT. MLD. DIE
PART
V-5872083
DRAWN BY R. Kirby
INSPECTED R. Kirby
EXTERNAL DIAGRAM
FIRST MADE FOR KC MOTOR-5 STUDS
FIRST CALLED FOR ON 5KC47AB1336
38
B44(2)
B74(2)
B84(2)
B88(3)
3128:4
MTD CAP.
START
A
B
T5 RED
T1 BLUE
T2 GREEN
MAIN
T6 BLACK
T3 WHITE
T4 YELLOW
L.V. LINE
C.C.W. ROTATION AS SHOWN FOR C.W. ROTATION INTERCHANGE LEADS T5 (RED) & T6 BLACK ON TERMINAL BOARD.
H.V. LINE
G.E.J. TAG
NONE
FILE D-75
THIRD ANGLE PROJECTION
GENERAL ELECTRIC CO. FORT WAYNE WORKS
V-5872083

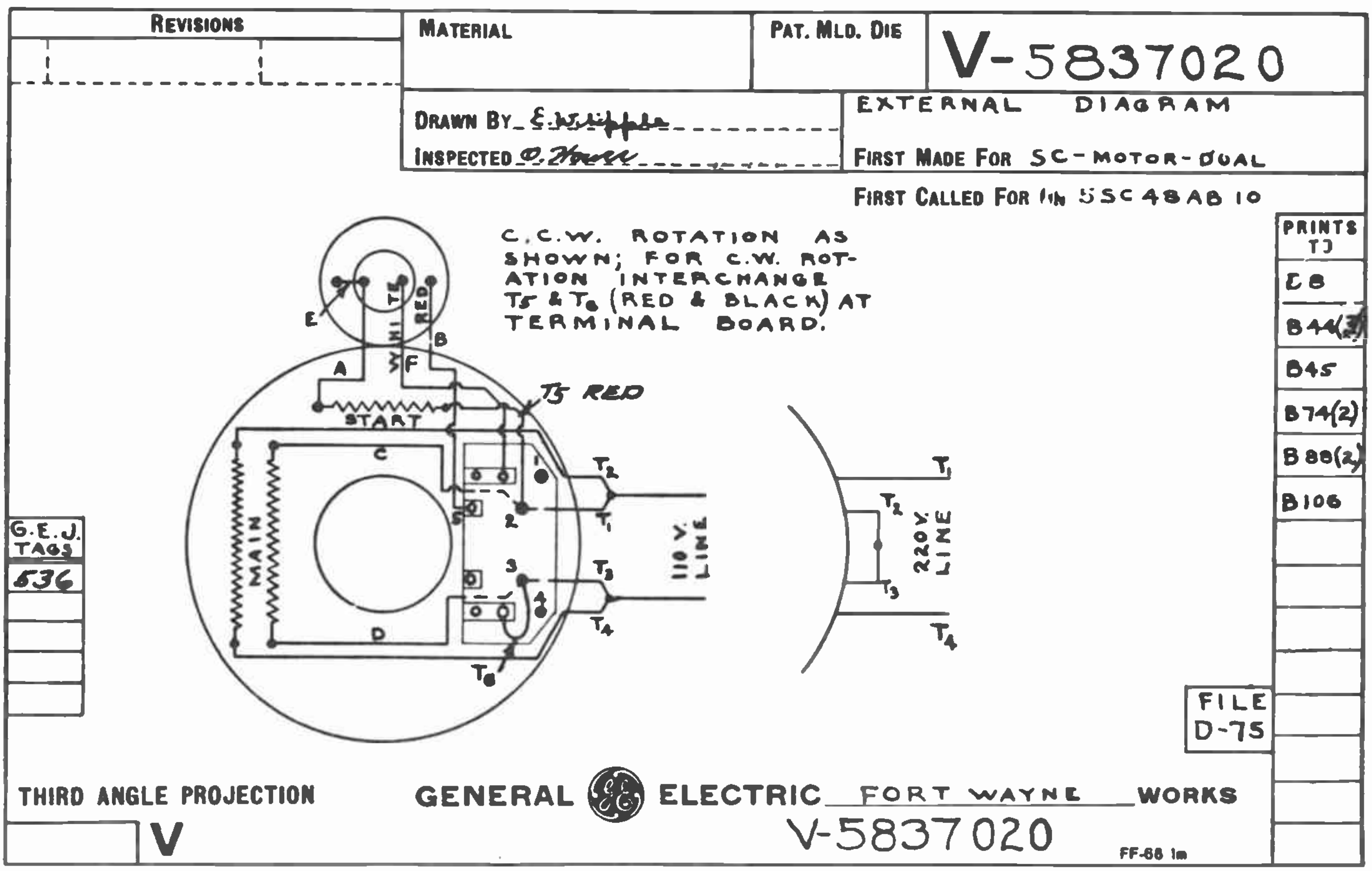

MATERIAL
PAT. MLD. DIE
PART
V-5870483
DRAWN BY R. Kirby
EXTERNAL DIAGRAM
FIRST MADE FOR
FIRST CALLED FOR ON 5K73AB357
B8
B44:2
B4:4
B74:2
3128:9
MTD. CAP.
A
B
START
"D" RED
T5
MAIN
"C" BLACK
T1
T2
T3
T4
110 V. LINE
220 V. LINE
C.C.W. ROTATION AS SHOWN; FOR C.W. ROTATION INTERCHANGE RED AND BLACK LEADS ON THE TERMINAL BOARD.
GEJ TAG
539
536 EXP.
FILE D-75
THIRD ANGLE PROJECTION
GENERAL ELECTRIC CO. FORT WAYNE WORKS
V-5870483


REVISIONS
MATERIAL
PAT. MLD. DIE
V-5835194
DRAWN BY
INSPECTED
EXTERNAL DIAGRAM
FIRST MADE FOR KC MOTOR REV- SEP. CAP.
FIRST CALLED FOR ON M-W 75696
PRINTS TO
B8
B44:2
B45
B14
B74:2
FOR C.C.W. ROTATION CONNECT T1 & T2 TO ONE SIDE OF LINE AND T3 TO THE OTHER FOR C.W. ROTATION INTERCHANGE T1 & T3
YELLOW
SEPARATE CAPACITOR
START
T5
RED
T1
T4
MAIN
T2
T3
THIRD ANGLE PROJECTION
V
GENERAL ELECTRIC FORT WAYNE WORKS
V-5835194

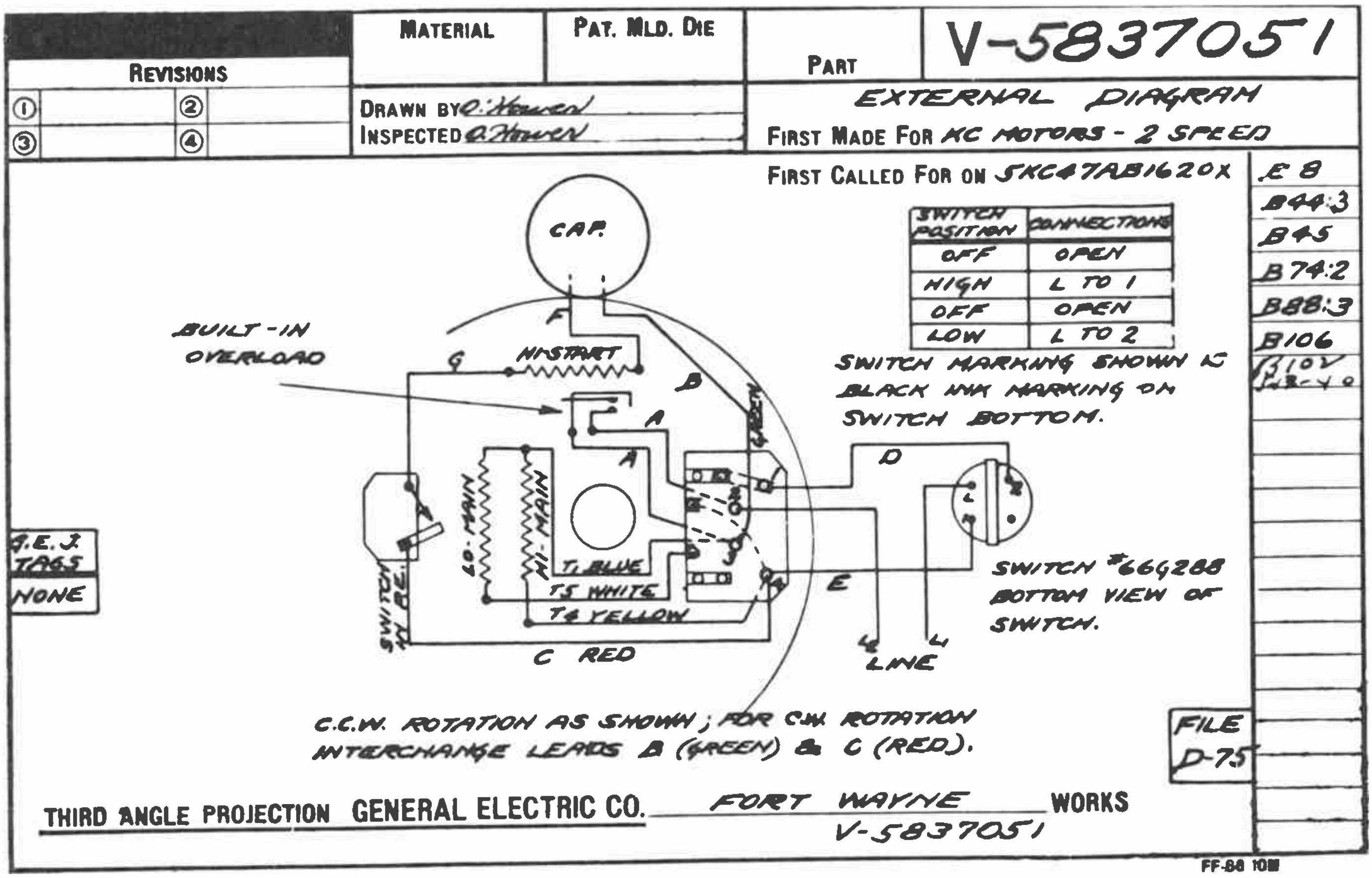

MATERIAL
PAT. MLD. DIE
PART
V-5870232
DRAWN BY
INSPECTED
EXTERNAL DIAGRAM
FIRST MADE FOR KC MOTORS -EITHER
FIRST CALLED FOR ON 5KC77AB40
B8
B44:2
B14:5
B74:2
B/29:4
RUN CAP
START CAP.
WHITE
D
A
C
START
RED
B
T1
T2
E
T5
RED
MAIN
F
BLACK
T4
T3
GE-J-TAG
539
C.C.W. ROTATION AS SHOWN; FOR C.W. ROTATION INTERCHANGE "E"(RED) AND "F"(BLACK) AT TERMINAL BOARD
115 V. LINE
230 V LINE
KC FILE D-75
THIRD ANGLE PROJECTION GENERAL ELECTRIC CO. FORT WAYNE WORKS
V-5870232

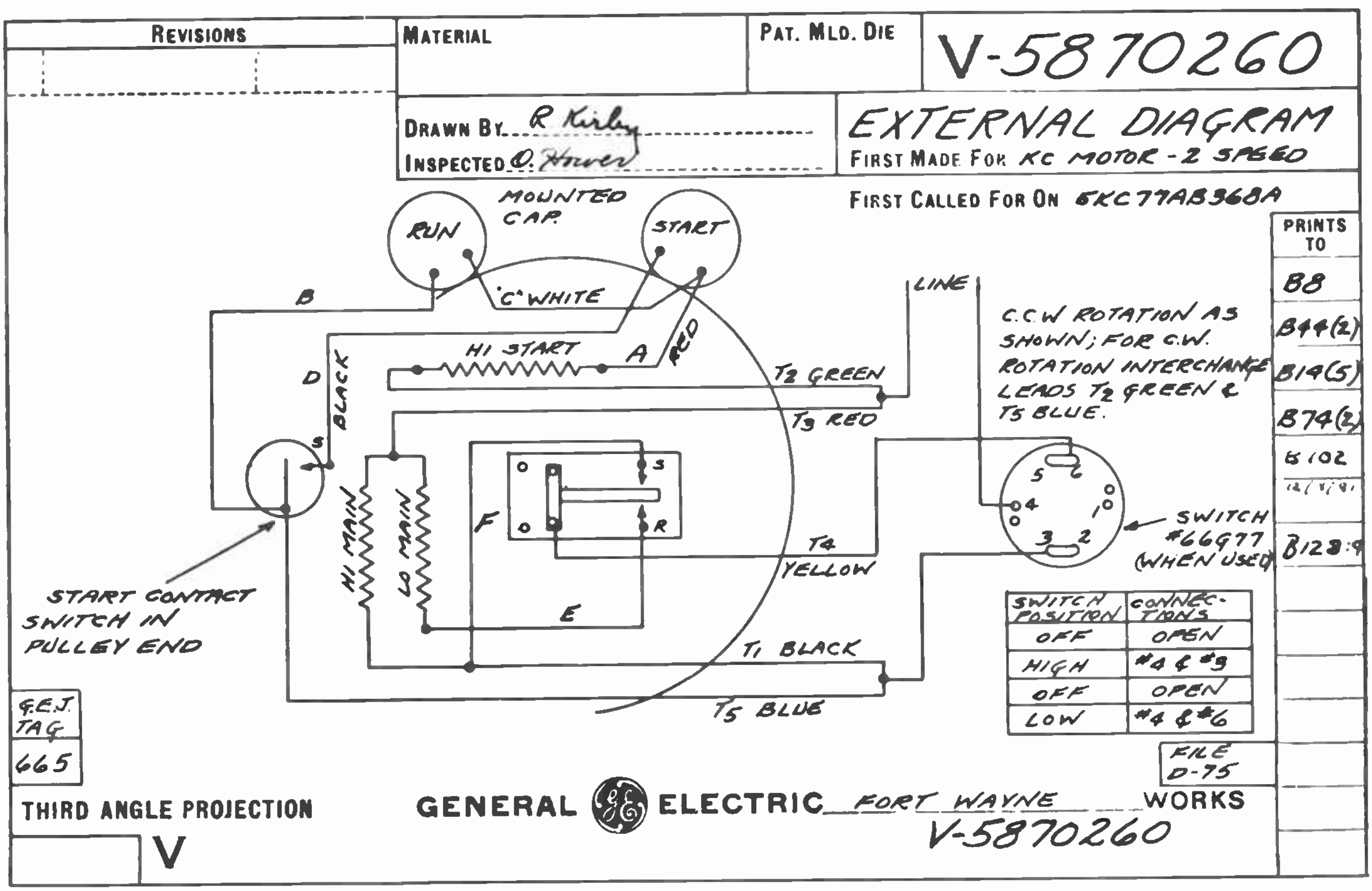


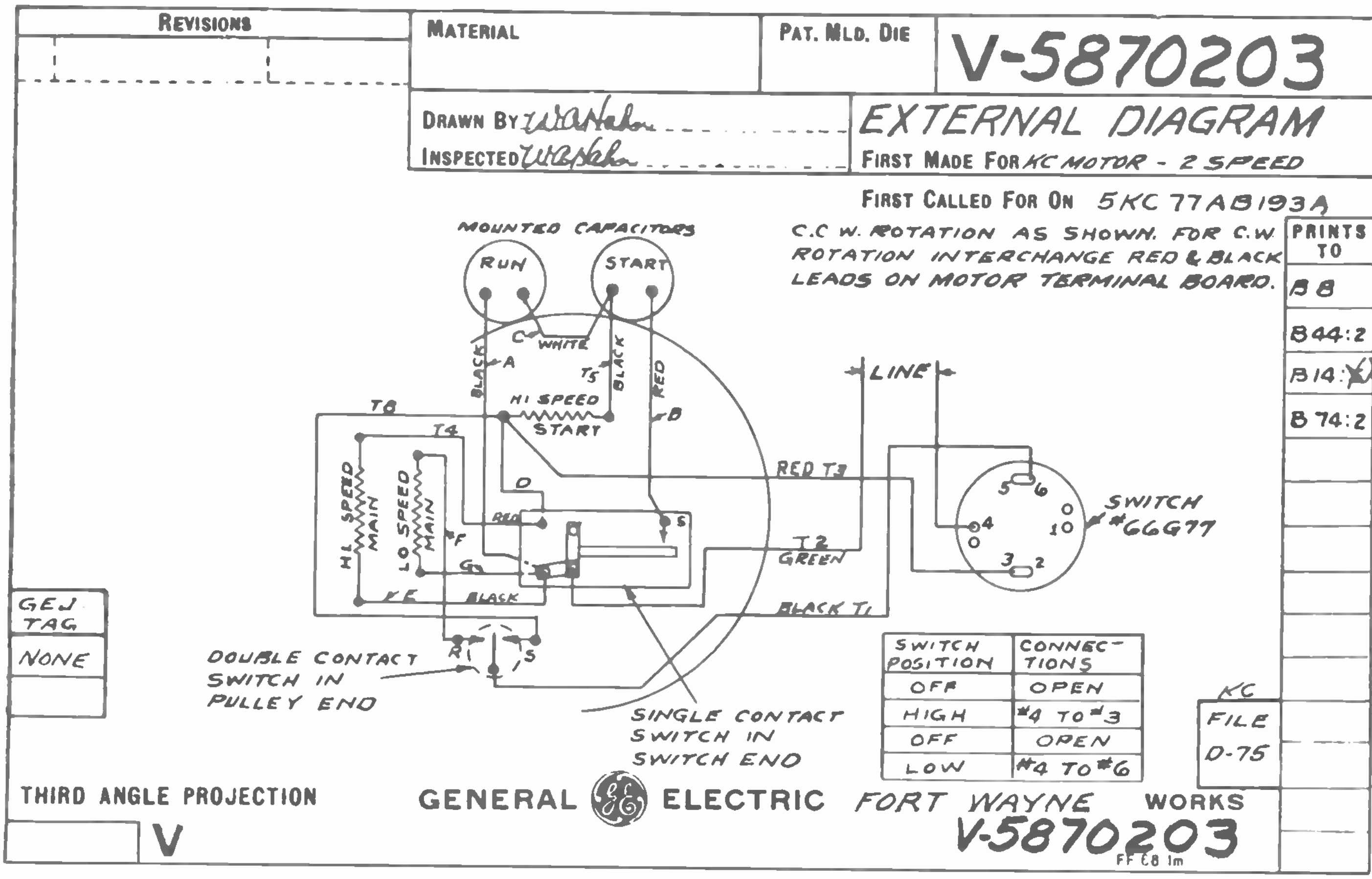
REVISIONS
MATERIAL
PAT. MLD. DIE
PART
V-5870485
① R. Kirby ADD GEJ TAG 905
DRAWN BY R. Kirby
INSPECTED
EXTERNAL DIAGRAM
FIRST MADE FOR KC MOTORS - REV-
FIRST CALLED FOR ON 5KCP73AB1
C.C.W. ROTATION AS SHOWN; FOR C.W. ROTATION INTERCHANGE LEADS T5 AND T6
MTD. CAP.
MTD. CAP.
C RED
B WHITE
A
START
MAIN
T6
T5
T1
T2
T4
T3
110 V. LINE
T2
T3
T6
T1
T4
T5
220 V. LINE
B44.2
B14.5
B128.9
B10
G.E.J. TAG
711 STD
905 EXP. PR.
FILE D-75
THIRD ANGLE PROJECTION
GENERAL ELECTRIC CO.
FORT WAYNE WORKS
V-5870485
FF-88 10M

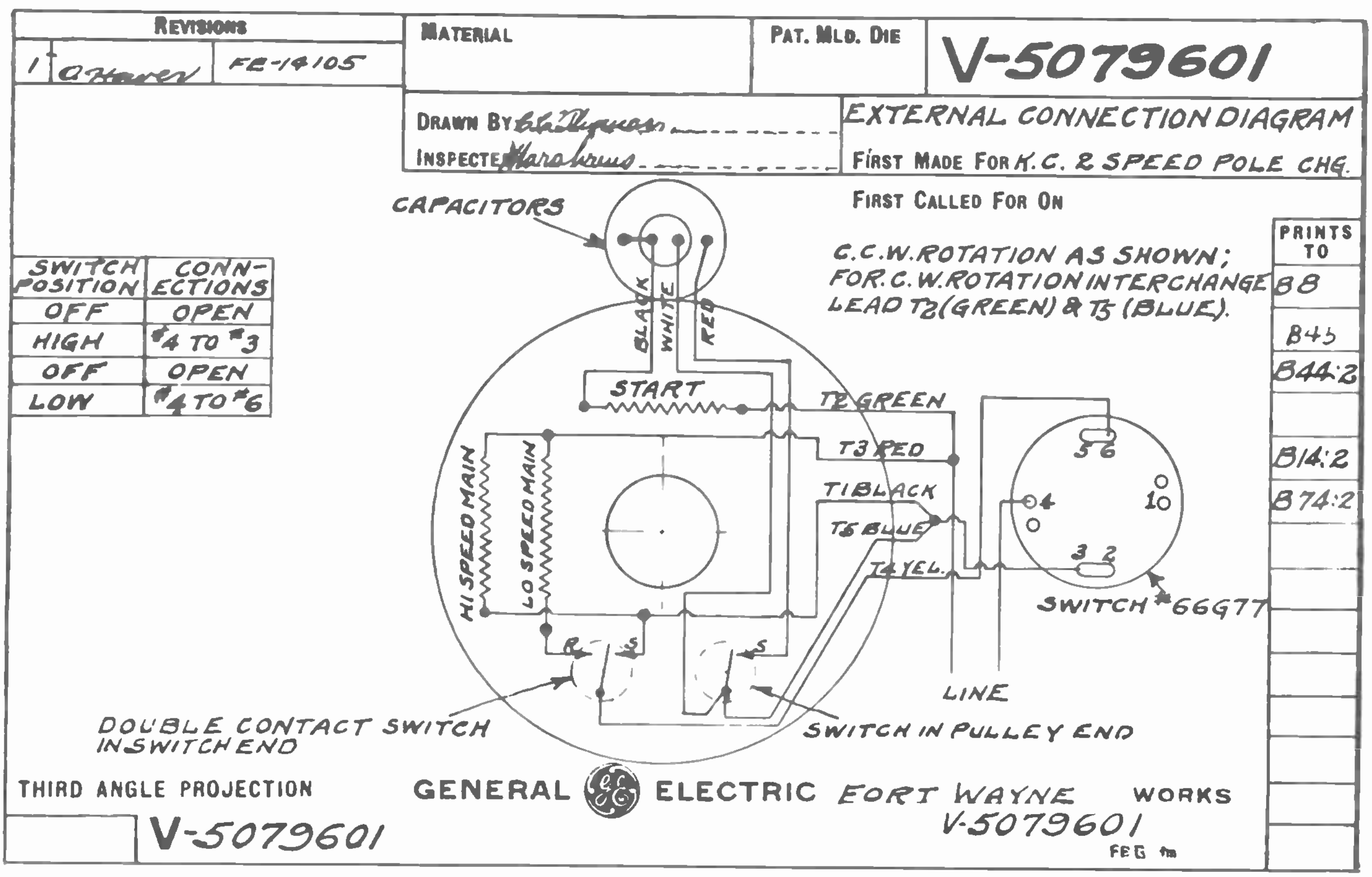


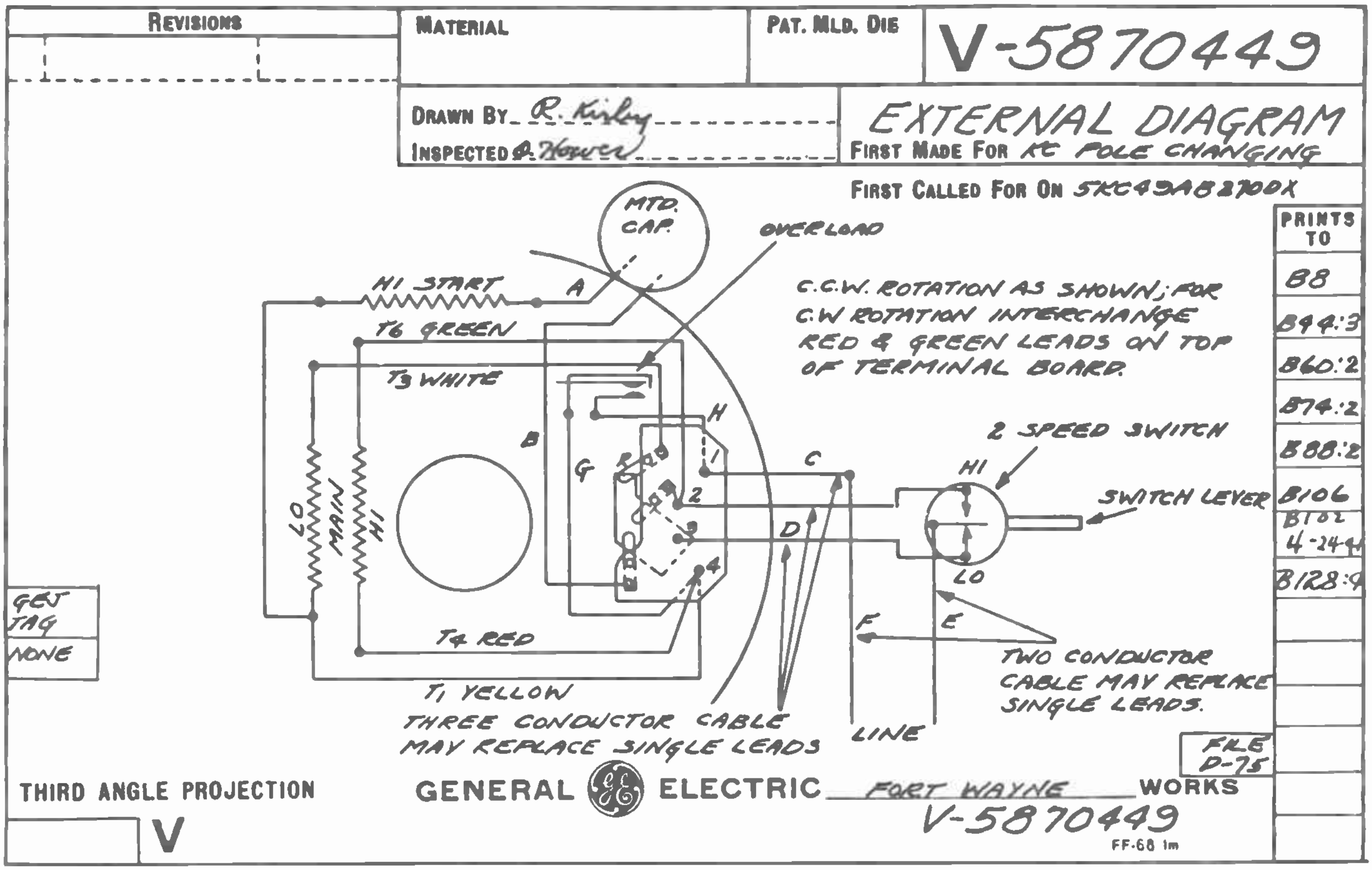
REVISIONS
MATERIAL
PAT. MLD. DIE
V-5837020
DRAWN BY
INSPECTED
EXTERNAL DIAGRAM
FIRST MADE FOR SC-MOTOR-DUAL
FIRST CALLED FOR ON 5SC48AB10
C.C.W. ROTATION AS SHOWN; FOR C.W. ROTATION INTERCHANGE T5 & T6 (RED & BLACK) AT TERMINAL BOARD.
E
WHITE
T5
RED
B
A
F
START
T5 RED
C
MAIN
D
T2
T1
T3
T4
T6
110 V. LINE
T1
T2
220 V. LINE
T3
T4
PRINTS TO
E8
B44(3)
B45
B74(2)
B88(2)
B106
G.E.J. TAGS
536
FILE D-75
THIRD ANGLE PROJECTION
GENERAL ELECTRIC
FORT WAYNE WORKS
V
V-5837020
FF-88 1M

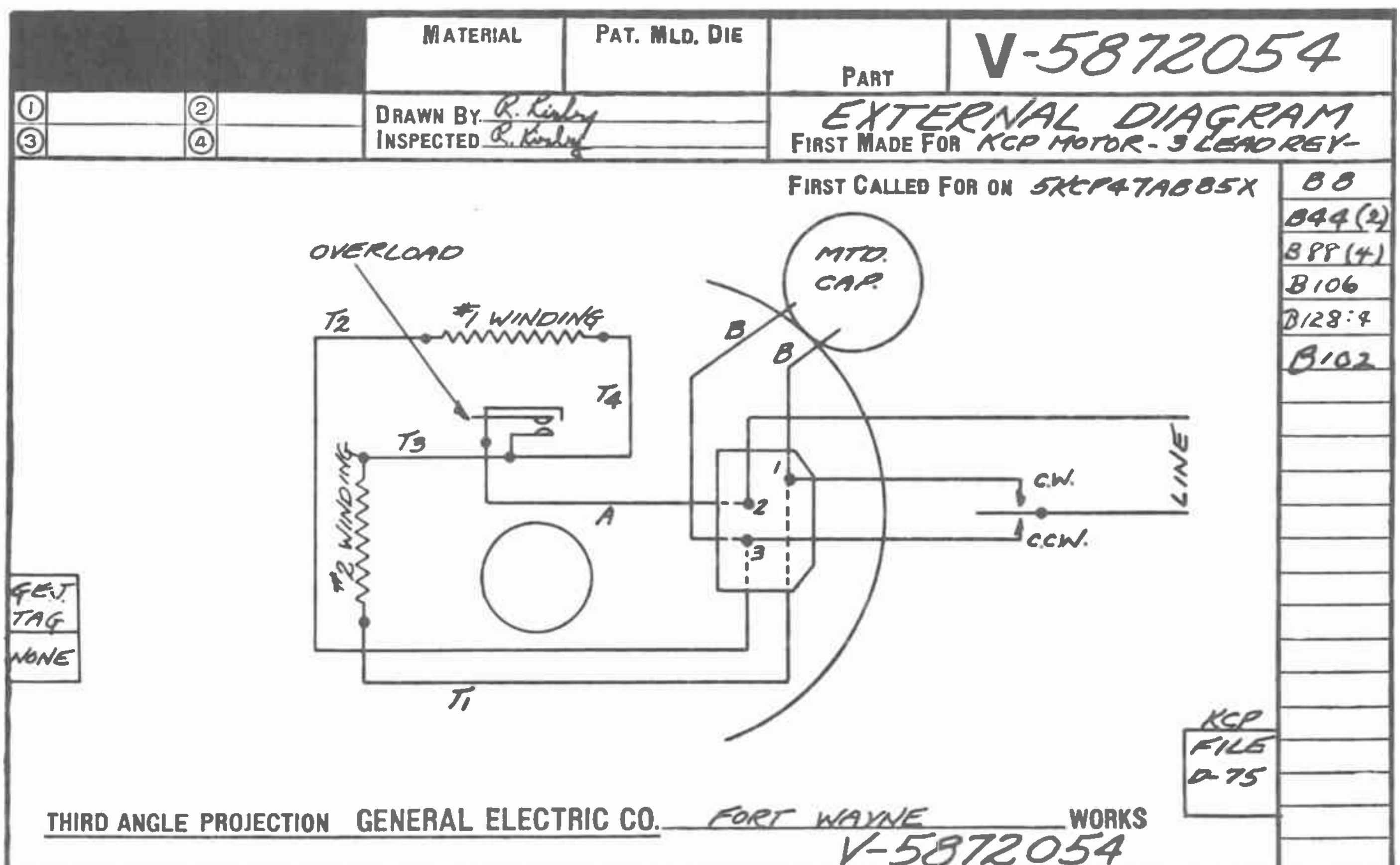

MATERIAL
PAT. MLD. DIE
PART
V-5837051
REVISIONS
DRAWN BY O. Hoover
INSPECTED O. Hoover
EXTERNAL DIAGRAM
FIRST MADE FOR KC MOTORS - 2 SPEED
FIRST CALLED FOR ON 5KC47AB1620X
E8
B44:3
B45
B74:2
B88:3
B106
CAP.
BUILT-IN OVERLOAD
HI-START
LO-MAIN
HI-MAIN
T1 BLUE
T5 WHITE
T4 YELLOW
C RED
GREEN
SWITCH IN BRG.
SWITCH POSITION | CONNECTIONS
OFF | OPEN
HIGH | L TO 1
OFF | OPEN
LOW | L TO 2
SWITCH MARKING SHOWN IS BLACK INK MARKING ON SWITCH BOTTOM.
SWITCH #664288 BOTTOM VIEW OF SWITCH.
LINE
G.E.J. TAGS
NONE
C.C.W. ROTATION AS SHOWN; FOR C.W. ROTATION INTERCHANGE LEADS B (GREEN) & C (RED).
FILE D-75
THIRD ANGLE PROJECTION
GENERAL ELECTRIC CO. FORT WAYNE WORKS
V-5837051
FF-88 10M

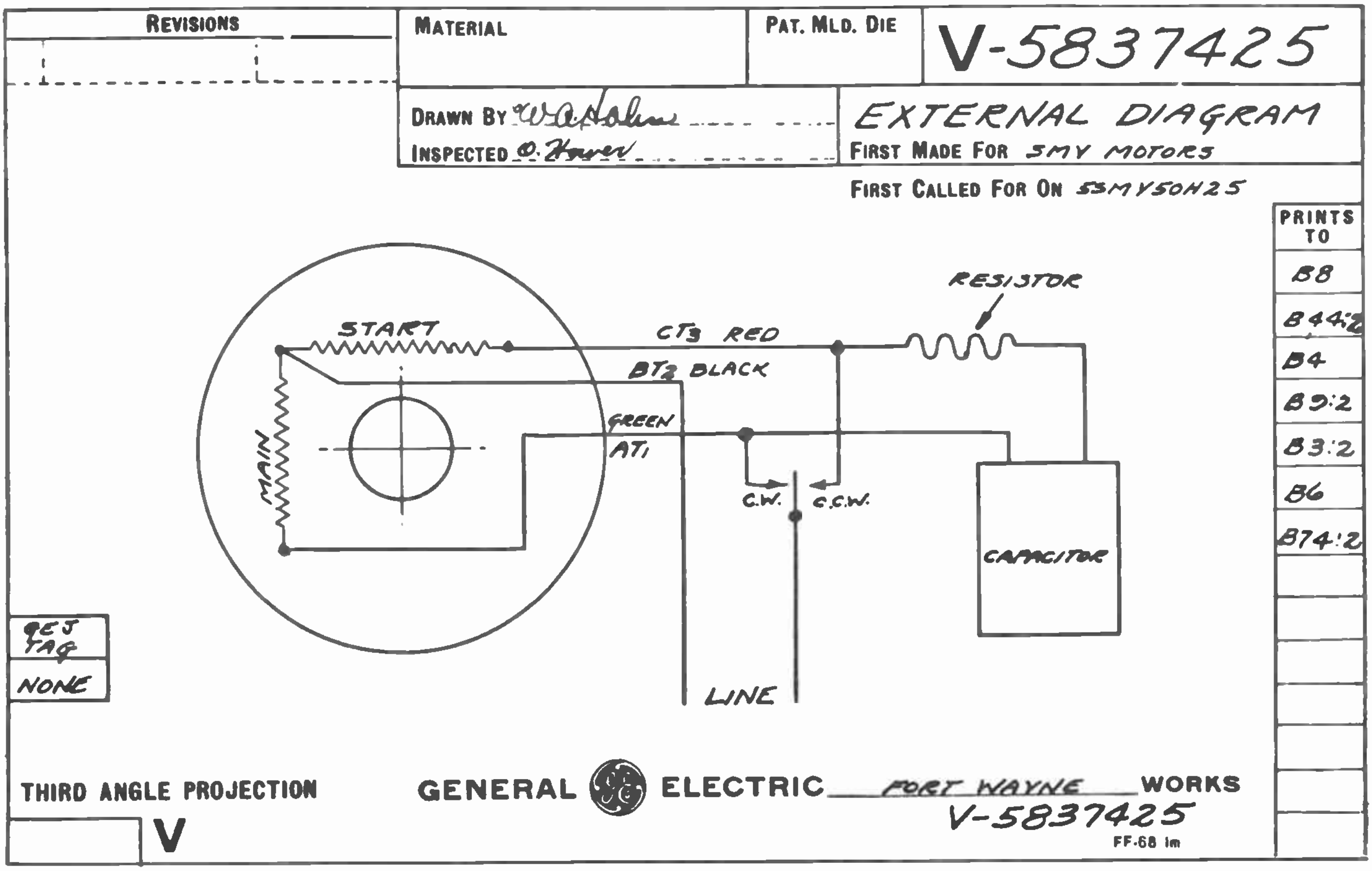

REVISIONS
MATERIAL
PAT. MLD. DIE
V-5870260
DRAWN BY R. Kirby
INSPECTED O. Hoover
EXTERNAL DIAGRAM
FIRST MADE FOR KC MOTOR - 2 SPEED
FIRST CALLED FOR ON 5KC77AB368A
PRINTS TO
B8
B44(2)
B14(5)
B74(2)
B102
B123:9
MOUNTED CAP.
RUN
START
'C' WHITE
HI START
RED
BLACK
T2 GREEN
T3 RED
LINE
HI MAIN
LO MAIN
T4 YELLOW
T1 BLACK
T5 BLUE
C.C.W. ROTATION AS SHOWN; FOR C.W. ROTATION INTERCHANGE LEADS T2 GREEN & T5 BLUE.
SWITCH #66677 (WHEN USED)
START CONTACT SWITCH IN PULLEY END
SWITCH POSITION | CONNECTIONS
OFF | OPEN
HIGH | #4 & #3
OFF | OPEN
LOW | #4 & #6
G.E.J. TAG
665
FILE D-75
THIRD ANGLE PROJECTION
GENERAL ELECTRIC FORT WAYNE WORKS
V-5870260


REVISIONS
MATERIAL
PAT. MLD. DIE
V-5870203
DRAWN BY
INSPECTED
EXTERNAL DIAGRAM
FIRST MADE FOR KC MOTOR - 2 SPEED
FIRST CALLED FOR ON 5KC 77AB193A
MOUNTED CAPACITORS
RUN
START
C.C.W. ROTATION AS SHOWN. FOR C.W. ROTATION INTERCHANGE RED & BLACK LEADS ON MOTOR TERMINAL BOARD.
PRINTS TO
B8
B44:2
B14:2
B74:2
LINE
WHITE
BLACK
RED
HI SPEED START
T5
T8
T4
HI SPEED MAIN
LO SPEED MAIN
RED T3
T2 GREEN
BLACK T1
SWITCH #66G77
GEJ TAG
NONE
DOUBLE CONTACT SWITCH IN PULLEY END
SINGLE CONTACT SWITCH IN SWITCH END
SWITCH POSITION | CONNECTIONS
OFF | OPEN
HIGH | #4 TO #3
OFF | OPEN
LOW | #4 TO #6
KC FILE D-75
THIRD ANGLE PROJECTION
V
GENERAL ELECTRIC FORT WAYNE WORKS
V-5870203

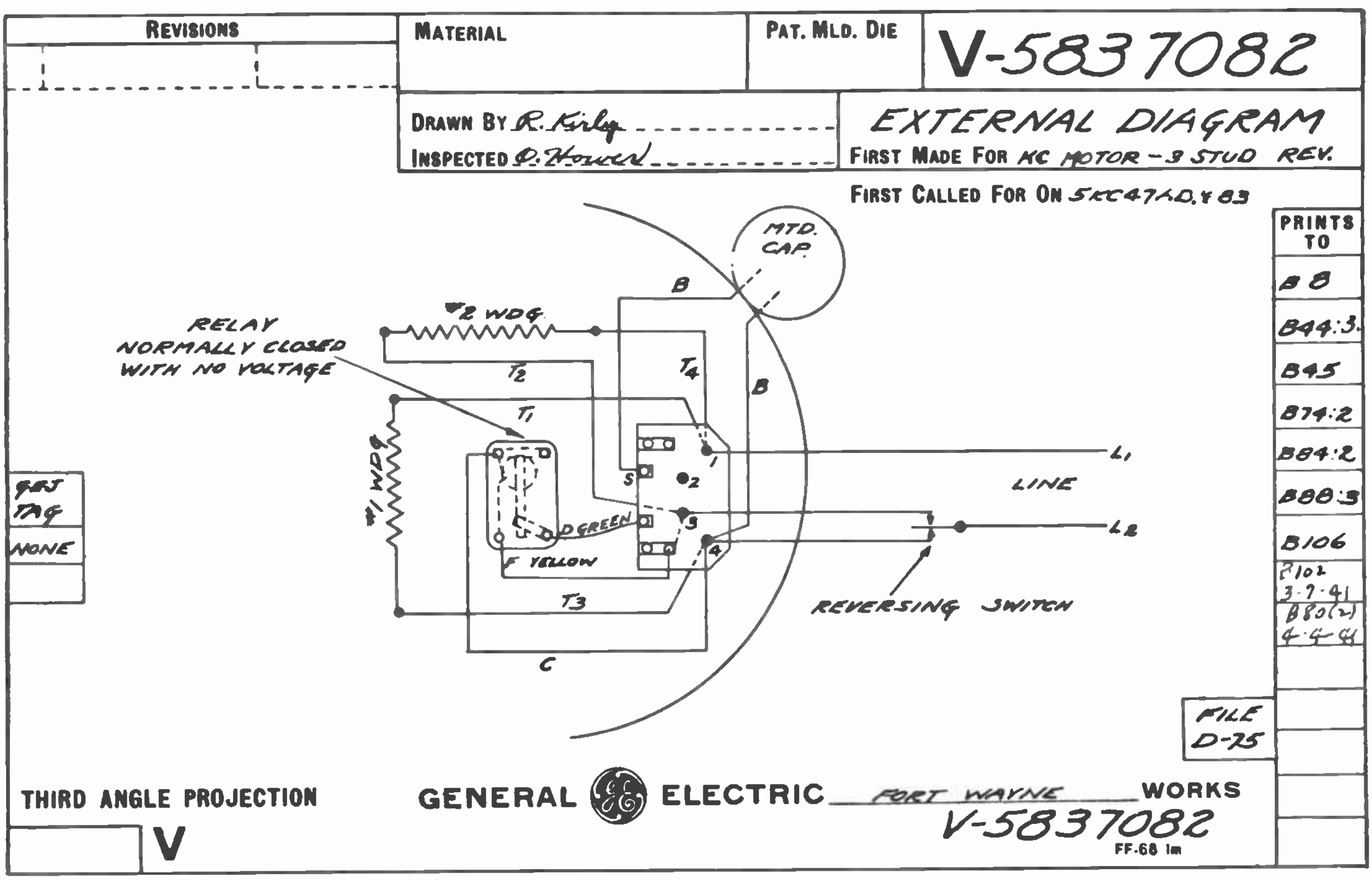

REVISIONS
1 FE-14105
MATERIAL
PAT. MLD. DIE
V-5079601
DRAWN BY
INSPECTED
EXTERNAL CONNECTION DIAGRAM
FIRST MADE FOR K.C. 2 SPEED POLE CHG.
FIRST CALLED FOR ON
CAPACITORS
C.C.W. ROTATION AS SHOWN; FOR C.W. ROTATION INTERCHANGE LEAD T2 (GREEN) & T5 (BLUE).
PRINTS TO
B8
B45
B44:2
B14:2
B74:2
SWITCH POSITION | CONNECTIONS
OFF | OPEN
HIGH | #4 TO #3
OFF | OPEN
LOW | #4 TO #6
BLACK
WHITE
RED
START
T2 GREEN
T3 RED
T1 BLACK
T5 BLUE
T4 YEL.
HI SPEED MAIN
LO SPEED MAIN
SWITCH #66G77
LINE
DOUBLE CONTACT SWITCH IN SWITCH END
SWITCH IN PULLEY END
THIRD ANGLE PROJECTION
GENERAL ELECTRIC FORT WAYNE WORKS
V-5079601


REVISIONS
MATERIAL
PAT. MLD. DIE
V-5870449
DRAWN BY R. Kirby
INSPECTED
EXTERNAL DIAGRAM
FIRST MADE FOR KC POLE CHANGING
FIRST CALLED FOR ON
PRINTS TO
88
B44:3
B60:2
B74:2
B88:2
B106
B128:4
MTD. CAP.
OVERLOAD
H1 START
A
T6 GREEN
T3 WHITE
B
G
H
C
D
LO
MAIN
HI
T4 RED
T1 YELLOW
C.C.W. ROTATION AS SHOWN; FOR C.W. ROTATION INTERCHANGE RED & GREEN LEADS ON TOP OF TERMINAL BOARD.
2 SPEED SWITCH
SWITCH LEVER
F
E
TWO CONDUCTOR CABLE MAY REPLACE SINGLE LEADS.
THREE CONDUCTOR CABLE MAY REPLACE SINGLE LEADS
LINE
GEJ TAG NONE
FILE D-75
THIRD ANGLE PROJECTION
GENERAL ELECTRIC FORT WAYNE WORKS
V-5870449
V
FF-68 1m

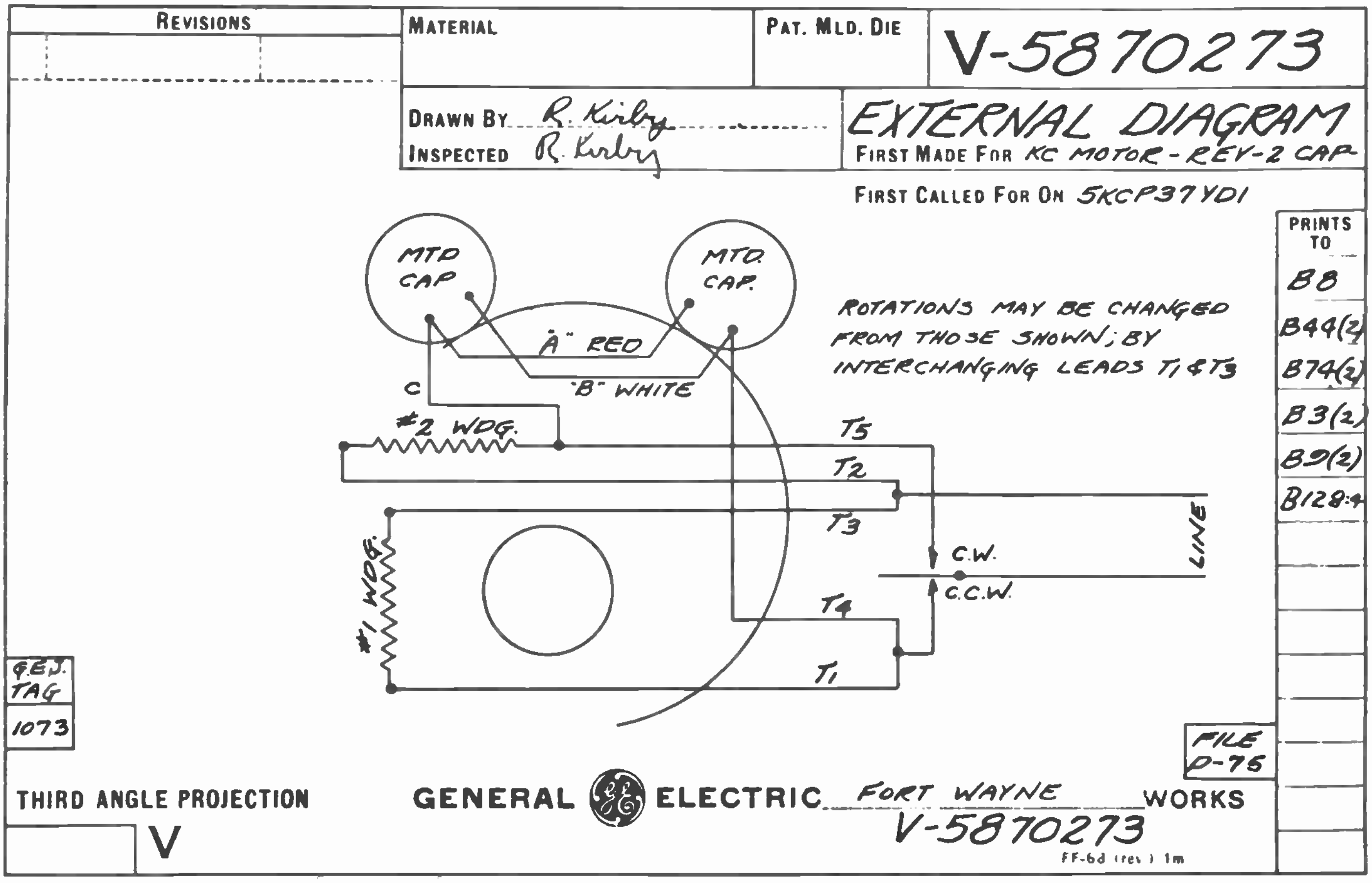

MATERIAL
PAT. MLD. DIE
PART
V-5872054
DRAWN BY R. Kirby
INSPECTED R. Kirby
EXTERNAL DIAGRAM
FIRST MADE FOR KCP MOTOR - 3 LEAD REV-
FIRST CALLED FOR ON 5KCP47AB85X
88
B44(2)
B88(4)
B106
B128:4
B102
OVERLOAD
MTD. CAP.
T2
#1 WINDING
T4
T3
B
B
A
#2 WINDING
T1
C.W.
C.C.W.
LINE
GEJ TAG NONE
KCP FILE D-75
THIRD ANGLE PROJECTION GENERAL ELECTRIC CO. FORT WAYNE WORKS
V-5872054

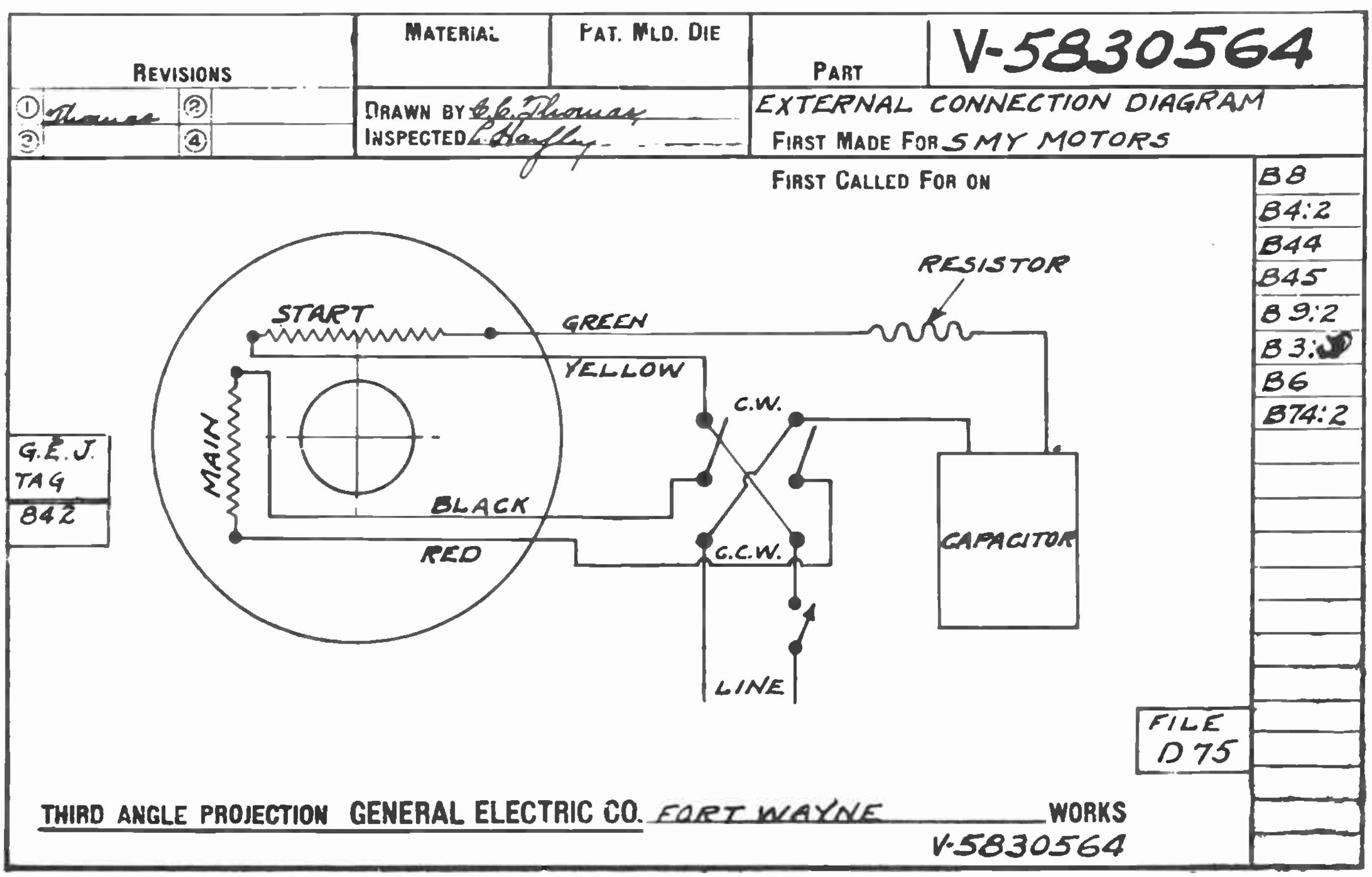


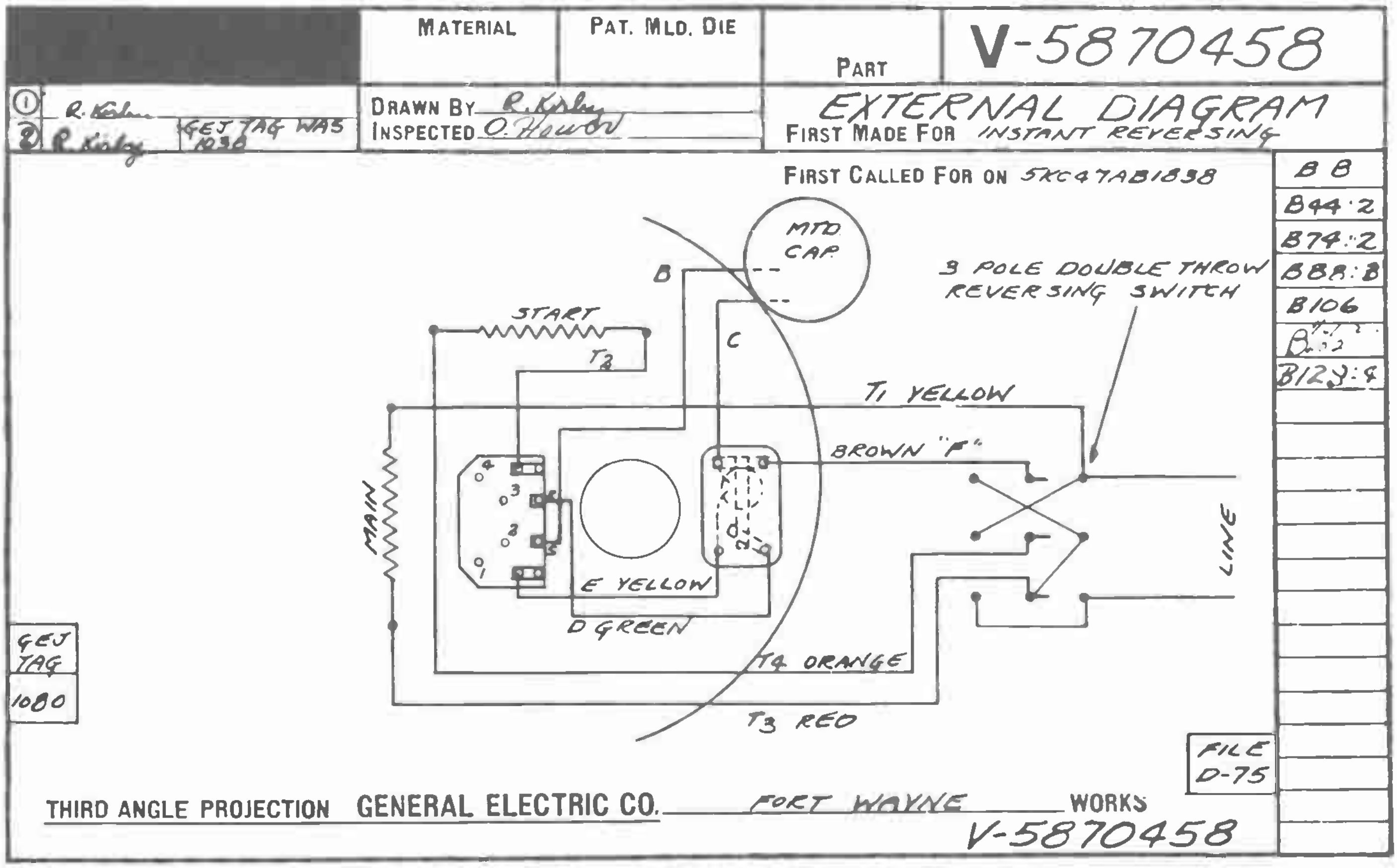
REVISIONS
MATERIAL
PAT. MLD. DIE
V-5837425
DRAWN BY
INSPECTED
EXTERNAL DIAGRAM
FIRST MADE FOR 5MY MOTORS
FIRST CALLED FOR ON 55MY50H25
PRINTS TO
B8
B4
B9:2
B3:2
B6
B74:2
RESISTOR
START
MAIN
CT3 RED
BT2 BLACK
GREEN
AT1
C.W.
C.C.W.
CAPACITOR
LINE
REJ TAG
NONE
THIRD ANGLE PROJECTION
GENERAL ELECTRIC FORT WAYNE WORKS
V
V-5837425
FF-68 Im

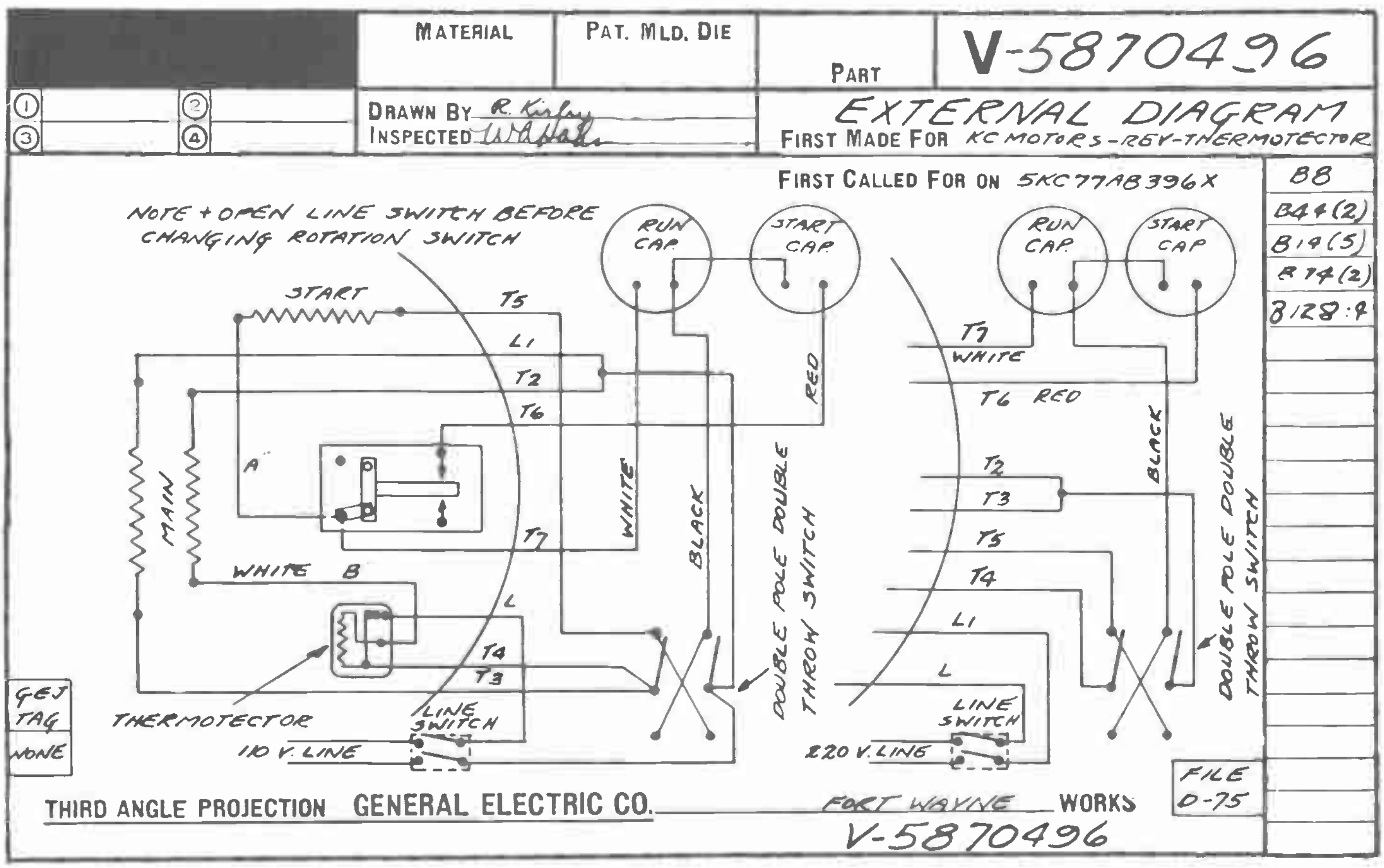


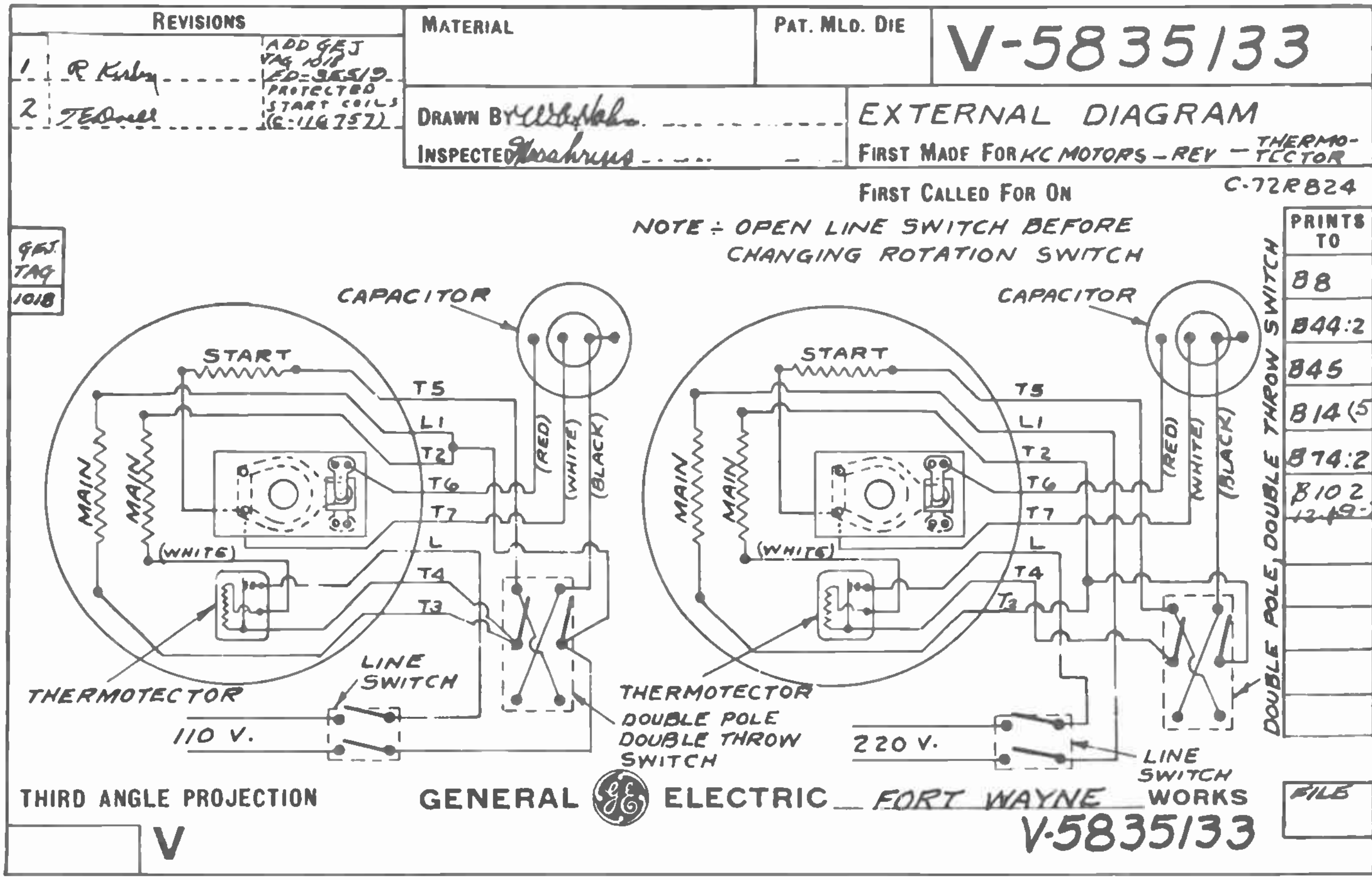
REVISIONS
MATERIAL
PAT. MLD. DIE
V-5837082
DRAWN BY
INSPECTED
EXTERNAL DIAGRAM
FIRST MADE FOR KC MOTOR - 3 STUD REV.
PRINTS TO
B8
B45
B74:2
B84:2
B88:3
B106
MTD. CAP.
B
#2 WDG
RELAY NORMALLY CLOSED WITH NO VOLTAGE
T2
T4
T1
#1 WDG
S
GREEN
YELLOW
T3
C
LINE
L1
L2
REVERSING SWITCH
REJ TAG
NONE
FILE D-75
THIRD ANGLE PROJECTION
GENERAL ELECTRIC FORT WAYNE WORKS
V
V-5837082
FF-68 Im


REVISIONS
MATERIAL
PAT. MLD. DIE
V-5870273
DRAWN BY R. Kirby
INSPECTED R. Kirby
EXTERNAL DIAGRAM
FIRST MADE FOR KC MOTOR - REV-2 CAP
FIRST CALLED FOR ON 5KCP37YD1
PRINTS TO
B8
B44(2)
B74(2)
B3(2)
B9(2)
B128:4
MTD CAP
MTD CAP
"A" RED
"B" WHITE
C
#2 WDG.
#1 WDG.
ROTATIONS MAY BE CHANGED FROM THOSE SHOWN; BY INTERCHANGING LEADS T1 & T3
T5
T2
T3
T4
T1
C.W.
C.C.W.
LINE
G.E.J. TAG
1073
FILE D-75
THIRD ANGLE PROJECTION
V
GENERAL ELECTRIC FORT WAYNE WORKS
V-5870273
FF-6d (rev.) 1m

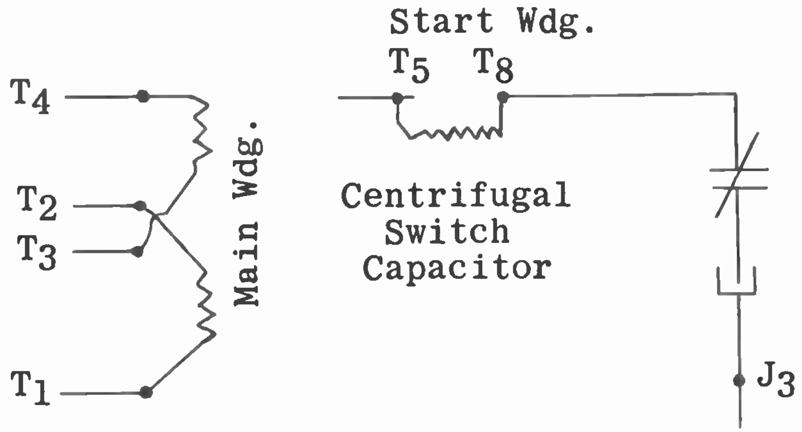

REVISIONS
① Thomas ②
③ ④
MATERIAL
PAT. MLD. DIE
PART
V-5830564
DRAWN BY C.C. Thomas
INSPECTED L. Haefly
EXTERNAL CONNECTION DIAGRAM
FIRST MADE FOR 5 MY MOTORS
FIRST CALLED FOR ON
B8
B4:2
B44
B45
B9:2
B3:
B6
B74:2
RESISTOR
START
GREEN
YELLOW
MAIN
BLACK
RED
C.W.
C.C.W.
CAPACITOR
LINE
G.E.J. TAG
842
FILE D75
THIRD ANGLE PROJECTION GENERAL ELECTRIC CO. FORT WAYNE WORKS
V-5830564


MATERIAL
PAT. MLD. DIE
PART
V-5870458
DRAWN BY R. Kirby
INSPECTED O. Howard
EXTERNAL DIAGRAM
FIRST MADE FOR INSTANT REVERSING
FIRST CALLED FOR ON 5KC47AB1838
GEJ TAG WAS 1030
MTD CAP
3 POLE DOUBLE THROW REVERSING SWITCH
START
T2
B
C
T1 YELLOW
BROWN "F"
MAIN
E YELLOW
D GREEN
T4 ORANGE
T3 RED
LINE
GEJ TAG 1080
FILE D-75
B8
B44:2
B74:2
B88:8
B106
B129:4
THIRD ANGLE PROJECTION
GENERAL ELECTRIC CO.
FORT WAYNE
WORKS
V-5870458


MATERIAL
PAT. MLD. DIE
PART
V-5870496
DRAWN BY R. Kirby
EXTERNAL DIAGRAM
FIRST MADE FOR KC MOTORS-REV-THERMOTECTOR
FIRST CALLED FOR ON 5KC77AB396X
NOTE + OPEN LINE SWITCH BEFORE CHANGING ROTATION SWITCH
RUN CAP
START CAP
START
T5
L1
T2
T6
A
MAIN
T7
WHITE
BLACK
RED
WHITE B
L
T4
T3
THERMOTECTOR
LINE SWITCH
110 V. LINE
DOUBLE POLE DOUBLE THROW SWITCH
T7 WHITE
T6 RED
T3
T4
220 V. LINE
GEJ TAG NONE
FILE D-75
B8
B44(2)
B14(5)
B74(2)
B128:4
THIRD ANGLE PROJECTION
GENERAL ELECTRIC CO.
FORT WAYNE
WORKS
V-5870496


REVISIONS
MATERIAL
PAT. MLD. DIE
V-5835133
DRAWN BY
INSPECTED
EXTERNAL DIAGRAM
FIRST MADE FOR KC MOTORS – REV – THERMO-TECTOR
FIRST CALLED FOR ON
C-72R824
NOTE:– OPEN LINE SWITCH BEFORE CHANGING ROTATION SWITCH
PRINTS TO
88
B44:2
845
B14
B74:2
B102
GEJ TAG 1018
CAPACITOR
START
MAIN
MAIN
(WHITE)
T5
L1
T2
T6
T7
L
T4
T3
(RED)
(WHITE)
(BLACK)
THERMOTECTOR
LINE SWITCH
110 V.
DOUBLE POLE DOUBLE THROW SWITCH
220 V.
DOUBLE POLE, DOUBLE THROW SWITCH
THIRD ANGLE PROJECTION
GENERAL ELECTRIC FORT WAYNE WORKS
FILE
V
V-5835133

CONNECTION DIAGRAM
SINGLE PHASE INDUCTION MOTOR
CAPACITOR START INDUCTION RUN



CCW ROTATION			
VOLTAGE	L1	L2	Together
LOW	T1-T3-J3	T2-T4-T5	- - -
HIGH	T1	T4-T5	T2-T3- J3

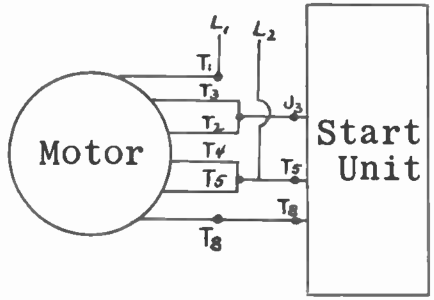
CW ROTATION			
VOLTAGE	L1	L2	Together
LOW	T1-T3-T5	T2-T4-J3	- - -
HIGH	T1	T4-J3	T2-T3-T5

NEMA STANDARD TAGGING

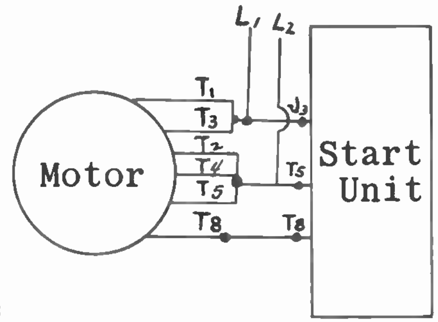
THE LOUIS ALLIS CO.
Milwaukee, Wis.

CONNECTION DIAGRAM
SINGLE PHASE INDUCTION MOTOR
CAPACITOR START INDUCTION RUN

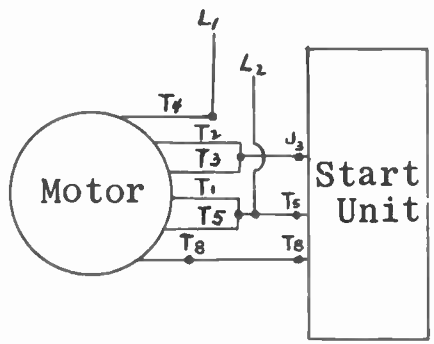
High Voltage
CCW Rotation



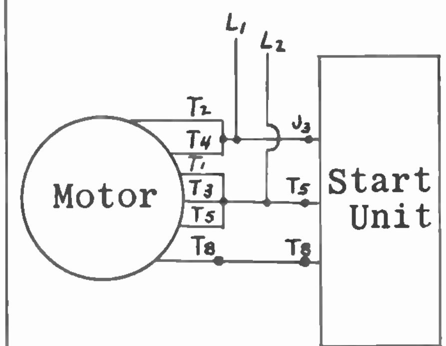
Low Voltage
CCW Rotation



High Voltage
CW Rotation

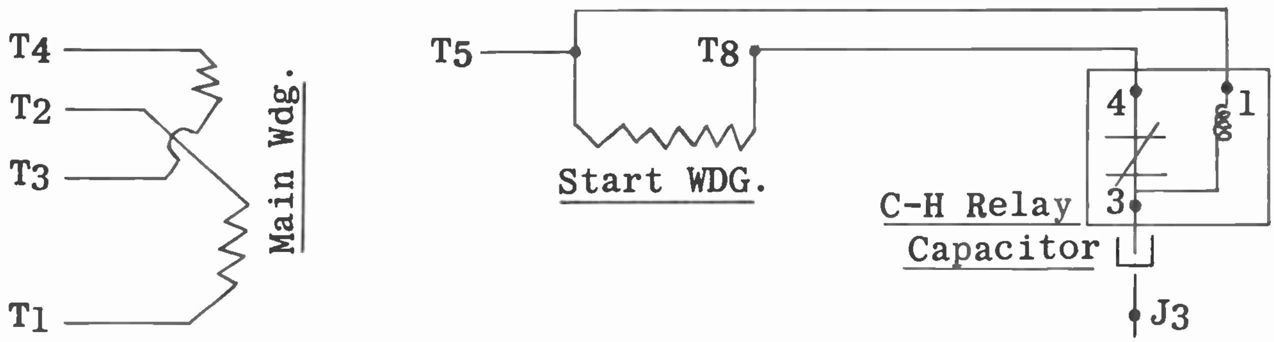


Low Voltage
CW Rotation



THE LOUIS ALLIS CO.
Milwaukee, Wis.

CONNECTION DIAGRAM
Single Phase Induction Motor
Capacitor - Start, Induction Run

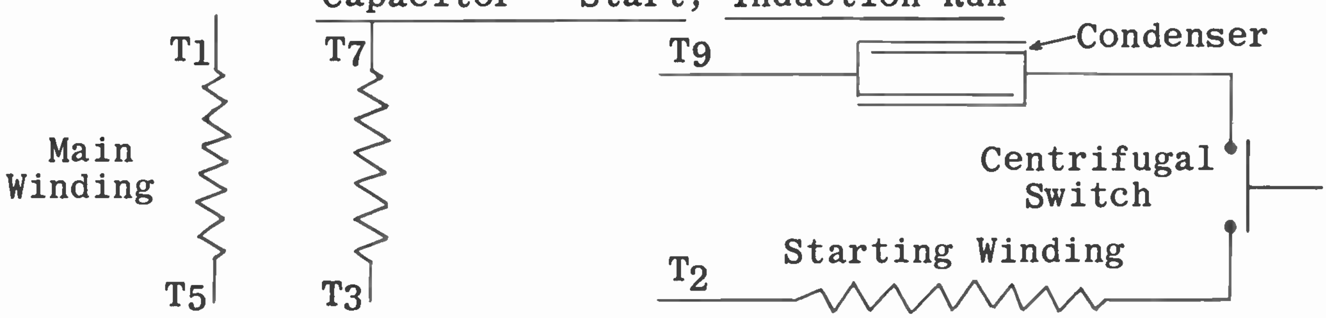


	C.C.W.Rotation			C.W.Rotation		
Voltage	L1	L2	Together	L1	L2	Together
High	T1-T3-J3	T2-T4-T5	- - -	T1-T3-T5	T2-T4-J3	- - -
Low	T1	T4-T5	T2-T3-J3	T1	T4-J3	T2-T3-T5

NEMA STANDARD TAGGING

THE LOUIS ALLIS CO. Milwaukee, Wis.

CONNECTION DIAGRAM
Single Phase Induction Motor
Capacitor - Start, Induction Run



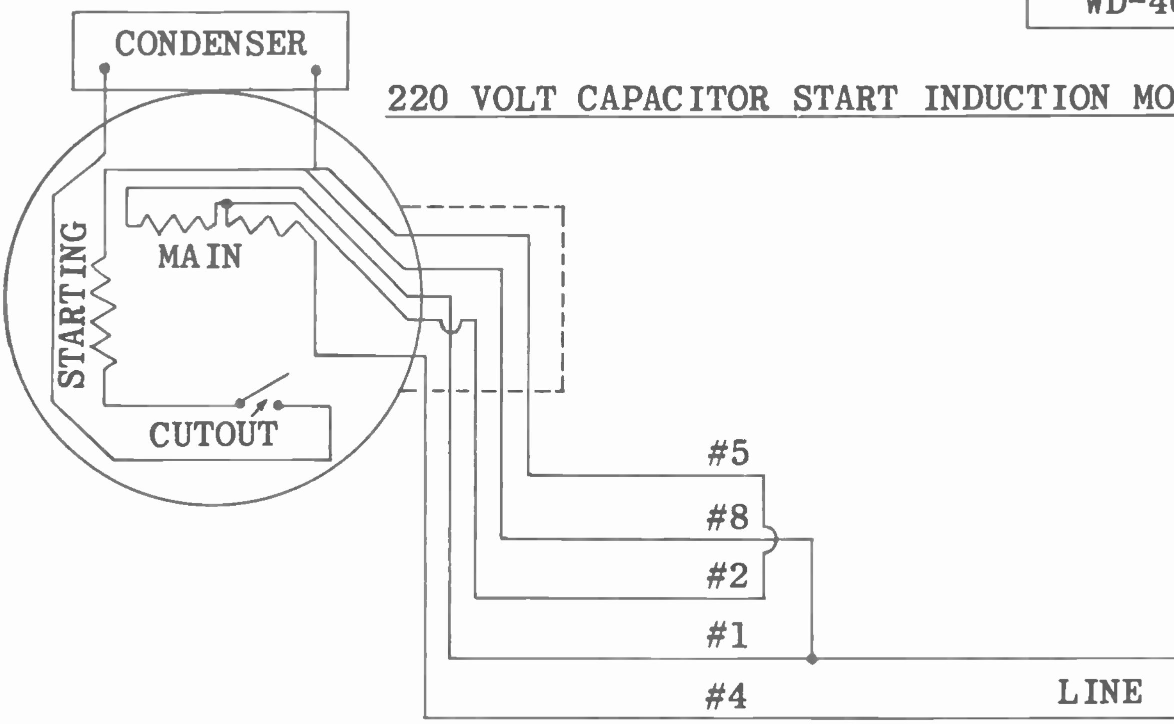
FOR 110 VOLTS	L1	L2
For C.W. Rotation Facing Front End (End Opp. Pulley)	T1-T7-T9	T2-T3-T5
For C.C.W. Rotation	T1-T2-T7	T3-T5-T3

FOR 220 VOLTS	L1	L2	Together
For C.W. Rotation Facing Front End.	T1	T2-T3	T5-T7-T9
For C.C.W. Rotation	T1	T3-T9	T2-T5-T7

THE LOUIS ALLIS CO. Milwaukee, Wis.

WD-460

220 VOLT CAPACITOR START INDUCTION MOTOR

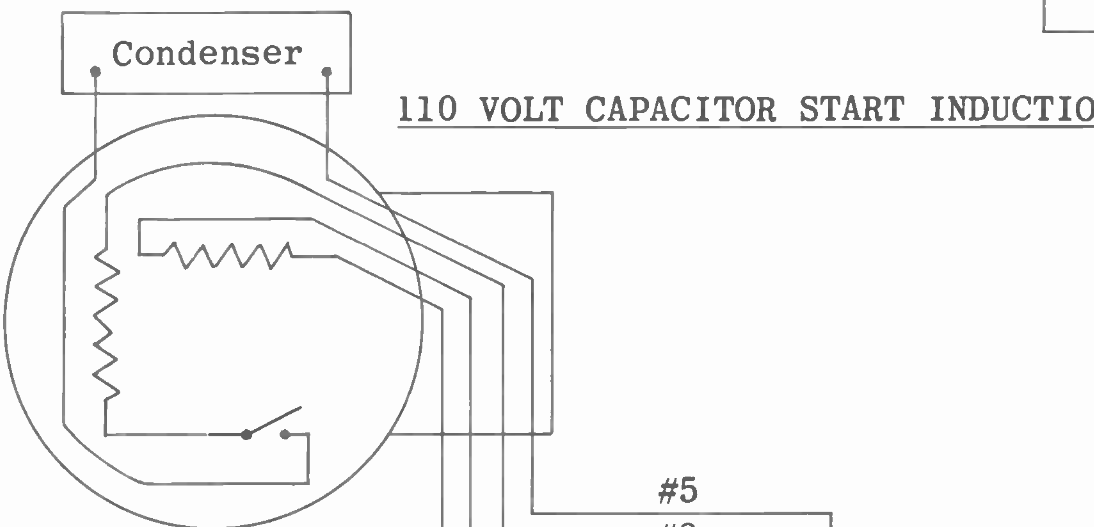


TO REVERSE ROTATION INTERCHANGE
LEADS #5 & #8

JANETTE MFG. CO.,
CHICAGO, ILL.,

WD-620

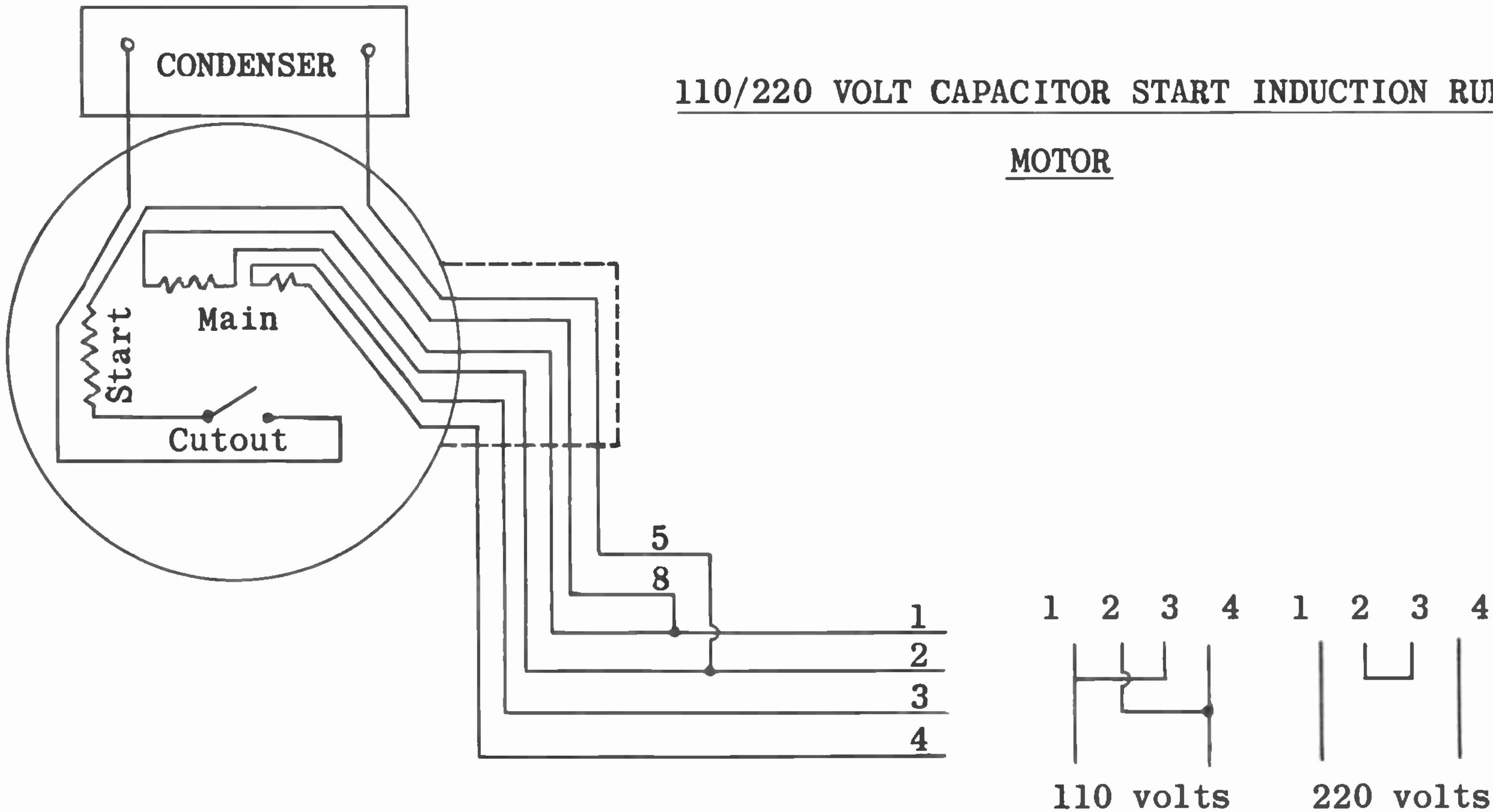
110 VOLT CAPACITOR START INDUCTION MOTOR



To Reverse Rotation Interchange
Leads #5 & #8

Janette Mfg.Co.
Chicago, Ill.

110/220 VOLT CAPACITOR START INDUCTION RUN MOTOR

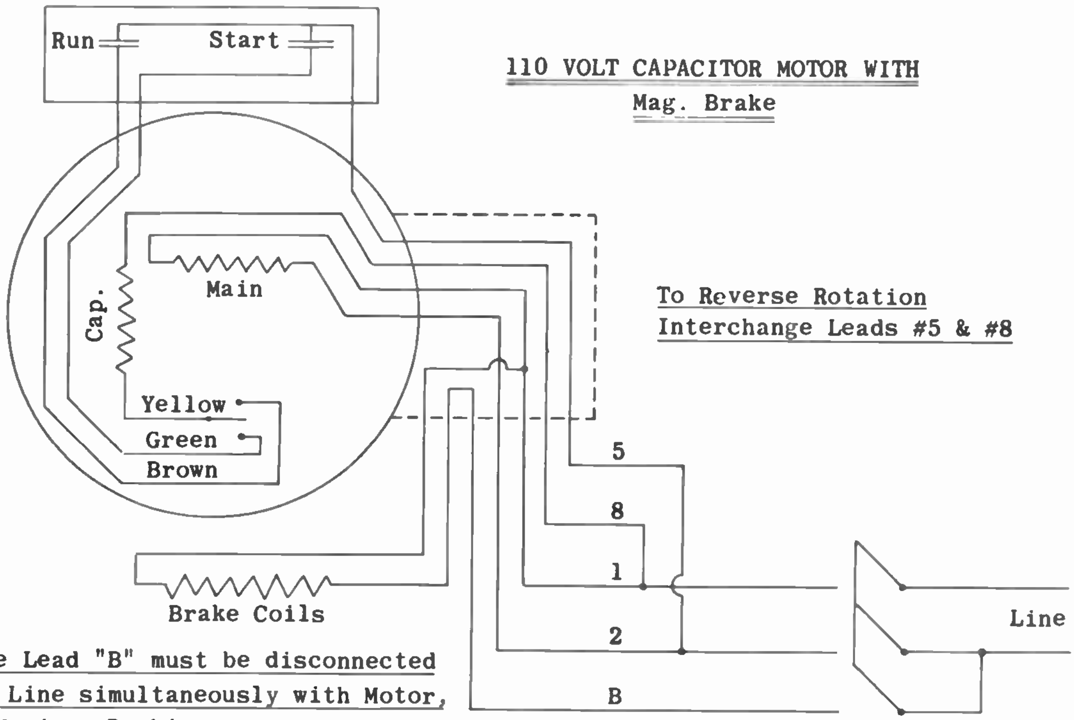


TO REVERSE ROTATION
INTERCHANGE LEADS
#5 & #8

Janette Mfg.Co.
Chicago, Ill.

WD-515

110 VOLT CAPACITOR MOTOR WITH
Mag. Brake



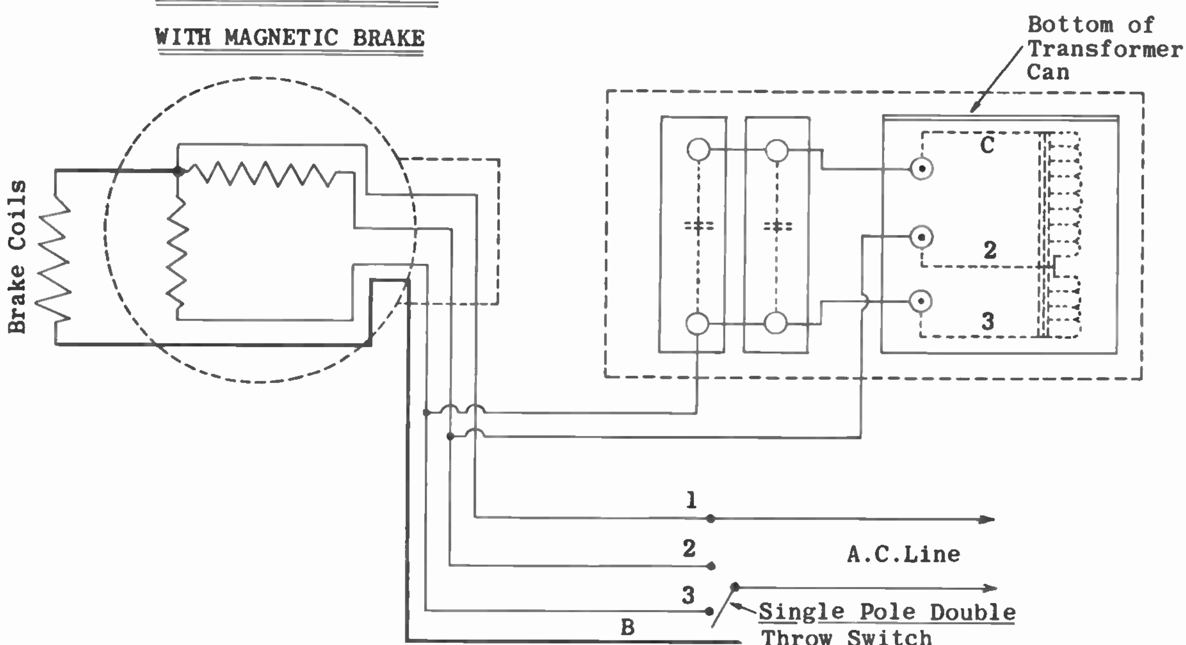
To Reverse Rotation
Interchange Leads #5 & #8

Brake Lead "B" must be disconnected from Line simultaneously with Motor, for Maximum Braking connect thru Switching Arrangement as indicated.

JANETTE MFG.CO.
CHICAGO, ILL.

WD-634

3 WIRE REVERSING CAPACITOR MOTOR
WITH AUTOTRANSFORMER
WITH MAGNETIC BRAKE

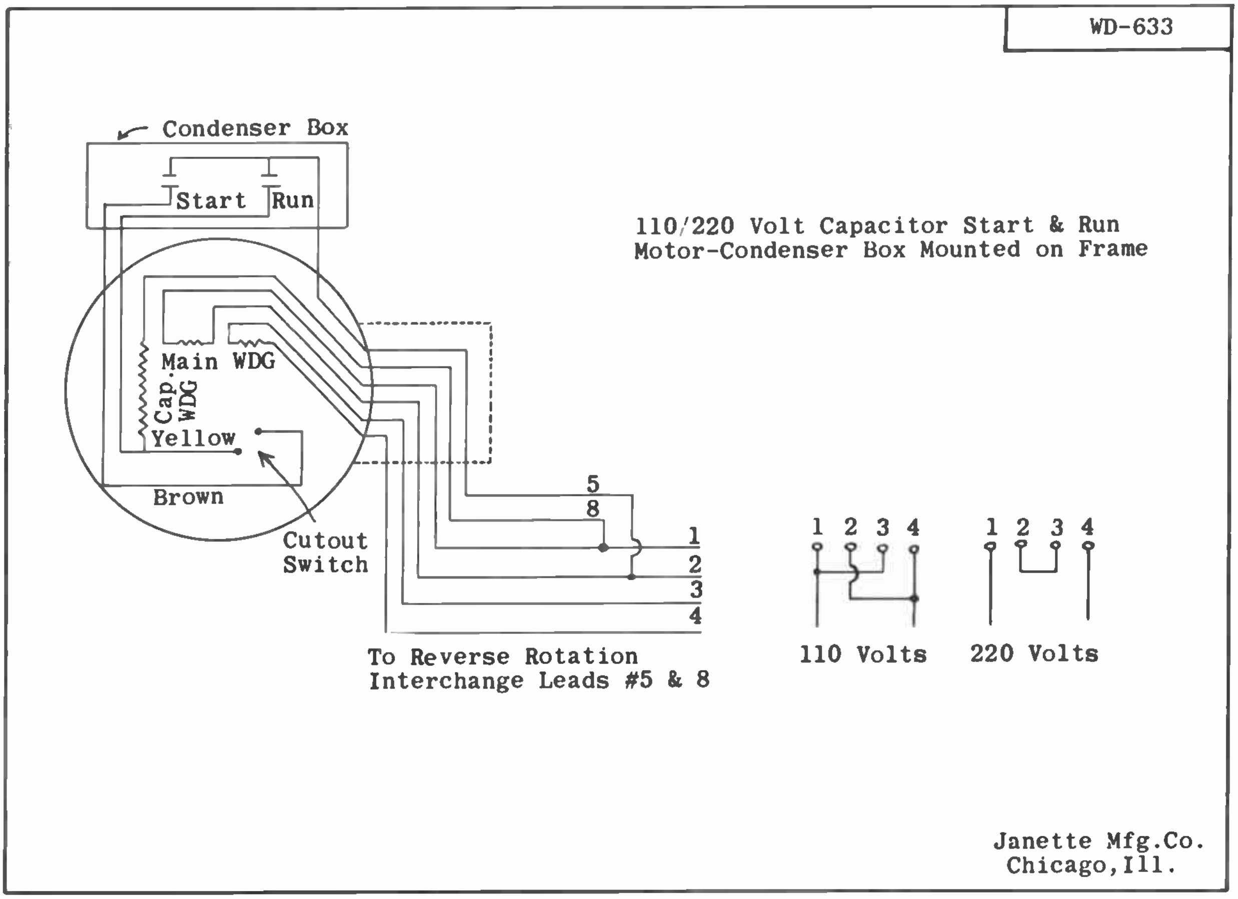


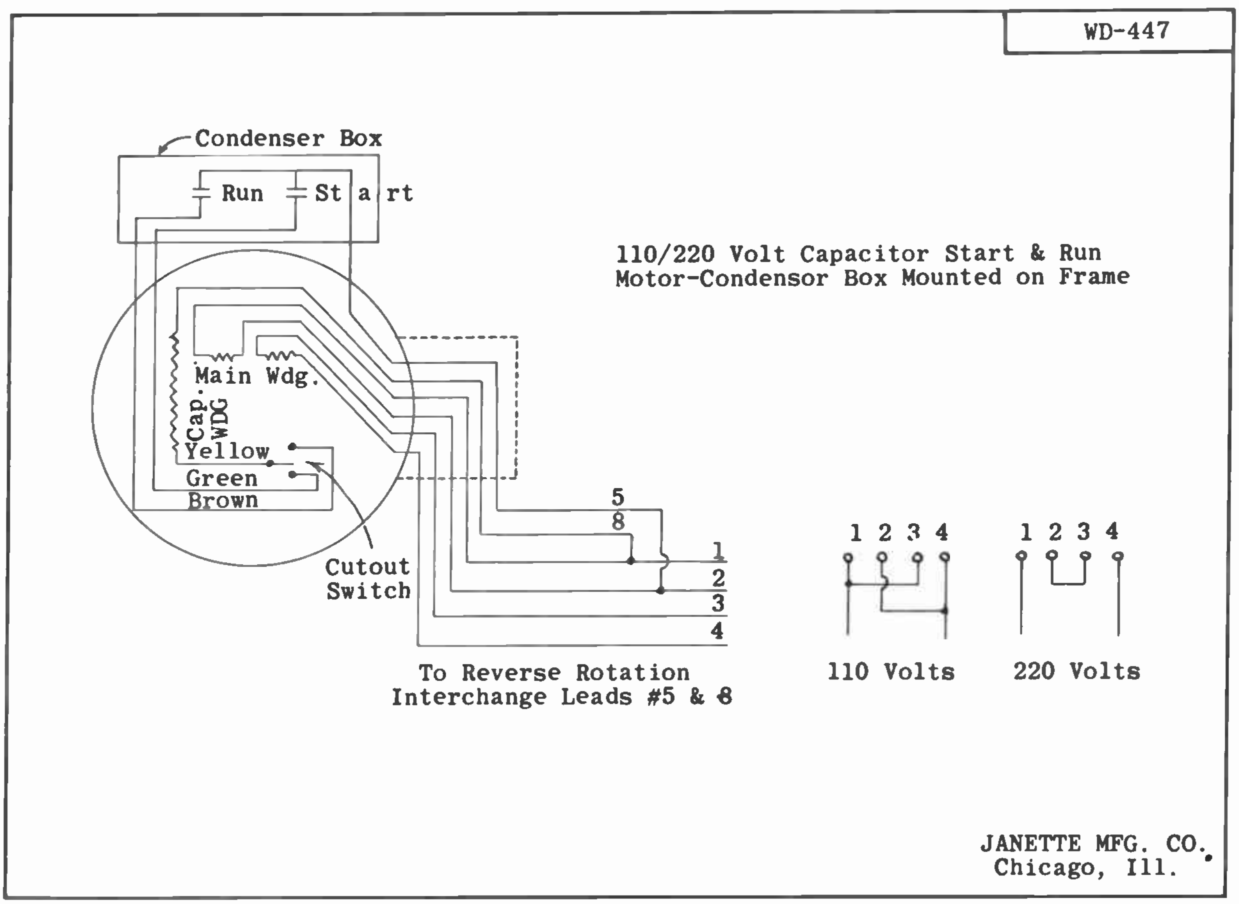
Connect 1 and 2 C.C.W.Rotation

Connect 1 and 3 C.W. Rotation

Lead "B" must be connected so circuit thru brake coils is opened when motor stops.

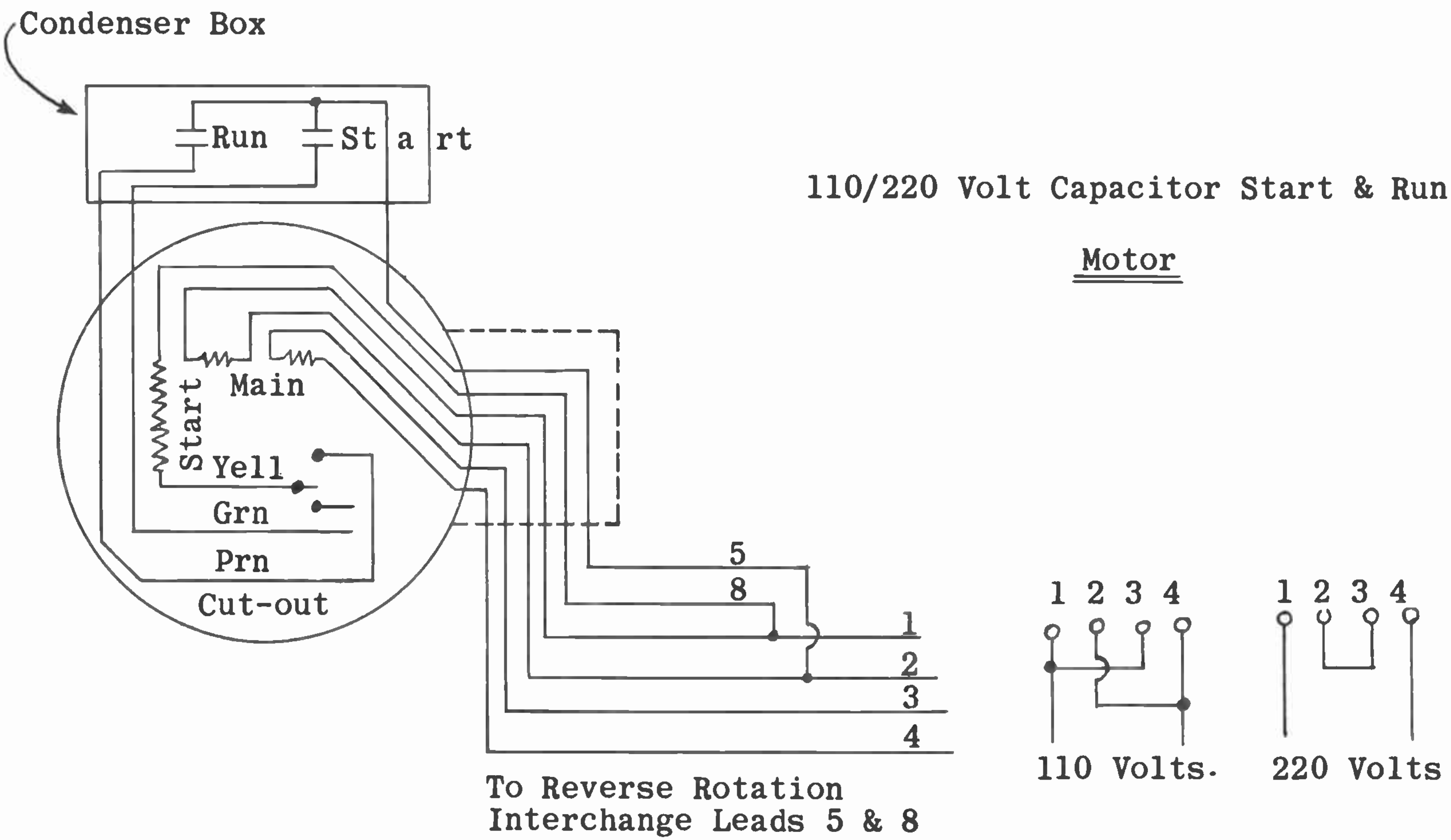
JANETTE MFG.CO.
CHICAGO, ILL.


WD-633
Condenser Box
Start
Run
110/220 Volt Capacitor Start & Run
Motor-Condenser Box Mounted on Frame
Main WDG
Cap. WDG
Yellow
Brown
Cutout Switch
5
8
1
2
3
4
1 2 3 4
1 2 3 4
110 Volts
220 Volts
To Reverse Rotation
Interchange Leads #5 & 8
Janette Mfg.Co.
Chicago, Ill.


WD-447
Condenser Box
Run
Start
110/220 Volt Capacitor Start & Run
Motor-Condensor Box Mounted on Frame
Main Wdg.
Cap. WDG
Yellow
Green
Brown
Cutout Switch
5
8
1
2
3
4
1 2 3 4
1 2 3 4
110 Volts
220 Volts
To Reverse Rotation
Interchange Leads #5 & 8
JANETTE MFG. CO.
Chicago, Ill.

WD-447

110/220 Volt Capacitor Start & Run Motor



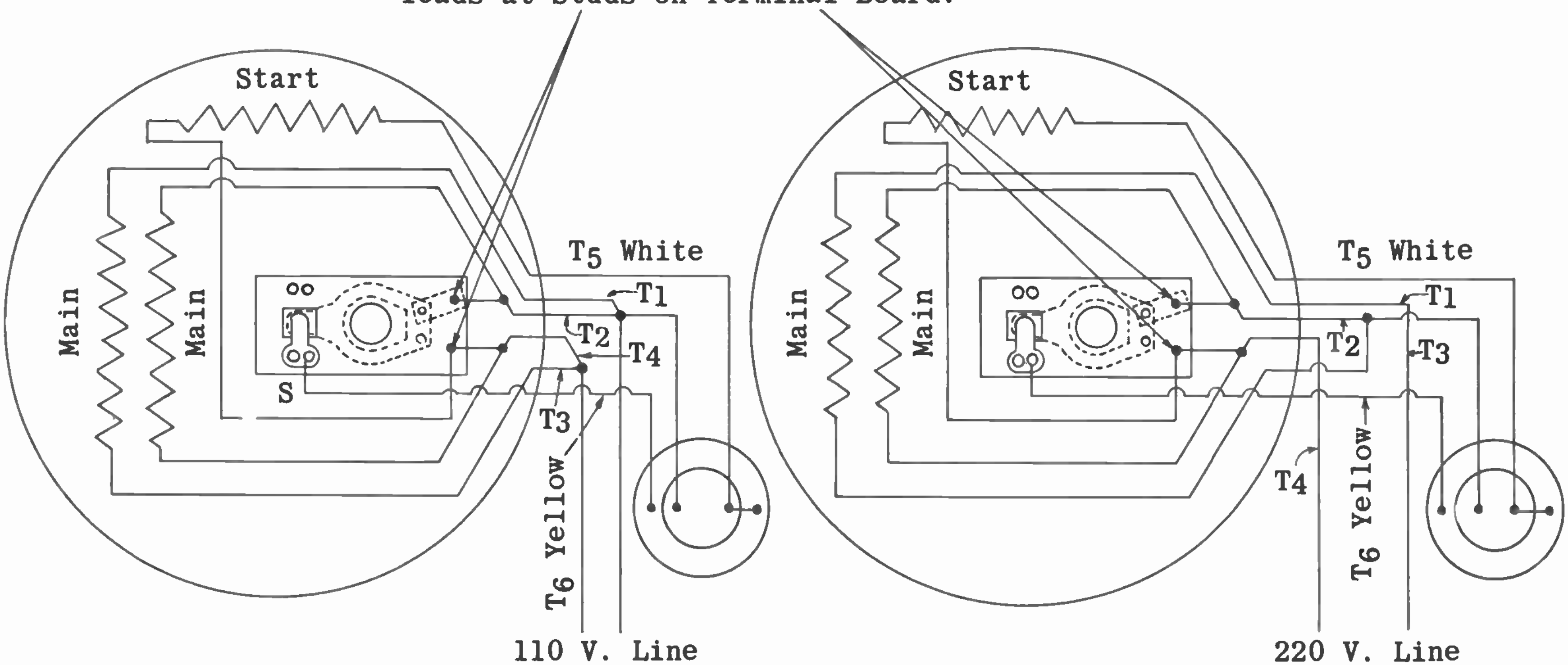
Janette Mfg.Co.
Chicago, Ill.

THE DUMORE COMPANY
RACINE, WISCONSIN

External Connection Diagram
for
No.12 Grinder

DUAL VOLTAGE, SINGLE PHASE, CAPACITOR MOTOR

NOTE:-For opposite direction of Rotation Interchange these leads at Studs on Terminal Board.



P.D.J.

Aug.10,1946.

3.6 CAPACITOR MOTORS

3.605 General

Where auxiliary devices (capacitors, transformers, contactors, relays or centrifugal switches) are included in or on the motor frame and permanently wired to the motor or where several auxiliary devices are assembled in a separate enclosure and are permanently wired together therein, terminal markings need be used only on leads coming out of the motor or from the separate enclosure. The terminal markings to be used for these leads shall be determined from the following standards.

3.610 Subscript Numerals for Capacitors and Transformers

Subscript numbers of the letters J, H and X shall be the same as the subscript number of the terminal marking T of the motor lead to which they connect when the motor is connected for standard rotation.

If the lead from a capacitor or transformer connects to a junction of two motor leads on a single voltage motor, the subscript number of H, J or X will be the lower of the numbers used for the interconnected motor leads when connected for standard rotation.

On dual voltage motors, the high voltage connection shall determine the subscript number of H, J or X, even though the low voltage connection is to be used.

3.615 Subscript Numerals for Relays, Contactors and Centrifugal Switches

External leads from the contacts of relays, contactors or centrifugal switches, when connected to motor, transformer or capacitor, shall bear the same terminal marking and subscript number as those used on the device to which each contact is connected when the motor is connected for standard rotation. (This is standard control practice.)

The coil terminals of relays or contactors shall bear the terminal marking and subscript number of the lead of the devices to which they connect, the lowest subscript being used when connected to a junction of two or more leads.

Interconnections solely between relays, contactors and centrifugal switches, either contacts or coils, shall bear a common numeral at each end, but no letter, and the numeral must be higher than the highest subscript numeral used on the motor, capacitor or transformer.

3.620 Subscript Numerals for Interconnections Between Auxiliary Devices

On an interconnection between a capacitor and a transformer or between either of these devices and a relay, contactor or centrifugal switch where there is no connection to a motor lead, a common subscript numeral shall be assigned to the letters J, H or X, used on the interconnected terminals which numeral must be higher than any subscript numeral used on any terminal marking of the motor leads. The relay, contactor or centrifugal switch terminal will take the same letter and subscript as the transformer or capacitor to which it connects.

3.625 Terminal Markings for the Starting and Running Windings

The terminals for starting and running windings for capacitor motors shall be marked in accordance with the principles established for single-phase motors in 3.505, Note II.

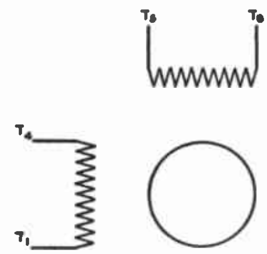
3.630 Terminal Markings for Dual Voltage, Single-Phase Capacitor Motors

The terminals for dual voltage, single-phase capacitor motors shall be marked in accordance with 3.510.

3.635 Connections and Terminal Markings—Capacitor Motors

The diagrams which illustrate most of the connections now in use for capacitor motors are shown on the next page.

AMERICAN STANDARD



A. CAPACITOR START, CAPACITOR RUN MOTORS‡
B CAPACITOR START, INDUCTION RUN MOTORS‡

FIG. I

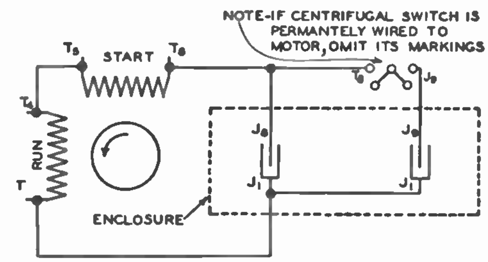


FIG. 5-HIGH TORQUE, CAPACITOR & CENTRIFUGAL SWITCH

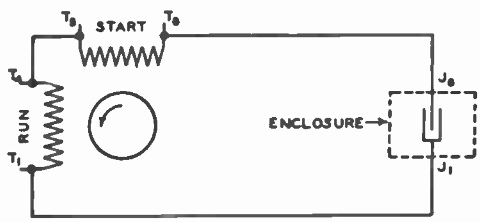


FIG. 2-LOW TORQUE, CAPACITOR ONLY

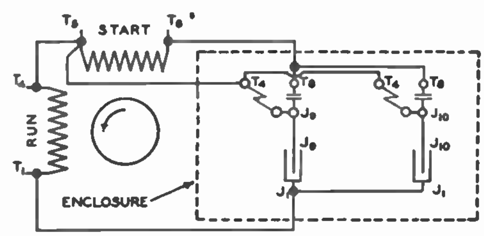


FIG. 6-HIGH TORQUE, CAPACITOR START, CAPACITOR RUN, TWO CONTACTORS

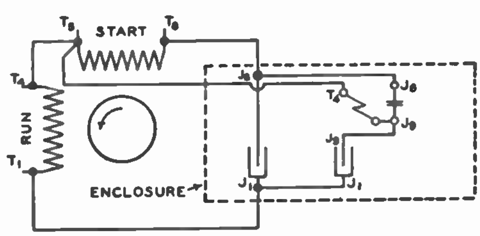


FIG. 3-HIGH TORQUE, CAPACITORS AND CONTACTOR

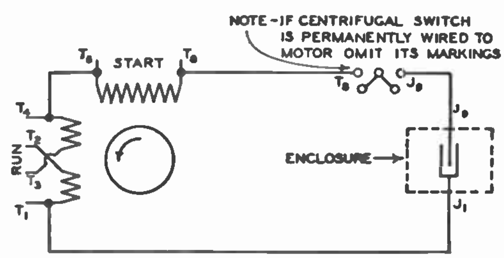


FIG. 7-CAPACITOR START, INDUCTION RUN, DUAL VOLTAGE

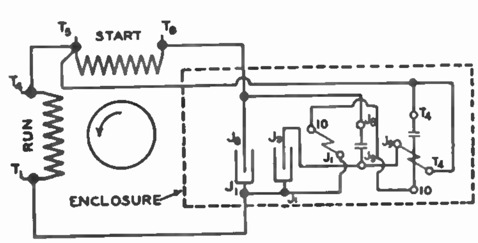


FIG. 4-HIGH TORQUE, CAPACITOR, RELAY AND CONTACTOR

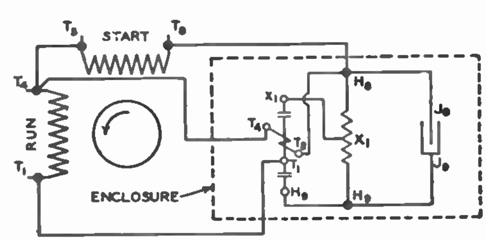
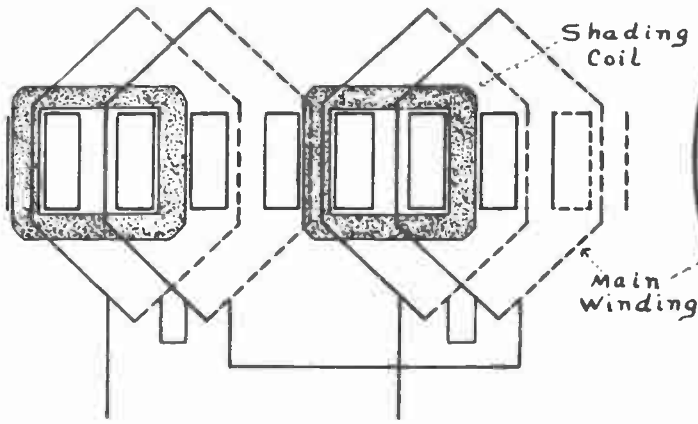


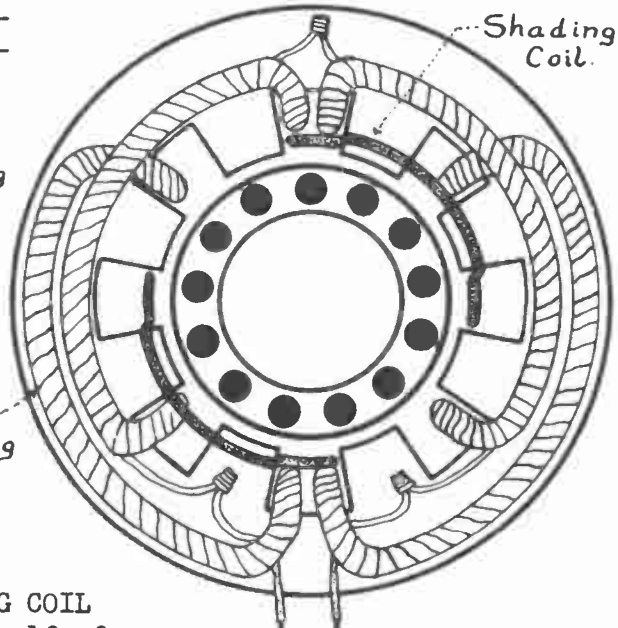
FIG. 8-CAPACITOR START AND RUN, WITH DOUBLE THROW CONTACTOR, TRANSFORMER AND CAPACITOR

‡ NOTE I—To be connected to capacitors in accordance with manufacturer's diagram.

NOTE II—Dotted lines show enclosures. If capacitor and relays are supplied with internal wiring in place, terminal markings to be applied only to external leads.

A SHADED POLE MOTOR is a single phase induction motor provided with an uninsulated and permanently short-circuited AUXILIARY WINDING displaced in magnetic position from the main winding.





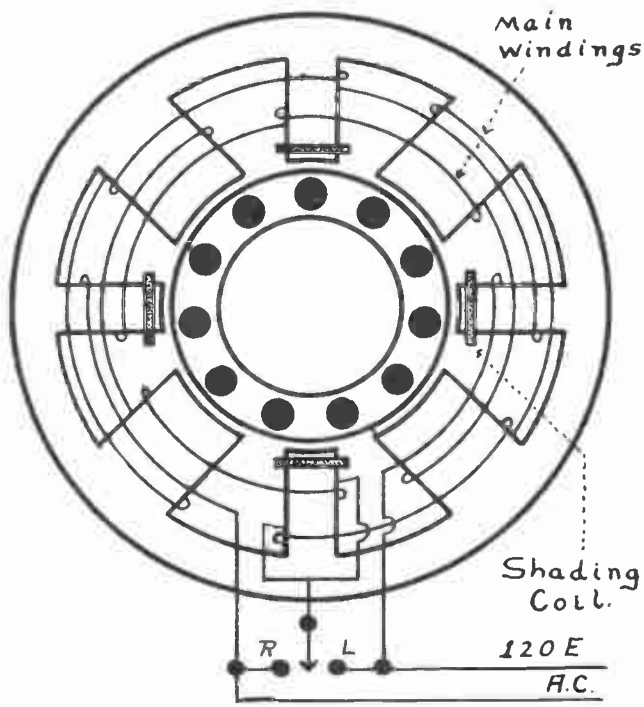
The AUXILIARY WINDING is known as the SHADING COIL and usually surrounds from one third to one half of the pole. The MAIN WINDING surrounds the entire pole and may consist of one or more coils per pole.

OPERATION: In the unshaded section of the pole, the magnetic flux produced by the main winding is in phase with the main winding current, whereas the flux produced by the shading coil is out of phase with the main flux. Thus the shading coil acts as a phase splitting device to produce the rotating field that is essential to the self-starting of all straight induction motors. As the movement of the flux across the pole face is always from the unshaded to the shaded section of the pole, the direction of rotation can be determined on the normally nonreversible motor by noting the position of the shading coil with respect to the pole itself, This type can be reversed by removing the stator from the frame, turning it through 180° and replacing it.

CHARACTERISTICS: The starting torque will not exceed 80% of full load torque at the instant of starting, increases to 120% at 90% of full speed, decreasing to normal at normal speed. This type motor operates at low efficiency and is constructed in sizes generally not exceeding one-twentieth H.P.

APPLICATION: Fans, timing devices, relays, radio dials, or in general any constant speed load not requiring high starting torque.

SHADED POLE MOTOR-2 MAIN WINDINGS: This type is externally reversible by means of a S.P.D.T. switch as shown in the lower diagram. Note that only one set of shading coils is used. Trace the circuits and establish the position of poles for both rotations.



Single-Phase Motors

Shaded-Pole Type

The shaded-pole type is one of the simplest self-starting single-phase motors. It has a stator, Fig. 1, like the field frame of a dc motor, built of laminated steel. A slot cut across each pole face holds a closed-circuit coil, called a shading coil, Figs. 1 and 2. This is often only a rectangular copper stamping.

When current increases in the main coils, a current is induced in the shading coils that opposes the magnetic field building up in the part of the polepieces they surround. This produces the condition of Fig. 3. When the main-coil current decreases, that in the shading coils also decreases until the polepieces are uniformly magnetized. As the main-coil current and the polepiece magnetic flux continue to decrease, current in the shading coils reverses and tends to maintain the flux in part of the polepieces.

When the main-coil current drops to zero, current still flows in the shading coils to give the magnetic effect, Fig. 5. By comparing Figs. 3, 4 and 5, one can see that the magnetic field has moved across the polepieces from left to right, showing how the shading coils produce a rotating magnetic field that makes the motor self-starting. This type of motor suits applications where starting torque is low, such as small fans, and comes in fractional horsepower sizes only.

The split-phase motor with running and starting windings in the stator, represents another self-starting single-phase type. The winding produces conditions at starting resembling those in a 2-phase motor.

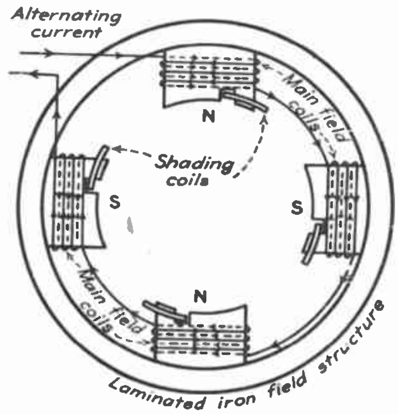


FIG. 1

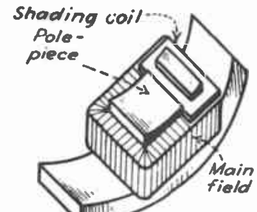


FIG. 2

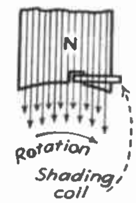


FIG. 4

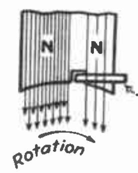


FIG. 3

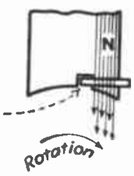


FIG. 5

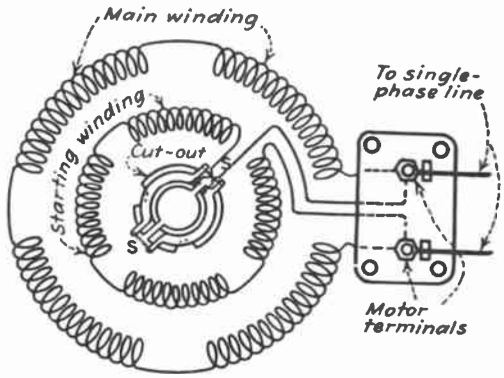


FIG. 6

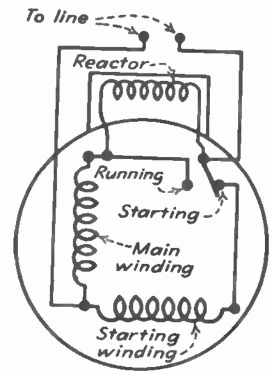
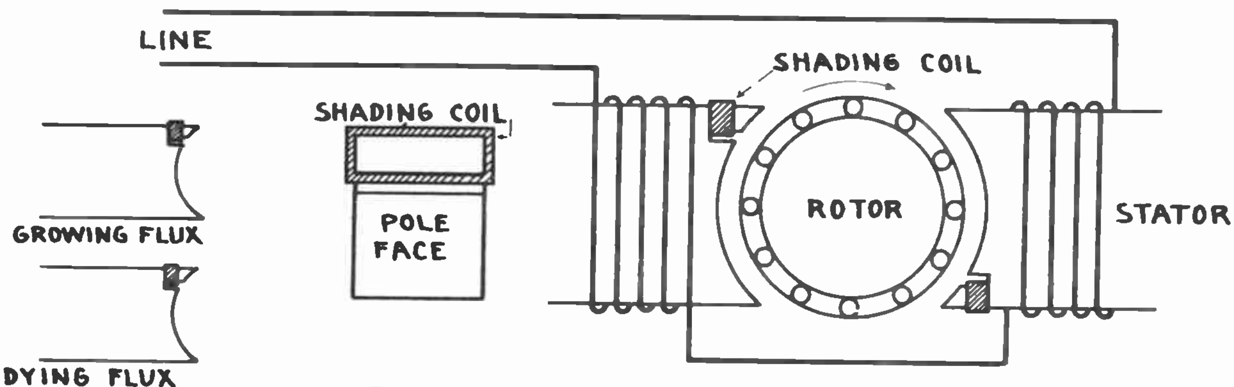


FIG. 7

Figs. 1 to 5—How a shaded-pole, single-phase motor operates. Fig. 6—Diagram of split-phase motor. Fig. 7—Diagram of split-phase motor with external reactor

Fig. 6 shows one design of split-phase motor. The main coils have comparatively low resistance and occupy about 75% of the slot space. A high-resistance starting winding fills the remaining slot space, displaced from the main winding by 90 electrical degrees.

Split-phase motors are also built with an external reactor, Fig. 7. connected in series with the main winding at starting. At about 75% operating speed the starting switch throws from start to run position, opens the starting winding circuit and short circuits the reactor. Adding the external reactor reduces the starting current and increases the current lag in the main winding.



SHADED POLE INDUCTION MOTOR.

Shaded Pole MOTORS

for Alternating Current Only

APPLICATION AND PERFORMANCE DATA

Application — The shaded pole induction motor is one of the most popular fractional horsepower motors in use today, chiefly because of its low cost of manufacture and its dependability. The only moving parts are the rotor and its shaft, so there is nothing to get out of order.

Motors of this type are successfully applied on applications such as fans, heaters, advertising displays and timers. All devices to be driven by motors of this type should require relatively little power or starting torque.

Characteristics—The more important of the many different characteristics of the shaded pole motors are included in the following tabulation:

1. **Simple construction.**
   No brushes or internal switches to introduce complications.

2. **Very quiet.**
   Favorable magnetic distribution and absence of brushes facilitate silent operation.

3. **Low starting current.**
   Most shaded pole motors may be stalled for extended periods without damage.

4. **Relatively constant speed.**
   Voltage changes have little effect on motor speed.

5. **Low starting torque.**
   Care must be taken to insure the motors having adequate torque to start loads under adverse conditions.

6. **Inexpensive.**
   Shaded pole motors are usually less costly in small sizes than any other type.

The shaded pole motor, being simply a salient pole single-phase induction motor with an ordinary squirrel cage rotor and with machine wound pole windings, is extremely simple in construction. This simplicity is responsible for its ability to carry loads for extended periods and under adverse conditions because there are not internal switches or brushes to cause trouble.

The construction also keeps the manufacturing cost down and it is to the inexpensiveness of the shaded pole motor that much of its popularity can be attributed. Shaded pole motors of very cheap construction are often used for small domestic appliances.

Simple construction also helps in securing quiet operation. In addition, the magnetic distribution of the shaded pole motor is rather favorable, and for this reason shaded pole motors are frequently used where quietness is an important consideration.

The motor speed is relatively constant at a given load, being affected but little by voltage fluctuations. If the load varies there will be some change in speed, but this is relatively small, especially in comparison with a series wound universal motor. Introducing a series resistance or reactor in the circuit will decrease the speed somewhat, but this is often not practical because the breakdown torque of the motor is decreased.

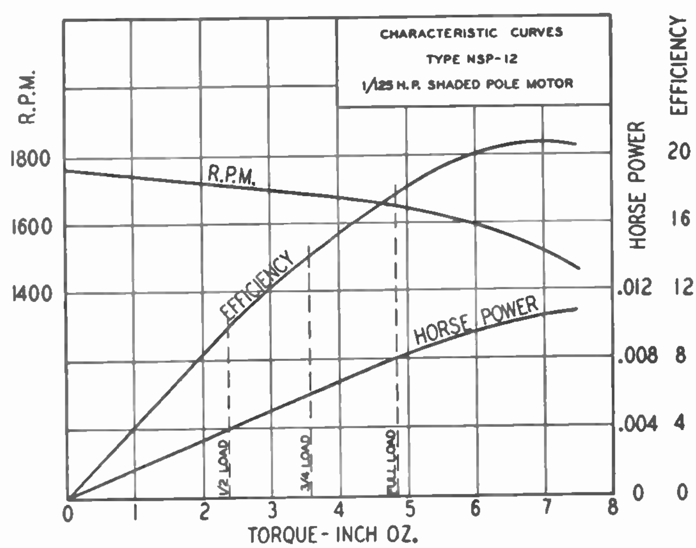


Fig. 1—Characteristic curves for one of the Bodine shaded pole motors.

The starting torque of a shaded pole motor is always low, and depends to some extent upon the position of the rotor. The shaded pole motor is therefore used chiefly for driving fans and other appliances in which there is very little load at starting.

Because the shading coils (or starting windings) are in the circuit during both starting and running, the efficiency of the motor is very low. It is therefore generally used only in small sizes where power consumption is a relatively unimportant factor.

Construction—The four salient poles of the shaded pole motor are arranged as shown in the accompanying diagram. Shading coils, punched from copper, like rectangular washers, are fitted over one of the pole tips. These form the starting winding or shading pole. Alternating current in the regular pole introduces an alternating current in this shading coil. The latter current lags considerably behind the current in the main winding. Since the two windings are not on the same center line, the current lag in the shading coil sets up a revolving field which, while not as smooth or as steady as that in a polyphase induction motor, pulls the rotor around in the same manner. The direction of rotation is always toward the shading coil.

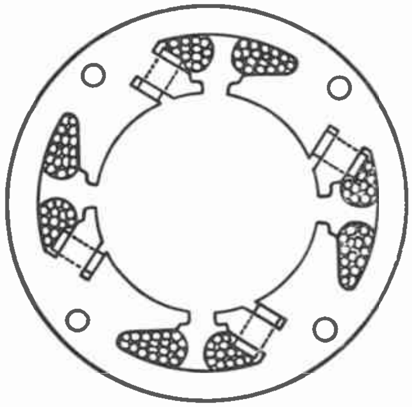


Fig. 2—Cross section of a small shaded pole motor. Note the large main coils which surround the field poles and the four stamped shading coils over the pole tips.

As the shaded pole motor has salient poles, the coils which go over them may be form wound by machine, rather than hand wound as would be necessary if the poles were distributed The simple stamped metal loop which forms the shading coil can then be easily slipped into place.

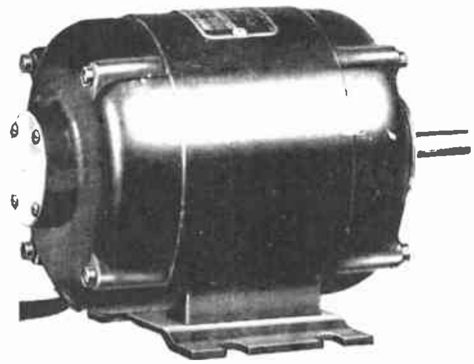


Fig. 3—A small shaded pole motor of high quality — Bodine Type NSP-12.

Motors of this type are generally wound with four poles as in the diagram, or with two poles. The number of poles determines the motor speed, which approximates 1600 rpm for the four pole windings.

Shaded pole motors are usually operated at the point where the speed tends to fall off appreciably with increase in load, to secure best efficiency and greatest output.

The rotor of a shaded pole motor is very similar in appearance to the squirrel cage rotors used on split-phase and polyphase motors. It consists of a number of laminations of high grade silicon steel stacked together, a copper lamination being placed at each end of the stack. Copper rivets, uniformly spaced around the periphery of the laminations, hold the stack together.

Bodine shaded pole motors may be obtained with speed reducers built as an integral part of the motor. Both single and double worm gear reductions are available, permitting a wide choice of drive shaft speeds. Speed reducer motors are described more completely in other catalog sheets.

For dimensions and ratings of shaded pole motors, consult the appropriate catalog pages.

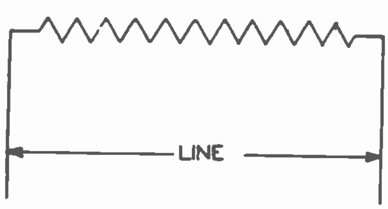
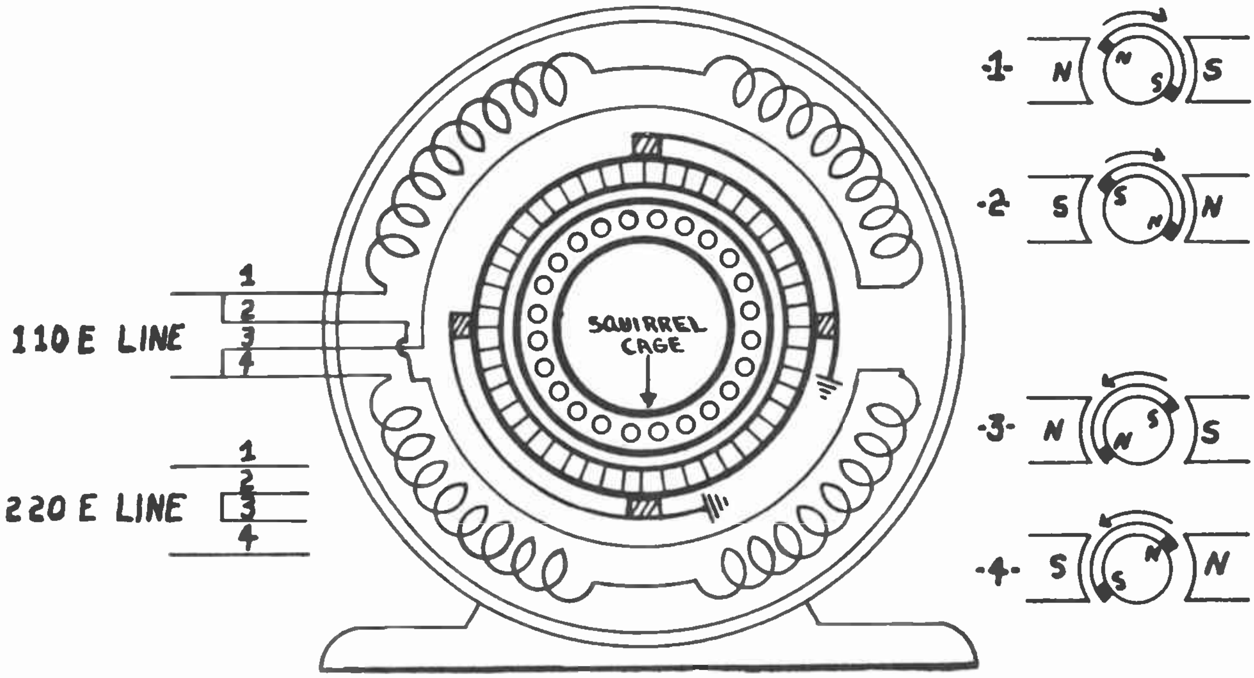


Fig. 4—Shaded pole motors have all coils connected in series with the line.

REPULSION-INDUCTION MOTOR



OPERATION

This motor is different from the repulsion-start-induction type in that it has no centrifugal switching mechanism, no short-circuiting device, and no brush raising equipment. Starting as a straight repulsion type, this motor combines both repulsion and induction operation when running. In addition to the regular winding, the rotor of this motor is equipped with a squirrel cage as shown in the diagram above. Both windings are located in the same slots and the squirrel cage, although inactive at the instant of starting, develops a gradually rising torque as the speed increases When normal speed is reached both windings are carrying load. A further advantage of the squirrel cage lies in its speed regulating action, this effect tending to maintain constant speed with variable load. The advantages claimed for this type of motor are no centrifugal or short-circuiting mechanism to give trouble, good commutation, simple construction, and a high power factor during operation at or near full load.

CHARACTERISTICS

This motor will develop 4 times normal full load torque with 3½ times normal full load current. The variation in speed from no load to full load will not exceed 5% of the normal full load speed. See curves below.

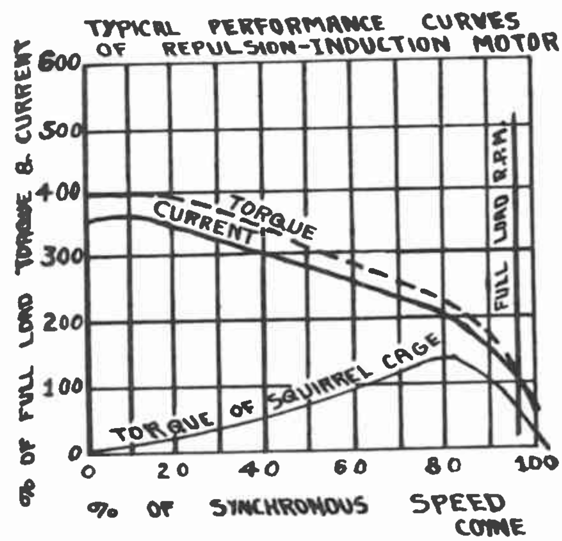
APPLICATION

Air compressors, pumps, strokes, hoists, conveyors, machine tools, dairy machinery, etc. In general, this motor is suitable for any type of load requiring a high starting torque and constant speed operation.

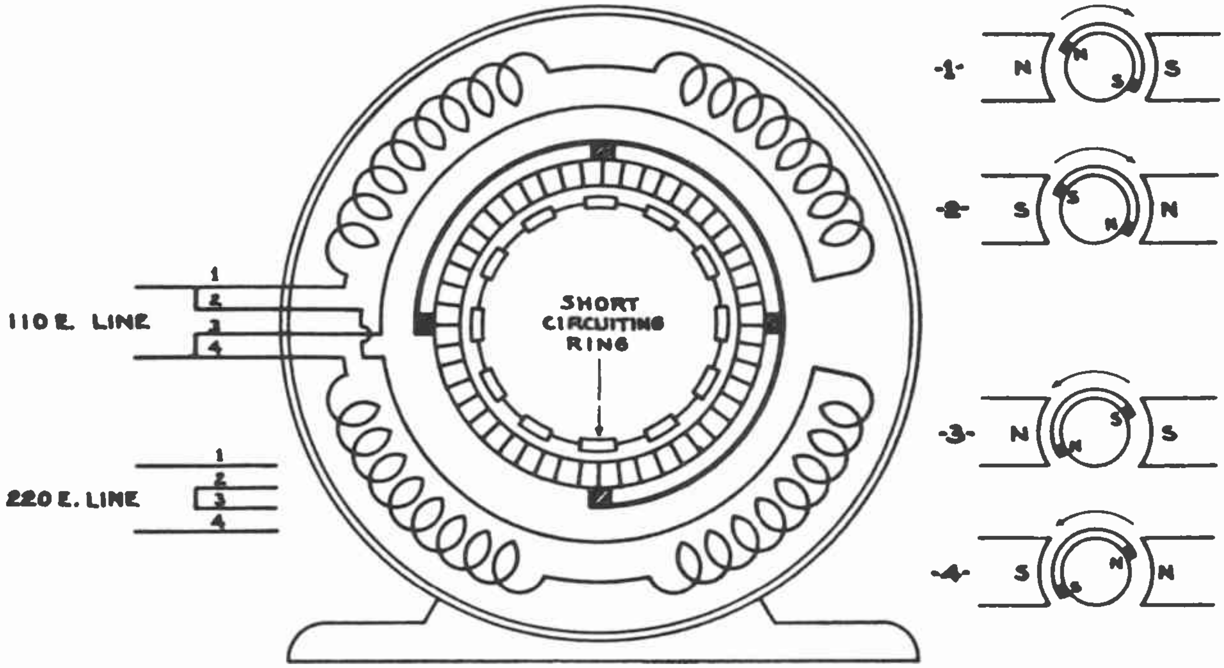
PRINCIPAL TROUBLES

Commutator, brushes, brush holder, bearings, insulation, and opens, grounds, shorts, and loose connections in either the rotor or stator windings.

The repulsion type motor is very sensitive to brush setting, and for this reason the manufacturer marks the brush holder and housing to facilitate brush positioning. One commutator bar from the correct position may cause unsatisfactory operation. To reverse the direction of rotation, shift the brushes.



REPULSION-START-INDUCTION MOTOR



OPERATION

In this motor are combined the high starting torque of the repulsion-type and the good speed regulation of the induction motor. The stator of this machine is provided with a regular single-phase winding, while the rotor winding is similar to that used on a D.C. motor. When starting, the changing single-phase stator flux cuts across the rotor windings inducing currents in them, that, when flowing through the commutator and brushes, set up poles on the rotor which remain stationary in space and maintain a continuous repulsive action upon the stator poles. This motor starts as a straight repulsion-type and accelerates to about 75% of normal full speed when a centrifugally operated device connects all the commutator bars together and converts the winding to an equivalent squirrel-cage type. The same mechanism usually raises the brushes to reduce noise and wear. Note that, when the machine is operating as a requlsion-type, the rotor and stator poles reverse at the same instant, and that the current in the commutator and brushes is A.C.

CHARACTERISTICS

This motor will develop 4 to 5 times normal full load torque and will draw about 3 times normal full load current when starting with full line voltage applied. The speed variation from no load to full load will not exceed 5% of normal full load speed. For complete data on current, torque, etc., see curves below.

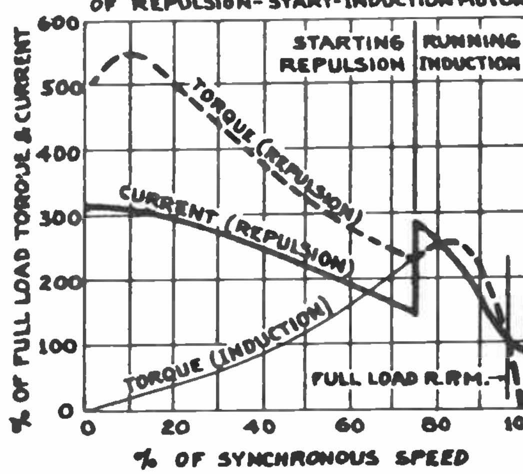
APPLICATION

Air compressors, refrigeration compressors, plunger-type pumps, meat-grinders, small lathes, small conveyors, stokers, etc. In general, this type of motor is suitable for any load that requires a high starting torque and constant speed operation. Most motors of this type are less than 5 h.p.

TROUBLES

Commutator, brushes, centrifugal switch, short-circuiting rig, bearings, oil-soaked insulation, solder thrown out of commutator, too much or too little tension on the throw-out spring; opens, shorts, or grounds in the rotor of stator windings. Rotation is reversed by shifting the brushes.

TYPICAL PERFORMANCE CURVES OF REPULSION-START-INDUCTION MOTOR



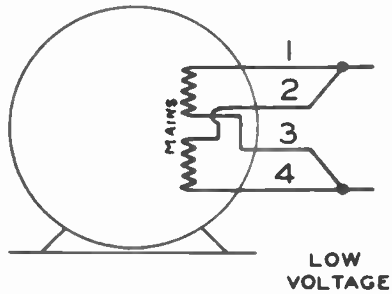
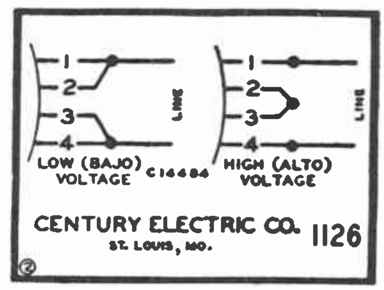
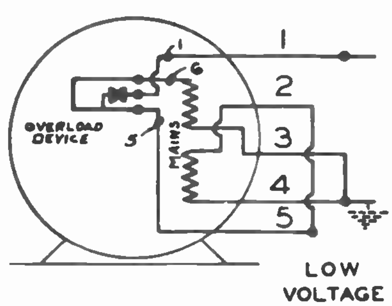
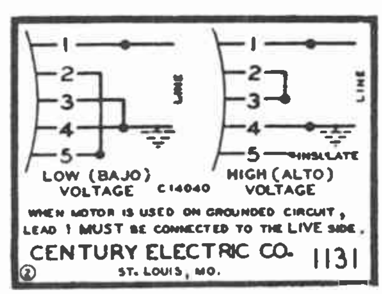
COYNE

Century

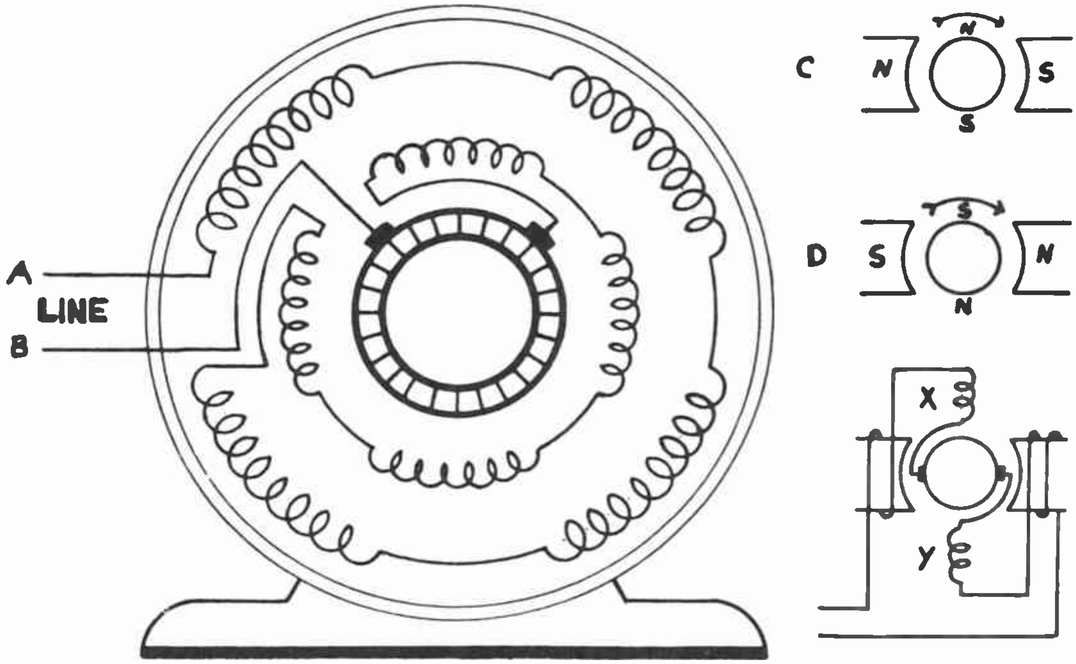
ENGINEERING INFORMATION

REPULSION START INDUCTION MOTORS

TYPE RS; 110/220 VOLTS; REVERSIBLE

	Frame	Internal Connection Diagrams	Label (Attached To Cover Over Terminals)
	WITHOUT OVERLOAD PROTECTION.		
	All		
	WITH OVERLOAD PROTECTION		
	1/8 HP	Dual Voltage Overload Device not available. 110 V. Device supplied - Connected in series in Line Lead.	Two (2) Lead Motors with Ground Marker On Lead without Overload Device. No Label Furnished
	All 1/6 HP and Larger	C-14241 	

UNIVERSAL SERIES MOTOR



The above motor operates on the magnetic interaction between the armature and field poles, and runs in the same direction whether the current flows in on line A or line B, since reversing the flow of current in the line wires changes the polarity of both armature and field poles at the same instant as shown at C and D. Therefore, if such a motor be supplied with A.C. the torque developed will always be in the same direction. Since this machine operates on both D.C. and A.C. it is called a Universal motor. To operate satisfactorily on A.C. all parts of the magnetic curcuit must be laminated to prevent undue heating from eddy currents, and element windings are usually desirable on the armature to ensure acceptable commutation. On the larger motors compensating windings are employed to improve operation and reduce sparking.

CHARACTERISTICS

This motor will produce about 4 times normal full load torque with 2 times normal full load current. The torque produced increases very rapidly with an increase in current as the curves below indicate. The variation in speed from no load to full load is so great that complete removal of load is dangerous in all motors of this type except those having fractional H.P. ratings.

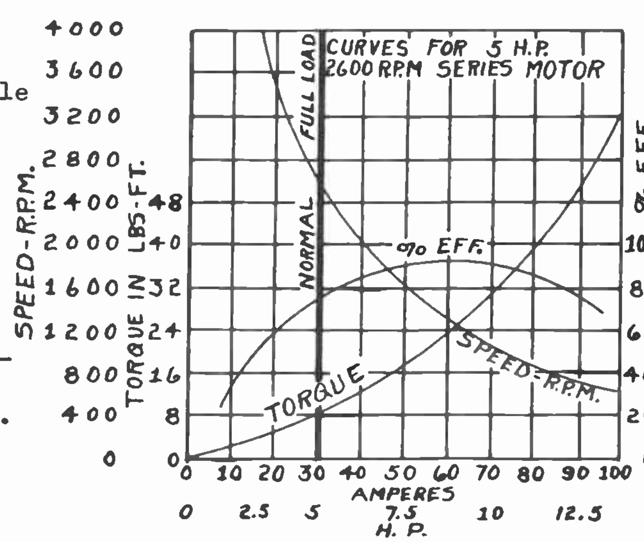
APPLICATIONS

This motor is widely used in fractional H.P. sizes for fans, vacuum cleaners, kitchen mixers, milk shakers, and portable equipment of all types such as electric drills, hammers, sanders, saws, etc. Higher ratings are employed in traction work, and for cranes, hoists, and so on. In general, they are suitable for applications where high starting torque or universal operation is desired.

PRINCIPAL TROUBLES

Commutator, brushes, brush holders, bearings. Opens, shorts, or grounds in the armature, field, or associated apparatus. Loose connections.

To reverse the direction of rotation, reverse the armature connections or the field connections, but not both.



Series MOTORS

AC, DC and Universal

APPLICATION AND PERFORMANCE DATA

Application—Series motors can be successfully applied to almost any device which does not require a constant motor speed. They are found on household food mixers and sewing machines, on typewriters and calculating machines, on portable tools, and on all equipment which must operate with the same motor on alternating and direct current. Devices requiring high motor speed or wide speed variation are usually equipped with motors of this type.

Series wound motors are used on either alternating or direct current, and when so designed the same motor can be used on both. It is then referred to as a universal motor.

Characteristics — Among the principal features of series motor operation are the following:

1. **Universal operation.**
   Motor usually designed for both a-c and d-c.
2. **Variable speed.**
   Motor speed drops with added load or decreased voltage. Rheostat control of speed is practical.
3. **High starting torque.**
   High speed series motors have a higher starting torque for a given rating than motors of any other type.
4. **High motor speeds.**
   Higher motor speeds can be obtained from series motors than from any other motors designed for use on commercial currents.
5. **High output for a given frame size.**
   Good efficiency and high speed combined produce maximum output.
6. **Reversible.**
   Motors may be wound for reversibility with either single or double pole switches. Reversing may be accomplished either at standstill or while rotating.

Series motors are most frequently used as universal motors. No universal motor, however, has exactly the same characteristics on alternating and on direct current. The output on d-c is higher at a given speed than it is on a-c, this effect being due to the increased impedance of the windings on a-c.

In selecting a series wound motor, allowance must be made for this difference in performance, which will depend upon the nature of the load and the speed at which it is driven. The higher the operating speed, the more nearly alike will be the characteristics.

Occasionally resistance is used to reduce the d-c speed, or a special tapped winding requiring the use of a switch in changing from d-c to a-c may be resorted to. These methods, however, complicate the mechanism and add to the cost.

Series motors change their speed inversely with change in load, and will not drive each of a number of similar machines at the same speed. There will be small load differences caused by bearing fits and similar mechanical factors. These same factors will also cause differences in friction within the motor, so that both the no load and full load speeds of similar motors will be somewhat different. If constant speed is desired, some motor other than the series type should be considered.

Voltage fluctuations also affect series motor speed, a drop in voltage producing a drop in speed. This makes it possible to secure variable speed by means of a rheostat.

Adding resistance to one side of the line reduces motor output as well as speed. It also reduces the starting torque, and unless care is used in the selec-

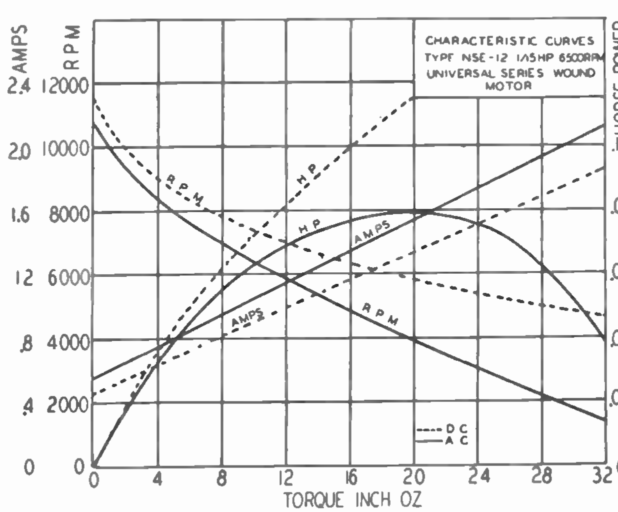


Fig. 1—Typical series wound motor performance curves.

tion of the resistance values the motor may fail to start under load.

Resistance is sometimes used across the motor armature. This tends to compensate for the difference in a-c and d-c operation, to increase the starting torque, and to generally stabilize motor operation. If a variable rheostat is used, it will function as a speed control, although not over as wide a range as if it were placed in the line as outlined in the preceding paragraph. A sufficiently high value of resistance should be selected to prevent overheating of the field coils.

The high efficiency of series wound motors makes possible more output from a given frame size than for other types of motors. This is an important factor in the selection of series wound motors for portable equipment. Where the duty cycle is very intermittent so that temperature rise can be disregarded, the output can be increased to several times that obtainable in a constant speed type of motor in the same frame size. Since series wound motors develop their maximum efficiency at relatively high speeds (4000-8000 rpm) they are especially desirable for high speed devices such as drills, saws and routers.

Motors wound for only one direction of rotation generally have longer brush life than do reversible motors, since the communtator is more advantageously connected for non-reversible units.

Due to the high speeds at which series wound motors usually operate, the life of brushes and bearings is appreciably less than for the constant speed type motors. The servicing factor, therefore, limits their application in general to intermittent duty applications. Series wound motors have, however, been applied successfully on many continuous duty applications where the operating characteristics required are favorable, or the nature of the application is such that a moderate amount of servicing is expected.

The brushes selected for Bodine series wound motors which are carried in stock are of a grade best suited for satisfactory all around performance. Where motors are built to order for a given application, the proper grade of brush is selected to give longest life for the operating conditions involved. All factors in design and application which affect motor performance also affect brush life. Special consideration is given to these by Bodine Engineers in building motors for a given application.

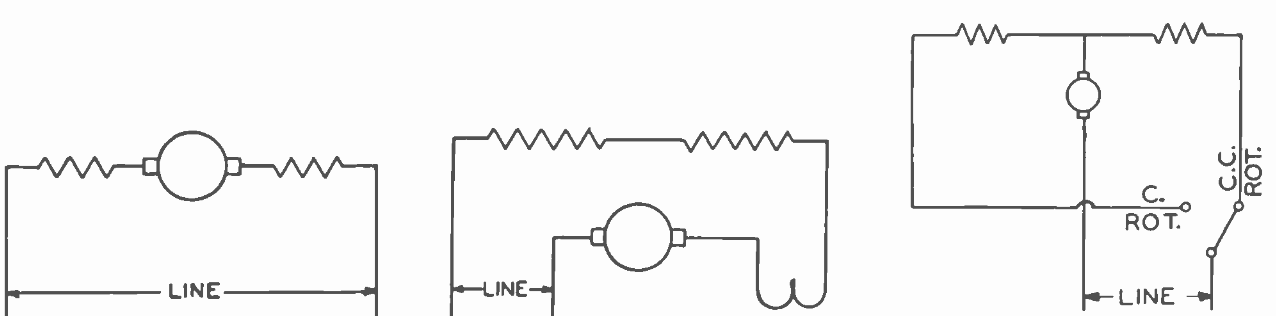
Construction—Bodine series wound motors may be obtained in a wide range of frame sizes from 2⅞" diameter upward. These frames are of several different designs so that the special requirements of any motor drive application may be most satisfactorily met.

The motor ratings are dependent upon the speed desired, the continuity of service, and other factors governed by the individual application. In general, series motors are rated at ⅛ hp and less at 3600 rpm, but higher ratings may be furnished if the operating conditions are favorable.

All Bodine motors are designed to give the most reliable operation. Special care is taken to provide good commutation, and to insure proper protection of armature windings at high speeds. Armatures are carefully balanced against vibration. Motor frames may be ventilated or enclosed, with sleeve or ball bearings.

Series motors are all of the wound armature type, with two salient field poles. Complete constructional details will be found in the Bulletins describing each motor frame.

Practically all frames may be furnished with speed reducers to simplify drive problems.



(a) 2 LEAD NON-REVERSIBLE (b) 4 LEAD REVERSIBLE (c) SPLIT-FIELD 3 LEAD REVERSIBLE

Fig. 2—Three of the most commonly used internal connections for series wound motors. Others can be furnished where required.

SPEC. NO.

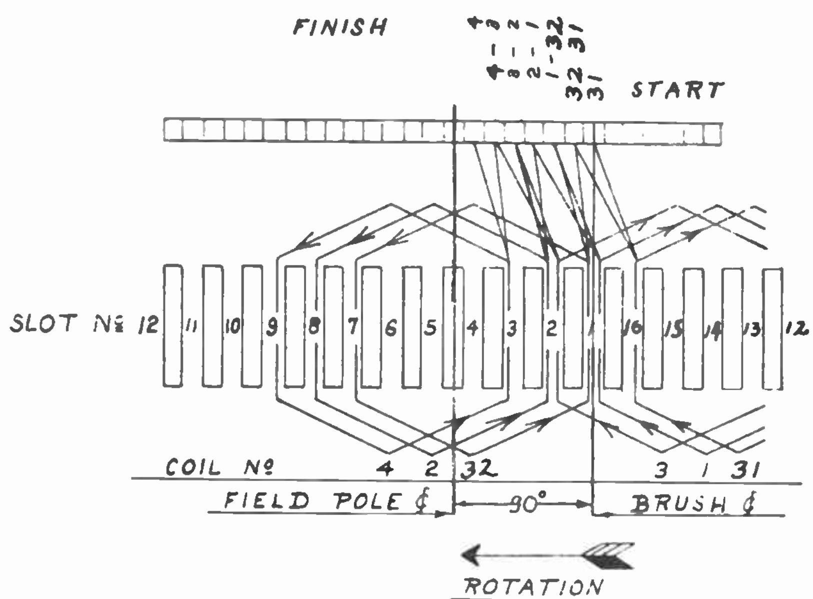
THE DUMORE COMPANY RACINE, WISCONSIN	STOCK NO.
WIRING DIAGRAM AND WINDING INFORMATION	
MATERIAL	
MATERIAL PER PIECE IN POUNDS	
SHEARING WIDTH SINGLE RUN / DOUBLE RUN	
NO. REQUIRED / DRAWN BY W.P.	PATT. NO.
SCALE / TRACED BY	
DATE / CHECKED BY GGF	CHANGES

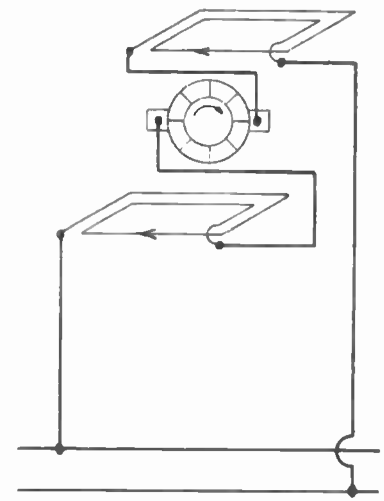
ARMATURE WINDING — LBS. MAGNET WIRE

VOLTS	6	8	10	12	18	24	32	40	48	60	80	90
TURNS PER COIL												
SIZE OF WIRE												
INSULATION												
VOLTS	100	110	115	125	150	180	200	210	220	230	240	250
TURNS PER COIL												
SIZE OF WIRE												
INSULATION												

FIELD WINDING — LBS. MAGNET WIRE

VOLTS	6	8	10	12	18	24	32	40	48	60	80	90
TURNS PER COIL												
SIZE OF WIRE												
INSULATION												
VOLTS	100	110	115	125	150	180	200	210	220	230	240	250
TURNS PER COIL												
SIZE OF WIRE												
INSULATION												





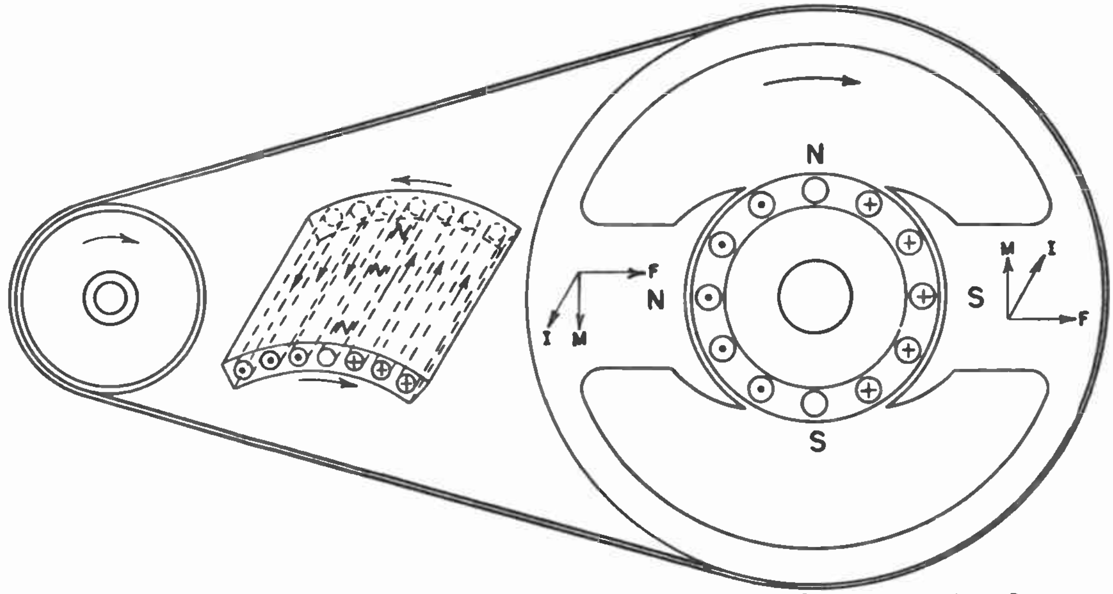
SERIES UNIVERSAL
C.W. ROTATION

H TYPE

COMM. CONN.	1-3L
COIL PITCH	1-8
SLOTS	16
BARS	32

ROTATING MAGNETIC FIELD

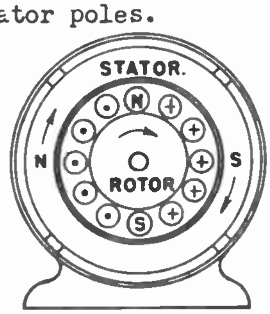
NOTE; FLEMINGS RULE IS APPLIED TO MOTION OF THE CONDUCTOR.
FLUX MOVING UP IS EQUIVALENT TO CONDUCTOR MOVING DOWN.



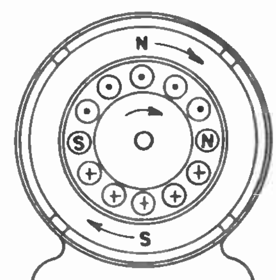
If a permanent magnet of the type shown above be rotated about a squirrel cage rotor, the flux of the magnet will cut across the squirrel rotor bars and induce voltage in them. The direction of these voltages at any instant may be determined by Fleming's Right Hand Rule. Application of this rule to the diagram above shows that currents will be flowing toward the observer under the North pole, and away from the observer under the South pole.

Viewed from above, current is circulating counter-clockwise around the rotor thereby establishing a North pole at the top and a South pole at the bottom. As the magnetic field is rotated, the rotor poles move at the same speed and in the same direction and maintain the same relative position; that is, midway between the stator poles.

A



B



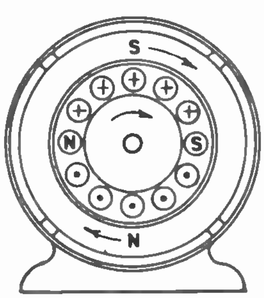
Diagrams A B C D show the relative position of the rotor and stator poles for four different points in one revolution.

In A there exists at the instant shown the same condition described above. In this case however, the rotating magnetic is produced by a different method.

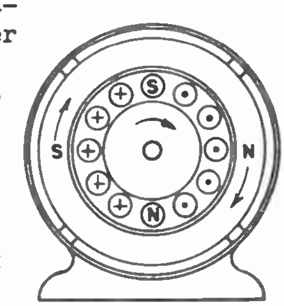
In B the revolving field has moved through one-quarter revolution. Note the change in current distribution in the rotor bars and the movement of the rotor poles. Diagrams C and D show the condition at later points in the revolution. Reversal of current in rotor bars causes rotor poles to revolve.

Although the diagrams show the current in the rotor bars changing direction in groups, the rotor bar currents actually reverse one at a time as the stator flux sweeps by. This produces a smooth progression of the poles around the rotor.

D



C



Squirrel-Cage Motors

FIG. 4

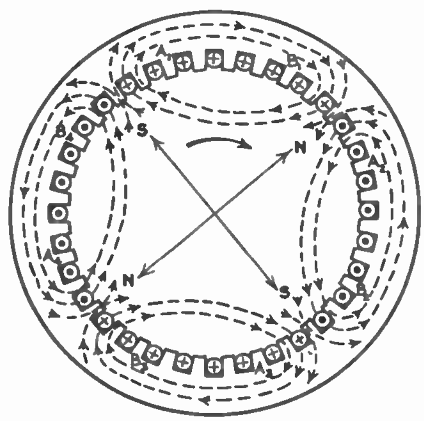


FIG. 5

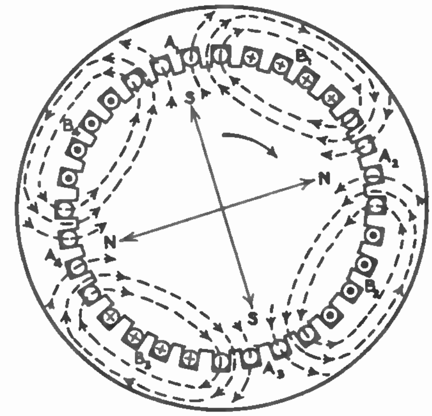


FIG. 6

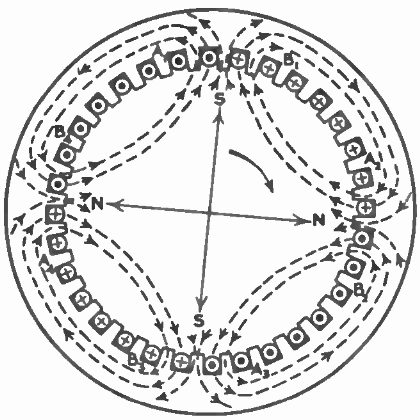


FIG. 7

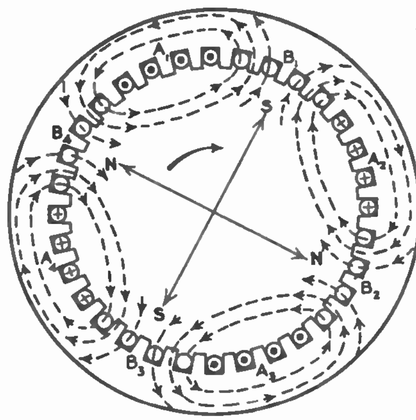


FIG. 8

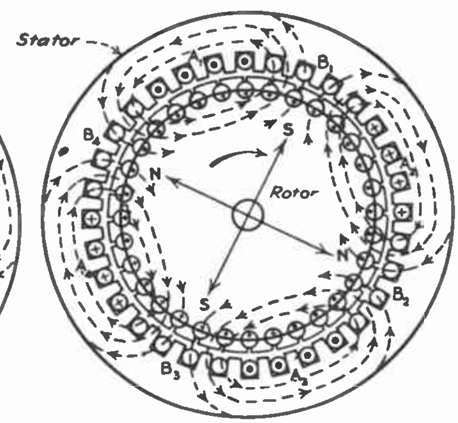


FIG. 9

Figs. 4 to 8—How the magnetic field in an induction-motor stator can be made to rotate when its windings are connected to a 2-phase circuit. Fig. 9—Direction of current generated in a rotor winding shown by dots and crosses on the rotor bars

Fig. 1

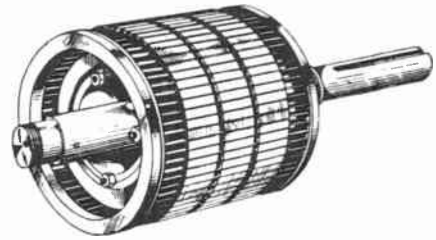


Fig. 2

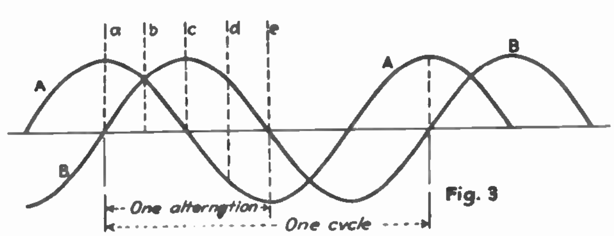


Fig. 3

Fig. 1—Stator of an induction motor. Fig. 2—Squirrel-cage rotor of an induction motor. Fig. 3—Two-phase voltage or current curves

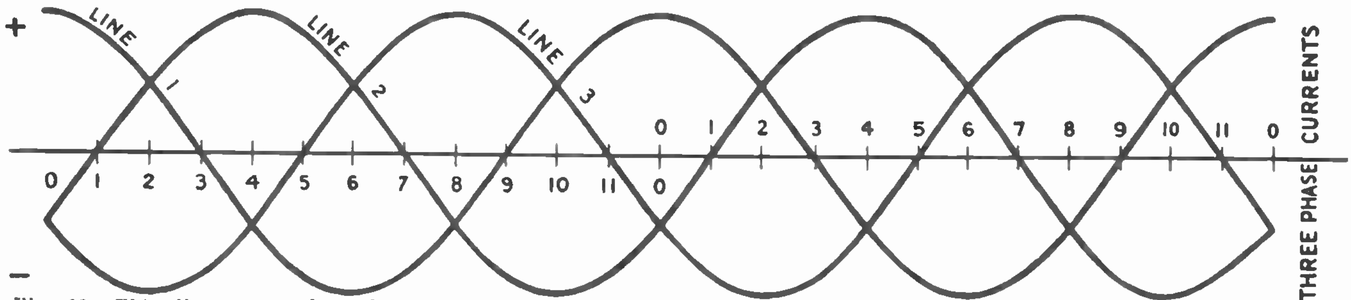
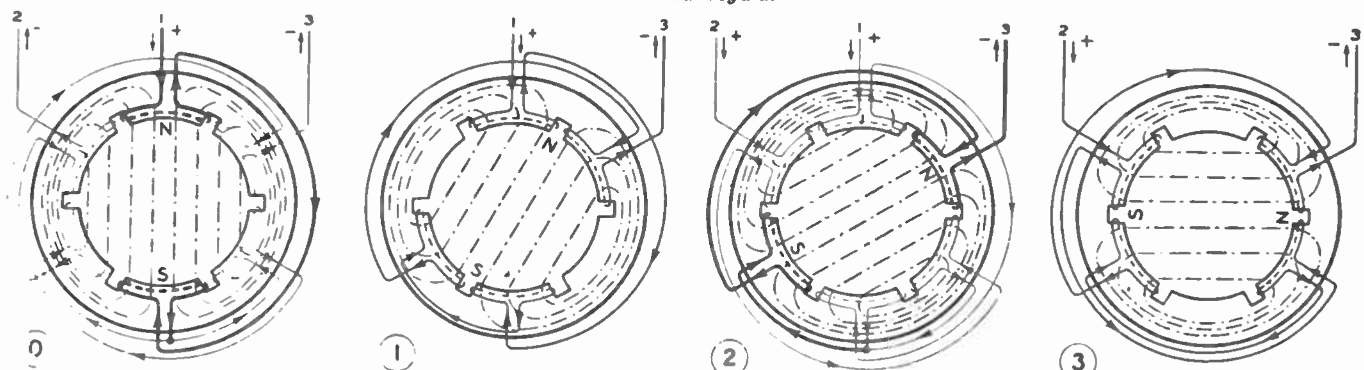


Fig. 60. This diagram of three-phase voltages covers two complete cycles. The numbers on it refer to the numbers on the diagrams below. Each diagram shows the condition in the armature at the instant indicated by the corresponding number on this curve. The action of the magnetic field is smooth and regular; the rise and fall of currents in the conductors is also smooth and regular



(0) *The current entering the motor on line 1 divides equally and leaves the motor on line 2 and line 3*

(1) *Now the current in line 2 is zero and that flowing in at line 1 leaves at line 3. The magnetic field revolves clockwise*

(2) *The current in line 1 is small and joining that from line 2 flows out in line 3 which carries a maximum negative current*

(3) *This and the following diagrams show how the magnetic field continues to rotate throughout the remainder of the cycle*

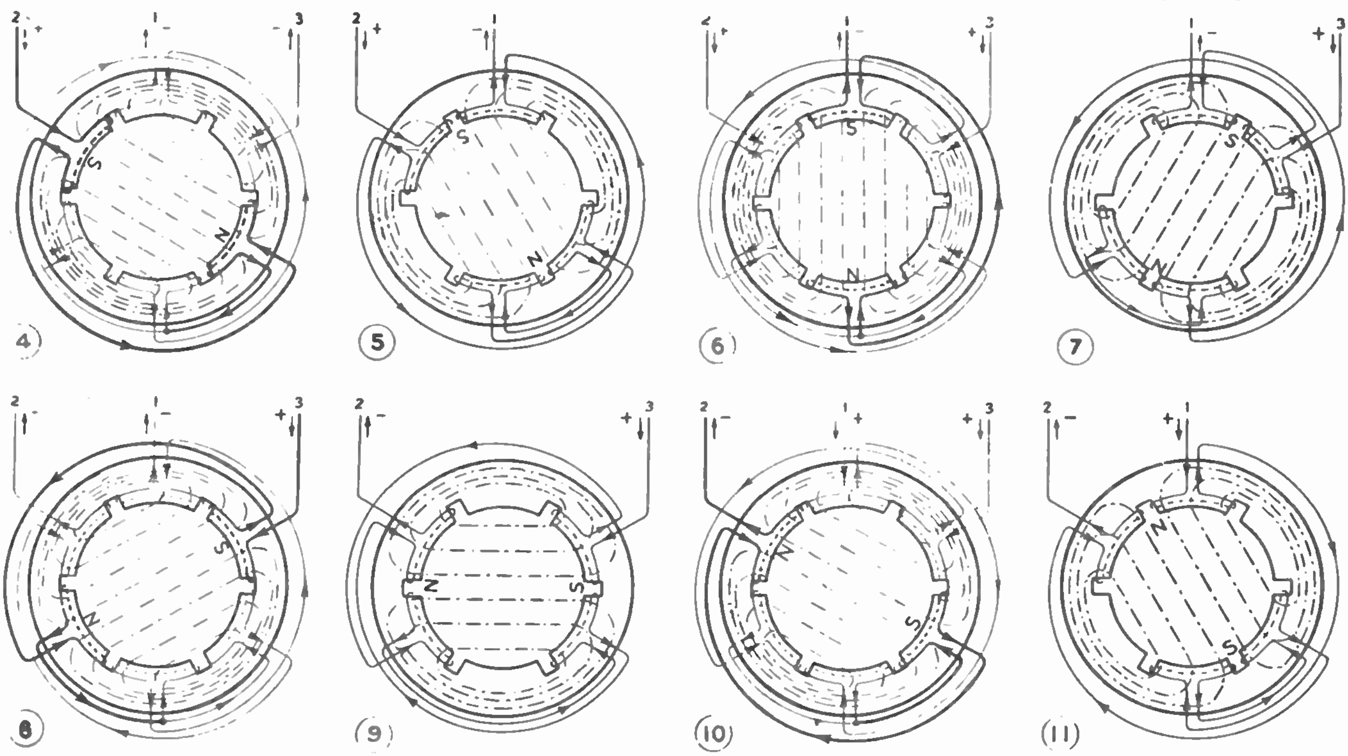


Fig. 61. This series of twelve diagrams shows the electric and magnetic conditions in a two-pole, three-phase motor at the end of twelve equal parts of one cycle

Polyphase MOTORS

Including Polyphase Synchronous
for Alternating Current
APPLICATION AND PERFORMANCE DATA

Application—Polyphase motors provide a highly reliable drive for machinery, and can be used on practically any constant speed machine where polyphase power is available. They are frequently used on industrial equipment, but are seldom found on domestic appliances in this country, where most service is single phase, from 110 to 120 volts.

Polyphase motors are most generally wound for 220 volts, although in some metropolitan centers there are 208 volt a-c networks for which the motors are usually made to order. Three phase motors are cataloged, but two phase motors can also be supplied.

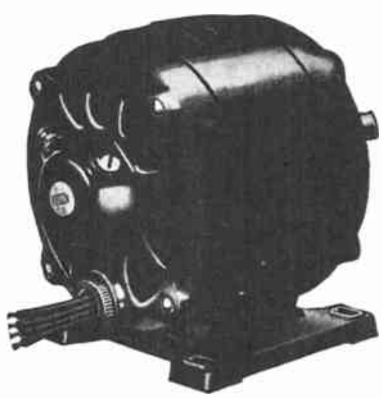


Fig. 1—The Type NPP-54, 1/8 hp, polyphase motor, 5 5/8" in diameter. Other motors vary from 3-21/64" to 5 5/8".

Bodine polyphase motors are regularly manufactured with ratings from 1/70 to 1/4 hp. at 1725 r.p.m. Lower speeds cannot, in general, be furnished because the stator of such small motors does not provide sufficient slots for the winding.

Polyphase synchronous motors develop less output, and carry ratings from 1/150 to 1/8 h.p. at 1800 r.p.m.

Characteristics—The most outstanding characteristics of polyphase motors are listed below:

1. Practically Constant Speed

The speed drops about 3% from no load to full load for non-synchronous motors.

2. Exceptional Reliability

There are no brushes to replace, and no centrifugal switches are used inside the motor. The only physical connection between the rotating shaft and the rest of the motor is at the bearings.

3. Easily Reversed

The motor can be reversed by merely interchanging two of the three line connections. This reversal can be accomplished either at standstill or while rotating, but frequent reversals will tend to make the motor run hot.

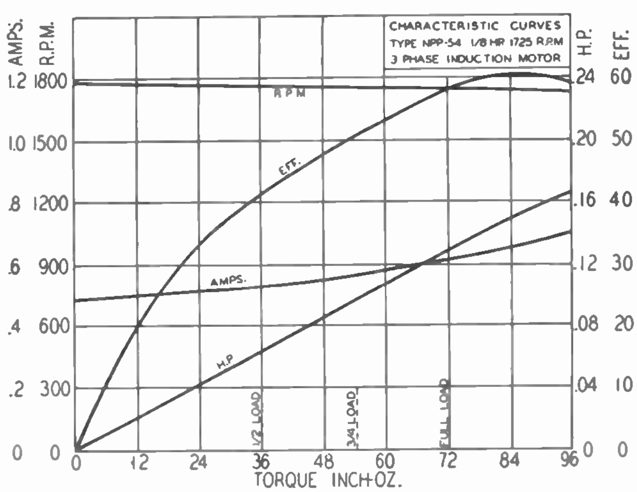
4. Definitely Fixed Speeds

Sixty cycle motors operate at 1725 r.p.m.; 25 and 50 cycle motors at 1425 r.p.m.

5. High Starting Torques

These motors develop starting torques from 200-350% of full load torque, depending upon motor size.

A polyphase squirrel cage induction motor is one of the simplest motors known, and in larger sizes is very commonly used. Most of its inherent advantages are also obtained in smaller frames; hence, where polyphase current can be obtained, it is preferred to single



phase motors. It gives the highest output for a given frame size, weight, and speed, its rating being greater than that of a single phase motor wound in the same frame. The starting torque, too, is greater, and is always uniform, regardless of the rotor position. The running torque is practically constant, and the pulsations, often found in single phase motors, are entirely absent. The polyphase motor is, therefore, quiet and smooth running, and has little vibration.

Polyphase motors do not have the high starting currents that split phase motors do, and may, therefore, be used where high starting torque and low starting current are required.

Some applications may require absolute constancy of speed. For these, a polyphase synchronous motor, operating at 1800 r.p.m., is recommended. Such a motor is similar to the standard induction type, except that the rotor has sections cut from the surface so as to form salient poles. These poles pull into step with the rotating magnetic field, and the motor operates at synchronous speed. Motors of this type do not have the high efficiency or starting torque of the polyphase induction motor, and the horsepower rating is somewhat less. They do develop better starting torque than does a single phase synchronous motor, and are simpler in construction. Hence, polyphase synchronous motors find application on specialized machines, particularly in sound recording.

Construction—Mechanically the construction of a polyphase motor is quite similar to that of any other modern a-c induction motor. It consists of the wound stator mounted within a center ring, the squirrel cage rotor mounted on the rotor shaft, and the two end shields to carry the bearings.

Bodine polyphase motors are regularly built in a number of different frame lengths and diameters. Motors as small as 3$\frac{21}{64}$" diameter are regularly cataloged. All polyphase motors are designed for long annual service, and may be depended upon to stand up as long as the machines to which they are connected, unless operating conditions are extremely unfavorable. Ball or sleeve bearings are available, and the motors can be furnished either ventilated or enclosed, and for horizontal or vertical mounting. The many details of motor construction are described in Bulletin 1021A.

Three phase motors, the most usual polyphase types, operate from three line service wires, and have three separate internal windings, distributed in slots around the stator bore, and displaced from each other by 120°. The windings may be connected with their respective ends together, and the leads brought out from the three common points, in what is known as the Delta connection. It is more usual, however, for small motors to have three of the ends of the windings connected together, and the other three brought out to the line. This is the so-called Star arrangement, and is used on Bodine motors, because of the lower currents and smaller wire size in each phase resulting from its use.

The squirrel cage rotor consists of a series of steel laminations with several copper laminations at each end, held together with copper rivets. It is these copper rivets that carry the current induced in the rotor. When polyphase current is applied to the stator windings, a rotating magnetic field is set up. The rotor is pulled around in the same direction and attempts to keep in step with the revolving field. The windings of each phase are of the same wire size, and all are connected to the line wires.

Speed reducers can be furnished with all Bodine polyphase units. See Bulletin 1022A (Section 3005, Pages 11-22, of the catalog) for complete details.

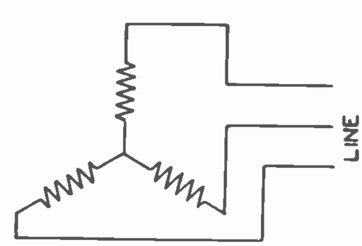


Fig. 2—Internal wiring arrangement of a Bodine Polyphase motor using the Star connection.

STAR OR Y CONNECTED

Century

ENGINEERING INFORMATION

POLYPHASE INDUCTION MOTORS

TYPES SC, SCN, SCH, SCT, SCX, AS, SR - 3 PHASE

Three Phase motors may be either Star or Delta connected and no general rule can be set down for use of either connection. Individual ratings must be checked by the general office.

Our standard method of marking leads and the schemetic representation of circuits* is as follows:

DUAL VOLTAGE* (110/220, 190/380, 220/440 etc.)

Consider T_1 and T_4 (Fig. 1) as the end of one circuit* and T_7 and the center of the star as the ends of the other circuit, in one phase. Do the same for each of the other two phases. To connect the stator winding for the higher voltage, the circuits in each phase are connected in series; therefore, connect T_4 to T_7, T_5 to T_8, and T_6 to T_9. Line connections will be made to T_1, T_2, and T_3 fig. 2 and 5 show these connections.

To connect the stator windings for the lower voltage, the circuits in each phase are connected in parallel. therefore connect T_1 to T_7, T_2 to T_8, and T_3 to T_9. T_4, T_5 and T_6 are connected together to form a point, thereby forming a second star in parallel with the star whose ends are T_7, T_8, and T_9. Line connections, as before, will be made to T_1, T_2 and T_3. Fig. 3 and 6 show these connections.

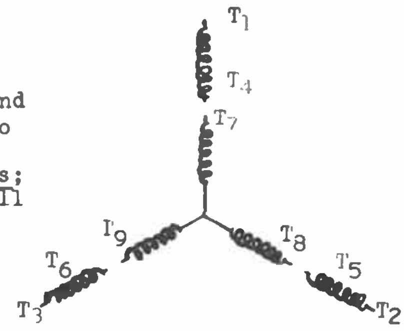


FIG. 1
All terminal lugs are stamped in accordance with this diagram.

These motors have permanent connection plate near terminal box.

SINGLE VOLTAGE* (199,208,220,440,550,2200 etc.)

Only leads T_1, T_2 and T_3 are brought out as shown in fig. 4 and 7 (Single voltage motors usually have single section windings rather than the double section winding shown in Fig. 1)

Connections are indicated on lubrication tags sent with motor.

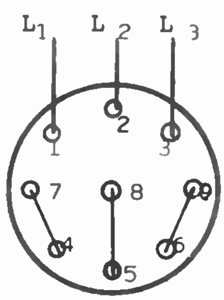


FIG. 2
High Voltage

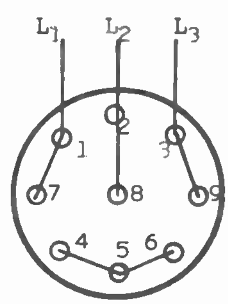


FIG. 3
Low Voltage

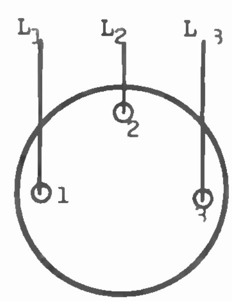


FIG. 4
Single Voltage

DUAL VOLTAGE CONNECTIONS (Similar to B6671 & B7203)

All Form A 204 and smaller; Form W, 224 to 326; Form T 204 and larger. (T superseded by W)

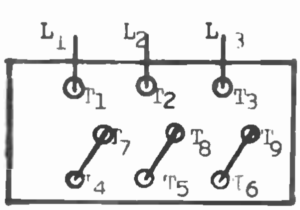


FIG. 5
High Voltage

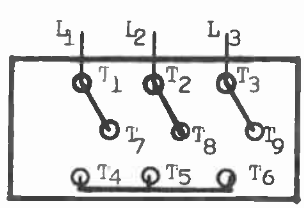


FIG. 6
Low Voltage

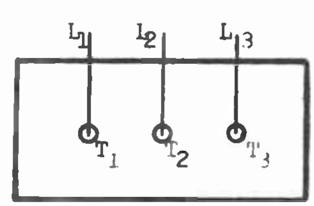


FIG. 7
Single Voltage

DUAL VOLTAGE CONNECTIONS (Similar to B4270 & B4271)

All Form S motors. Form T motors 444 and larger.

Century

ENGINEERING INFORMATION

POLYPHASE INDUCTION MOTORS

TYPES SC, SCN, SCH, SCT, SCX, AS, SR - 2 PHASE

Our standard method of marking leads, and the schemetic representation of circuits ✱ is as follows:

TWO PHASE FOUR WIRE

DUAL VOLTAGE * (110/220. 220/440 etc.)

Consider T_1 and T_5 (Fig.15) as the ends of one circuit ✱, and T_7 and T_3 as the ends of the circuits in the second phase. To connect the stator windings for the higher voltage, the circuits in each phase are connected in series; therefore. connect T_5 to T_7, and T_6 to T_8. Line connections will be made to T_1, T_2, T_3 and T_4. FIGS. 16 and 19 show these connections.

To connect the stator windings for the lower voltage, the circuits in each phase are connected in parallel; therefore, connect T_1 to T_7, T_5 to T_3, T_2 to T_8, and T_6 to T_4. Line connection, as before, will be made to T_1, T_2, T_3 and T_4. Figs 17 and 20 show these connections.

These motors have permanent connection plate near terminal box.

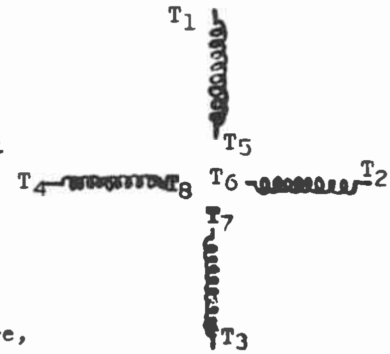


FIG. 15

All terminal lugs are stamped in accordance with this diagram.

SINGLE VOLTAGE * (199, 208, 220, 440, 550, 2200 etc.)

Only leads T_1, T_2 and T_3 are brought out as shown in Fig. 18 and 7 (Single voltage motors usually have single section windings rather than the double section winding shown in Fig. 15)

Connections are indicated on lubrication tags sent with motor

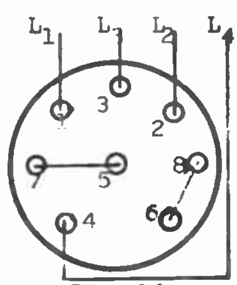


FIG. 16
High Voltage

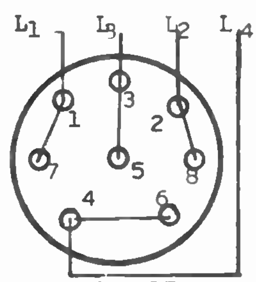


FIG. 17
Low Voltage

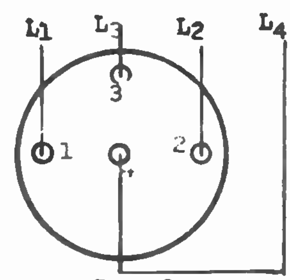


FIG. 18
Single Voltage

DUAL VOLTAGE CONNECTIONS (Similar to B6672 & B7204)

All Form A 204 and smaller; Form W, 224 to 326; Form T 204 and larger (T superseded W)

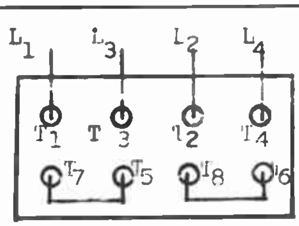


FIG. 19
High Voltage

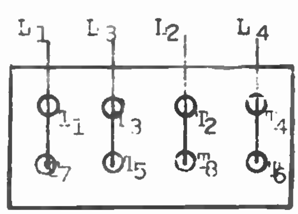


FIG. 20
Low Voltage

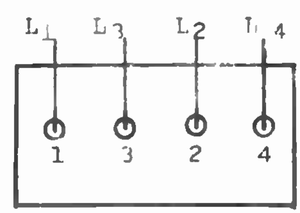


FIG. 21
Single Voltage

DUAL VOLTAGE CONNECTIONS (Similar to B4269 & B4272)

All Form S motors. Form T motors 444 and larger

TWO PHASE THREE WIRE

For connection to a three wire system, connect motor leads T_3 and T_2, together. Line connections will then be made to T_1, T_{3-2}, and T_4; the common (or return wire) being connected to T_{3-2}.

✱ - The terms "circuit" as here used refers to one-half of the number of poles in one phase.

* - See price sheet for standard voltage and horsepower of individual ratings.

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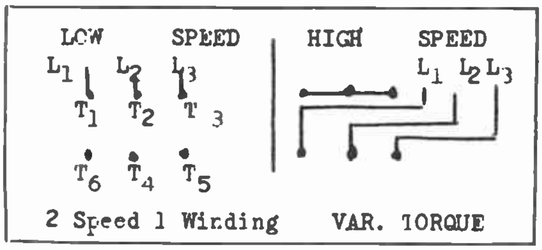
ENGINEERING INFORMATION
CONNECTION PLATES MULTI-SPEED SQUIRREL CAGE MOTORS
2 SPEED 1 AND 2 WINDINGS

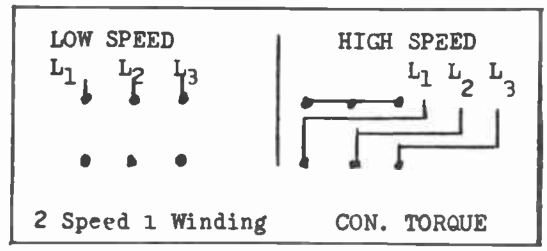
3 PHASE

THESE LEAD MARKINGS APPLY TO MOTORS MADE IN 1940 AND LATER

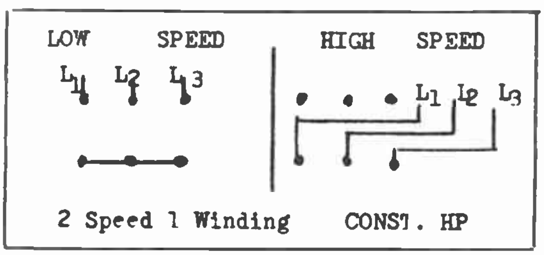
STAMPING OF AUXILIARY NAME PLATE 2 SPEED 1 WINDING 3 PHASE



SIMILAR TO B4494

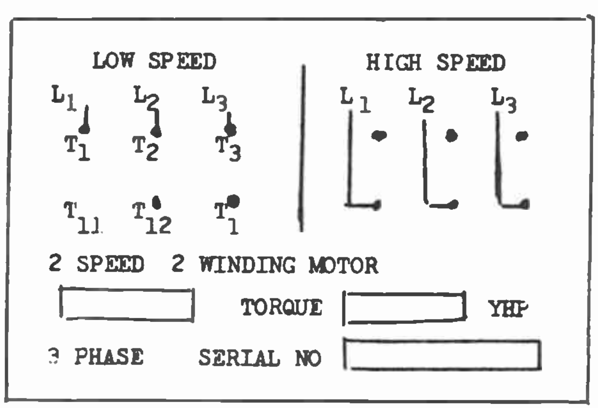


SIMILAR TO B4494



SIMILAR TO C17131

AUXILIARY NAME PLATE 2 SPEED 2 WINDING 3 PHASE



SIMILAR TO B4248

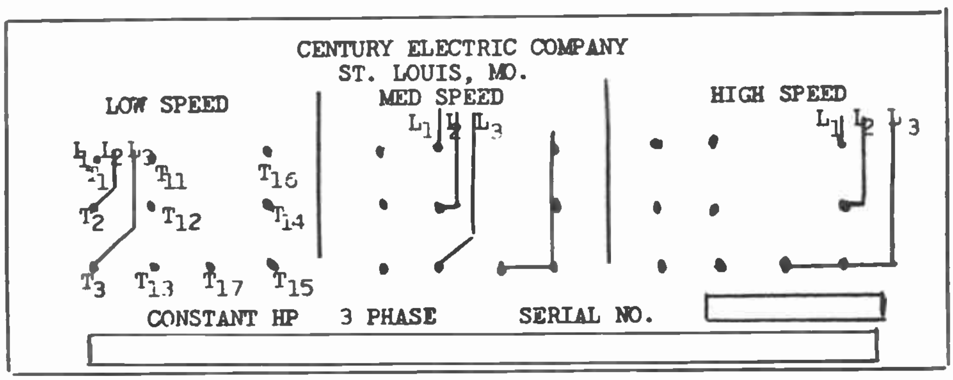
THESE DIAGRAMS ARE REPRODUCTIONS OF PLATES ATTACHED TO MOTORS WHEN THEY LEAVE THE FACTORY.

Century

ENGINEERING INFORMATION
CONNECTION PLATES MULTI-SPEED SQUIRREL CAGE MOTORS
3 SPEED - 2 WINDING - CONSTANT HP

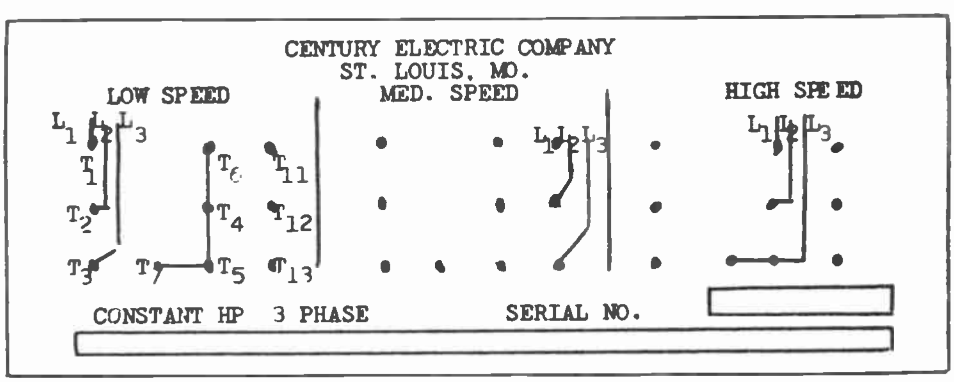
THESE LEAD MARKINGS APPLY TO MOTORS MADE IN 1940 AND LATER 3 PHASE

AUXILIARY NAME PLATE 3 SPEED 2 WINDING CONSTANT HORSEPOWER
2-4-6; 4-8-12; 6-12-16 POLE



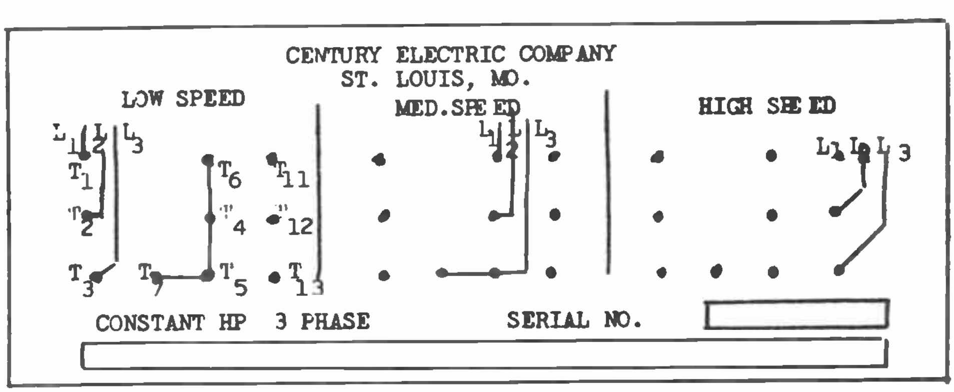
SIMILAR TO C17132

AUXILIARY NAME PLATE 3 SPEED 2 WINDING CONSTANT HORSEPOWER
4-6-8; 6-8-12; 8-12-16 POLE



SIMILAR TO C17134

AUXILIARY NAME PLATE 3 SPEED 2 WINDING CONSTANT HORSEPOWER
4-6-12; 6-8-16 POLE



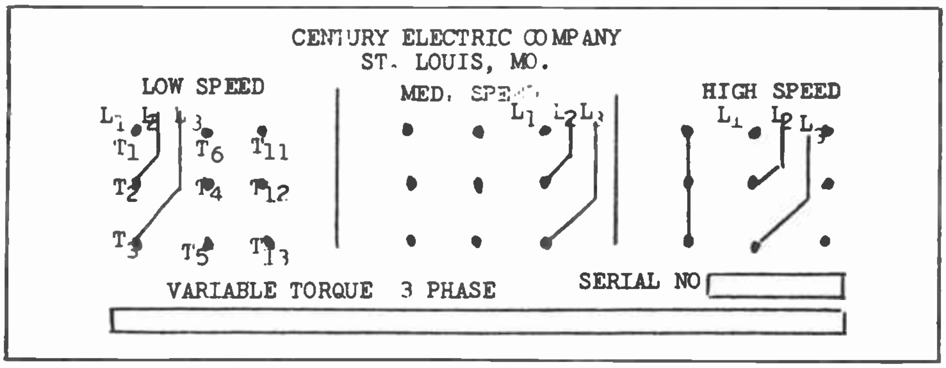
Century

ENGINEERING INFORMATION
CONNECTION PLATES MULTI-SPEED SQUIRREL CAGE MOTORS
3 SPEED - 2 WINDING - VARIABLE TORQUE

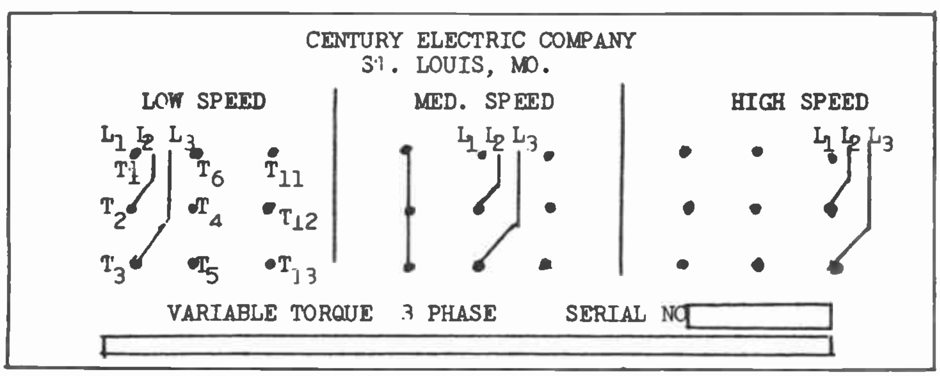
3 PHASE

THESE LEAD MARKINGS APPLY TO MOTORS MADE IN 1940 AND LATER

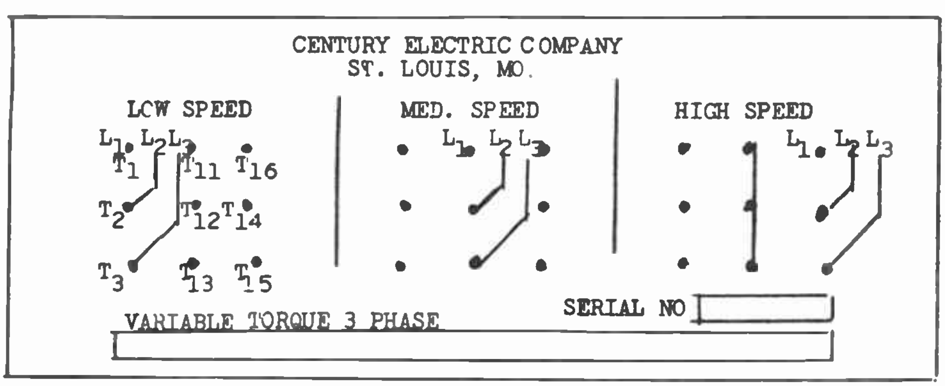
AUXILIARY NAME PLATE 3 SPEED 2 WINDING VARIABLE TORQUE
4-6-8; 6-8-12, 8-12-16 POLE



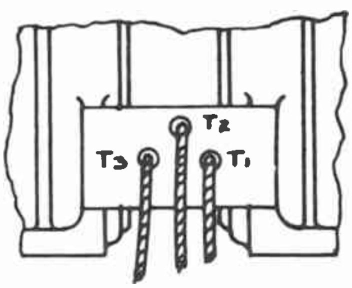
AUXILIARY NAME PLATE 3 SPEED 2 WINDING VARIABLE TORQUE
4-6-12; 6-8-16 POLE



AUXILIARY NAME PLATE 3 SPEED 2 WINDING VARIABLE TORQUE
2-4-6; 4-8-12; 6-12-16 POLE



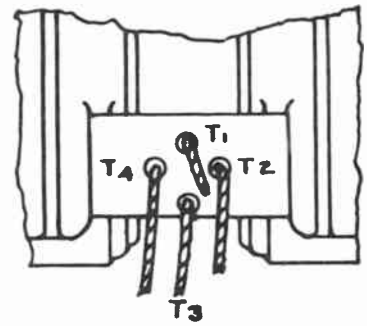
TERMINAL MARKING & CONNECTIONS
A.C. SQUIRREL CAGE MOTORS



To Reverse Direction of Rotation, Interchange T1 & T2

352A

THREE PHASE - STAR
SINGLE VOLTAGE
and
THREE PHASE—DELTA
Single Voltage

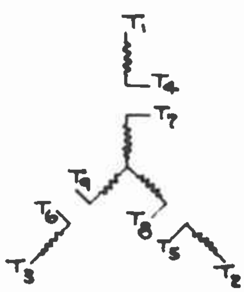


PHASE	1	2
LEADS	T1-T3	T2-T4

To Reverse Direction of Rotation, Interchange T1 & T3

352A

TWO PHASE
Single Voltage

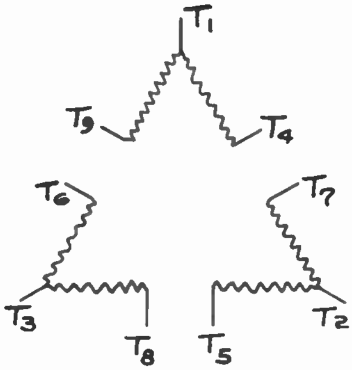


440 VOLT ON STATOR	LEADS T1 - T2 - T3
	CONNECT T4 TO T7
	" T5 TO T8
	" T6 TO T9
220 VOLT ON STATOR	FOR LEAD 1 JOIN T1 TO T7
	" " 2 " T2 " T8
	" " 3 " T3 " T9
	CONNECT T4 - T5 - T6

364

THREE PHASE - STAR 220/440 Volts

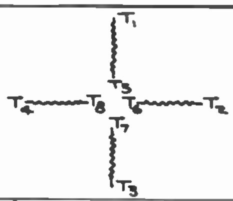
TERMINAL MARKING & CONNECTIONS
A.C. SQUIRREL CAGE MOTORS



440 Volt On Stator	Leads T_1-T_2-T_3
	Connect T_4 to T_7
	" T_5 to T_8
	" T_6 to T_9
220 Volt On Stator	For Lead #1 Join T_1-T_6-T_7
	" " #2 " T_2-T_4-T_8
	" " #3 " T_3-T_5-T_9

368

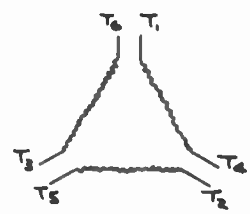
THREE PHASE--DELTA
220/440 Volts



440 Volt On Stator	Leads T_1-T_2-T_3-T_4
	Connect T_5 To T_7
	" T_6 To T_8
220 Volt On Stator	For Lead 1 Join T_1 To T_7
	" " 2 " T_2 " T_8
	" " 3 " T_3 " T_5
	" " 4 " T_4 " T_6

Phase A - Leads T_1 & T_3
Phase B - Leads T_2 & T_4

380



	L_1	L_2	L_3	Together
Normal Torque-Δ	T_1, T_6	T_2, T_4	T_3, T_5	
One Third Torque-Y	T_1	T_2	T_3	T_4, T_5, T_6

To Reverse Direction of Rotation Interchange Line Connections L_1 and L_2

421

TWO PHASE
220/440 Volts

THREE PHASE
STAR--DELTA

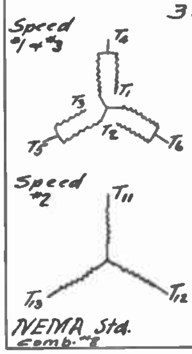
TERMINAL MARKING & CONNECTIONS

A.C. MULTI-SPEED MOTORS

3 SPEED - 3 PHASE - 2 WINDING

#497

Terminal Markings
3 speed 2 Wdg Variable Torque



Speed	Use for Leads			Open	Together
#1 Low	T_1	T_2	T_3	T_4-T_5-T_6	–
#2	T_{11}	T_{12}	T_{13}	–	–
#3 High	T_6	T_4	T_5	–	T_1-T_2-T_3
Foreward	L_1	L_2	L_3		
Reverse	L_2	L_1	L_3		

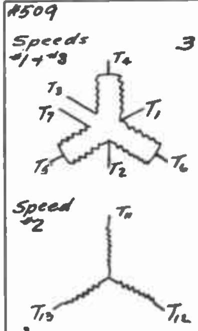
The Louis Allis Co.
Milwaukee, Wis.

NEMA Std.
Comb. #8

#497

#509

Terminal Markings
3 Speed 2 Wdg. Constant Torque



Speed	Used for Leads			Open	Together
#1 Low	T_1	T_2	T_3T_7	T_4-T_5-T_6	–
#2	T_{11}	T_{12}	T_{13}	–	–
#3 High	T_6	T_4	T_5	–	T_1-T_2-T_3-T_7
Foreward	L_1	L_2	L_3		
Reverse	L_2	L_1	L_3		

Speed #1 - x Par Δ Conseq Pole
" #2 - Ser Y
" #3 - 2 x Ser Y

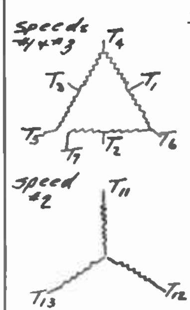
The Louis Allis Co.
Milwaukee Wis.

NEMA Std.
Comb. #8

#509

#521

Terminal Markings.
3 Speed 2 Wdg. Constant Horse Power



Speed	Use for Leads			Open	Together
#1 Low	T_1	T_2	T_3	—	T_4-T_5-T_6-T_7
#2	T_{11}	T_{12}	T_{13}	–	–
#3 High	T_6	T_4	T_5T_7	T_1-T_2-T_3	—
Forward	L_1	L_2	L_3		
Reverse	L_2	L_1	L_3		

Speed #1 - 2 x Par Y - Conseq. Pole
" #2 - Ser Y
" #3 - x Par Δ

The Louis Allis Co.
Milwaukee Wis.

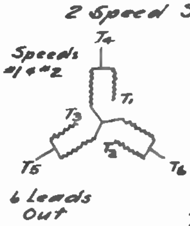
NEMA Std.
Comb. #2

521

2 SPEED - 3 PHASE - SINGLE WINDING

492

Terminal Markings
2 Speed Single Wdg Variable Torque



Speed	Used for Leads			Open	Together
#1 Low	T_1	T_2	T_3	T_4-T_5-T_6	–
#2 High	T_6	T_4	T_5	–	T_1-T_2-T_3
Foreward	L_1	L_2	L_3		
Reverse	L_2	L_1	L_3		

Low.- x Par Y Conseq. Pole Speed N
High - 2 x Par Y - - Speed 2 N

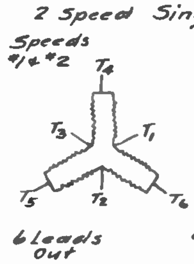
The Louis Allis Co.
Milwaukee Wis.

NEMA Std.
Comb. #12

492

504

Terminal Markings
2 Speed Single Wdg Constant Torque



Speed	Used for Leads			Open	Together
#1 Low	T_1	T_2	T_3	T_4-T_5-T_6	–
#2 High	T_6	T_4	T_5	–	T_1-T_2-T_3
Foreward	L_1	L_2	L_3		
Reverse	L_2	L_1	L_3		

Low - x Par Δ Conseq. Pole - Speed N
High - 2 x Par Y - - Speed 2N

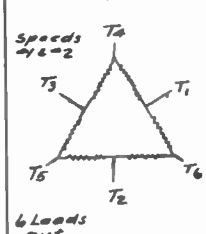
NEMA Std.
Comb #12

The Louis Allis Co.
Milwaukee Wis.

504

516

Terminal Markings
2 Speed Single Wd'g Constant Horse Power



Speed	Used for Leads			Open	Together
#1 Low	T_1	T_2	T_3	–	T_4-T_5-T_6
#2 High	T_6	T_4	T_5	T_1-T_2-T_3	
Foreward	L_1	L_2	L_3		
Reverse	L_2	L_1	L_3		

Low - 2 x Par Y - Conseq Pole - Speed N
High - x Par Δ - - Speed 2 N

NEMA Std.
Comb #6

The Louis Allis Co.
Milwaukee, Wis.

516

TERMINAL MARKING & CONNECTIONS

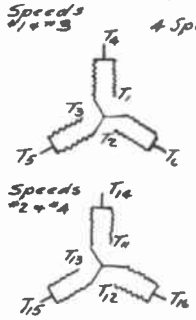
A.C. MULTI-SPEED MOTORS

4 SPEED - 3 PHASE - 2 WINDING

#493

Terminal Markings

4 Speed 2 Wdg. Variable Torque



Speed	Used for Leads			Open	Together
#1 Low	T_1	T_2	T_3	T_4-T_5-T_6	—
#2	T_{11}	T_{12}	T_{13}	T_{14}-T_{15}-T_{16}	—
#3	T_6	T_4	T_5	—	T_1-T_2-T_3
#4 High	T_{16}	T_{14}	T_{15}	—	T_{11}-T_{12}-T_{13}
Foreward	L_1	L_2	L_3		
Reverse	L_2	L_1	L_3		

Speeds #1 + #2 x Par. Y Conseq. Pole
" #3 + #4 - 2 x Par Y — —

The Louis Allis Co
Milwaukee Wis.

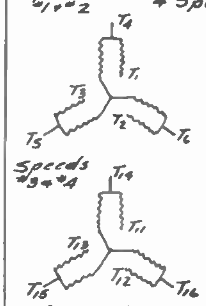
NEMA Std
Comb #7

#493

#494

Terminal Markings.

4 Speed 2 Wdg. Variable Torque



Speed	Used for Leads			Open	Together
#1 Low	T_1	T_2	T_3	T_4-T_5-T_6	—
#2	T_6	T_4	T_5		T_1-T_2-T_3
#3	T_{11}	T_{12}	T_{13}	T_{14}-T_{15}-T_{16}	—
#4 High	T_{16}	T_{14}	T_{15}		T_{11}-T_{12}-T_{13}
Foreward	L_1	L_2	L_3		
Reverse	L_2	L_1	L_3		

Speeds #1 + #3 - x Par Y Conseq Pole
" #2 + #4 - 2 x Par Y — —

The Louis Allis Co.
Milwaukee Wis.

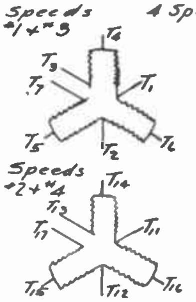
NEMA Std.
Comb. #11

#494

#505

Terminal Markings

4 Speed 2 Wdg. Constant Torque



Speed	Used for Leads			Open	Together
#1 Low	T_1	T_2	T_3 T_7	T_4-T_5-T_6	—
#2	T_{11}	T_{12}	T_{13} T_{17}	T_{14}-T_{15}-T_{16}	—
#3	T_6	T_4	T_5		T_1-T_2-T_3-T_7
#4 High	T_{16}	T_{14}	T_{15}		T_{11}-T_{12}-T_{13}-T_{17}
Foreward	L_1	L_2	L_3		
Reverse	L_2	L_1	L_3		

Speeds #1 + #2 - x Par Δ Conseq Pole
" #3 + #4 - 2 x Par Y — —

The Louis Allis Co.
Milwaukee, Wis.

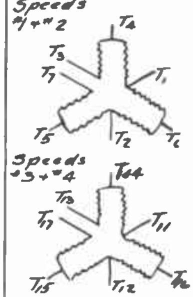
NEMA Std.
comb #7

#505

#506

Terminal Markings.

4 Speed 2 Wdg Constant Torque



Speed	Used for Leads			Open	Together
#1 Low	T_1	T_2	T_3 T_7	T_4-T_5-T_6	
#2	T_6	T_4	T_5		T_1-T_2-T_3-T_7
#3	T_{11}	T_{12}	T_{13} T_{17}	T_{14}-T_{15} T_{16}	
#4 High	T_{16}	T_{14}	T_{15}		T_{11}-T_{12} T_{13}-T_{17}
Forward	L_1	L_2	L_3		
Reverse	L_2	L_1	L_3		

Speeds #1 + #3 - x Par Δ Conseq. Pole
" #2 + #4 - 2 x Par Y — —

The Louis Allis Co.
Milwaukee Wis.

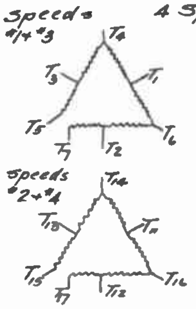
NEMA Std.
comb. #11

#506

#517

Terminal Markings

4 Speed 2 Wdg. Constant Horse Power



Speed	Use for Leads			Open	Together
#1 Low	T_1	T_2	T_3	—	T_4-T_5-T_6-T_7
#2	T_{11}	T_{12}	T_{13}		T_{14}-T_{15} T_{16}-T_{17}
#3	T_6	T_4	T_5-T_7	T_1-T_2-T_3	
#4 High.	T_{16}	T_{14}	T_{15}-T_{17}	T_{11}-T_{12}-T_{13}	
Foreward	L_1	L_2	L_3		
Reverse	L_2	L_1	L_3		

Speeds #1 + #2 - 2 x Par. Y Conseq. Pole
" #3 + #4 - x Par. Δ — —

The Louis Allis Co.
Milwaukee Wis.

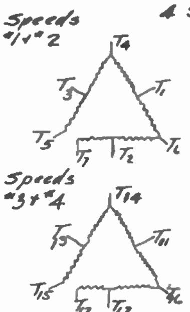
NEMA Std.
Comb. #1

#517

#518

Terminal Markings.

4 Speed 2 Wdg. Constant Horse Power



Speed	Use for Leads			Open	Together
#1 Low	T_1	T_2	T_3	—	T_4-T_5 T_6-T_7
#2	T_6	T_4	T_5 T_7	T_1-T_2-T_3	—
#3	T_{11}	T_{12}	T_{13}	—	T_{14}-T_{15}-T_{16}-T_{17}
#4 High	T_{16}	T_{14}	T_{15} T_{17}	T_{11}-T_{12}-T_{13}	—
Forward	L_1	L_2	L_3		
Reverse	L_2	L_1	L_3		

Speeds #1 + #3 - 2 x Par Y Conseq Pole
" #2 + #4 - x Par Δ — —

The Louis Allis Co
Milwaukee Wis.

NEMA Std.
Comb. #5.

#518

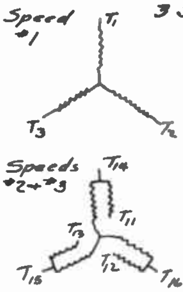
TERMINAL MARKING & CONNECTIONS

A.C. MULTI-SPEED MOTORS

3 SPEED - 3 PHASE - 2 WINDING

#495

Terminal Markings. 3 Speed 2 Wdg. Variable Torque



Speed	Use for Leads			Open	
#1 Low	T_1	T_2	T_3		
#2	T_{11}	T_{12}	T_{13}	$T_{14}-T_{15}-T_{16}$	
#3 High	T_{16}	T_{14}	T_{15}	–	$T_{11}-T_{12}-T_{13}$
Foreward	L_1	L_2	L_3		
Reverse	L_2	L_1	L_3		

Speed #1 - Ser Y
" #2 - x Par Y Conseq. Pole
" #3 - 2X Par. Y

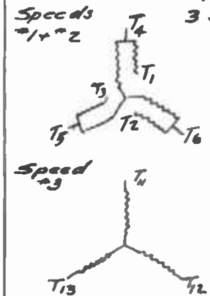
The Louis Allis Co.
Milwaukee. Wis.

NEMA Std.
Comb. #9

#495

#496

Terminal Markings. 3 Speed 2 Wdg. Variable Torque.



Speed.	Use for Leads			Open	Together
#1 Low	T_1	T_2	T_3	$T_4-T_5-T_6$	
#2	T_6	T_4	T_5	–	$T_1-T_2-T_3$
#3 High	T_{11}	T_{12}	T_{13}		
Foreward	L_1	L_2	L_3		
Reverse	L_2	L_1	L_3		

Speed #1 - x Par Y Conseq. Pole
" #2 - 2 x Par Y " "
" #3 - Ser Y

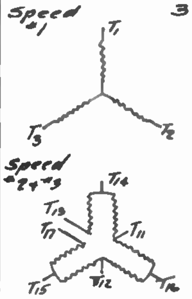
The Louis Allis Co.
Milwaukee. Wis.

NEMA Std.
Comb. #10

#496

#507

Terminal Markings. 3 Speed 2 Wdg. Constant Torque



Speed	Used for Leads			Open	Together
#1 Low	T_1	T_2	T_3	–	–
#2	T_{11}	T_{12}	$T_{13}T_{17}$	$T_{14}-T_{15}-T_{16}$	–
#3 High	T_{16}	T_{14}	T_{15}		$T_{11}-T_{12}-T_{13}-T_{17}$
Foreward	L_1	L_2	L_3		
Reverse	L_2	L_1	L_3		

Speed #1 - Ser Y
" #2 - x Par Δ Conseq. Pole
" #3 - 2 x Par Y

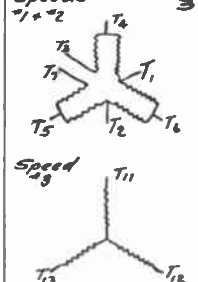
The Louis Allis Co.
Milwaukee, Wis.

NEMA Std.
Comb. #9

#507

#508

Terminal Markings. 3 Speed 2 Wdg. Constant Torque



Speed	Used for Leads			Open	Together
#1 Low	T_1	T_2	T_3T_7	$T_4-T_5-T_6$	–
#2	T_6	T_4	T_5	–	$T_1-T_2-T_3-T_7$
#3 High	T_{11}	T_{12}	T_{13}	–	–
Foreward	L_1	L_2	L_3		
Reverse	L_2	L_1	L_3		

Speed #1 - x Par Δ Conseq Pole
" #2 - 2 x Par Y
" #3 - Ser Y

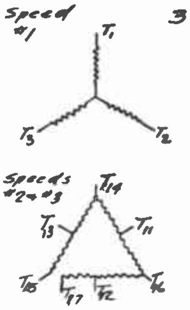
The Louis Allis Co.
Milwaukee Wis

NEMA Std.
Comb. #10

#508

#519

Terminal Markings. 3 speed 2 Wdg. Constant Horse Power



Speed	Used for Leads			Open	Together
#1 Low	T_1	T_2	T_3		
#2	T_{11}	T_{12}	T_{13}	–	$T_{14}-T_{15}-T_{16}-T_{17}$
#3 High	T_{16}	T_{14}	$T_{15}T_{17}$	$T_{11}-T_{12}-T_{13}$	–
Foreward	L_1	L_2	L_3		
Reverse	L_2	L_1	L_3		

Speed #1 - Ser Y
" #2 - Par. Y Conseq. Pole
" #3 - Ser Δ

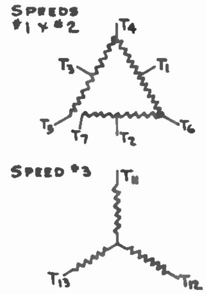
The Louis Allis Co.
Milwaukee Wis.

NEMA Std.
Comb. #3

#519

#520

TERMINAL MARKINGS 3 SPEED - 2 W'D'G. - CONSTANT HORSE POWER



SPEED	USE FOR LEADS			OPEN	TOGETHER
#1 LOW	T_1	T_2	T_3	–	$T_4T_5T_6T_7$
#2	T_6	T_4	T_5T_7	$T_1-T_2-T_3$	–
#3 HIGH	T_{11}	T_{12}	T_{13}	–	–
FOREWARD	L_1	L_2	L_3		
REVERSE	L_2	L_1	L_3		

SPEED #1 - 2 x PAR Y CONSEQ. POLE
" #2 - x PAR Δ " "
" #3 - SER Y

THE LOUIS ALLIS CO.
MILWAUKEE-WIS.

NEMA STD.
COMB. #4

#520

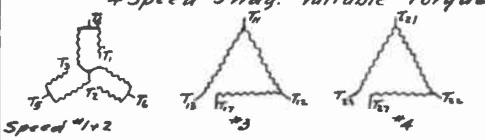
TERMINAL MARKING & CONNECTIONS

A.C. MULTI-SPEED MOTORS

4 SPEED - 3 PHASE - 3 WINDING

#498

Terminal Marking.
4 Speed 3 Wdg. Variable Torque



Speed #1+2

Winding #3 or #4 may be Y and T_{17} & T_{27} will not be present

Speed	Use for Leads			Open	Together
#1 Low	T_1	T_2	T_3	T_4-T_5-T_6	—
#2	T_6	T_4	T_5	All others	T_1-T_2-T_3
#3	T_{11}	T_{12}	$T_{13}T_{17}$	"	—
#4 High	T_{21}	T_{22}	$T_{23}T_{27}$	"	—
Forward	L_1	L_2	L_3		
Reverse	L_2	L_1	L_3		

NEMA STD.

The Louis Allis Co
Milwaukee Wis.
#498

#499

Terminal Marking.
4 Speed 3 Wdg. Variable Torque.

Speed #1+3

Winding #2 or #4 may Y and T_{17} + T_{27} will not be present

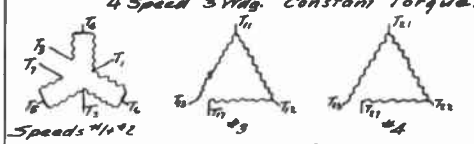
Speed	Use for Leads			Open	Together
#1 Low	T_1	T_2	T_3	All others	—
#2	T_{11}	T_{12}	$T_{13}T_{17}$	"	—
#3	T_6	T_4	T_5	"	T_1-T_2-T_3
#4 High	T_{21}	T_{22}	$T_{23}T_{27}$	"	—
Forward	L_1	L_2	L_3		
Reverse	L_2	L_1	L_3		

NEMA STD

The Louis Allis Co
Milwaukee Wis.
#499

#510

Terminal Marking.
4 Speed 3 Wdg. Constant Torque.



Speeds #1+#2

Winding #3 or #4 may be Y and T_{17}+T_{27} will not be present.

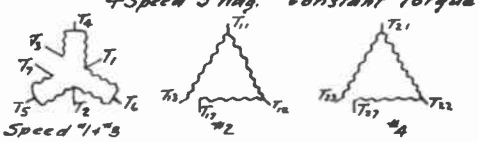
Speed	Used for Leads			Open	Together
#1 Low	T_1	T_2	T_3T_7	All others	—
#2	T_6	T_4	T_5	"	T_1-T_2-T_3-T_7
#3	T_{11}	T_{12}	$T_{13}T_{17}$	"	—
#4 High	T_{21}	T_{22}	$T_{23}T_{27}$	"	—
Forward	L_1	L_2	L_3		
Reverse	L_2	L_1	L_3		

NEMA. STD.

The Louis Allis Co.
Milwaukee Wis.
#510

#511

Terminal Marking.
4 Speed 3 Wdg. Constant Torque.



Speed #1+#3

Winding #2 or #4 may be Y and T_{17}+T_{27} will not be present.

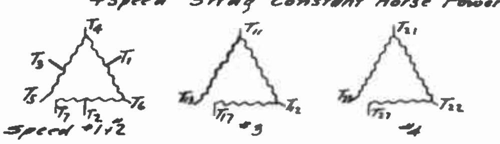
Speed	Use for Leads			Open	Together
#1 Low	T_1	T_2	T_3-T_7	All others	—
#2	T_{11}	T_{12}	$T_{13}T_{17}$	"	
#3	T_6	T_4	T_5	"	T_1-T_2-T_3-T_7
#4 High	T_{21}	T_{22}	$T_{23}T_{27}$	"	
Forward	L_1	L_2	L_3		
Reverse	L_2	L_1	L_3		

NEMA STD.

The Louis Allis Co
Milwaukee Wis.
#511

#522

Terminal Marking
4 Speed 3 Wdg Constant Horse Power.



Speed #1+#2

Winding #3 or #4 may be Y and T_{17}+T_{27} will not be present

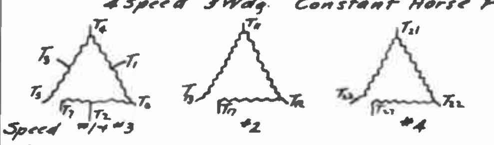
Speed	Use for Leads			Open	Together
#1 Low	T_1	T_2	T_3	All others	T_4-T_5-T_6-T_7
#2	T_6	T_4	T_5T_7	"	—
#3	T_{11}	T_{12}	T_{13}-T_{17}	"	—
#4 High	T_{21}	T_{22}	$T_{23}T_{27}$	"	—
Forward	L_1	L_2	L_3		
Reverse	L_2	L_1	L_3		

NEMA STD.

The Louis Allis Co.
Milwaukee Wis.
#522

#523

Terminal Marking.
4 Speed 3 Wdg. Constant Horse Power



Speed #1+#3

Winding #2 or #4 may be Y and T_{17}+T_{27} will not be present.

Speed	Use for Leads			Open	Together
#1 Low	T_1	T_2	T_3	All others	T_4-T_5-T_6-T_7
#2	T_{11}	T_{12}	T_{13}-T_{17}	"	—
#3	T_6	T_4	T_5T_7	"	—
#4	T_{21}	T_{22}	T_{23}-T_{27}	"	—
Forward	L_1	L_2	L_3		
Reverse	L_2	L_1	L_3		

NEMA STD

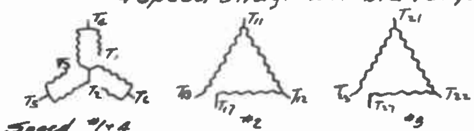
The Louis Allis Co.
Milwaukee Wis
#523

TERMINAL MARKING & CONNECTIONS

A.C. MULTI-SPEED MOTORS

4 SPEED - 3 PHASE - 3 WINDING

#500 Terminal Marking.
4 speed 3 Wdg. Variable Torque.



Speed #1+4

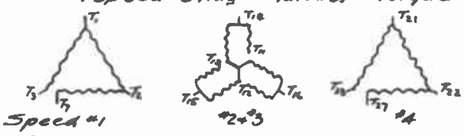
Winding #2 or #3 may be Y and T_{17} + T_{27} will not be present.

Speed	Use for Leads			Open	Together
#1 Low	T_1	T_2	T_3	All others	—
#2	T_{11}	T_{12}	$T_{13}T_{17}$	"	
#3	T_{21}	T_{22}	$T_{23}T_{27}$	"	
#4 High	T_6	T_4	T_5	"	T_1-T_2-T_3
Forward	L_1	L_2	L_3		
Reverse	L_2	L_1	L_3		

NEMA STD

The Louis Allis Co.
Milwaukee Wis
#500

#501 Terminal Marking
4 speed 3 Wdg. Variable Torque.



Speed #1

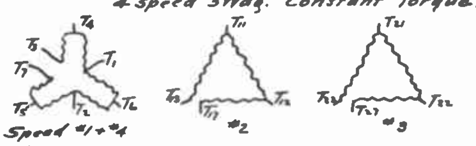
Winding #1 or #4 may be Y and T_7 + T_{27} will not be present.

Speed	Used for Leads			Open	Together
#1 Low	T_1	T_2	T_3T_7	All others	—
#2	T_{11}	T_{12}	T_{13}	"	—
#3	T_{16}	T_{14}	T_{15}	"	T_{11}-T_{12}-T_{13}
#4 High	T_{21}	T_{22}	$T_{23}T_{27}$	"	—
Forward	L_1	L_2	L_3		
Reverse	L_2	L_1	L_3		

NEMA STD

The Louis Allis Co.
Milwaukee Wis.
#501

#512 Terminal Marking
4 speed 3 Wdg. Constant Torque.



Speed #1 + #4

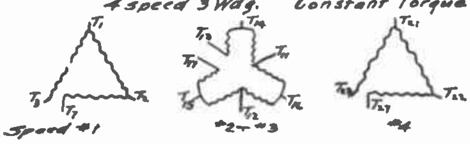
Winding #2 or #3 may be Y and T_{17} + T_{27} will not be present.

Speed	Use for Leads			Open	Together
#1 Low	T_1	T_2	T_3T_7	All others	—
#2	T_{11}	T_{12}	$T_{13}T_{17}$	"	—
#3	T_{21}	T_{22}	$T_{23}T_{27}$	"	—
#4 High	T_6	T_4	T_5	"	T_1-T_2-T_3-T_7
Forward	L_1	L_2	L_3		
Reverse	L_2	L_1	L_3		

NEMA STD

The Louis Allis Co
Milwaukee Wis.
#512

#513. Terminal Marking
4 speed 3 Wdg. Constant Torque.



Speed #1

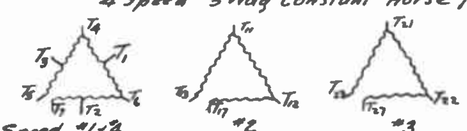
Winding #1 or #4 may be Y and T_7 + T_{27} will not be present.

Speed	Used for Leads			Open	Together
#1 Low	T_1	T_2	T_3T_7	All others	—
#2	T_{11}	T_{12}	$T_{13}T_{17}$	"	—
#3	T_{16}	T_{14}	T_{16}	"	T_{11}-T_{12}-T_{13}-T_{17}
#4 High	T_{21}	T_{22}	$T_{23}T_{27}$	"	—
Forward	L_1	L_2	L_3		
Reverse	L_2	L_1	L_3		

NEMA STD

The Louis Allis Co.
Milwaukee Wis.
#513

#524 Terminal Marking.
4 Speed 3 Wdg Constant Horse Power



Speed #1 + #4

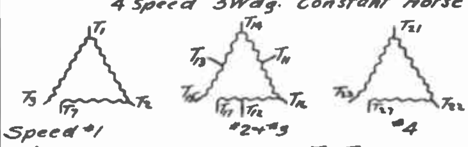
Winding #2 or #3 may be Y and T_{17} + T_{27} will not be present.

Speed	Use for Leads			Open	Together
#1 Low	T_1	T_2	T_3	All others	T_4-T_5-T_6-T_7
#2	T_{11}	T_{12}	$T_{13}T_{17}$	"	—
#3	T_{21}	T_{22}	$T_{23}T_{27}$	"	—
#4 High	T_6	T_4	T_5T_7	"	—
Forward	L_1	L_2	L_3		
Reverse	L_2	L_1	L_3		

NEMA STD

The Louis Allis Co
Milwaukee Wis.
#524

#525 Terminal Marking
4 Speed 3 Wdg. Constant Horse Power



Speed #1

Winding #1 or #4 may be Y and T_7 + T_{27} will not be present.

Speed	Use for Leads			Open	Together
#1 Low	T_1	T_2	T_3-T_7	All others	—
#2	T_{11}	T_{12}	T_{13}	"	T_{14}-T_{15}-T_{16}-T_{17}
#3	T_{16}	T_{14}	$T_{15}T_{17}$	"	—
#4 High	T_{21}	T_{22}	$T_{23}T_{27}$	"	
Forward	L_1	L_2	L_3		
Reverse	L_2	L_1	L_3		

NEMA STD.

The Louis Allis Co.
Milwaukee Wis.
#525

TERMINAL MARKING & CONNECTIONS

A.C. MULTI-SPEED MOTORS

4 SPEED - 3 PHASE - 3 WINDING

#502

Terminal Marking.
4 speed 3 Wdg. Variable Torque.

Winding #1 or #3 may be Y and T_7 + T_{27} will not be present.

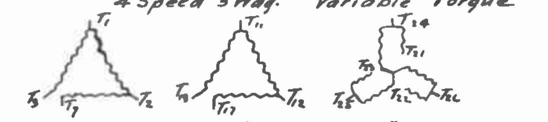
Speed	Use for Leads			Open	Together
#1 Low	T_1	T_2	T_3T_7	All others	—
#2	T_{11}	T_{12}	T_{13}	"	—
#3	T_{21}	T_{22}	$T_{23}T_{27}$	"	—
#4 High	T_{16}	T_{14}	T_{15}	"	$T_{11}-T_{12}-T_{13}$
Forward	L_1	L_2	L_3		
Reverse	L_2	L_1	L_3		

NEMA Std.

The Louis Allis Co.
Milwaukee Wis.
#502

#503

Terminal Marking.
4 Speed 3 Wdg. Variable Torque



Winding #1 or #2 may be Y and T_7 + T_{17} will not be present.

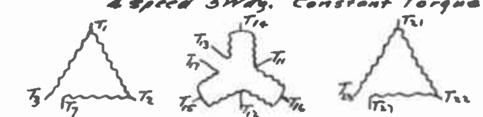
Speed	Use for Leads			Open	Together
#1 Low	T_1	T_2	$T_3 \cdot T_7$	All others	—
#2	T_{11}	T_{12}	$T_{13}T_{17}$	"	—
#3	T_{21}	T_{22}	T_{23}	"	—
#4 High	T_{26}	T_{24}	T_{25}	"	$T_{21}-T_{22}-T_{23}$
Forward	L_1	L_2	L_3		
Reverse	L_2	L_1	L_3		

NEMA Std

The Louis Allis Co
Milwaukee Wis.
#503

#514

Terminal Marking
4 speed 3 Wdg. Constant Torque.



Winding #1 or #3 may be Y and T_7 + T_{27} will not be present

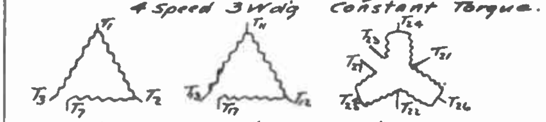
Speed	Use for Leads			Open	Together
#1 Low	T_1	T_2	T_3T_7	All others	—
#2	T_{11}	T_{12}	$T_{13}T_{17}$	"	—
#3	T_{21}	T_{22}	$T_{23}T_{27}$	"	—
#4 High	T_{16}	T_{14}	T_{15}		$T_{11}-T_{12}-T_{13}-T_{17}$
Forward	L_1	L_2	L_3		
Reverse	L_2	L_1	L_3		

NEMA Std

The Louis Allis Co.
Milwaukee Wis.
#514

#515

Terminal Marking.
4 Speed 3 Wdg Constant Torque.



Winding #1 or #2 may be Y and T_7 + T_{17} will not be present.

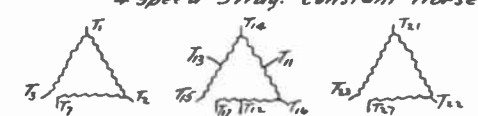
Speed	Use for Leads			Open	Together
#1 Low	T_1	T_2	T_3T_7	All others	—
#2	T_{11}	T_{12}	$T_{13}T_{17}$	"	—
#3	T_{21}	T_{22}	$T_{23}T_{27}$	"	—
#4 High	T_{26}	T_{24}	T_{25}		$T_{21}-T_{22}-T_{23}-T_{27}$
Forward	L_1	L_2	L_3		
Reverse	L_2	L_1	L_3		

NEMA. Std

The Louis Allis Co.
Milwaukee Wis.
#515

#526

Terminal Marking.
4 Speed 3 Wdg. Constant Horse Power.



Winding #1 or #3 may be Y and T_7 + T_{27} will not be present.

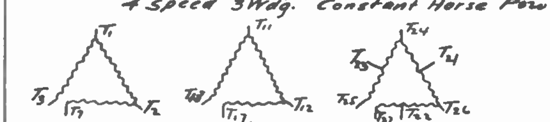
Speed	Use for Leads			Open	Together
#1 Low	T_1	T_2	T_3T_7	All others	—
#2	T_{11}	T_{12}	T_{13}	"	$T_{14}-T_{15}-T_{16}-T_{17}$
#3	T_{21}	T_{22}	$T_{23}T_{27}$	"	—
#4 High	T_{16}	T_{14}	$T_{15}T_{17}$	"	—
Forward	L_1	L_2	L_3		
Reverse	L_2	L_1	L_3		

NEMA Std.

The Louis Allis Co
Milwaukee Wis.
526

#527

Terminal Marking
4 speed 3 Wdg. Constant Horse Power



Winding #1 or #2 may be Y and T_7 + T_{27} will not be present.

Speed	Use for Leads			Open	Together
#1 Low	T_1	T_2	T_3T_7	All others	—
#2	T_{11}	T_{12}	$T_{13}-T_{17}$	"	—
#3	T_{21}	T_{22}	T_{23}	"	$T_{24}-T_{25}-T_{26}-T_{27}$
#4 High	T_{26}	T_{24}	$T_{25}T_{27}$	"	—
Forward	L_1	L_2	L_3		
Reverse	L_2	L_1	L_3		

NEMA .Std

The Louis Allis Co.
Milwaukee Wis.
#527

TERMINAL MARKING & CONNECTIONS

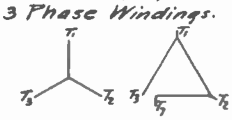
A.C. MULTI-SPEED MOTORS

2 - 3 - 4 SPEED - 3 & 2 PHASE

#528

Terminal Marking.

2-3 or 4 speed – Separate Winding for each speed
Variable Torque, Constant Torque or Constant Horse Power.
3 Phase Windings.



Speed	Use for Leads		
#1 Low	T_1	T_2	T_3-T_7
#2	T_{11}	T_{12}	T_{13}-T_{17}
#3	T_{21}	T_{22}	T_{23}-T_{27}
#4 High	T_{31}	T_{32}	T_{33}-T_{37}
Forward	L_1	L_2	L_3
Reverse	L_2	L_1	L_3

Any of these Wdgs. may be either Y or △.

"Y" Wdgs have only 3 leads, so disregard T_7-T_{17} etc., terminals on control.

"△" Wdgs have 4 leads so as to open Delta when not in use. The control takes care of opening this circuit

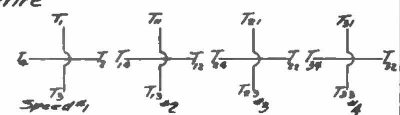
The Louis Allis Co.
Milwaukee Wis.

NEMA std. #528

#529

Terminal Marking.

2-3 or 4 Speed – Separate Winding for each speed
Variable Torque, Constant Torque or Constant Horse Power
2 Phase, 3 or 4 Wire



Speed	Phase #1		Phase #2	
#1 Low	T_1	T_3	T_2	T_4
#2	T_{11}	T_{13}	T_{12}	T_{14}
#3	T_{21}	T_{23}	T_{22}	T_{24}
#4 High	T_{31}	T_{33}	T_{32}	T_{34}
Forward	L_1	L_3	L_2	L_4
Reverse	L_3	L_1	L_2	L_4

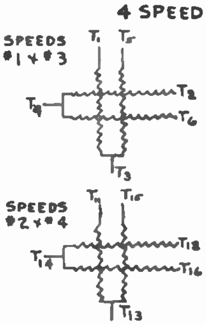
All windings are separate and each phase is separate so either 3 wire or 4 wire circuits can be used.
For 3 wire circuit T_3 + T_4 etc. may be connected together. T_3 is then used.

The Louis Allis Co.
Milwaukee Wis.

NEMA Std. #529

#588

TERMINAL MARKINGS - 2 PHASE
4 SPEED - 2 W'D'G. - VARIABLE TORQUE



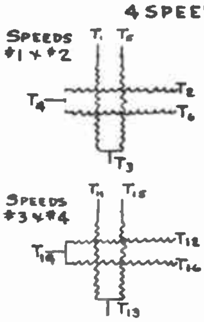
SPEED	USE FOR LEADS PH. #1		PH. #2		OPEN
#1 LOW	T_1	T_5	T_2	T_6	ALL OTHERS
#2	T_{11}	T_{15}	T_{12}	T_{16}	"
#3	$T_1 T_5$	T_3	$T_2 T_6$	T_4	"
#4 HIGH	$T_{11} T_{15}$	T_{13}	$T_{12} T_{16}$	T_{14}	"
FOREWARD	L_1	L_3	L_2	L_4	
REVERSE	L_3	L_1	L_2	L_4	

THE LOUIS ALLIS CO.
MILWAUKEE - WIS.

NEMA STD. #588

#589

TERMINAL MARKINGS - 2 PHASE
4 SPEED - 2 W'D'G. - VARIABLE TORQUE



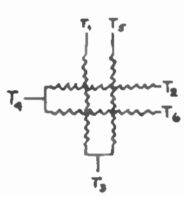
SPEED	USE FOR LEADS PH #1		PH #2		OPEN
#1 LOW	T_1	T_5	T_2	T_6	ALL OTHERS
#2	$T_1 T_5$	T_3	$T_2 T_6$	T_4	"
#3	T_{11}	T_{15}	T_{12}	T_{16}	"
#4 HIGH	$T_{11} T_{15}$	T_{13}	$T_{12} T_{16}$	T_{14}	"
FOREWARD	L_1	L_3	L_2	L_4	
REVERSE	L_3	L_1	L_2	L_4	

THE LOUIS ALLIS CO.
MILWAUKEE - WIS.

NEMA STD. #589

#590

TERMINAL MARKINGS - 2 PHASE
2 SPEED - 1 W'D'G. - VARIABLE TORQUE



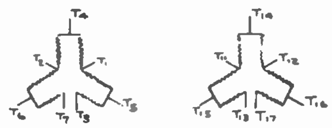
SPEED	USE FOR LEADS PH #1		PH #2		OPEN
#1 LOW	T_1	T_5	T_2	T_6	T_3 · T_4
#2 HIGH	$T_1 T_5$	T_3	$T_2 T_6$	T_4	—
FOREWARD	L_1	L_3	L_2	L_4	
REVERSE	L_3	-1	L_2	L_4	

THE LOUIS ALLIS CO.
MILWAUKEE - WIS.

NEMA STD. #590

TERMINAL MARKING & CONNECTIONS

A.C. MULTI-SPEED MOTORS -- FOUR SPEED

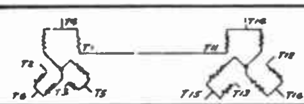


14 LEADS OUT– NO COMMON LEAD.

SPEED	USED FOR LEADS			OPEN	TOGETHER
1 - LOWEST	T_1	T_2	$T_3 T_7$	ALL OTHERS	
2 -	T_{11}	T_{12}	$T_{13} T_{17}$	ALL OTHERS	
3 -	T_4	T_5	T_6	T_{11} TO T_{17}	$T_1 - T_2 - T_3 - T_7$
4 - HIGHEST	T_{14}	T_{15}	T_{16}	T_1 TO T_7	$T_{11} - T_{12} - T_{13} - T_{17}$
FORWARD	L_1	L_2	L_3		
REVERSE	L_2	L_1	L_3		

390

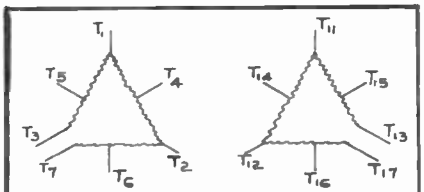
TWO WINDINGS -- CONSTANT TORQUE - THREE PHASE SPEEDS (1800/1200/900/600) (1200/ 900/600/450)



SPEED	USED FOR LEADS			OPEN	TOGETHER
1 LOWEST	T_1	T_2	T_3	ALL OTHERS	
2 -	T_{11}	T_{12}	T_{13}	" "	
3 -	T_4	T_5	T_6	T_{11} TO T_{16}	$T_1 - T_2 - T_3$
4 HIGHEST	T_{14}	T_{15}	T_{16}	T_1 TO T_6	$T_{11} - T_{12} - T_{13}$
FORWARD	L_1	L_2	L_3		
REVERSE	L_2	L_1	L_3		

357

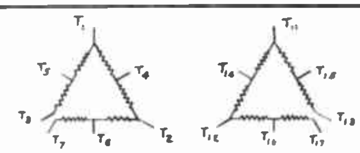
TWO WINDING - VARIABLE TORQUE - THREE PHASE SPEEDS (1800/1200/900/600) (1200/ 900/600/450)



SPEED	USED FOR LEADS			OPEN	TOGETHER
1 - LOWEST	T_4	T_5	T_6		$T_1 - T_2 \cdot T_3 \cdot T_7$
2 -	T_1	T_2	$T_3 T_7$	$T_4 \cdot T_5 \cdot T_6$	
3 -	T_{14}	T_{15}	T_{16}		$T_{11} \cdot T_{12} \cdot T_{13} \cdot T_{17}$
4 - HIGHEST	T_{11}	T_{12}	$T_{13} T_{17}$	$T_{14} \cdot T_{15} \cdot T_{16}$	
FORWARD	L_1	L_2	L_3		
REVERSE	L_2	L_1	L_3		

435

TWO WINDING - CONSTANT HORSEPOWER - THREE PHASE SPEEDS 3600/1800/1200/600

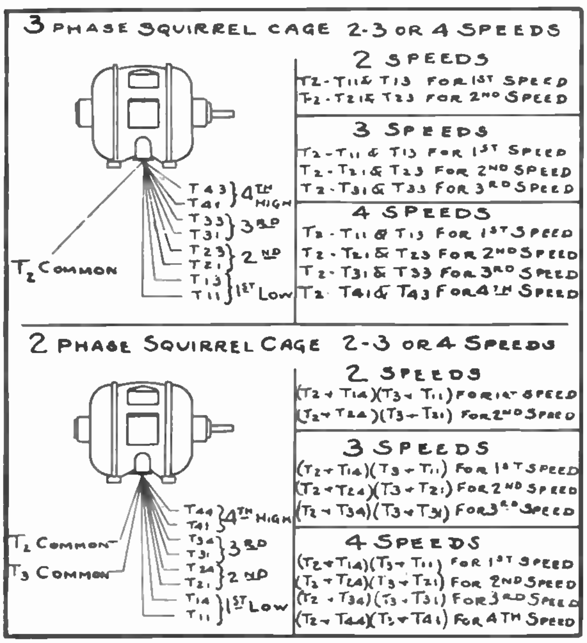


MOTOR LEADS T_1 & T_{11} TO BE CONNECTED TOGETHER.

SPEED.	USED FOR LEADS.			OPEN.	TOGETHER.
1 LOWEST.	T_4	T_5	T_6		$T_1 - T_2 - T_3 - T_7$
2	T_{14}	T_{15}	T_{16}		$T_{11} - T_{12} - T_{13} - T_{17}$
3	T_1	T_2	$T_3 \cdot T_7$	$T_4 - T_5 - T_6$	
4 HIGHEST	T_{11}	T_{12}	$T_{13} \cdot T_{17}$	$T_{14} - T_{15} - T_{16}$	
FORWARD.	L_1	L_2	L_3		
REVERSE	L_2	L_1	L_3		

414

TWO WINDING - CONSTANT HORSEPOWER - THREE PHASE SPEEDS 1800/1200/900/600 1200/ 900/600/450

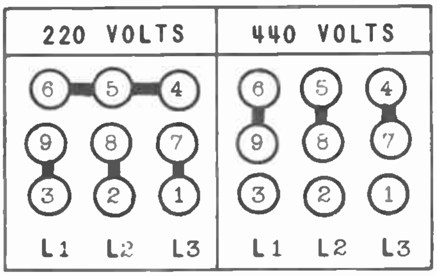


353

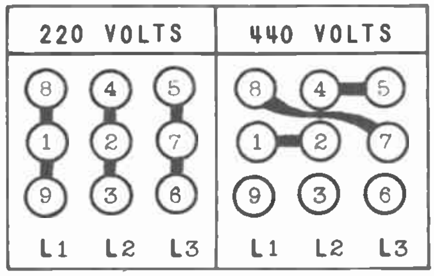
Terminal Markings Which Include FOUR WINDING CT, VT or C.H.P. 3 and 2 Phase

3 PHASE SINGLE SPEED

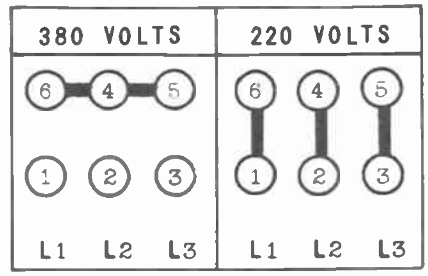
NO. 1 STAR-Y-CONNECTION



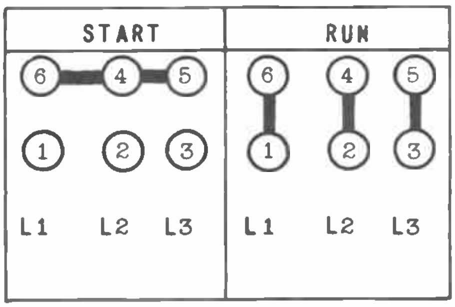
NO. 2 DELTA-CONNECTION



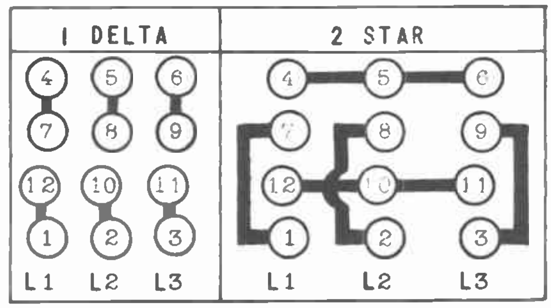
NO. 3 STAR-DELTA CONNECTION



NO. 4 STAR START DELTA RUN

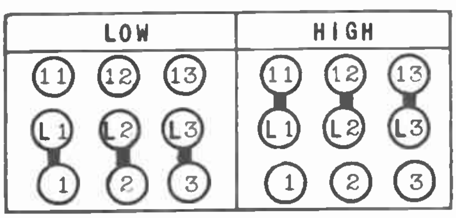


NO. 5 1 DELTA CONNECTION 2 STAR CONNECTION



3 PHASE 2 SPEED

NO. 6 TWO SPEED TWO WINDING



NO. 7 TWO SPEED SINGLE WINDING CONSTANT TORQUE or VARIABLE TORQUE

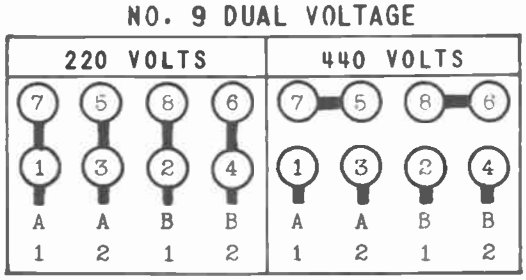
SPEED	L1	L2	L3	
LOW	T1	T2	T3	T4, T5, T6. Open
HIGH	T6	T4	T5	T1, T2, T3 Together

NO. 8 TWO SPEED SINGLE WINDING CONSTANT HORSEPOWER

SPEED	L1	L2	L3	
LOW	T1	T2	T3	T4, T5, T6, Together
HIGH	T6	T4	T5	T1, T2, T3 Open

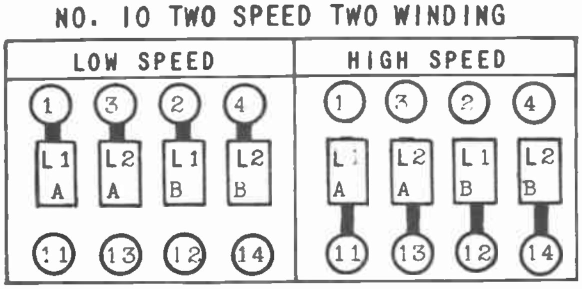
2 PHASE SINGLE SPEED

NO. 9 DUAL VOLTAGE



2 PHASE TWO SPEED

NO. 10 TWO SPEED TWO WINDING



NO. 11 TWO SPEED ONE WINDING VARIABLE TORQUE

Speed	L1 A	L2 A	L1 B	L2 B	Open
Low	T1	T5	T2	T6	T3, T4
High	T1. T5	T3	T2. T6	T4	

3 PHASE 4 SPEED

NO. 12 FOUR SPEED TWO WINDING CONSTANT TORQUE

For 4, 6, 8, 12 or 6, 8, 12, 16 POLES

Speed	L1	L2	L3	Leads Together	Leads Open
Low #1	T1	T2	T3, T7	None	All Others
#2	T11	T12	T13, T17	None	All Others
#3	T6	T4	T5	T1, T2, T3, T7	All Others
#4	T16	T14	T15	T11, T12, T13, T17	All Others

NO. 13 FOUR SPEED TWO WINDING CONSTANT TORQUE

For 2, 4, 6, 12 or 4, 8, 10, 20 Poles

Speed	L1	L2	L3	Leads Together	Leads Open
Low #1	T1	T2	T3, T7	None	All Others
#2	T6	T4	T5	T1, T2, T3-T7	All Others
#3	T11	T12	T13, T17	None	All Others
#4	T16	T14	T15	T11, T12, T13-T17	All Others

NO. 14 FOUR SPEED TWO WINDING VARIABLE TORQUE

For 4, 6, 8. 12 or 6, 8, 12, 16 Poles

Speed	L1	L2	L3	Leads Together	Leads Open
Low #1	T1	T2	T3	None	All Others
#2	T11	T12	T13	None	All Others
#3	T6	T4	T5	T1, T2, T3,	All Others
#4	T16	T14	T15	T11, T12, T13	All Others

NO. 15 FOUR SPEED TWO WINDING VARIABLE TORQUE

For 2, 4, 6, 12 or 4, 8, 10, 20 Poles

Speed	L1	L2	L3	Leads Together	Leads Open
Low #1	T1	T2	T3	None	All Others
#2	T6	T4	T5	T1, T2, T3	All Others
#3	T11	T12	T13	None	All Others
#4	T16	T14	T15	T11, T12, T13	All Others

NO. 16 FOUR SPEED TWO WINDING CONSTANT HORSEPOWER

For 4, 6, 8, 12 or 5, 8, 12, 16 POLES

Speed	L1	L2	L3	Leads Together	Leads Open
Low #1	T1	T2	T3	T4, T5, T6, T7	All Others
#2	T11	T12	T13	T14, T15, T16, T17,	All Others
#3	T6	T4	T5, T7	None	All Others
#4	T16	T14	T15, T17	None	All Others

NO. 17 FOUR SPEED TWO WINDING CONSTANT HORSEPOWER

For 2, 4, 6, 12 or 4, 8, 10, 20 Poles

Speed	L1	L2	L3	Leads Together	Leads Open
Low #1	T1	T2	T3	T4, T5, T6, T7	All Others
#2	T6	T4	T5, T7	None	All Others
#3	T11	T12	T13	T14, T15, T16, T17	All Others
#4	T16	T14	T15, T17	None	All Others

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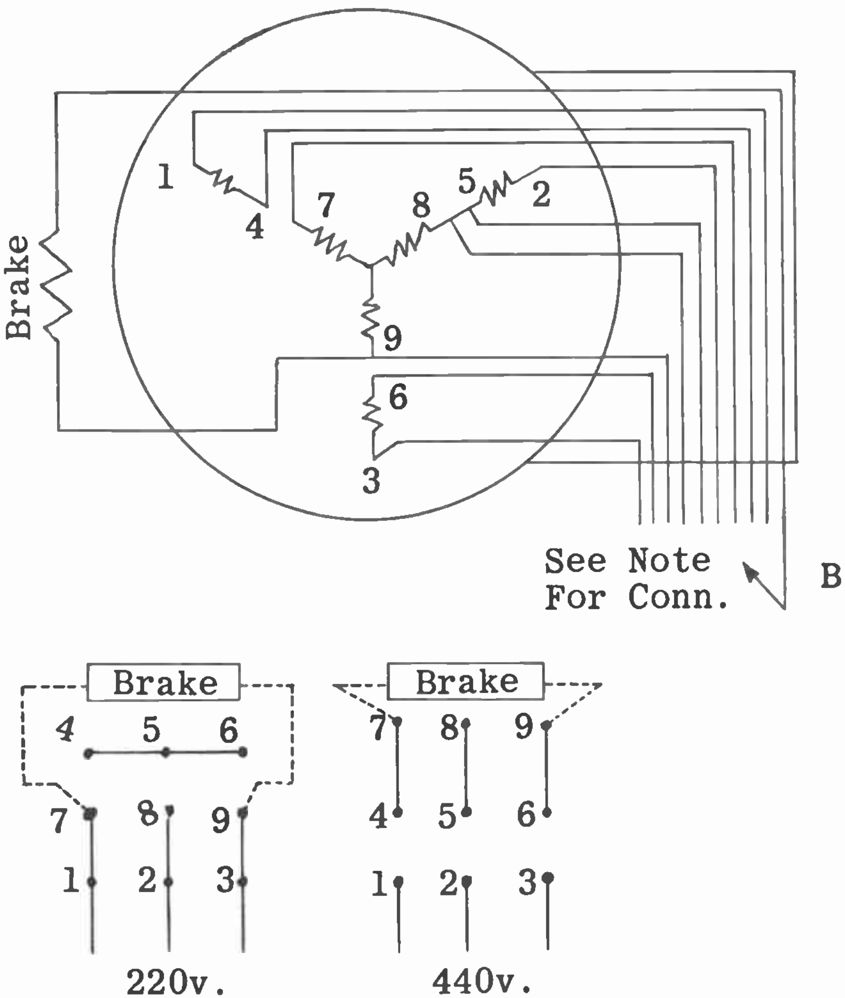
CONNECTIONS FOR 220/440 v. MOTOR WITH STD. 220 BRAKE



NOTE ON BRAKE CONNECTIONS

For normal braking requirements, connect lead "B" to motor Lead #7 on either voltage.

For more rapid braking, provide a 4th pole on motor disconnect so that brake lead "B" is disconnected from lead #7 when motor line switch is opened.

Janette Mfg.Co.
Chicago,Ill.

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3.7 POLYPHASE INDUCTION MOTORS

3.705 Classes of Polyphase Induction Motors

Induction motors of the slip-ring or squirrel-cage type are divided into the following classes for determining terminal markings:

Class 1—Three-phase motors having only one synchronous speed. (See 3.715.)

Class 2—Three-phase motors having two synchronous speeds obtained from a reconnectible winding. (See 3.720.)

Class 3—Three-phase motors having two or more synchronous speeds obtained from two or more independent windings. (See 3.725.)

Class 4—Two-phase motors having only one synchronous speed. (See 3.730.)

Class 5—Two-phase motors having two synchronous speeds obtained from a reconnectible winding. (See 3.735.)

Class 6—Two-phase motors having two or more synchronous speeds obtained from two or more independent windings. (See 3.740.)

3.710 Purpose of Rules Applying to Induction Motors

The markings of the terminals of a motor serve the best purpose if they indicate the electrical relations between the several circuits within the motor. The windings of a motor are seldom accessible and the arrangement of the terminal numbers on the terminal board varies with the combinations of connections which are required. However, if a definite system of numbering is used, the marking of the terminals may be made to tell the exact relations of the windings within the motor. As far as practical, 3.715-3.740 are formulated to embody such a system, which system employs as one of its fundamental points a clockwise rotation in the sequence of terminal numbering.

For three-phase motors having two synchronous speeds obtained from a reconnectible winding, it is undesirable to adhere to the clockwise system of numbering for all terminals, as this would cause the motor to run with clockwise shaft rotation on one speed and counter-clockwise on the other speed if the power lines are connected to each set of terminals in the same sequence. This feature may be considered an advantage, as a winding with part of its terminals following a clockwise sequence and part a counter-clockwise sequence can be recognized immediately as a two-speed motor with a reconnectible winding.

For two-phase motors, regardless of the class of motor or the type of winding, the rules are such that all odd subscript numbers are in one phase and all even subscript numbers are in the other phase. The markings of all motors except those for two-speed motors using a single reconnectible winding are based, as are the rules for three-phase windings, on a clockwise spiral system of rotation in the sequence of terminal numbering.

3.715 Class 1. Three-Phase Induction Motors

First—A schematic vector diagram should be drawn showing an inverted Y connection with the individual circuits in each phase arranged for series connection with correct polarity relation of circuits. The diagram for two circuits per phase, for example, is as shown in Fig. 1.

Second—Starting with T_1 at the outside and top of the diagram, the ends of the circuits are numbered consecutively in a clockwise direction proceeding on a spiral towards the center of the diagram. For two circuits per phase, for example, the terminals are marked as shown in Fig. 2.

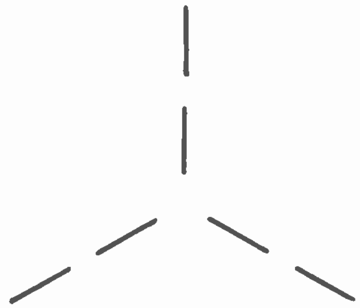

Fig. 1. Diagram for two circuits per phase

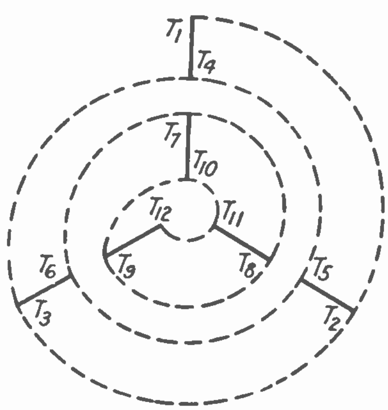

Fig. 2. Terminal markings for two circuits per phase

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Third—A schematic vector diagram is now drawn showing the particular interconnection of circuits for the motor under consideration and the terminal markings as determined from the preceding paragraphs are arranged to give the correct polarity relation of circuits. If the winding in Fig. 2 is to be connected with two circuits in multiple per phase, the diagram and markings are shown in Fig. 3.

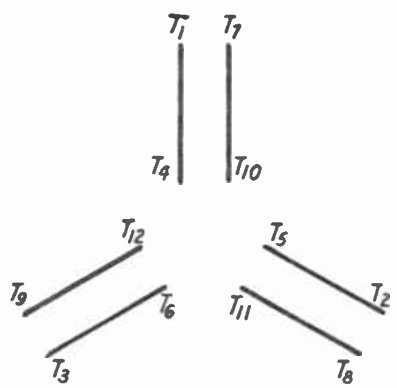

Fig. 3. Terminal markings for two circuits in multiple per phase

Fourth—The highest numbers are dropped and only the lowest number is retained where two or more terminals are permanently connected together. If the winding in Fig. 3 is to have the two circuits in each phase permanently connected together with three line leads and three neutral leads brought out, the terminal markings are as shown in Fig. 4.

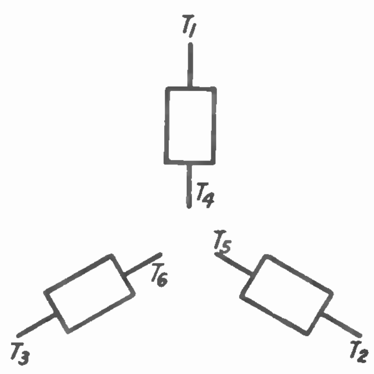

Fig. 4. Terminal markings for two circuits in multiple per phase, permanently connected

If the winding in Fig. 2 is to be arranged for either a series or a multiple connection with the neutral point brought out, the vector diagram and terminal markings become as shown in Fig. 5.

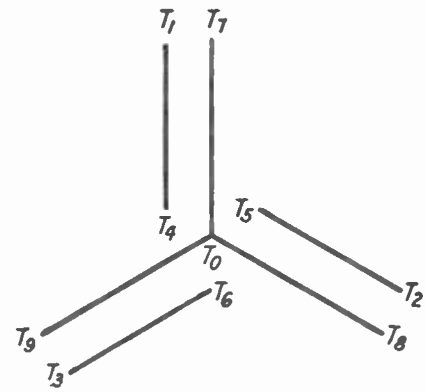

Fig. 5. Terminal markings with neutral point brought out

Fifth—Where the ends of three coils are connected together to form a permanent neutral, the terminal markings of the three leads so connected should be dropped. If the neutral point is brought out it should always be marked T_0. (See Fig. 5.)

NOTE I—The above rules can be applied to determine the terminal markings of any three-phase induction motor stator having only one synchronous speed regardless of how many circuits per phase there may be or how they are connected and they determine definitely which circuits belong in the same phase and also the polarity of the circuits.

NOTE II—Delta-connected windings. If a winding is to be delta-connected, rotate the inverted Y diagram (Fig. 1) 30 degrees counter-clockwise. Assign T_1 to the outer end of the top leg and proceed with the numbering as instructed in part 2 and Fig. 2. Then construct a schematic delta in which the T_1 leg of the rotated Y becomes the right hand side of the delta, the T_2 leg becomes the bottom (horizontal) side and the T_3 leg becomes the left side of the delta. Apply parts 3, 4 and 5 as far as they are applicable to a delta connection. See Fig. 6 below.

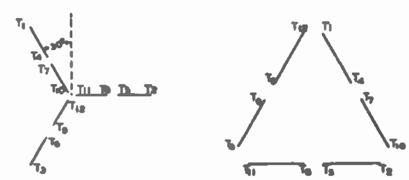

Fig. 6.

NOTE III—The following illustrates the application of the foregoing standards in determining terminal markings of Y and delta-connected dual-voltage motors with nine leads brought out.

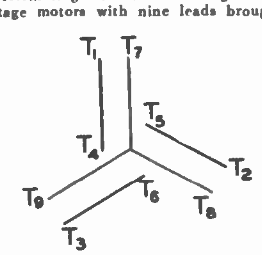

Fig. 7. Y-connection

Voltage	L_1	L_2	L_3	Tie Together		
Low	T_1	T_2	T_3	T_1, T_7	T_2, T_8, T_4, T_5, T_6	T_3, T_9
High	T_1	T_2	T_3	T_4, T_7	T_5, T_8	T_6, T_9

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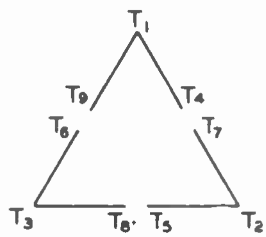

Fig. 8. Delta connection

Voltage	L_1	L_2	L_3	Tie Together		
Low	T_1	T_2	T_3	T_1, T_6, T_7	T_2, T_4, T_8	T_3, T_5, T_9
High	T_1	T_2	T_3	T_4, T_7	T_5, T_8	T_6, T_9

3.720 Class 2. Three-Phase Induction Motors

These windings do not lend themselves readily to the use of a written rule for determining the terminal markings on account of the desirability of having part of the terminals follow a clockwise rotation and part a counter-clockwise rotation in order to get the same direction of rotation for both speeds when the line leads are connected to each set of terminals in the same sequence. For this reason it has been felt best to show each schematic diagram with its terminal markings, rather than attempt to formulate a complicated written rule, and as there are very few types of reconnectible windings, this becomes feasible. The rule for Class 2 motors then becomes:

First—For Class 2 motors the terminal markings shown in Figs. 1, 2, 3, 4, and 5 should be used. (Other winding diagrams to be added if and when necessary.)

Second—If a neutral lead is brought out it should be marked T_0.

NOTE—T_1, T_2 and T_3 are clockwise in all cases and are always the line terminals for low speed.

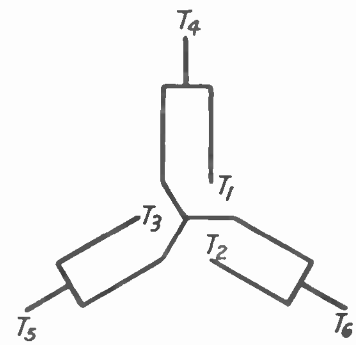

Fig. 1.
Variable Torque Motors

Speed	L_1	L_2	L_3	Open	Tie Together
Low	T_1	T_2	T_3	T_4, T_5, T_6	——
High	T_6	T_4	T_5	——	T_1, T_2, T_3

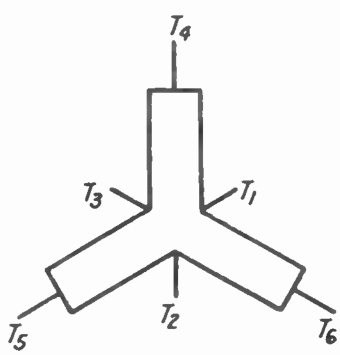

Fig. 2.

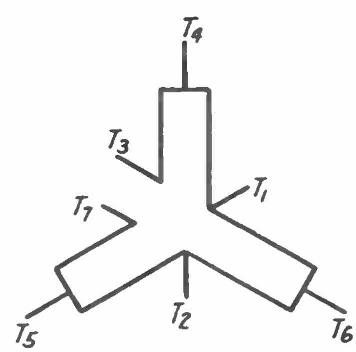

Fig. 3.

Constant Torque Motors

Speed	L_1	L_2	L_3	Open	Tie Together
Low	T_1	T_2	T_3	T_4, T_5, T_6	——
High	T_6	T_4	T_5	——	T_1, T_2, T_3

Speed	L_1	L_2	L_3	Open	Tie Together
Low	T_1	T_2	T_3T_7	T_4, T_5, T_6	——
High	T_6	T_4	T_5	——	T_1, T_2, T_3, T_7

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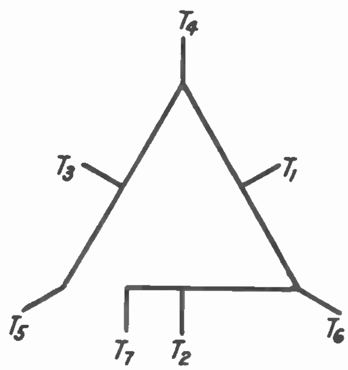

Fig. 4.

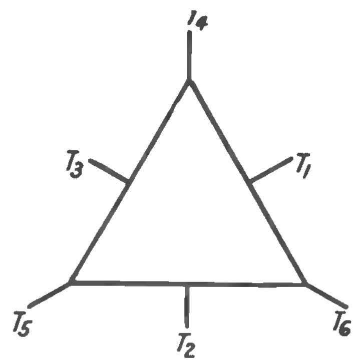

Fig. 5.

Constant Horsepower Motors

Speed	L_1	L_2	L_3	Open	Tie Together
Low	T_1	T_2	T_3	—	T_4, T_5, T_6, T_7
High	T_6	T_4	T_5, T_7	T_1, T_2, T_3	—

Speed	L_1	L_2	L_3	Open	Tie Together
Low	T_1	T_2	T_3	—	T_4, T_5, T_6
High	T_6	T_4	T_5	T_1, T_2, T_3	—

3.725 Class 3. Three-Phase Induction Motors

1. If each independent winding gives only one synchronous speed, the winding giving the lowest speed shall take the same terminal markings as determined from 3.715 for Class 1 motors for the particular winding used. The terminal markings for the higher speed windings shall be obtained by adding 10, 20, or 30, etc., to the erminal markings as determined by 3.715 for Class 1 motors for the particular winding used, the sequences being determined by progressing each time to the next higher speed. The terminal markings for a three-speed motor using three windings are given in Fig. 1 below.

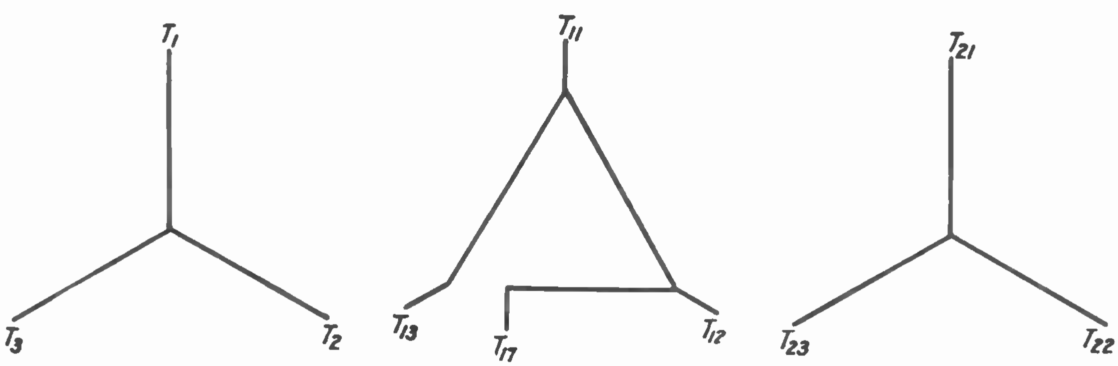

Fig. 1. Three-speed motor using three windings

Speed	L_1	L_2	L_3	Open	Tie Together
Low	T_1	T_2	T_3	T_{11}, T_{12}, T_{13}, T_{17}, T_{21}, T_{22}, T_{23}	—
2nd	T_{11}	T_{12}	T_{13}, T_{17}	T_1, T_2, T_3, T_{21}, T_{22}, T_{23}	—
High	T_{21}	T_{22}	T_{23}	T_1, T_2, T_3, T_{11}, T_{12}, T_{13}, T_{17}	—

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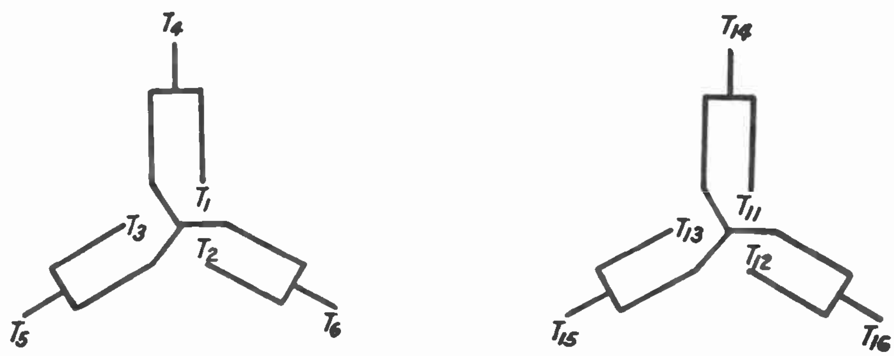
2. If each independent winding is reconnectible to give two synchronous speeds:

First—Vector diagrams of the windings to be used are drawn and each winding is given the terminal markings shown in 3.720 for Class 2 motors.

Second—No further change is made in any of the terminal markings of the winding giving the lowest speed, irrespective of whether the other speed obtained from this winding is an intermediate or the highest speed.

Third—Ten is added to all terminal markings of the winding giving the next higher speed, and an additional 10 is added to all the terminal markings for each consecutively higher speed winding. The terminal markings for a four-speed motor using two windings are given in Fig. 2.



Low Speed and 3rd

2nd Speed and High

Fig. 2. Four-speed motor using two windings

Speed	L_1	L_2	L_3	Open	Tie Together
Low	T_1	T_3	T_3	T_4, T_5, T_6	—
2nd	T_{11}	T_{12}	T_{13}	T_{14}, T_{15}, T_{16}	—
3rd	T_6	T_4	T_5	—	T_1, T_2, T_3
High	T_{16}	T_{14}	T_{15}	—	T_{11}, T_{12}, T_{13}

3. If two or more types of independent windings are used, part of which give only one synchronous speed and the rest give two synchronous speeds by reconnection:

First—Each winding is given the markings as determined from 3.715 for Class 1 and 3.720 for Class 2 motors as the case may be.

Second—No further change is made in any of the terminal markings of the winding giving the lowest speed.

Third—Ten is added to all terminal markings of the winding giving the next higher speed and an additional 10 is added to all the terminal markings of each consecutively higher speed winding. The terminal markings for a three-speed motor using two windings are given in Fig. 3.

NOTE I—If, under any of the sections of the rule for Class 3 motors, the addition of 10, 20, 30, etc., to the basic terminal markings causes a duplication of markings due to more than 9 leads being brought out on any one winding, then 20, 40, 60, etc., should be added instead of 10, 20, 30, etc., to obtain the markings for the higher speeds.

NOTE II—The illustrative figures under Class 3 motors apply when all leads are brought out on the same end of the motor. When one or more of the windings have leads brought out on one end of the motor and part on the other end, the rotation of the terminal markings for leads brought out on one end may be shown on the diagram as shown on the illustrative figures and the terminal markings for those brought out on the opposite end may be shown reversed in rotation. When diagrams use this reversed rotation of markings, an explanatory note should be included for the benefit of the control manufacturer who will then understand that when L_1, L_2, and L_3 are connected to any winding with the same sequence of subscript numbers (T_1, T_2, T_3 or T_4, T_5, T_6 or T_{11}, T_{12}, T_{13}, etc.), the shaft rotation will be the same.

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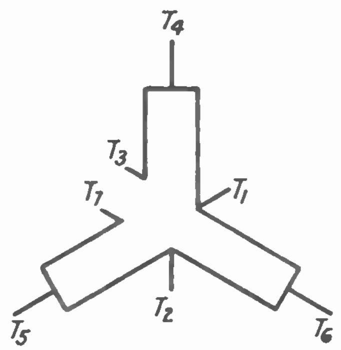
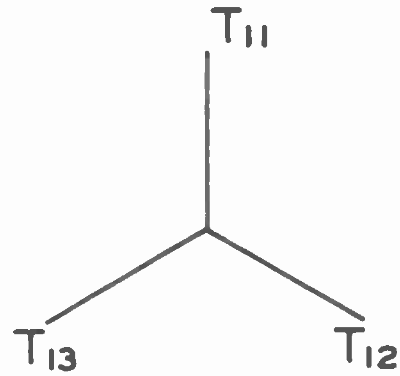


Low Speed and 2nd



High Speed

Fig. 3. A three-speed motor using two windings

Speed	L_1	L_2	L_3	Open	Tie Together
Low	T_1	T_2	T_3, T_7	T_4, T_5, T_6	—
2nd	T_6	T_4	T_5	—	T_1, T_2, T_3, T_7
High	T_{11}	T_{12}	T_{13}	—	—

3.730 Class 4. Two-Phase Induction Motors

First—A schematic vector diagram should be drawn showing a + connection with the individual circuits in each phase arranged for series connection with correct polarity relation of circuits. The diagram for three circuits per phase, for example, is as shown in Fig. 1.

Second—Starting with T_1 at the outside and top of the diagram, the ends of the circuits are numbered consecutively in a clockwise direction proceeding on a spiral towards the center of the diagram. For three circuits per phase, for example, the terminals are marked as in Fig. 2.

Third—A schematic vector diagram is now drawn showing the particular interconnection of circuits for the motor under consideration and the terminal markings as determined from the preceding paragraphs are arranged to give correct polarity relation of circuits. If the winding in Fig. 2 is to be connected with three circuits in multiple per phase, the diagram and markings are shown in Fig. 3.

Fourth—The highest numbers are dropped and only the lowest number is retained where two or more terminals are permanently connected together. If the winding in Fig. 3 is to have the three circuits in each phase permanently connected together with a single line lead brought out from each end of each phase, the terminal markings are as shown in Fig. 4.

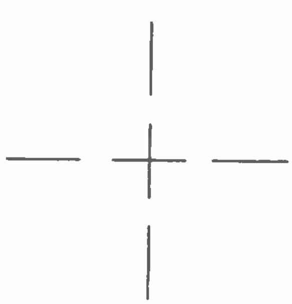


Fig. 1. Diagram for three circuits per phase

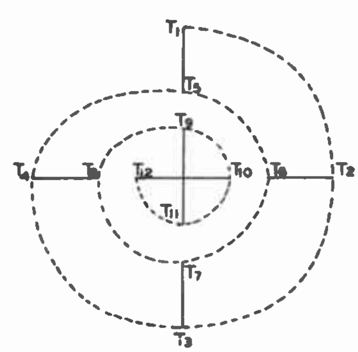


Fig. 2. Terminal markings for three circuits per phase

AMERICAN STANDARD

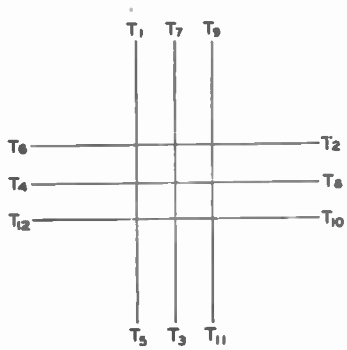


Fig. 3. Terminal markings for three circuits per phase —all circuit leads brought out

Fifth—If a two-phase three-wire power supply is used, connect T_3 and T_4 together and retain only the T_3 marking for the common wire.

Sixth—If the two phases are to be interconnected at the mid-point to connect to a two-phase five-wire system, the mid-point terminal will be marked T_0.

NOTE—The above rules can be applied to determine the terminal marking of any two-phase induction motor stator having only one synchronous speed regardless of how many circuits per phase there may be or how they are connected and they determine definitely which circuits belong in the same phase and also the polarity of the circuits.

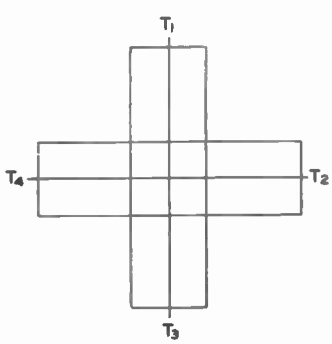


Fig. 4. Terminal markings for three circuits per phase connected in parallel inside the motor

3.735 Class 5. Two-Phase Induction Motors

These windings do not readily lend themselves to the use of a written rule for determining their terminal markings. For this reason it seemed best to show each schematic diagram with its terminal markings. Since there are very few types of reconnectible windings, this becomes feasible.

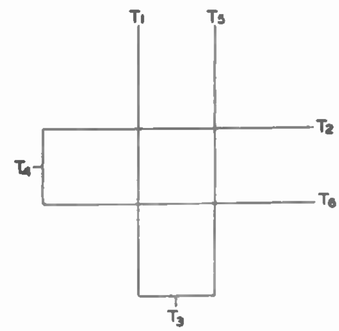


Fig. 5. Two-speed, two-phase variable torque

Speed	L_1	L_3	L_2	L_4	Open
Low	T_1	T_5	T_2	T_6	T_3, T_4
High	T_1, T_5	T_3	T_2, T_6	T_4	——

Fig. 5 shows terminal markings for Class 5 motors. Other diagrams to be added if and when necessary.

3.740 Class 6. Two-Phase Induction Motors

1. If each independent winding gives only one synchronous speed, the winding giving the lowest speed shall take the same terminal markings as determined from 3.730 for Class 4 motors for the particular winding used. The terminal markings for the higher speed windings shall be obtained by adding 10, 20, or 30, etc., to the terminal markings as determined by 3.730 for Class 4 motors for the particular winding used, the sequences being determined by progressing each time to the next higher speed. The terminal markings for a two-speed motor using two single-speed windings are given in Fig. 6.

2. If each independent winding is reconnectible to give two synchronous speeds:

First—Vector diagrams of the windings to be used are drawn and each winding is given the terminal markings shown in 3.735 for Class 5 motors.

Second—No further change is made in any of the terminal markings of the winding giving the lowest speed, irrespective of whether the other speed obtained from this winding is an intermediate or the highest speed.

AMERICAN STANDARD

Third—Ten is added to terminal markings of the winding giving the next higher speed and an additional 10 is added to all the terminal markings for each consecutively higher speed winding. The terminal markings for a four-speed motor using two windings are given in Fig. 7.

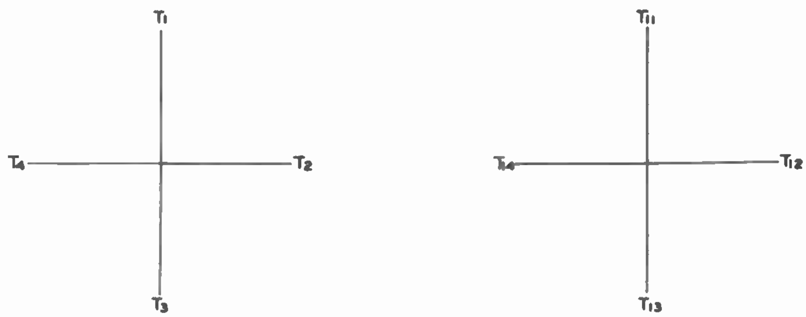
3. If two or more types of independent windings are used, part of which give only one synchronous speed and the rest give two synchronous speeds by reconnection:

First—Each winding is given the markings as determined from 3.730 for Class 4 motors and 3.735 for Class 5 motors as the case may be.

Second—No change is made in any of the terminal markings of the winding giving the lowest speed.

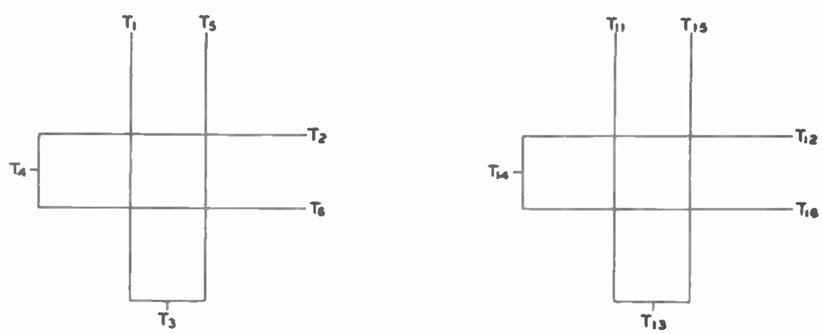
Third—Ten is added to all terminal markings of the winding giving the next higher speed and an additional 10 is added to all the terminal markings of each consecutively higher speed winding. The terminal markings for a three-speed motor using two windings are shown in Fig. 8.

NOTE—If, under any of the sections of the rule for Class 6 motors, the addition of 10, 20, 30, etc., to the basic terminal markings causes a duplication of markings due to more than nine leads being brought out on any one winding, then 20, 40, 60, etc., should be added instead of 10, 20, 30 to obtain the markings for the higher speeds.



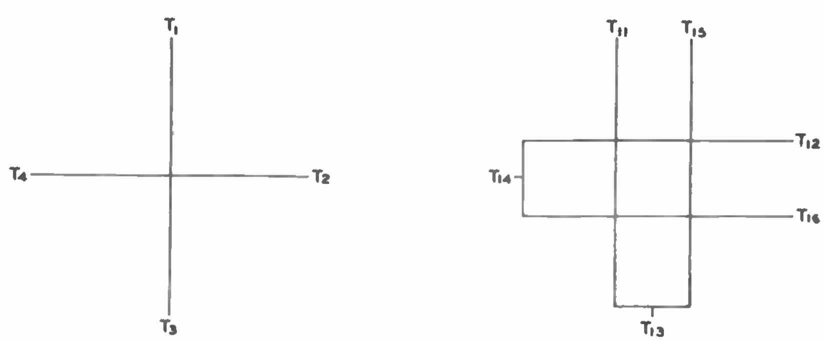
Low-speed High-speed

Fig. 6.



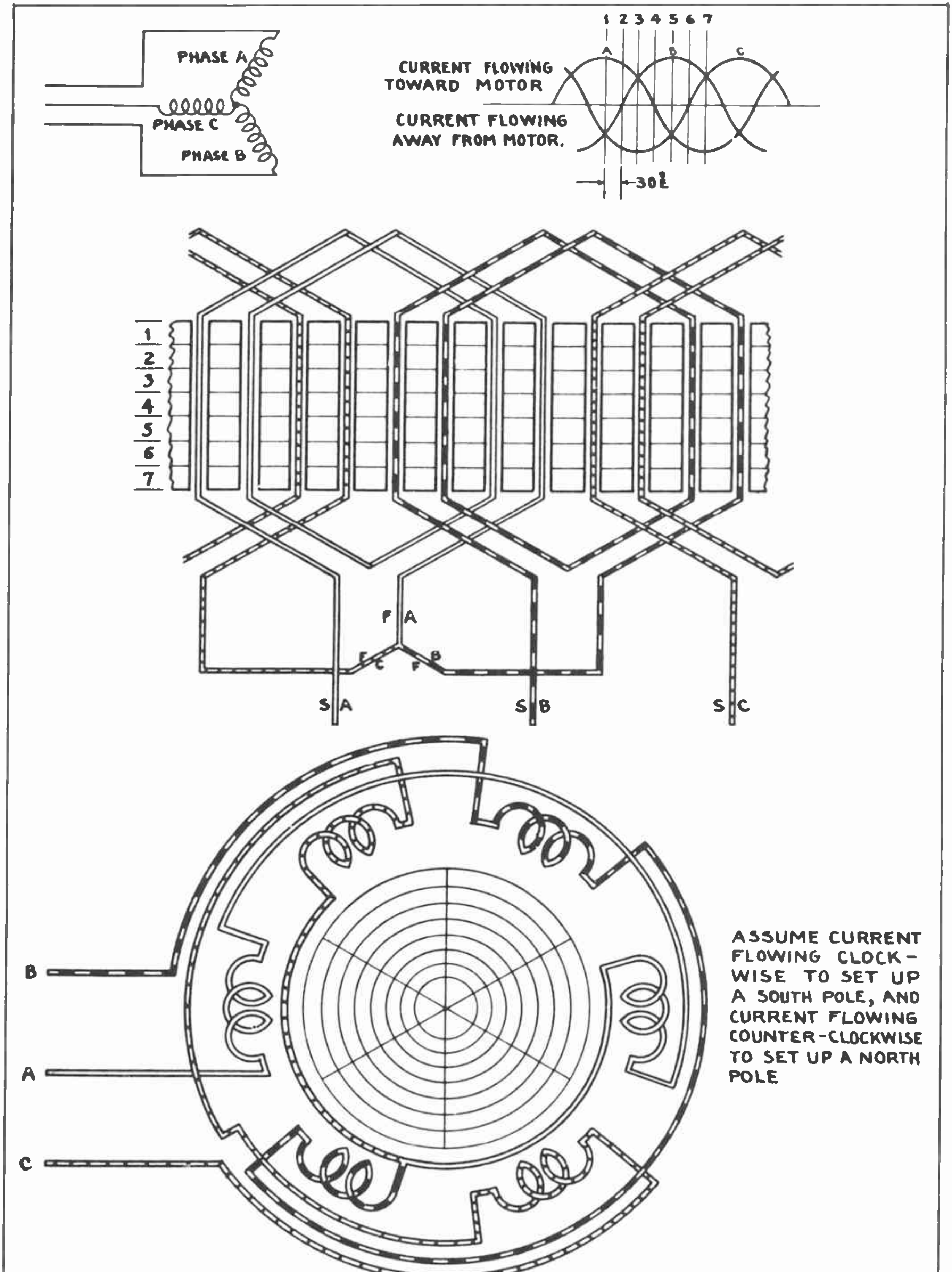
Low and 3rd speed 2nd and high-speed

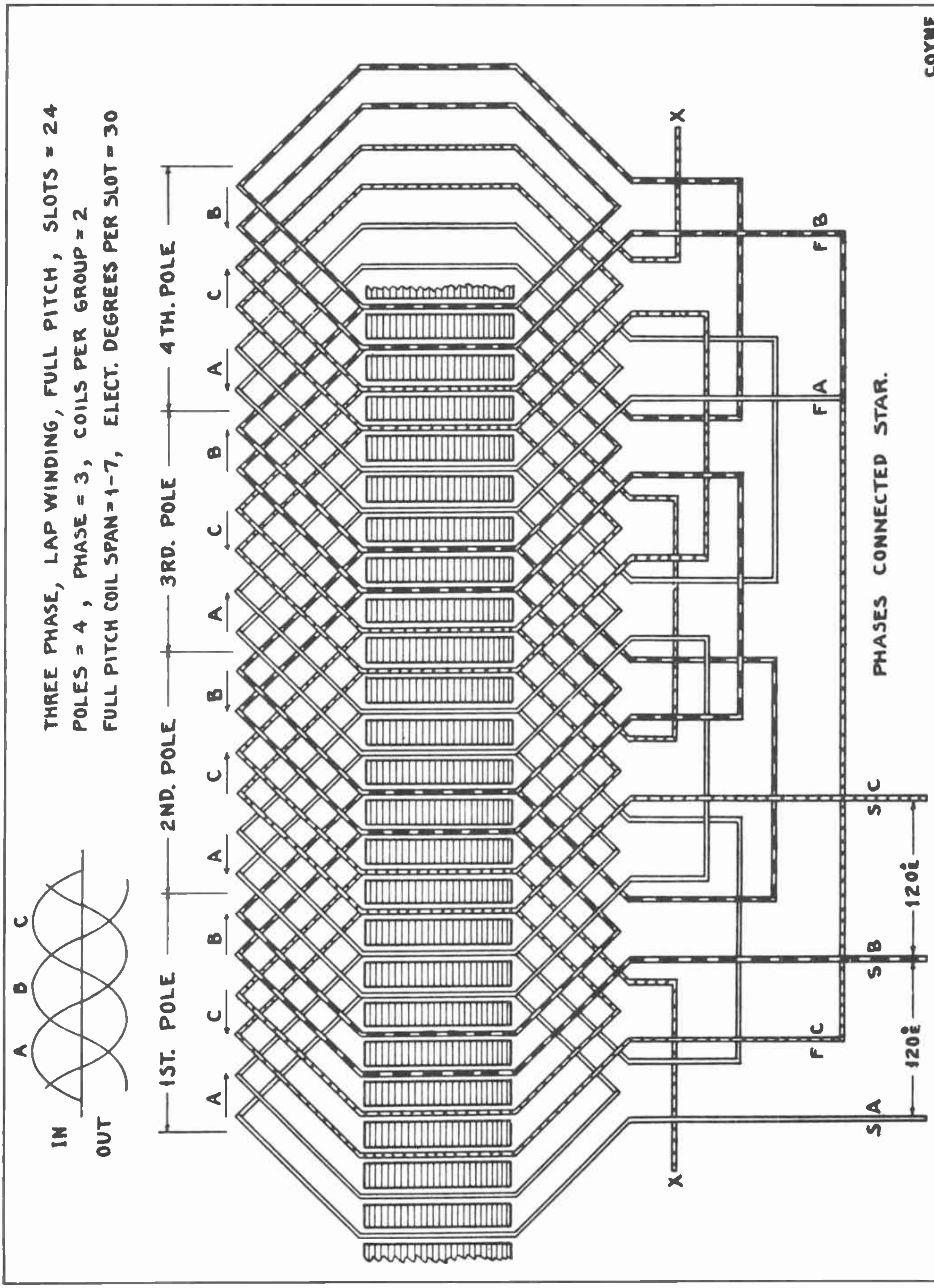
Fig. 7.

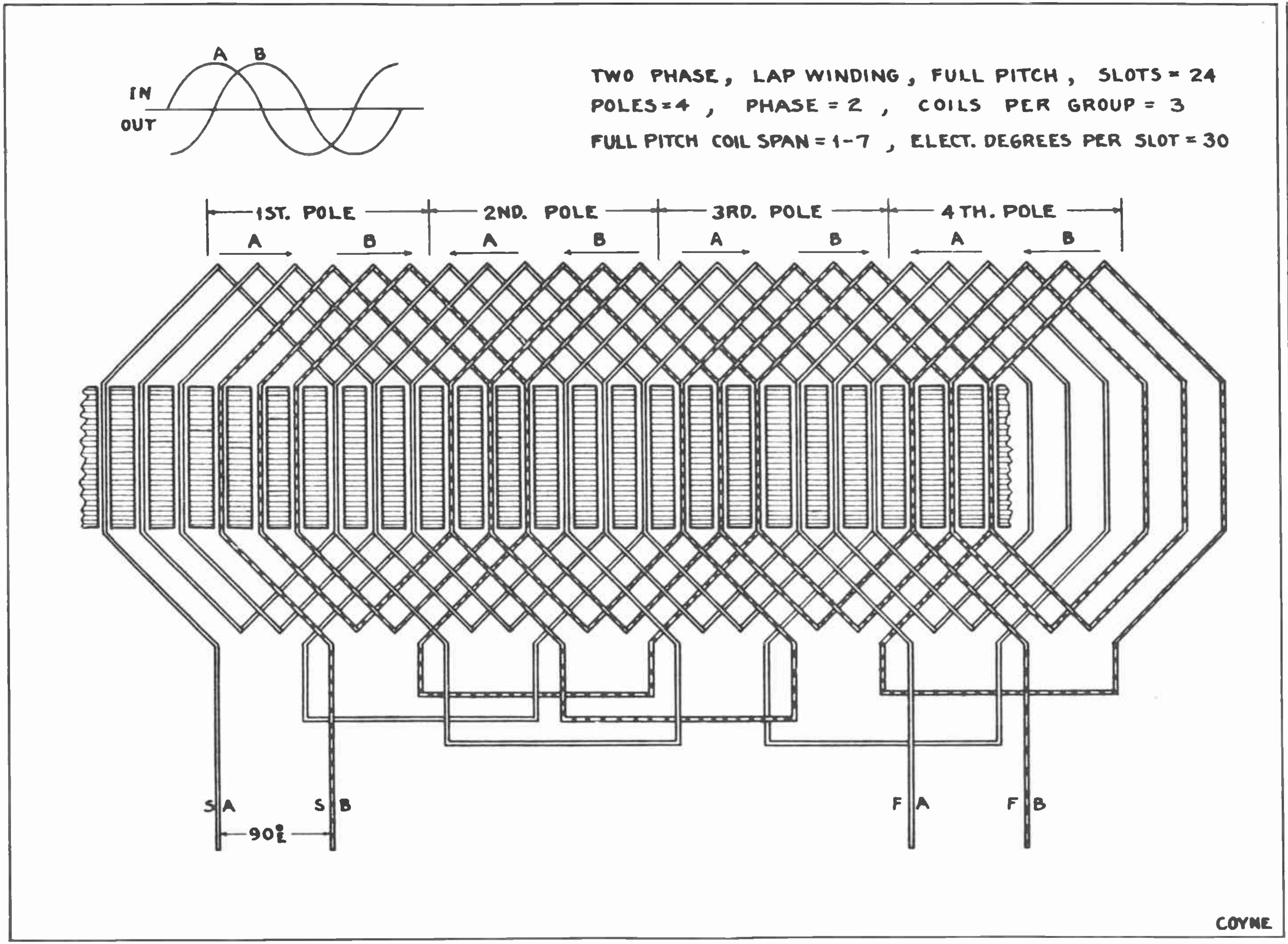


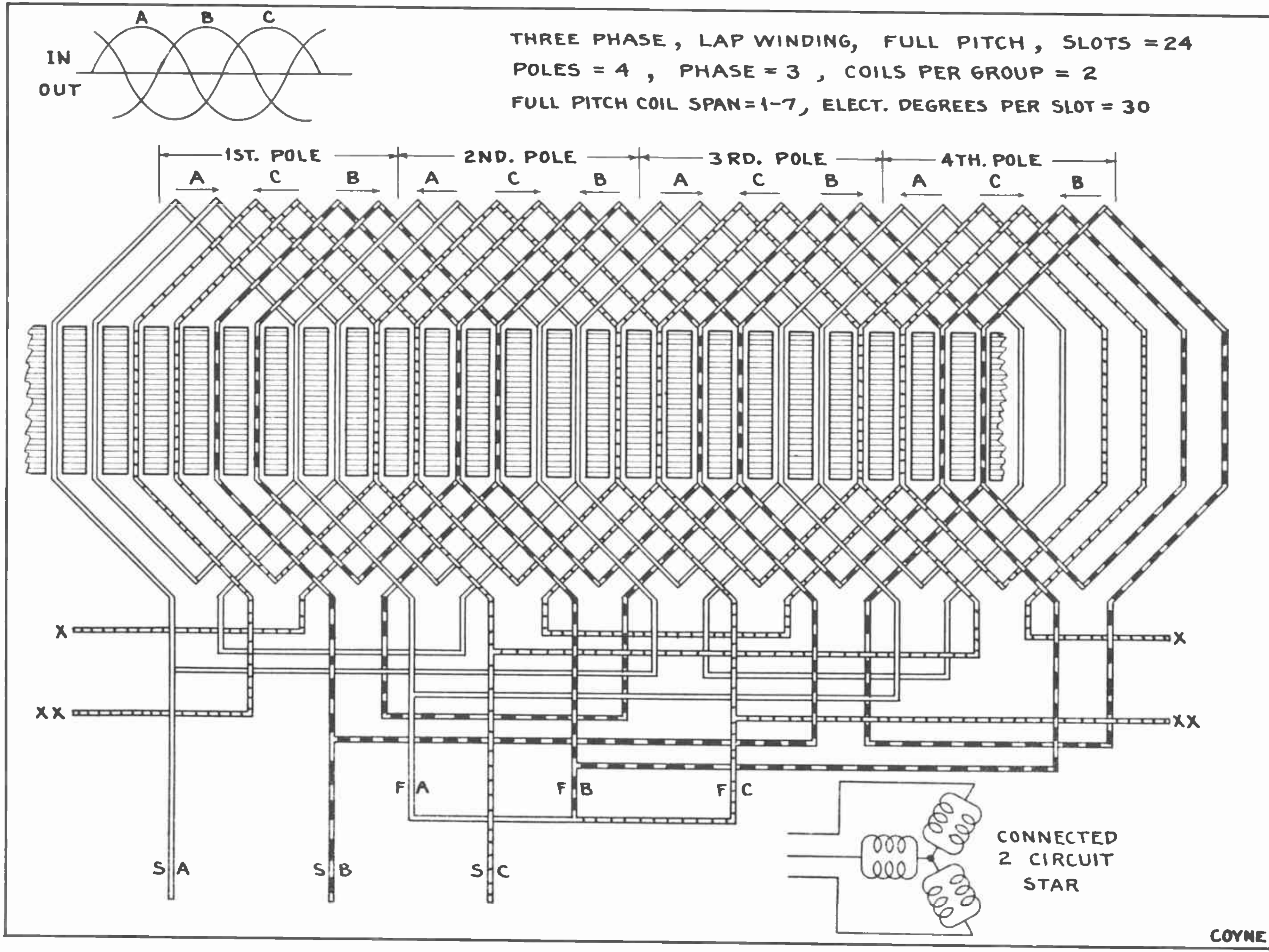
Low-speed 2nd and high-speed

Fig. 8.

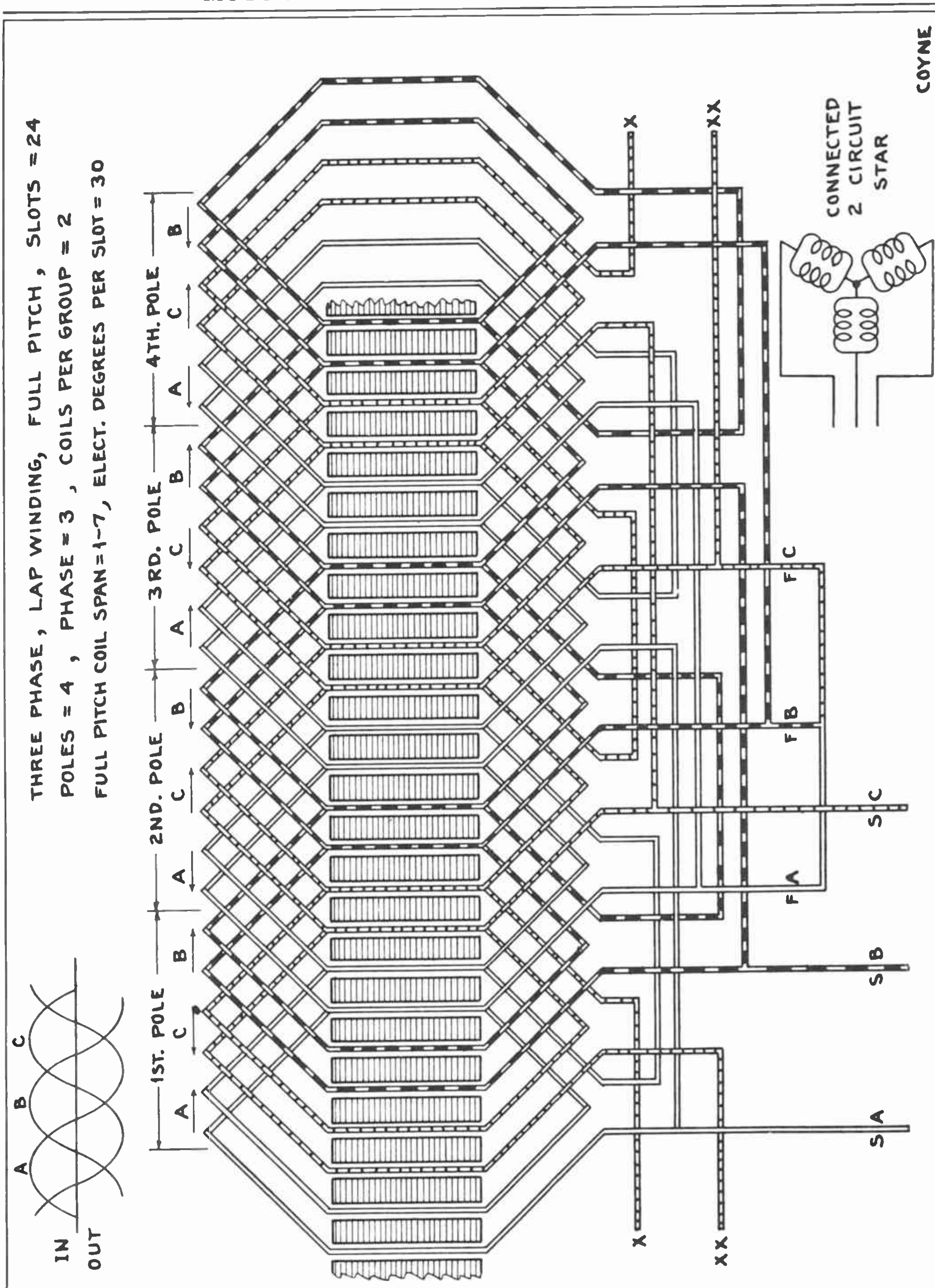

PHASE A
PHASE C
PHASE B
1 2 3 4 5 6 7
CURRENT FLOWING TOWARD MOTOR
CURRENT FLOWING AWAY FROM MOTOR.
1
2
3
4
5
6
7
F A
S A
S B
S C
B
A
C
ASSUME CURRENT FLOWING CLOCK-WISE TO SET UP A SOUTH POLE, AND CURRENT FLOWING COUNTER-CLOCKWISE TO SET UP A NORTH POLE

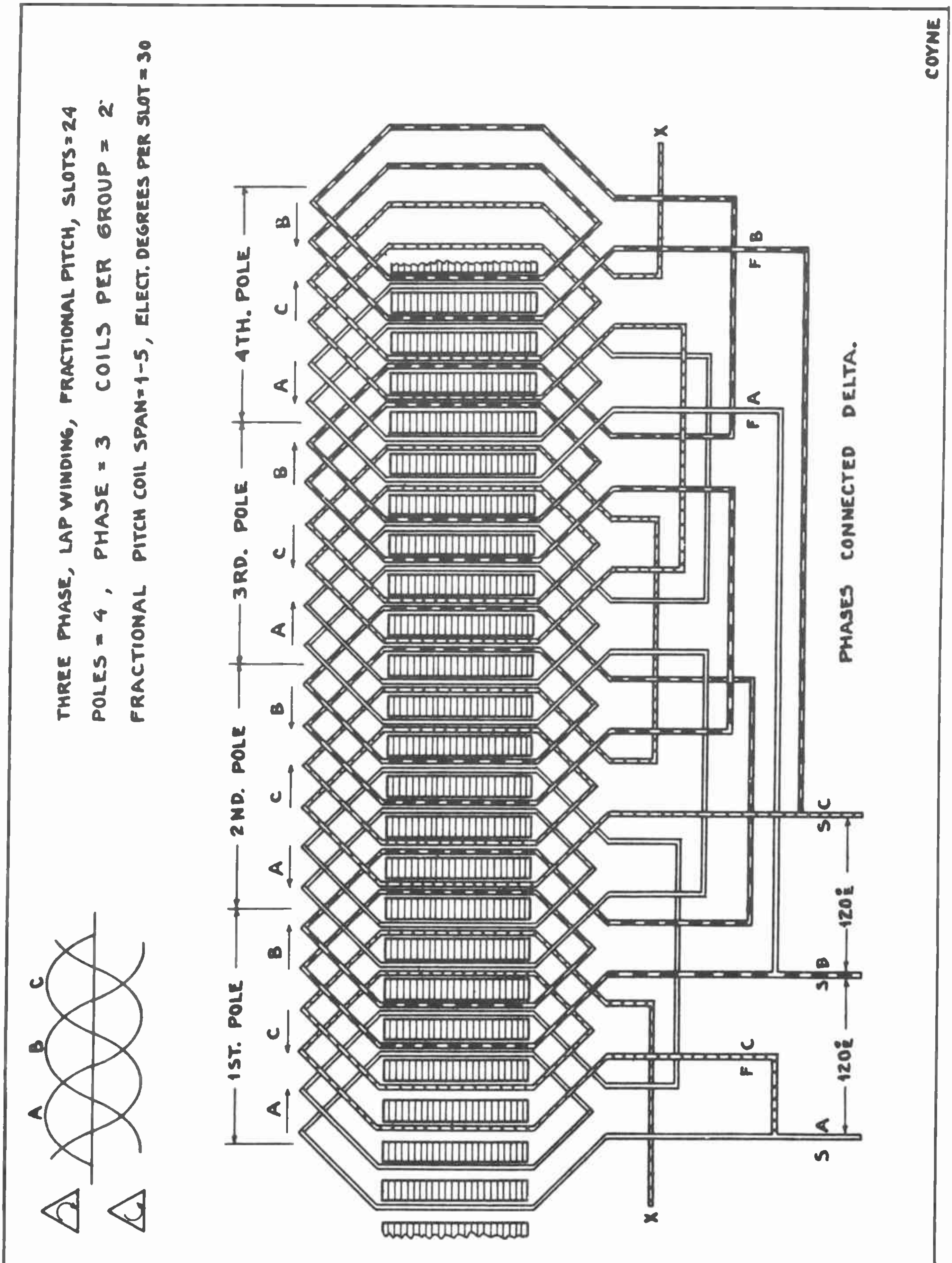

THREE PHASE, LAP WINDING, FULL PITCH, SLOTS = 24
POLES = 4, PHASE = 3, COILS PER GROUP = 2
FULL PITCH COIL SPAN = 1-7, ELECT. DEGREES PER SLOT = 30
IN
OUT
A B C
1ST. POLE
2ND. POLE
3RD. POLE
4TH. POLE
A C B A C B A C B A C B
X
X
F B
F A
F C
S A
S B
S C
120°E
120°E
PHASES CONNECTED STAR.
COYNE


A B
IN
OUT
TWO PHASE, LAP WINDING, FULL PITCH, SLOTS = 24
POLES = 4, PHASE = 2, COILS PER GROUP = 3
FULL PITCH COIL SPAN = 1-7, ELECT. DEGREES PER SLOT = 30
1ST. POLE
2ND. POLE
3RD. POLE
4TH. POLE
A B A B A B A B
S A
S B
90°E
F A
F B
COYNE

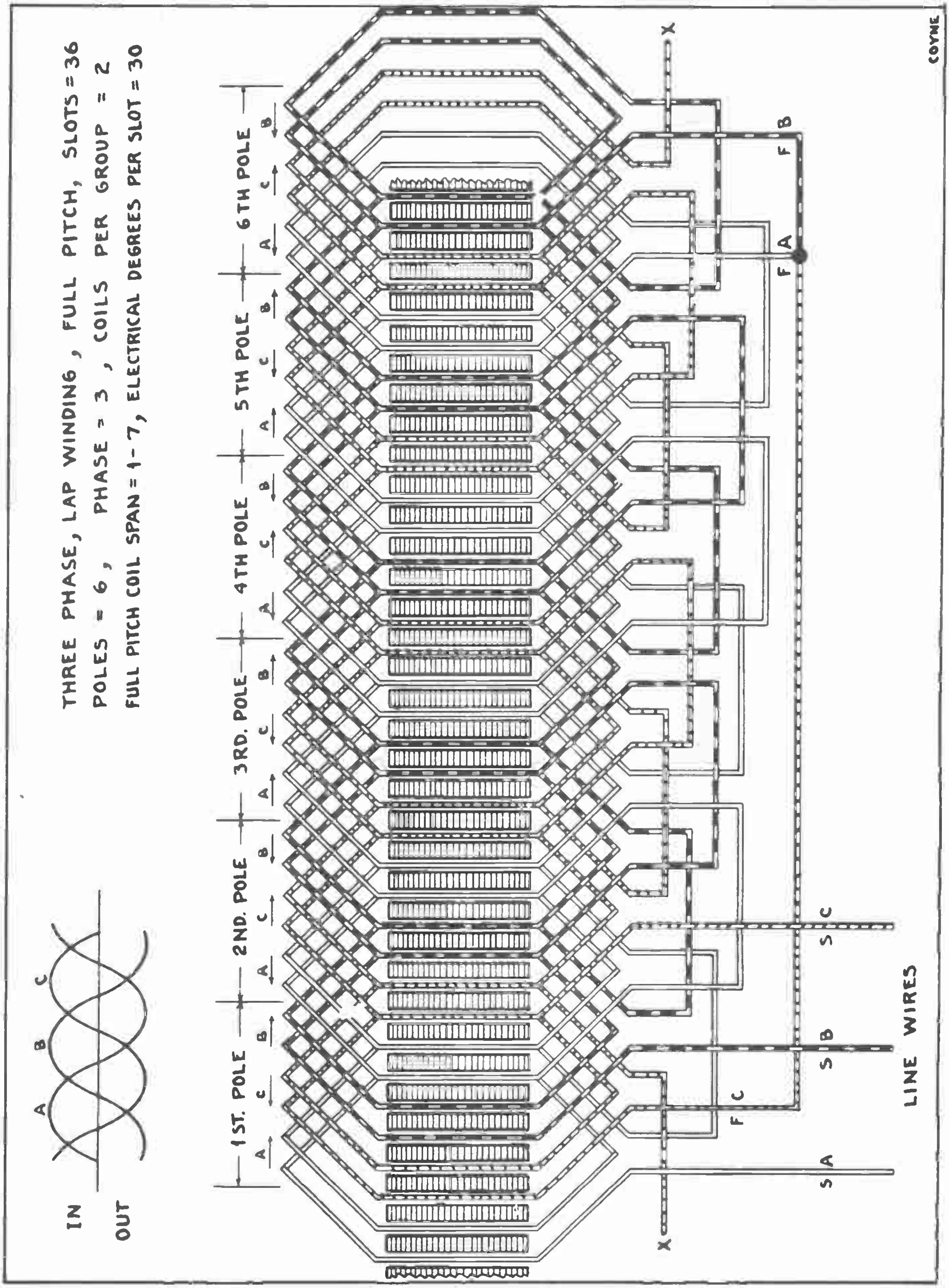


A B C
IN
OUT
THREE PHASE, LAP WINDING, FULL PITCH, SLOTS = 24
POLES = 4, PHASE = 3, COILS PER GROUP = 2
FULL PITCH COIL SPAN = 1-7, ELECT. DEGREES PER SLOT = 30
1ST. POLE
2ND. POLE
3RD. POLE
4TH. POLE
A C B A C B A C B A C B
X
XX
X
XX
F A
F B
F C
S A
S B
S C
CONNECTED
2 CIRCUIT
STAR
COYNE

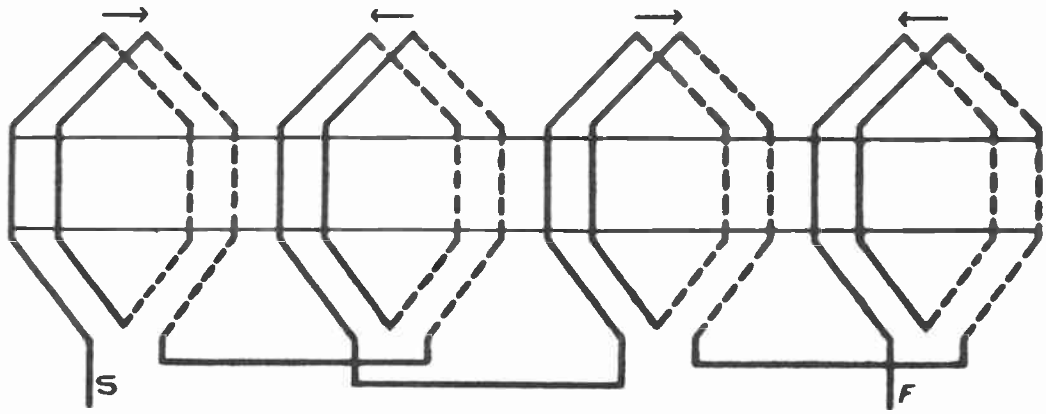

THREE PHASE, LAP WINDING, FULL PITCH, SLOTS = 24
POLES = 4, PHASE = 3, COILS PER GROUP = 2
FULL PITCH COIL SPAN = 1-7, ELECT. DEGREES PER SLOT = 30
IN
OUT
A B C
1ST. POLE
2ND. POLE
3RD. POLE
4TH. POLE
A C B A C B A C B A C B
X
XX
SA
SB
SC
FA
FB
FC
CONNECTED 2 CIRCUIT STAR
COYNE



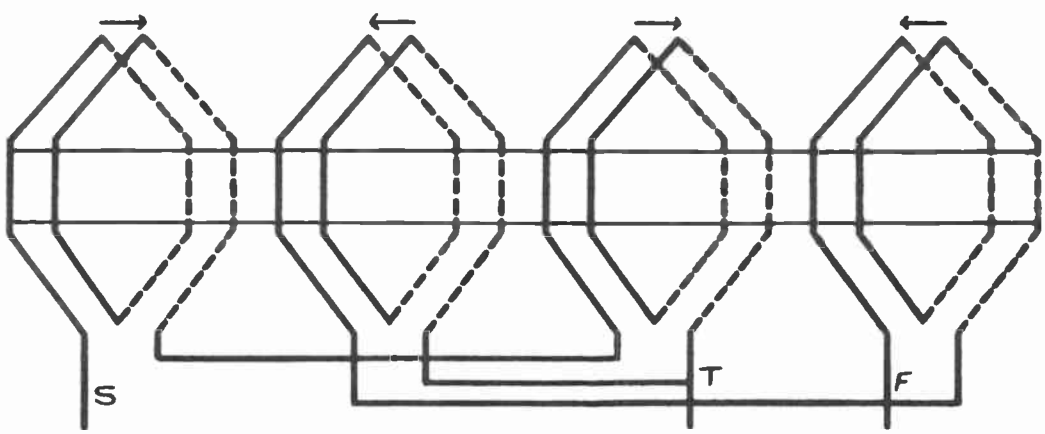
THREE PHASE, LAP WINDING, FRACTIONAL PITCH, SLOTS = 24
POLES = 4 , PHASE = 3 COILS PER GROUP = 2
FRACTIONAL PITCH COIL SPAN = 1-5 , ELECT. DEGREES PER SLOT = 30
COYNE
1ST. POLE
2ND. POLE
3RD. POLE
4TH. POLE
A C B A C B A C B A C B
X
X
F C
F A
F B
S A
S B
S C
120°E
120°E
PHASES CONNECTED DELTA.
A B C


THREE PHASE, LAP WINDING, FULL PITCH, SLOTS = 36
POLES = 6, PHASE = 3, COILS PER GROUP = 2
FULL PITCH COIL SPAN = 1 - 7, ELECTRICAL DEGREES PER SLOT = 30
IN
OUT
A
B
C
1 ST. POLE
2 ND. POLE
3 RD. POLE
4 TH POLE
5 TH POLE
6 TH POLE
X
F B
F A
F C
S C
S B
S A
LINE WIRES
COYNE

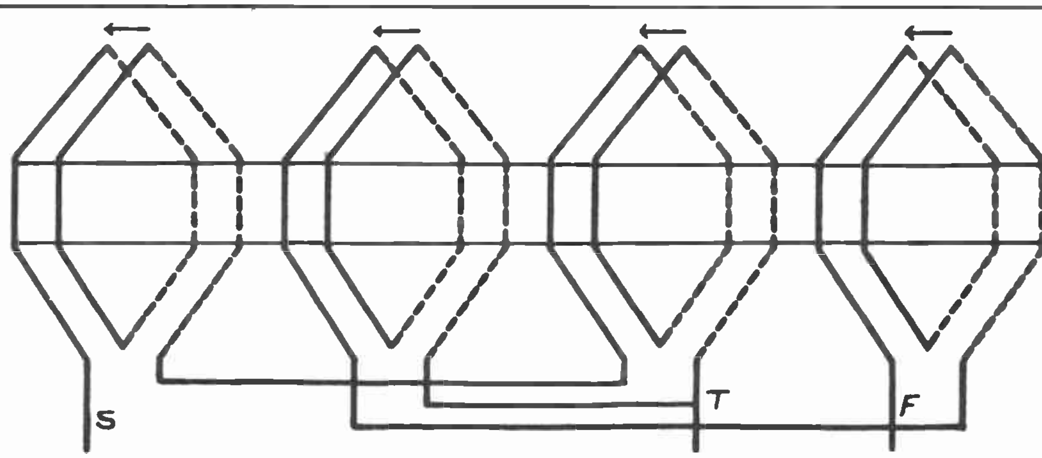
PRINCIPLES OF CONSEQUENT POLE WINDINGS FOR 3 PHASE INDUCTION MOTORS.



Slots = 24, Poles = 4, Fractional Pitch Coil Span = 1 to 5.
"A" Phase only of a 3 phase winding illustrating common method of short jumpers. (Top to Top, Bottom to Bottom) Trace the circuit and mark the polarities in the proper position. This type of jumper connection is not suitable for consequent pole windings.

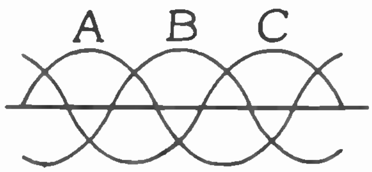


"A" Phase only of 3 phase winding illustrating long jumper method of connection. (Top to Bottom, Bottom to Top) Trace the circuit for 4 poles disregarding the center tap, and mark the polarities in the proper position. Note that the poles are established in the same position as for the common method of connection.

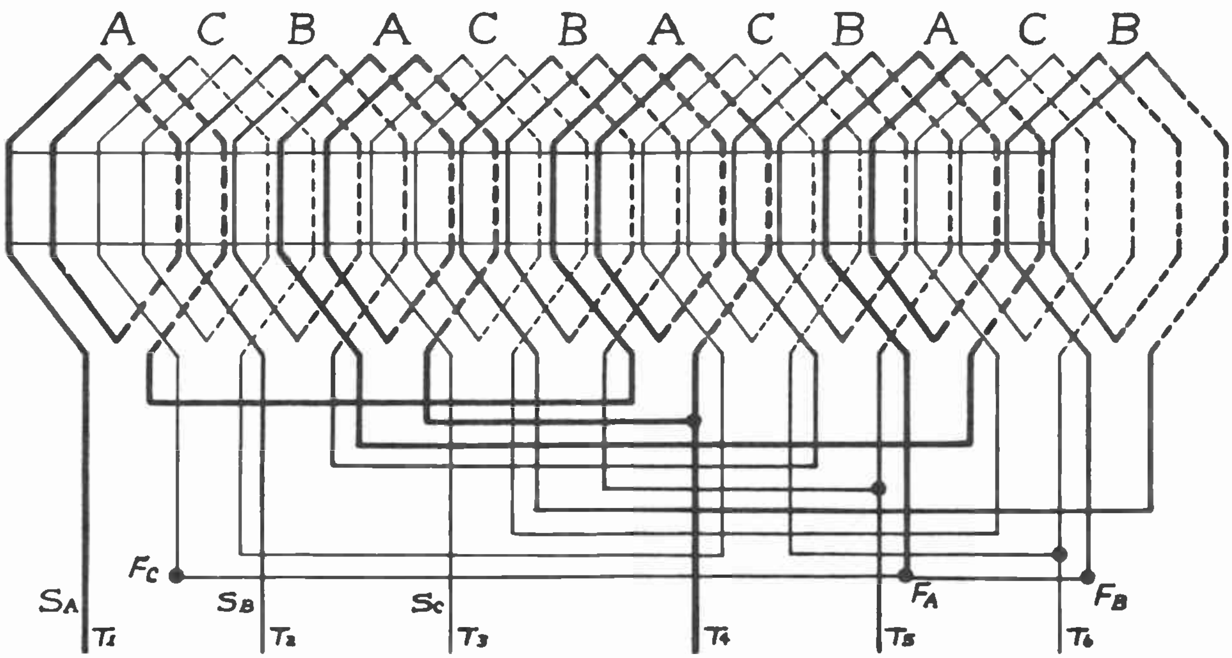


Same connection as shown above. Trace the circuit from the center tap. This places the 2 sections of the phase winding in parallel, reversing the current in ½ of the coil groups, producing 4 regular & 4 consequent poles. Note that phase rotation is reversed and it will be necessary to reverse 2 leads on this connection to obtain the same rotor rotation.

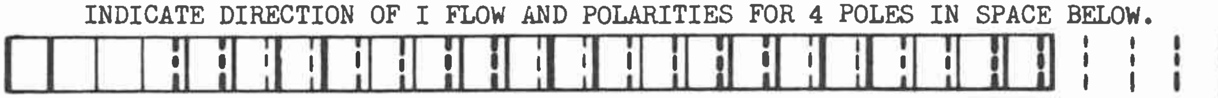
SIMPLE DIAGRAM, 4-8 POLE, 3 PHASE CONSEQUENT POLE STATOR WINDING.



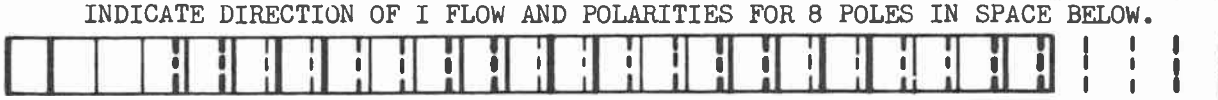
VARIABLE TORQUE, CONSTANT HORSEPOWER.
3 PHASE, LAP WINDING, SLOTS = 24.
POLES = 4-8, COILS PER GROUP = 2.
FRACTIONAL PITCH COIL SPAN = 1 TO 5.
COIL PITCH = 66.6% OF FULL PITCH.
ELECTRICAL DEGREES PER SLOT = 30-60.

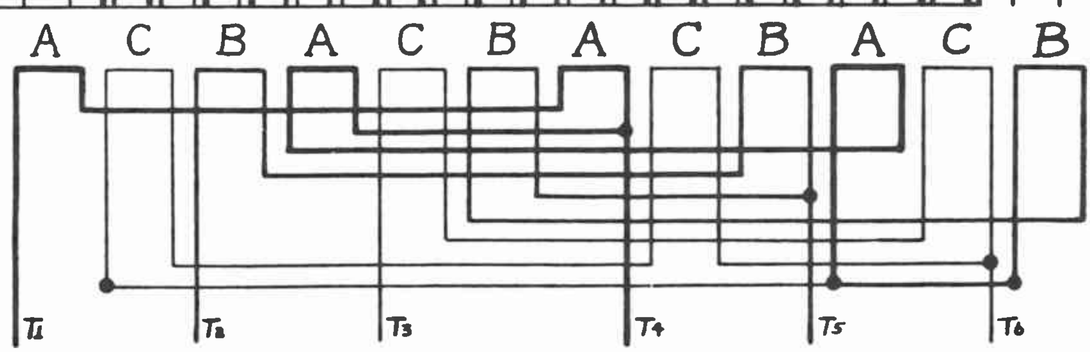


INDICATE DIRECTION OF I FLOW AND POLARITIES FOR 4 POLES IN SPACE BELOW.



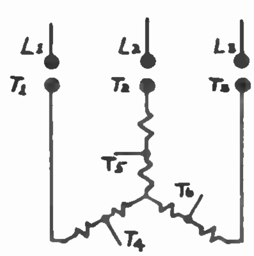
INDICATE DIRECTION OF I FLOW AND POLARITIES FOR 8 POLES IN SPACE BELOW.





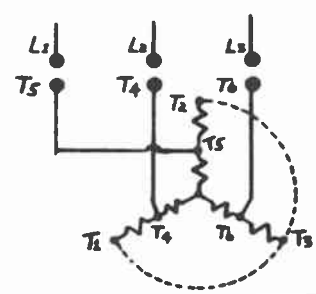
SERIES STAR
4 POLES
T1, T2, T3 TO LINE

T4, T5, T6 OPEN

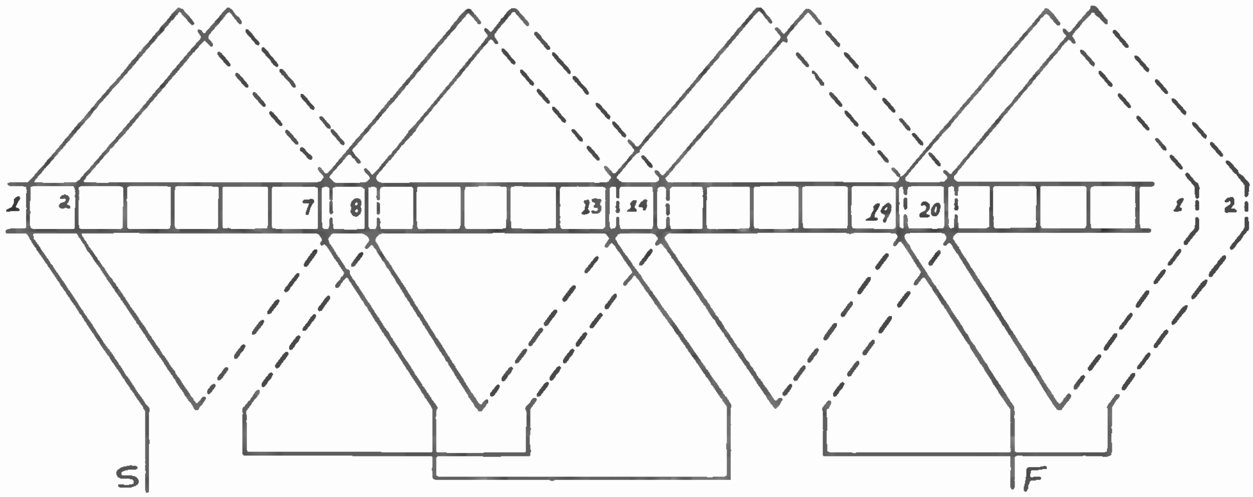


PARALLEL STAR
8 POLES
T4, T5, T6 TO LINE

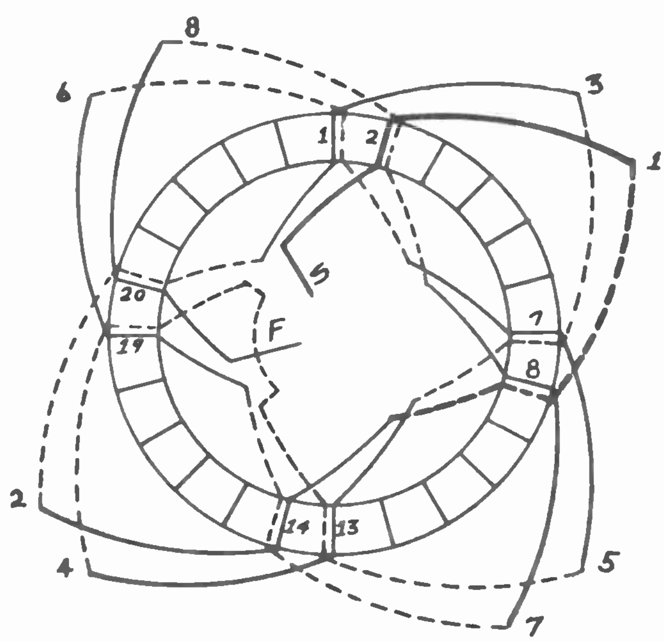
T1, T2, T3 SHORTED



COMPARISON OF LAP AND WAVE WINDINGS.



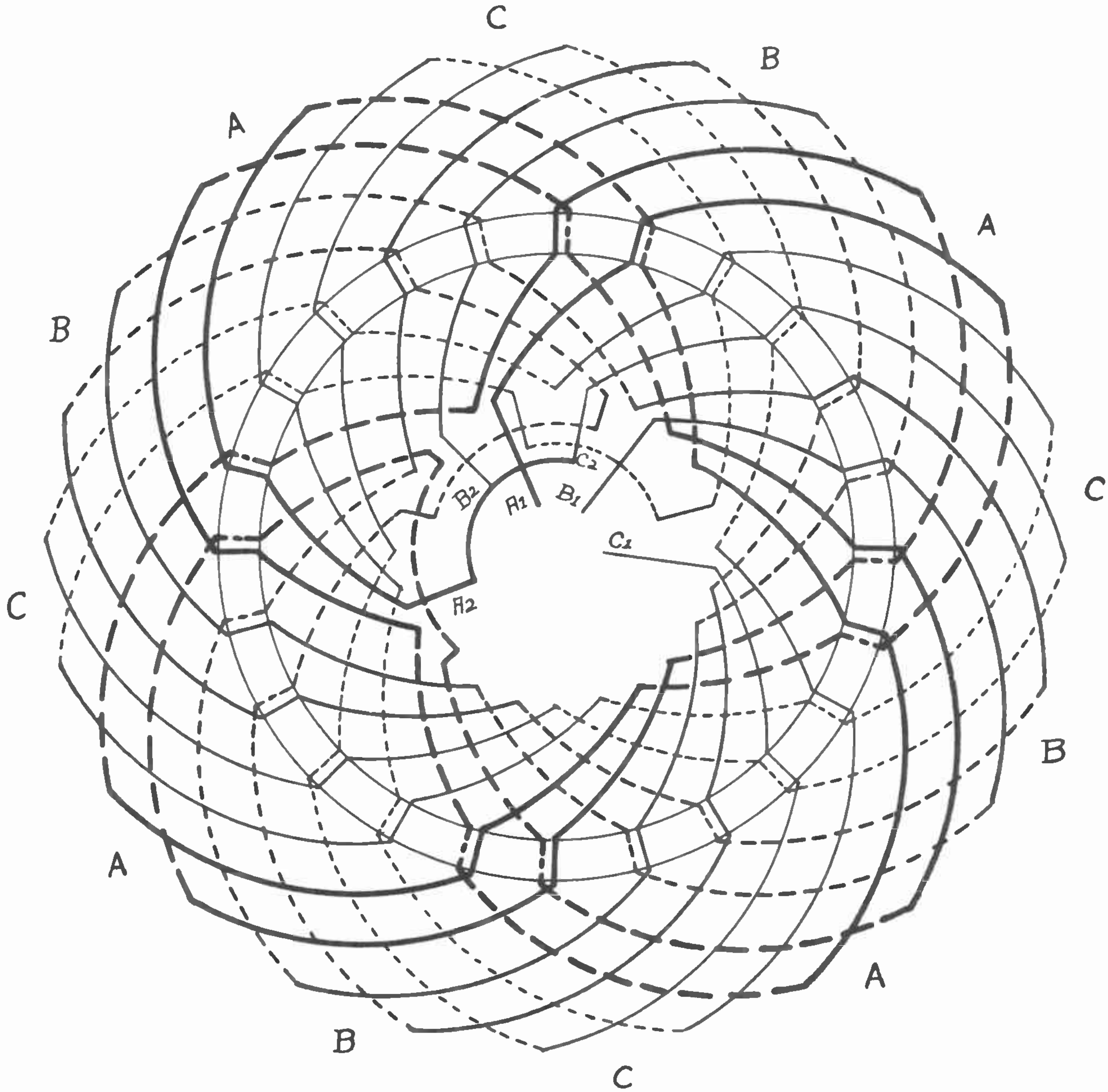
A LAP WINDING is one in which the coils of each pole phase group are connected directly in series with each other or forward and back on itself. Lap windings are generally used on A.C. machines because they are more readily adaptable to stators with various numbers of slots.

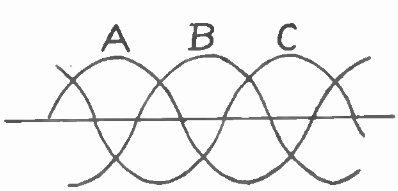


A WAVE WINDING is one in which correspondingly placed coils under adjacent poles are connected in series so that the circuit proceeds from pole to pole one or more times around the stator core, and not forward and back upon itself as on a lap winding. On a wave winding, the circuit re-enters the first coil group after it has passed thru at least one other coil group of the winding. The total number of these circuits must be a multiple of the number of phases and is ordinarily two times the number of phases. Wave windings in large machines are always of strap or bar copper coils with two layers. Principal use is for wound rotors of large slip ring motors because such windings have greater mechanical strength at end connections when made of bar or strap copper. WAVE WINDINGS in stators of induction motors must be electrically balanced, ie., each phase must contain the same number of coils or turns. The number of active slots in each phase and section must be a multiple of poles times phases. For 4 pole, 3-phase, slots would have to be 12-24-36-48-60-72, etc.

THREE PHASE WAVE WINDING.

PHASES CONNECTED STAR.





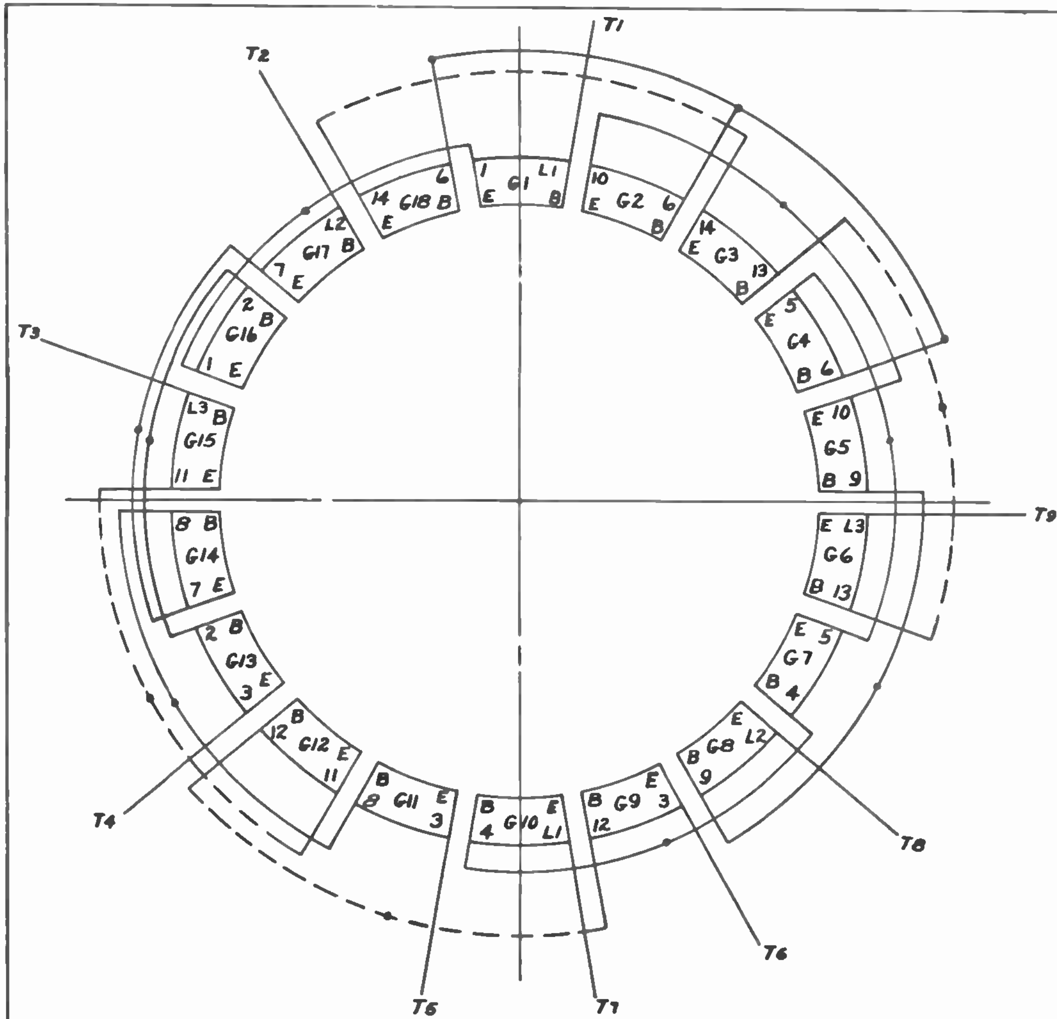
THREE PHASE, WAVE WINDING.

SLOTS = 24, POLES = 4.

FULL PITCH COIL SPAN = 1:7.

COILS PER POLE PHASE GROUP = 2.

ELECTRICAL DEGREES PER SLOT = 30.



Connection Diagram

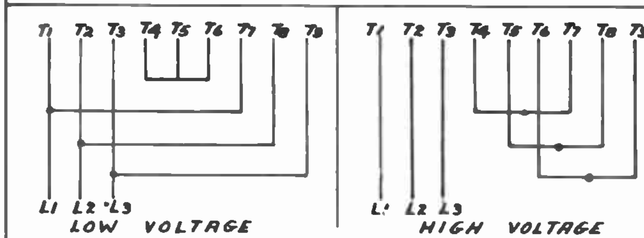
6 Pole-3 Phase-2 Circuit Star or
1 Circuit Star

Internal connections and method of connecting and bringing out of external leads.

This diagram can be used for connecting a stator of any number of slots, as G1, G2, etc., represent any number of coils in series, per pole, per phase.

B designates the beginning or bottom lead of coil or group of coils connected in series.

E designates the end or top lead of coil or group of coils connected in series.



3 PHASE DOUBLE VOLTAGE (220/440)

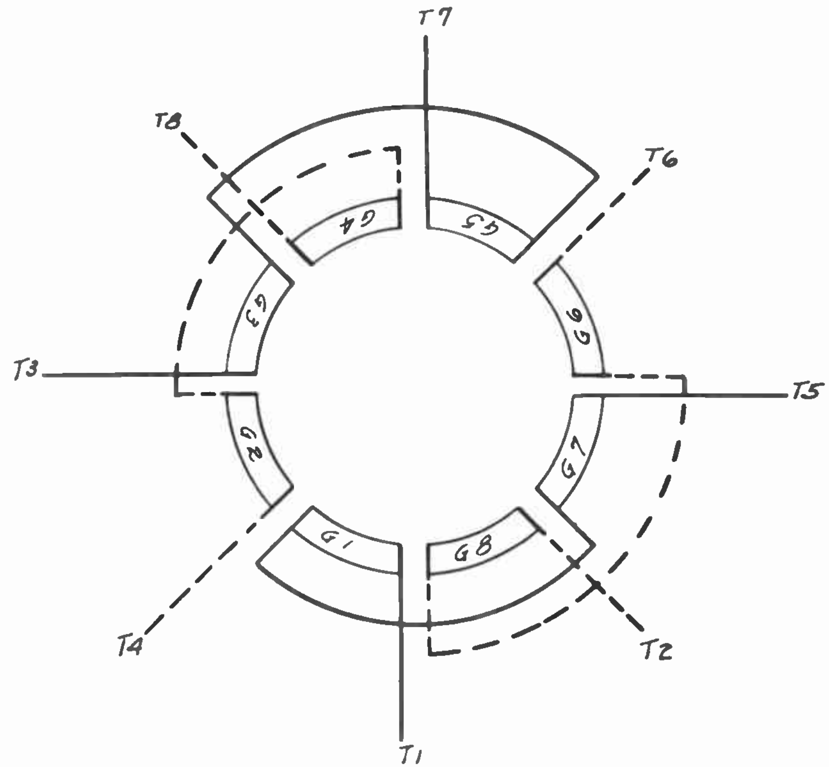
BROWN - BROCKMEYER COMPANY
DAYTON, OHIO U.S.A.

A-2090

LA421-2

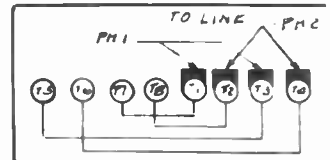
"4-pole, 2-phase, 1 or 2 circuits"

This diagram can be used for connecting a stator of any number of slots as G1, G2, etc; represent any number of coils in series per pole per phase

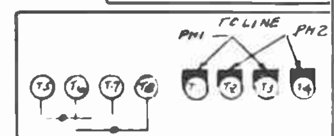


CONNECTION DIAGRAM

LA421-2



DR BY F. TEED
CH BY G.B. Pollard

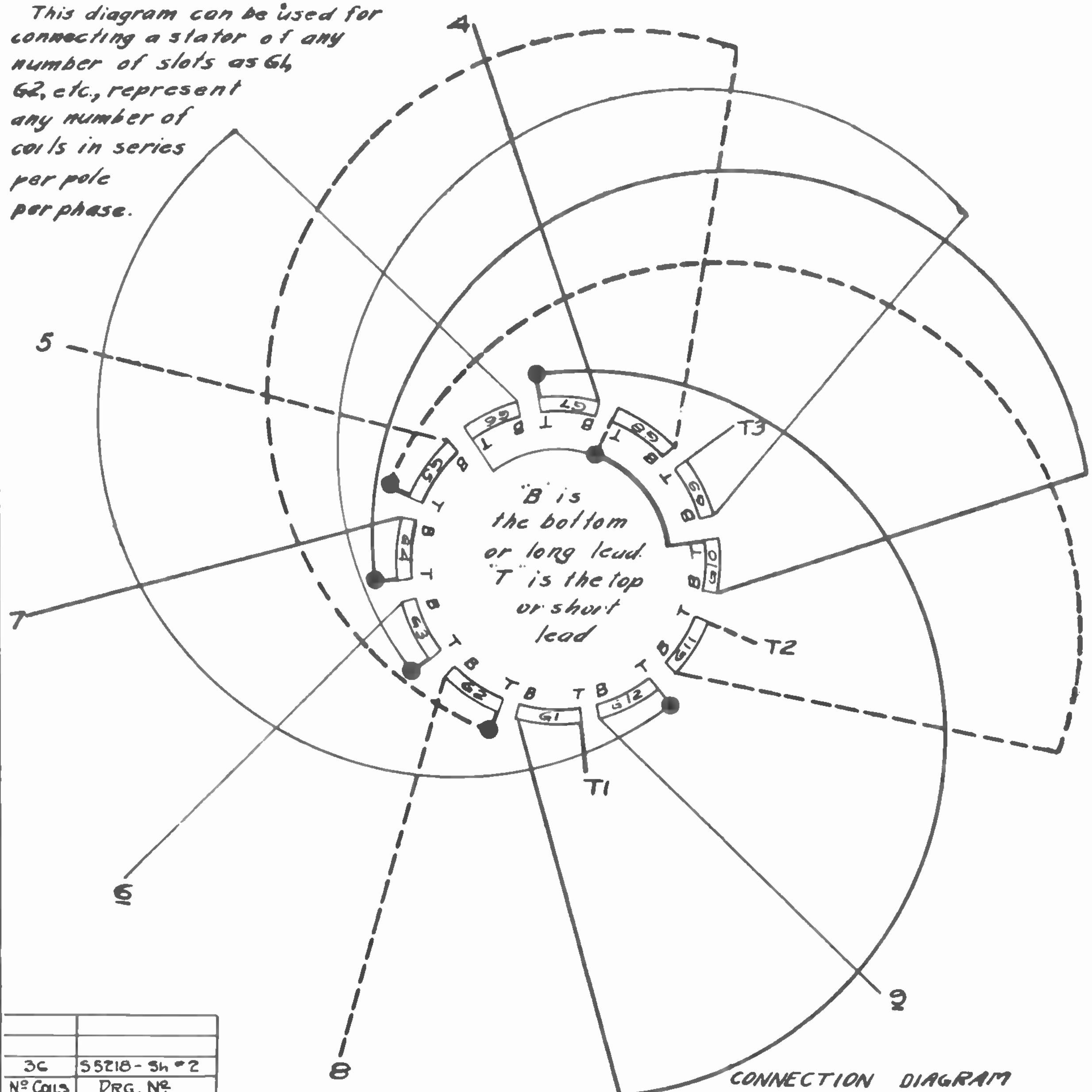


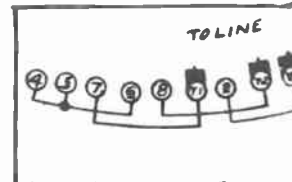
FAIRBANKS MORSE & CO
BELOIT WORKS

"4-pole, 3-phase, 1 or 2 circuit, star"

L431-2Y

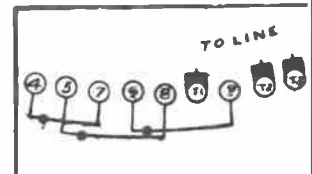
This diagram can be used for connecting a stator of any number of slots as G1, G2, etc., represent any number of coils in series per pole per phase.





DR.	H.J.R.
CH.	C.J.

SUPERSEDES L431-2Y OF



36	55218 - Sh 2
Nº COILS	DRG. Nº

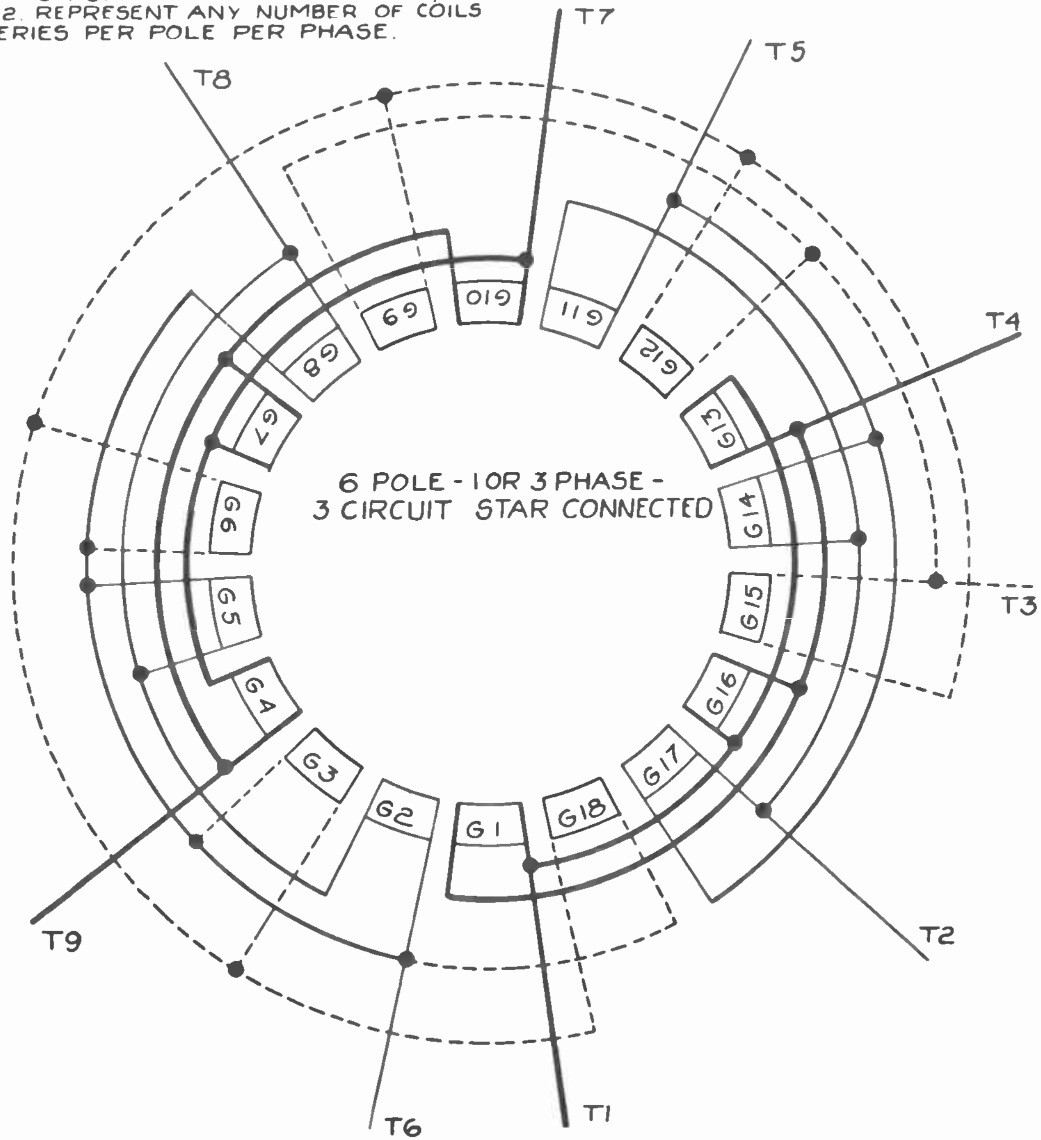
WINDING & LAYOUT DIAG.

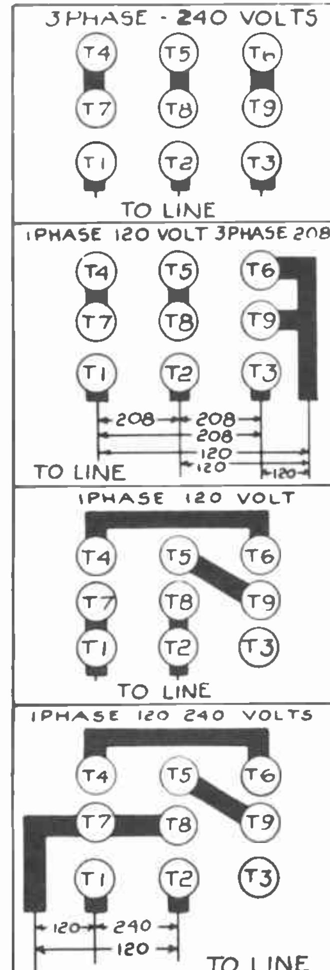
FAIRBANKS, MORSE & CO.
INDIANAPOLIS WORKS

FAIRBANKS MORSE & CO.
BELOIT WORKS

"6-pole, 3-phase, 3 circuit star"

THIS DIAGRAM CAN BE USED FOR CONNECTING A STATOR OF ANY NUMBER OF SLOTS, AS G1, G2, REPRESENT ANY NUMBER OF COILS IN SERIES PER POLE PER PHASE.





DR BY	G. K. Gibbs
CH BY	Geo. B. Pollard
DATE	

A633Y

LN633Y

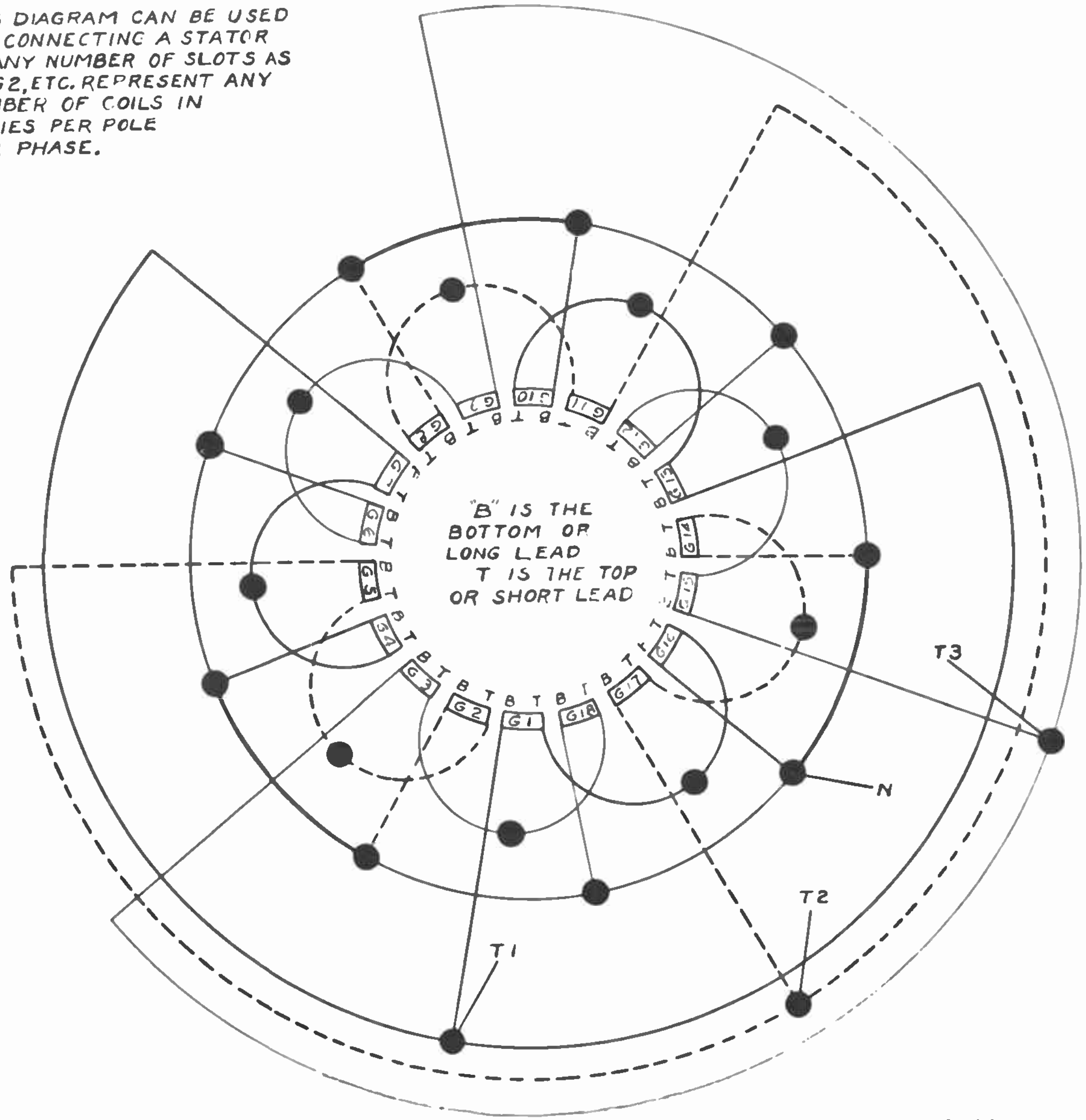
"6-pole, 3-phase,3-circuit star, with neutral lead"

LN633Y

DR.	"B
CH.	GB Pollard
DATE	8-19-41

FAIRBANKS, MORSE & CO.
BELOIT WORKS

THIS DIAGRAM CAN BE USED FOR CONNECTING A STATOR OF ANY NUMBER OF SLOTS AS G1, G2, ETC. REPRESENT ANY NUMBER OF COILS IN SERIES PER POLE PER PHASE.



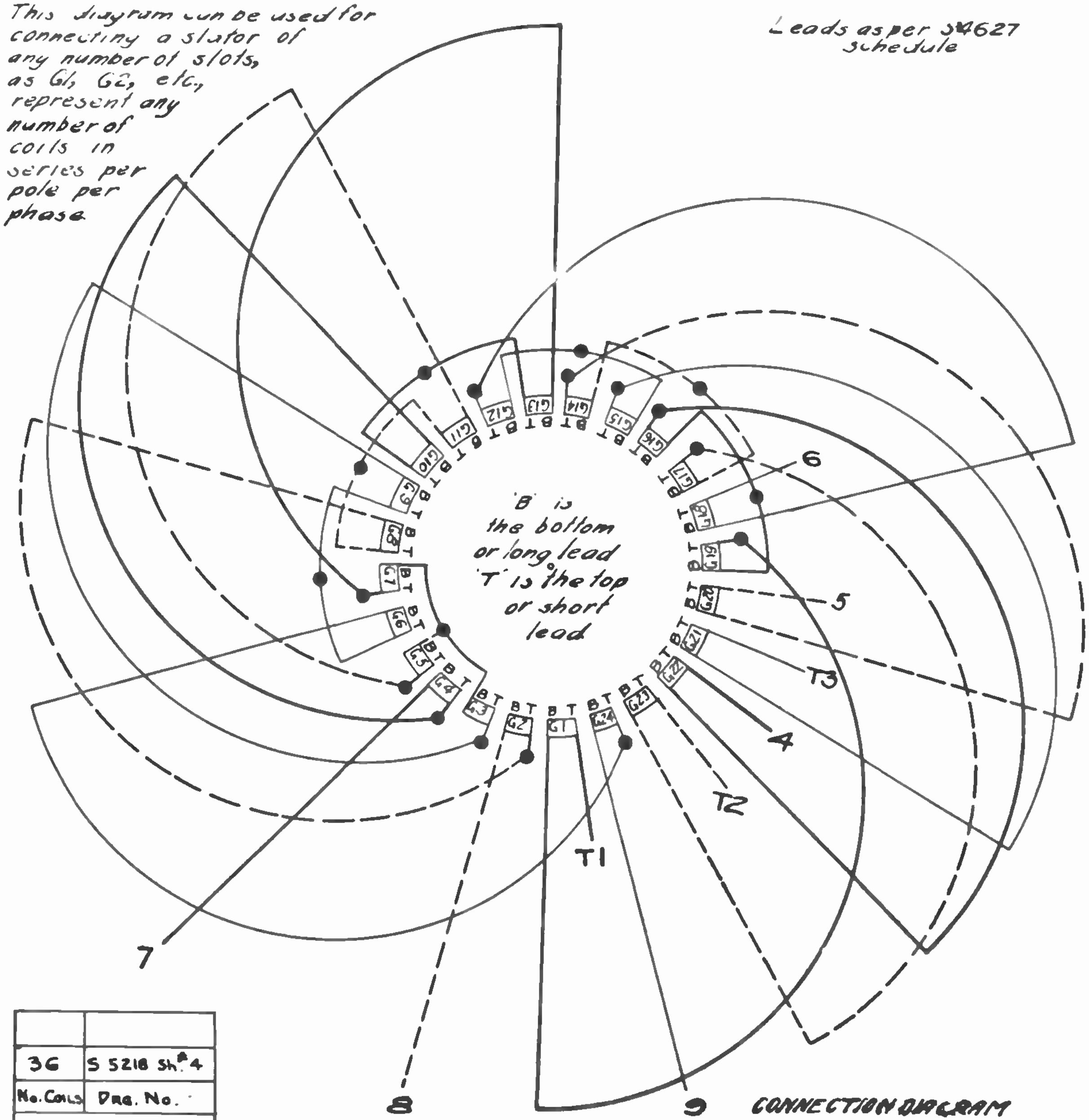
CONNECTION DIAGRAM

"8-pole, 3-phase, 1 or 2 circuit,. star"

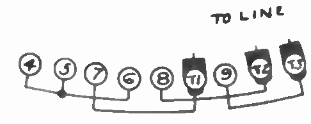
LA831-2Y

This diagram can be used for connecting a stator of any number of slots, as G1, G2, etc., represent any number of coils in series per pole per phase

Leads as per S4627 schedule



CONNECTION DIAGRAM

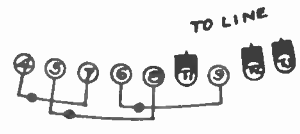


220 VOLTS CONNECTION

DR.	K.J.R.
CH.	O.W.

Supersedes LA831-2Y of 12-29-25

6-23-26



440 VOLTS CONNECTION

36	S 5218 Sh. 4
No. Coils	Drg. No.
WINDING & LAYOUT DIAG.	

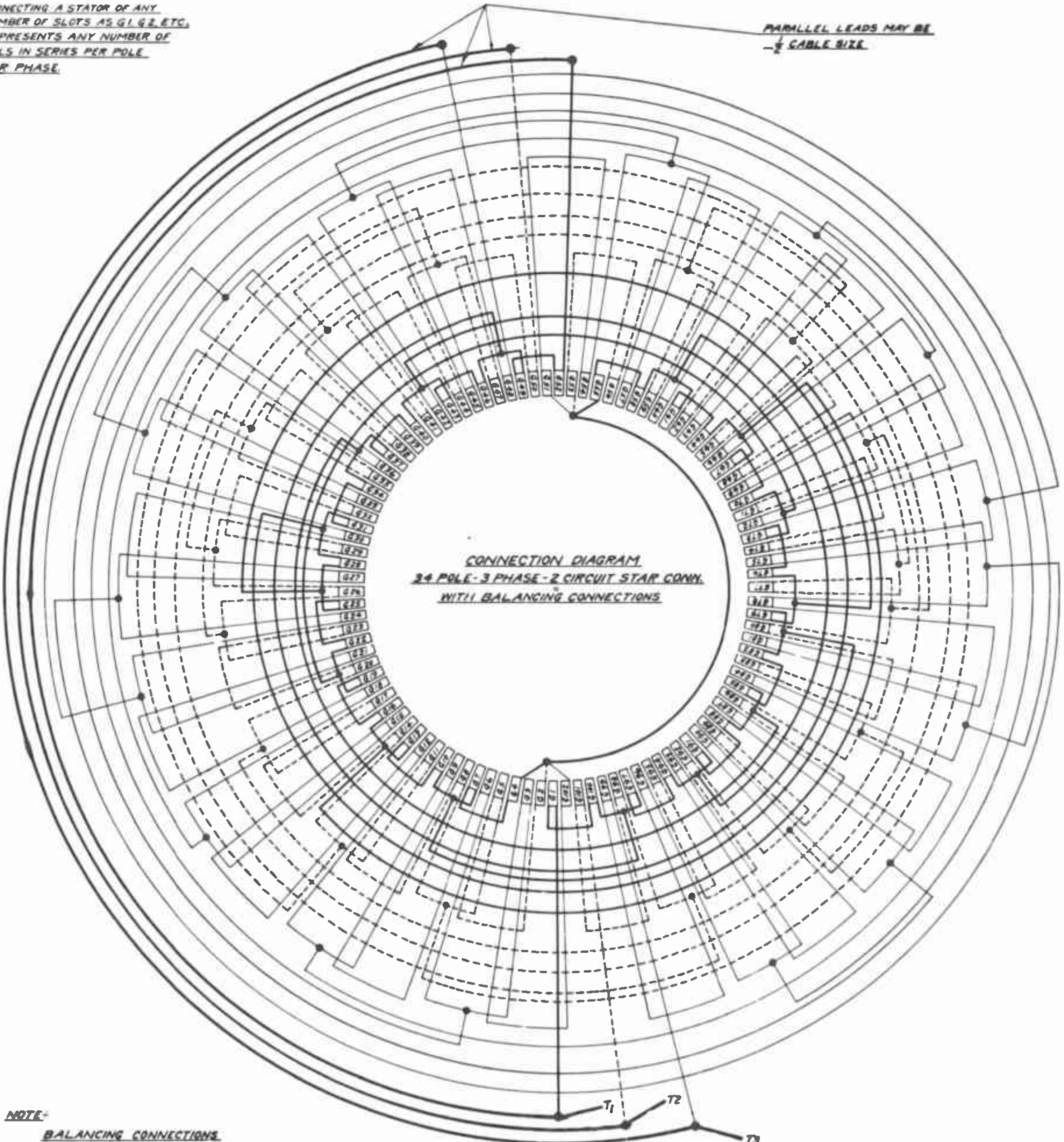
FAIRBANKS, MORSE & CO
INDIANAPOLIS WORKS

"34-pole, 3-phase, 2 circuit star, with 24 balancing connections"

M24B3432Y

DR J.J.
GTS No. CK [redacted]
DATE
Lead Changed ... G.B. Tolland.

THIS DIAGRAM CAN BE USED FOR CONNECTING A STATOR OF ANY NUMBER OF SLOTS AS G1 G2, ETC. REPRESENTS ANY NUMBER OF COILS IN SERIES PER POLE PER PHASE.



NOTE-
BALANCING CONNECTIONS MAY BE 1/4 CABLE SIZE

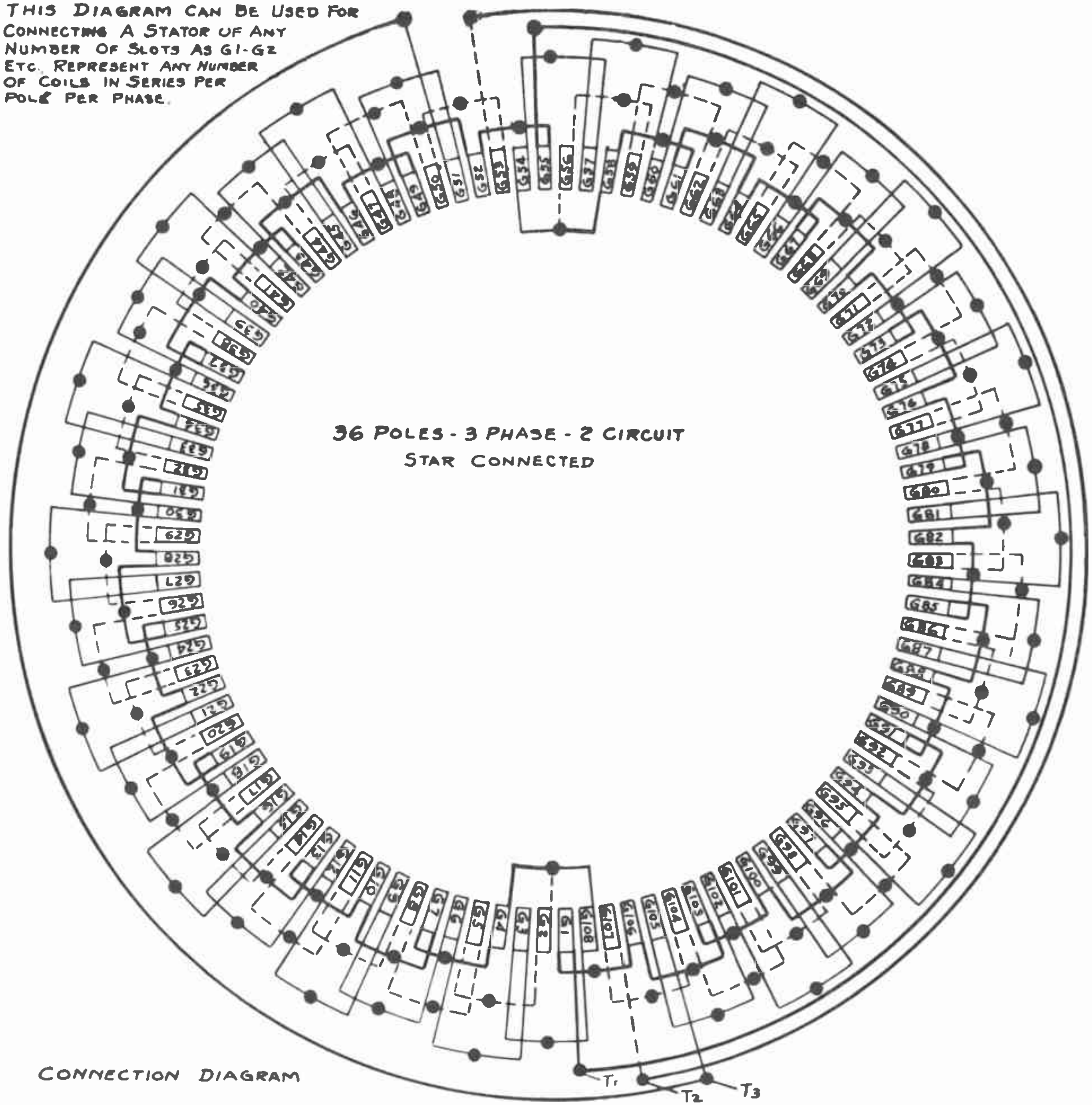
FAIRBANKS, MORSE & CO.
INDIANAPOLIS, INDIANA.

"36-pole, 3-phase, 2 circuit, star"

M3632Y

DR.	STARLING
CH.	Geo. B. Pollard
DATE	

THIS DIAGRAM CAN BE USED FOR CONNECTING A STATOR OF ANY NUMBER OF SLOTS AS G1-G2 ETC. REPRESENT ANY NUMBER OF COILS IN SERIES PER POLE PER PHASE.



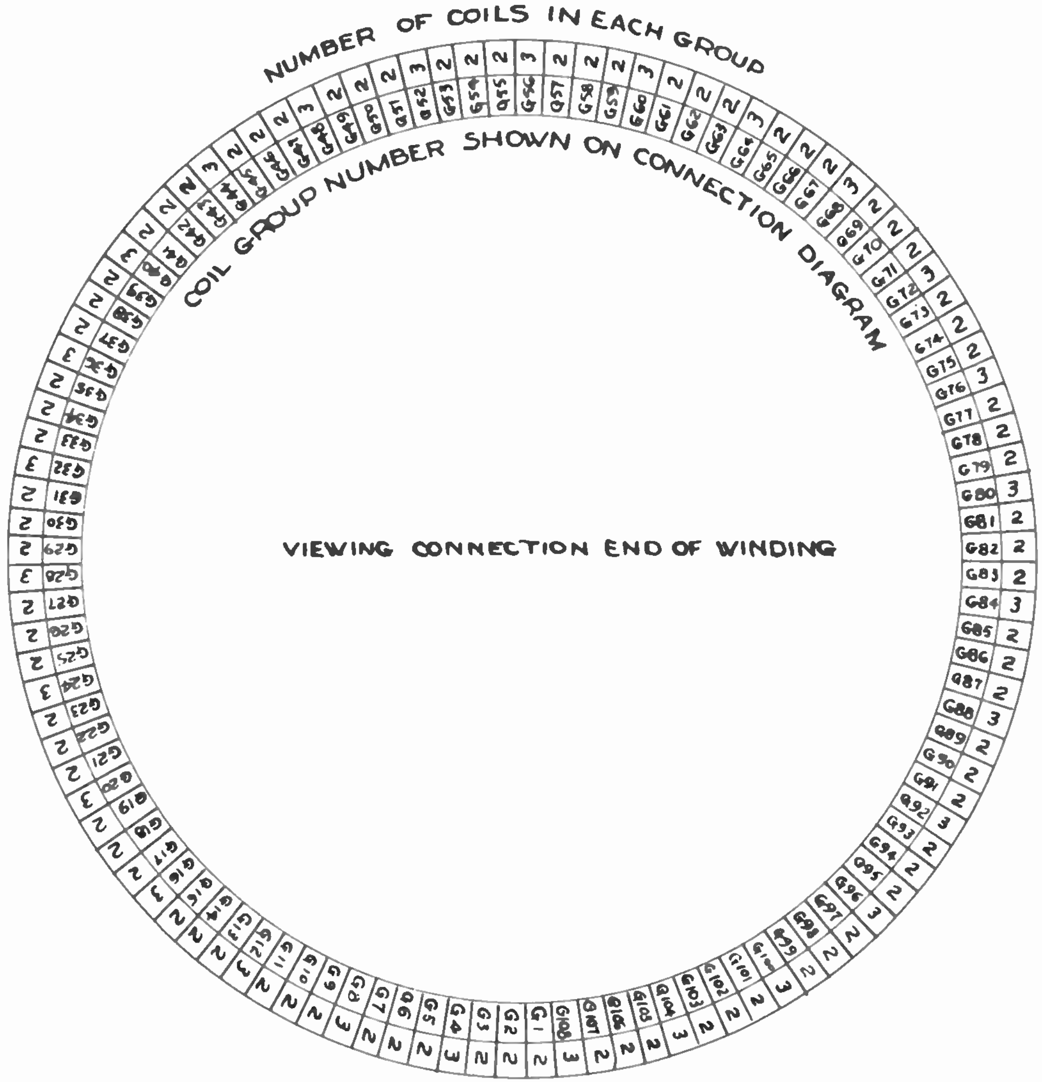
CONNECTION DIAGRAM

G 363 - 243

"36 poles, 3-phase, 243 coils"

G 363-243

DR.	fanshen
CH.	Geo B. Pollard
DATE	

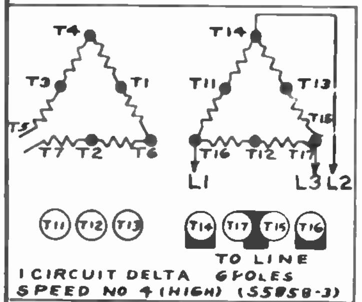


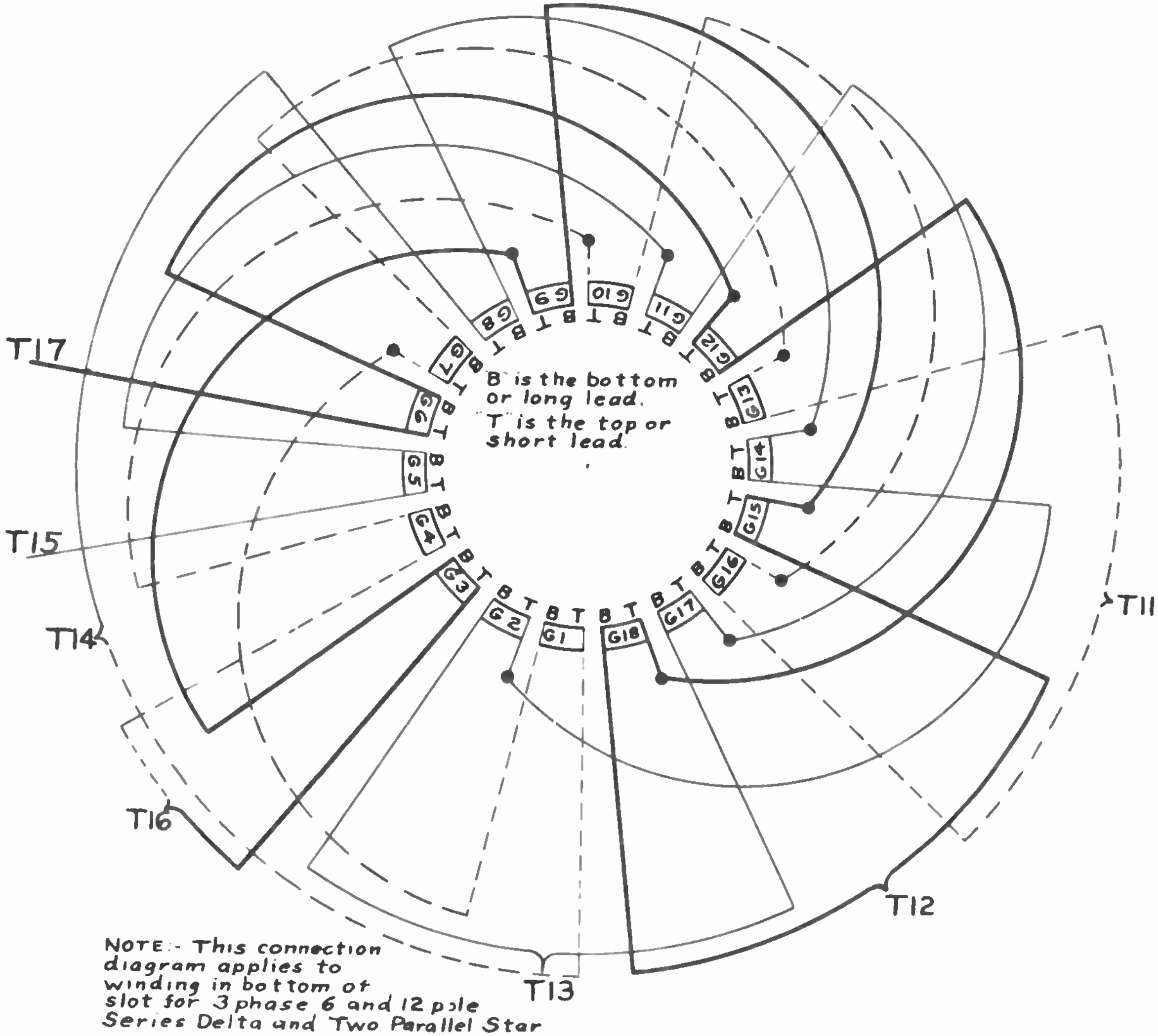
WINDING DIAGRAM

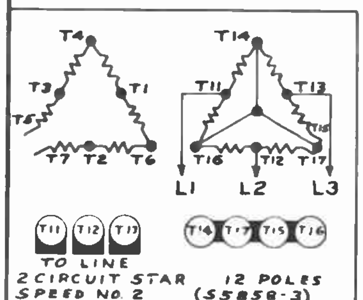
FAIRBANKS MORSE & CO.

BELOIT WORKS

"Winding No. 1. 6-pole, 3-phase, 1 circuit delta
12-pole, 3-phase, 2 circuit star"





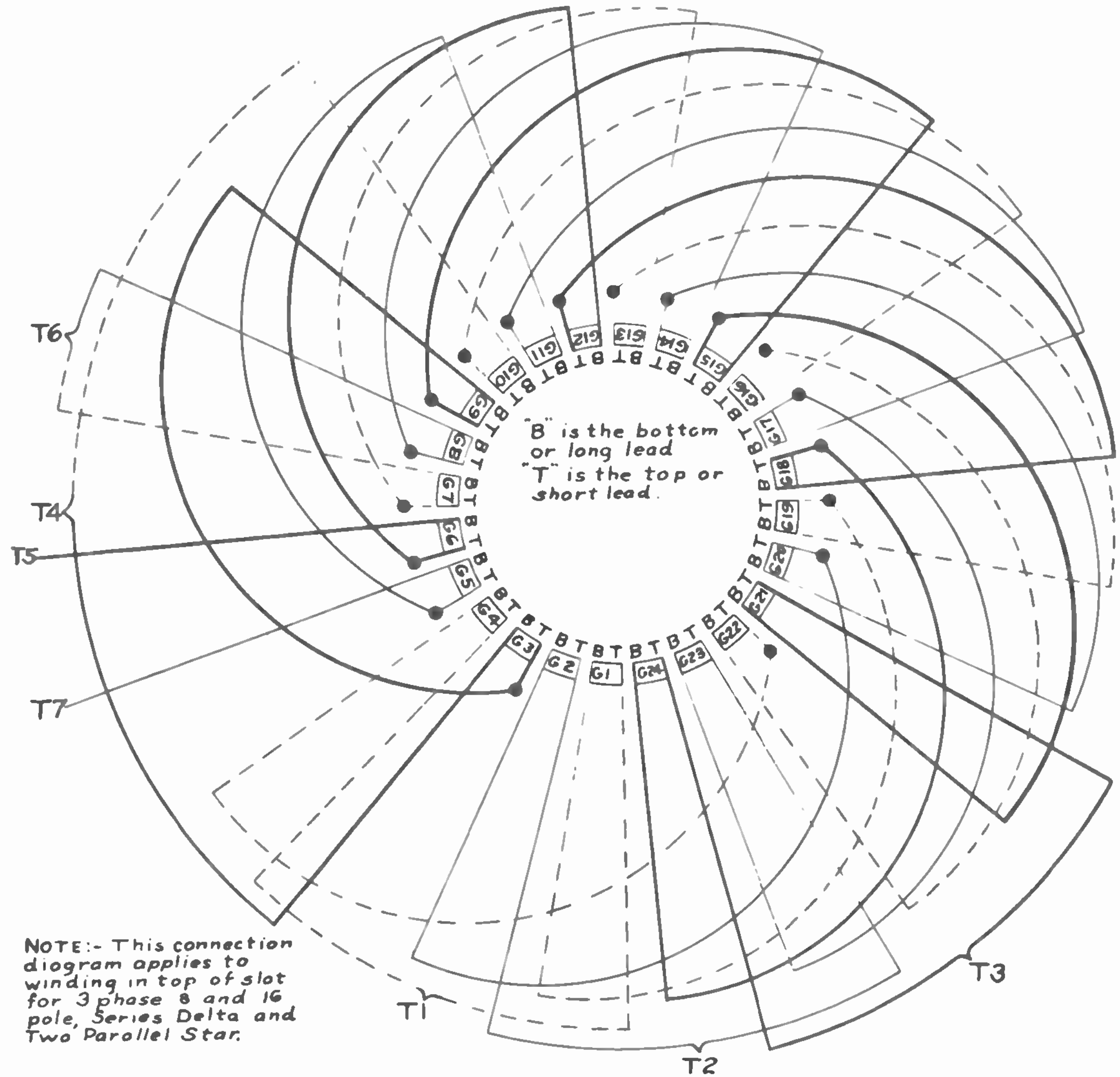


A1570

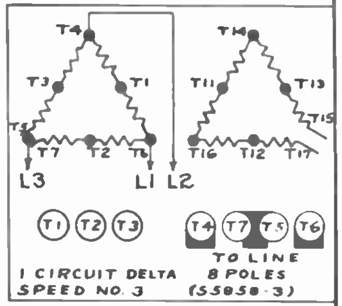
"Winding No. 2 8-pole, 3-phase, 1 circuit delta
16-pole, 3-phase, 2 circuit star"

A1570

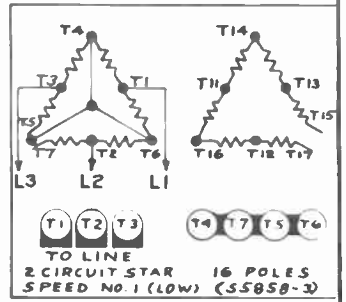
These diagrams can be used for connecting a stator of any number of slots as G1, G2, etc., represent any number of coils in series per pole per phase.



NOTE:- This connection diagram applies to winding in top of slot for 3 phase 8 and 16 pole, Series Delta and Two Parallel Star.



DR. BY C. D. S
CH. BY G B Pollard
DATE



FAIRBANKS, MORSE & CO.
BELOIT WORKS

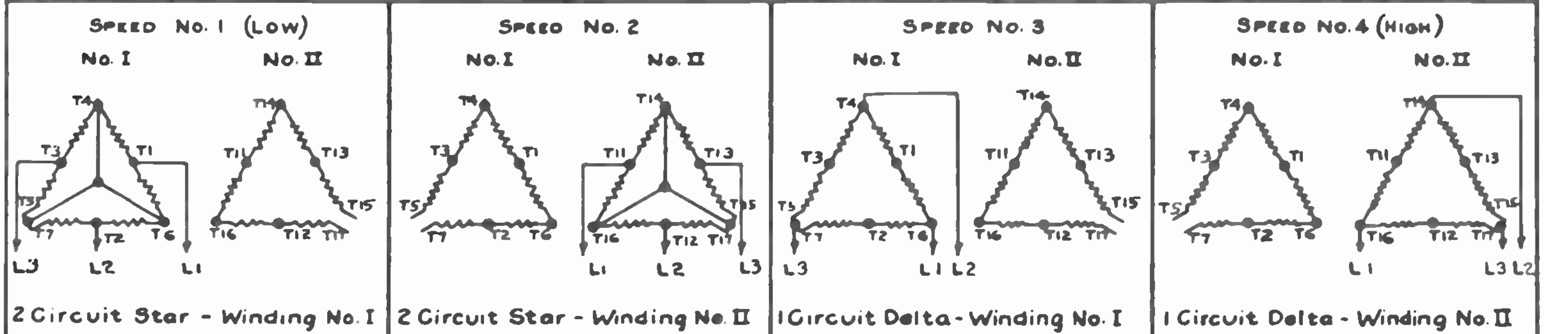
S5858-3

"External lead connection for Diagram A1570"

S5858-3

MULTI-SPEED MOTOR CONNECTION DIAGRAM

4 SPEED CONSTANT HORSE-POWER

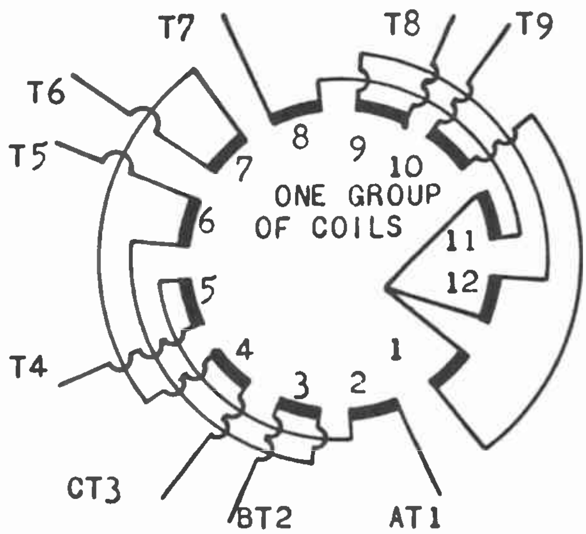


SYNOPSIS OF CONNECTIONS

FORWARD	L_1	L_2	L_3		
REVERSE	L_2	L_1	L_3	OPEN	SHORTED
SPEED No 1 [redacted] R.P.M.	T_1	T_2	T_3	T_{11}, T_{12}, T_{13}, T_{14}, T_{15}, T_{16}, T_{17},	T_4, T_5, T_6, T_7,
SPEED No. 2 [redacted] R.P.M.	T_{11}	T_{12}	T_{13}	T_2, T_3, T_4, T_5, T_6, T_7, T_1,	T_{14}, T_{15}, T_{16}, T_{17},
SPEED No. 3 [redacted] R.P.M.	T_6	T_4	T_5, T_7	T_1, T_2, T_3, T_{11}, T_{12}, T_{13}, T_{14}, T_{15}, T_{16}, T_{17}	
SPEED No. 4 [redacted] R.P.M.	T_{16}	T_{14}	T_{15}, T_{17}	T_{11}, T_{12}, T_{13}, T_1, T_2, T_3, T_4, T_5, T_6, T_7	

TYPE	HORSE-POWER	PHASE	CYCLE	VOLTS	FRAME	MFG. ORDER NO.	BRANCH HOUSE ORDER NUMBER
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

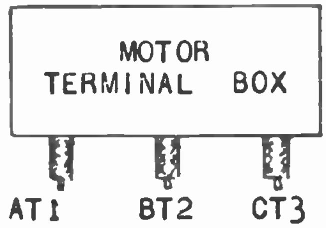
FAIRBANKS-MORSE & CO.



4 POLE 3 PHASE
3 COILS PER GROUP
STATOR CONNECTION DIAGRAM

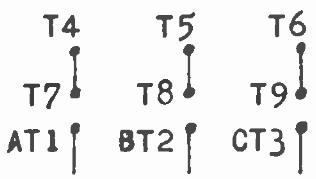
THREE PHASE WINDING AND CONNECTION DATA

B-4811

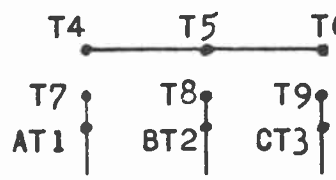


CONNECT TO LINES

IF MOTOR RUNS IN WRONG DIRECTION INTERCHANGE ANY TWO LEADS



HIGH VOLTAGE



LOW VOLTAGE

GROUP LEAD CONNECTIONS

EITHER OF TWO VOLTAGES MAY BE BROUGHT OUT BY CONNECTING COIL GROUPS AS SHOWN ABOVE

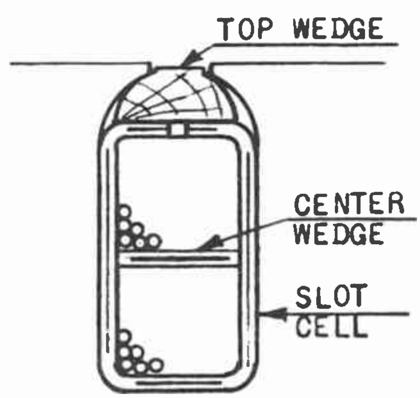
TREATMENT OF COMPLETED STATOR

IMERSION METHOD 17-M-10 PARAGRAPH C-7-d (6)

DIP IN BB-52-V-15 VARNISH BAKE 6 HOURS AT 240 TO 250 FARENHEIT REPEAT 3 TIMES

INSULATION MATERIAL		
	MATERIAL	NAVY SPEC.
SLOT CELL AND SPACER	.020 #1 WHITE ROPE PAPER	17-1-10
TOP WEDGE	MAPLE	WOOD
"U" WEDGE CENTER	.020 COPAREX	17-1-10
INS. BETWEEN PHASES	.007 Y.V. CAMBRIC	17-1-13
INS. ON COIL EXT.	.007 WHITE COTTON TAPE	27-T-11
INS. ON COIL LEADS	PAPER TUBE	1/16 DIA.
COMPLETED STATOR	VARNISHED PER	ABOVE

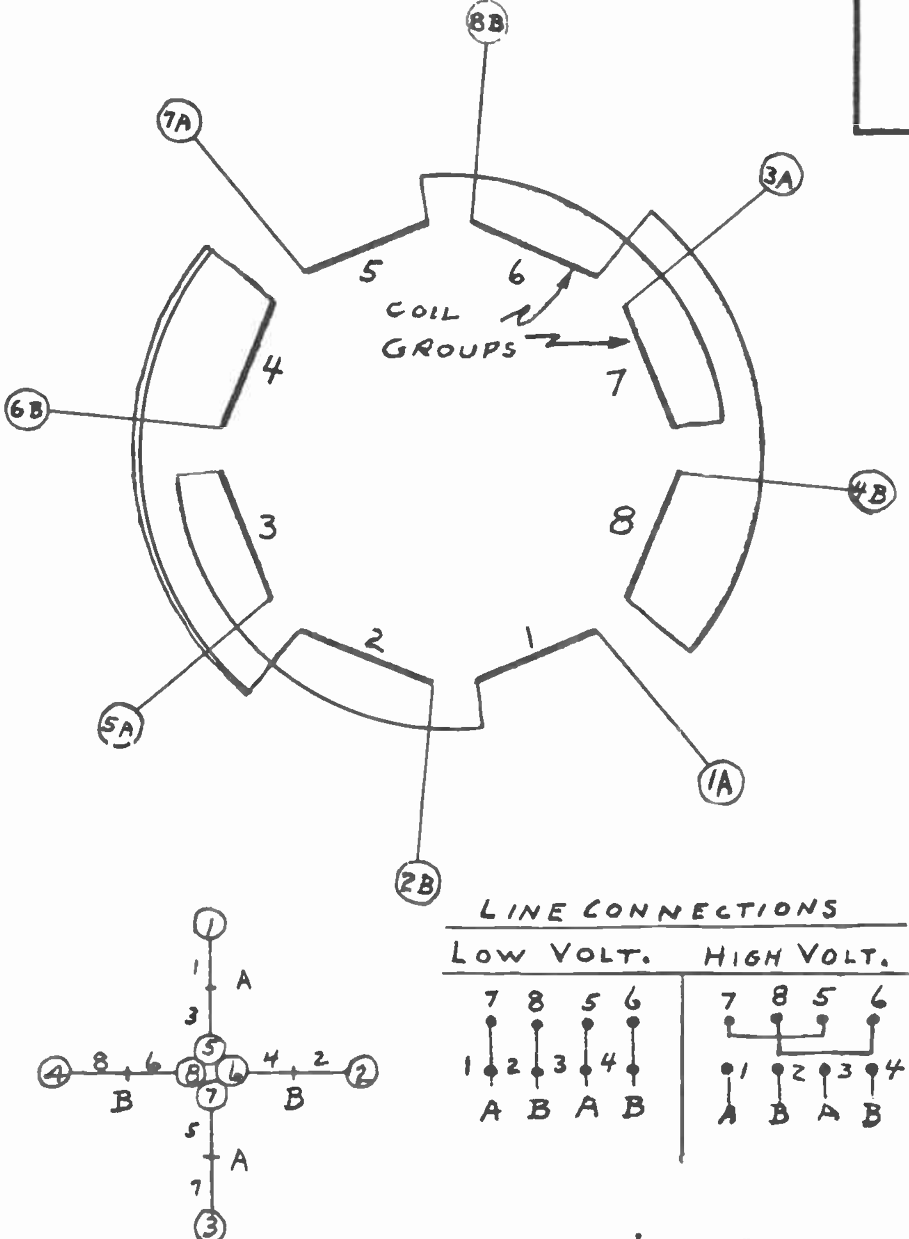
THE PEERLESS ELECTRIC CO.



STATOR SLOT ENLARGED

STATOR WDG DIAGRAM

2 PHASE 8 LEADS 4 POLES

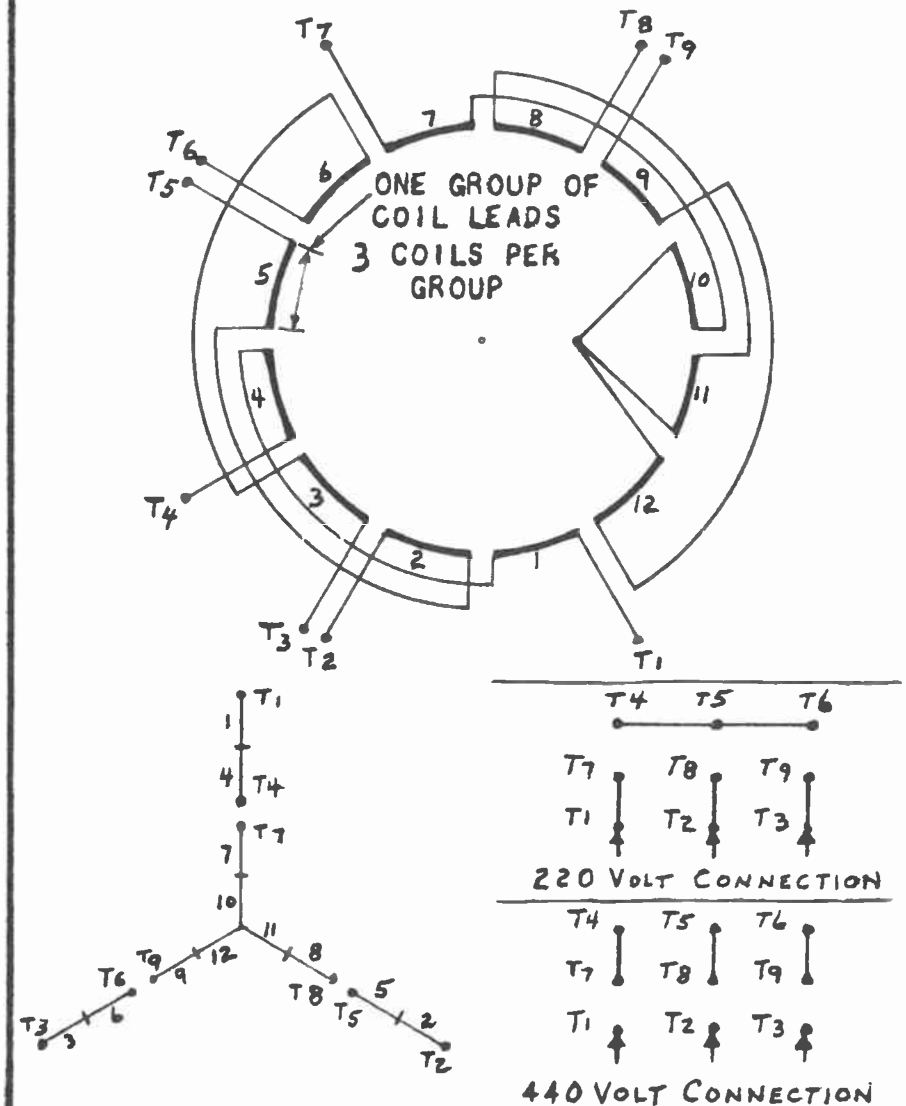


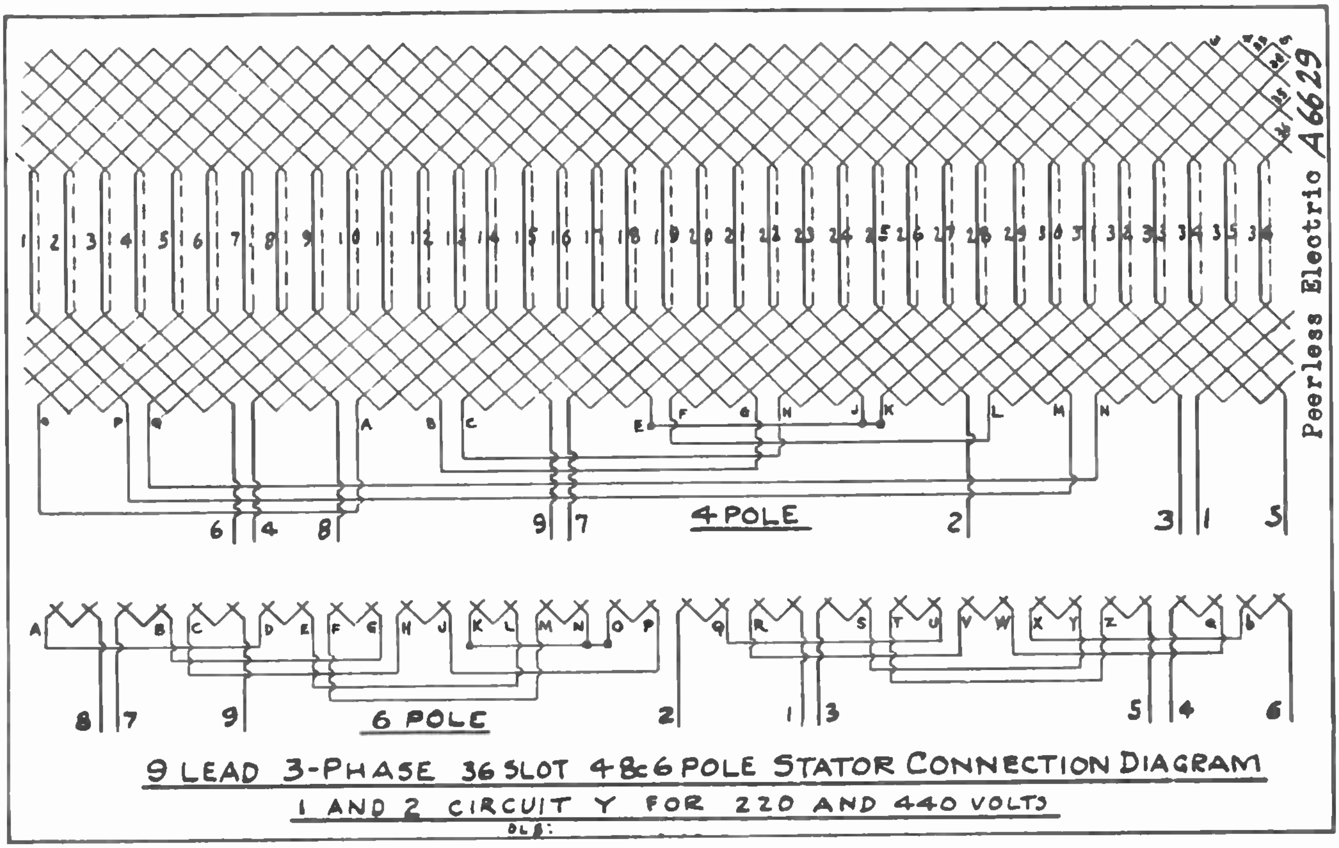
THE PEERLESS' ELECTRIC CO.

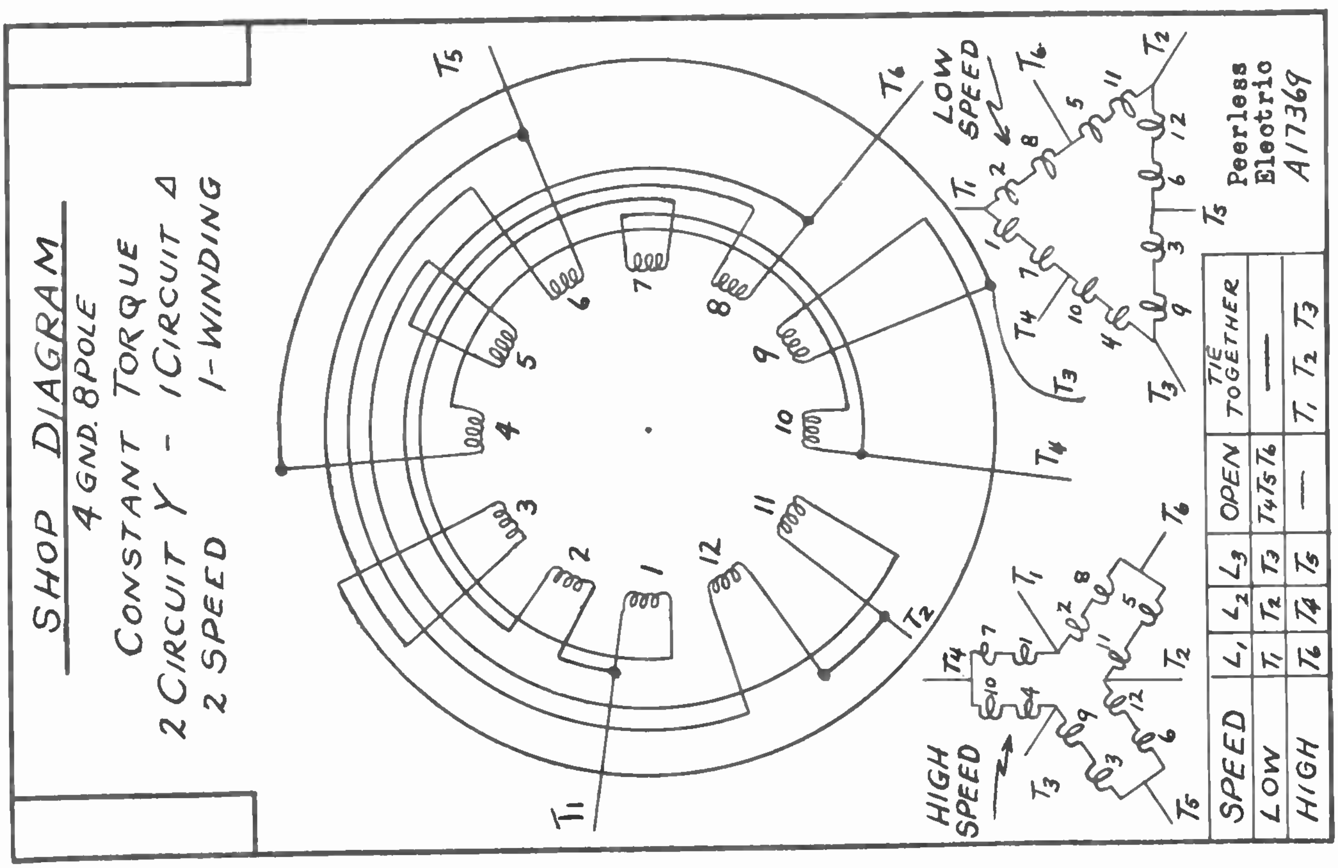
STATOR CONNECTION DIAGRAM

DUAL VOLTAGE 3 PHASE 4 POLE

THE PEERLESS ELECTRIC CO.



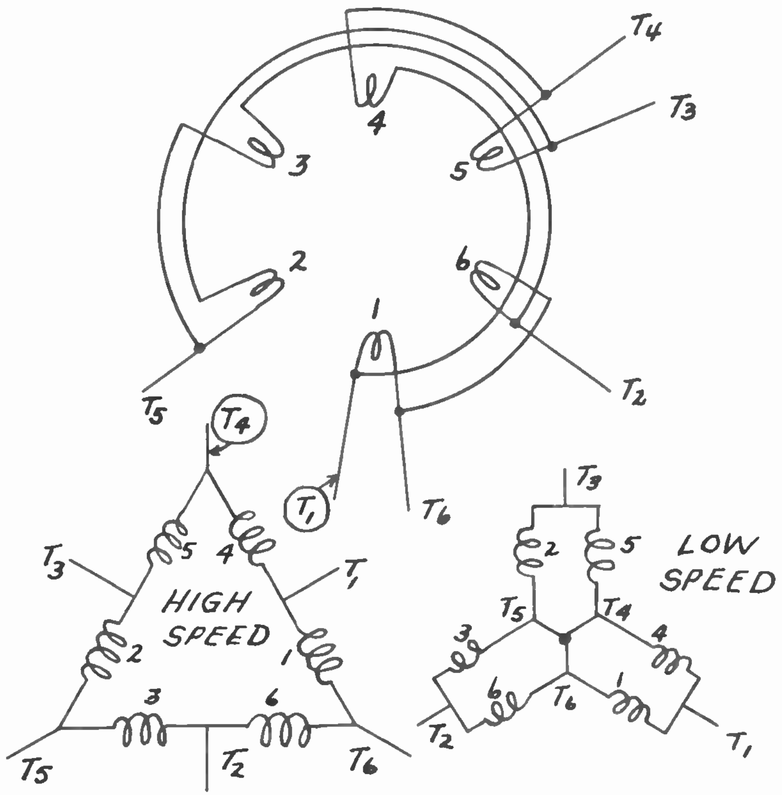

4 POLE
6 POLE
9 LEAD 3-PHASE 36 SLOT 4 & 6 POLE STATOR CONNECTION DIAGRAM
1 AND 2 CIRCUIT Y FOR 220 AND 440 VOLTS
Peerless Electric A6629


SHOP DIAGRAM
4 GND. 8 POLE
CONSTANT TORQUE
2 CIRCUIT Y - 1 CIRCUIT Δ
2 SPEED 1-WINDING
HIGH SPEED
LOW SPEED
SPEED | L1 | L2 | L3 | OPEN | TIE TOGETHER
LOW | T1 | T2 | T3 | T4 T5 T6 | —
HIGH | T6 | T4 | T5 | — | T1 T2 T3
Peerless Electric A17369

SHOP DIAGRAM

2 POLE 3 PHASE 2 SPEED CONSTANT H.P. MOTOR

6/19/41



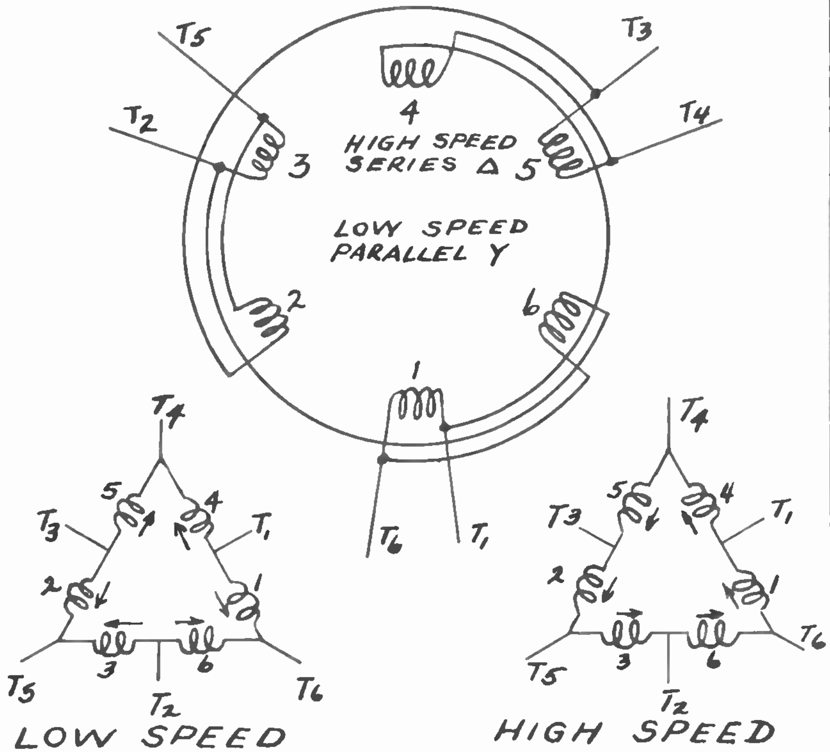
SPEED	L_1	L_2	L_3	OPEN	TIE TOGETHER
LOW	T_1	T_2	T_3		T_4 T_5 T_6
HIGH	T_6	T_4	T_5	T_1 T_2 T_3	

PEERLESS ELECTRIC A 16629

SHOP DIAGRAM

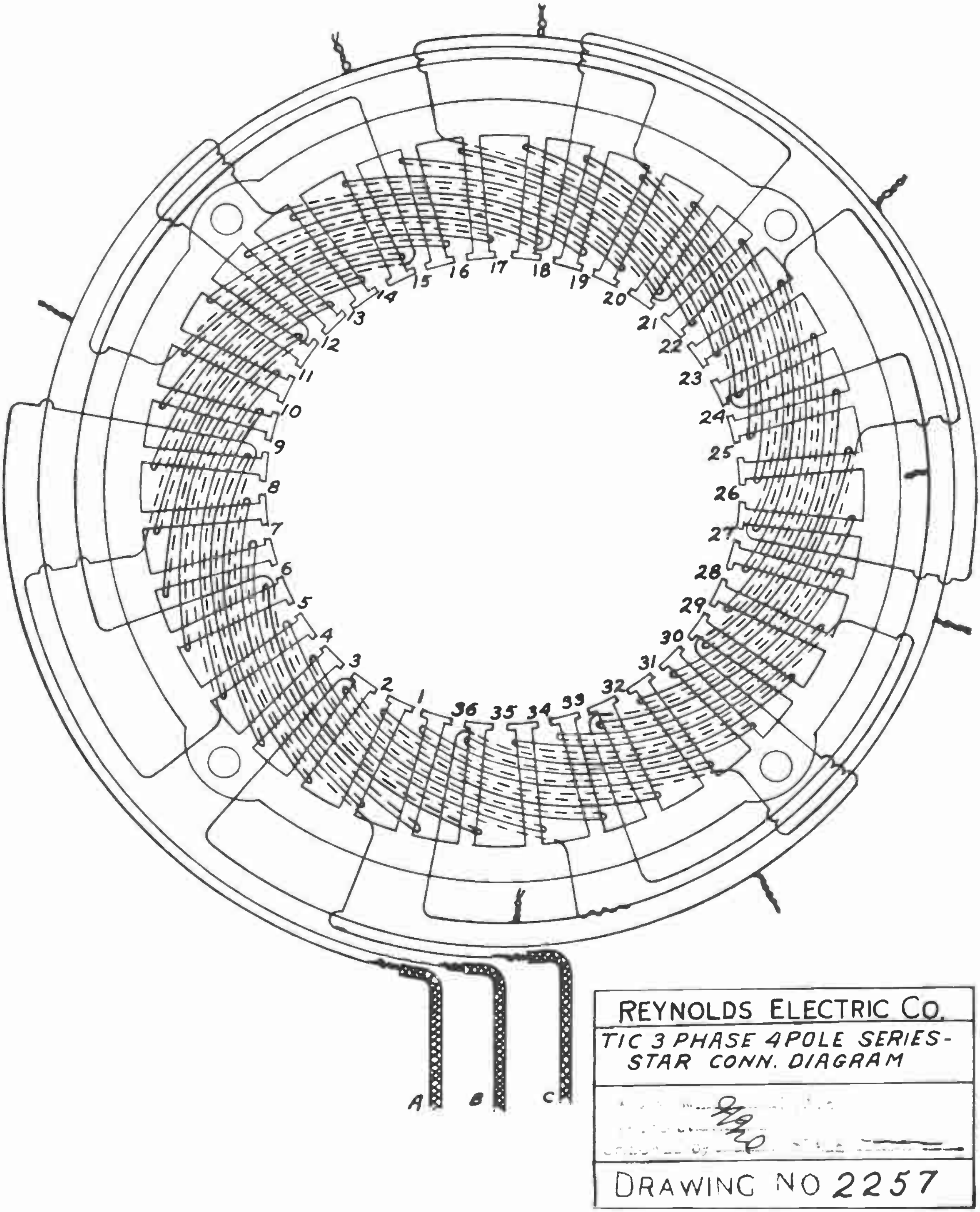
2 POLE 3φ SERIES Δ AND PARALLEL Y 2 SPEED CONSTANT H.P. MOTOR

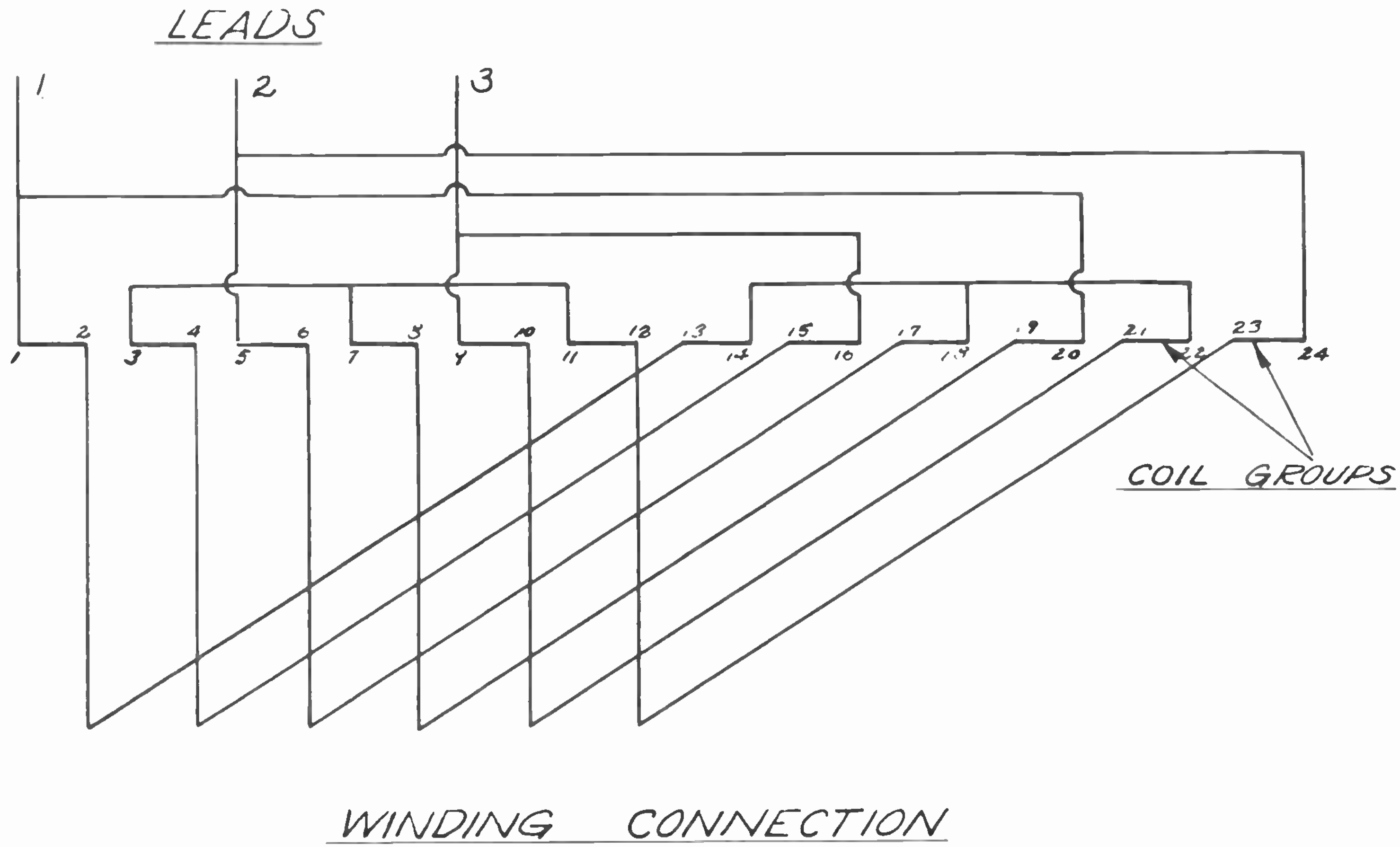
11-17-41



SPEED	L_1	L_2	L_3	OPEN	TIE TOGETHER
LOW SPEED	T_1	T_2	T_3	—	T_4 T_5 T_6
HIGH SPEED	T_6	T_4	T_5	T_1 T_2 T_3	—

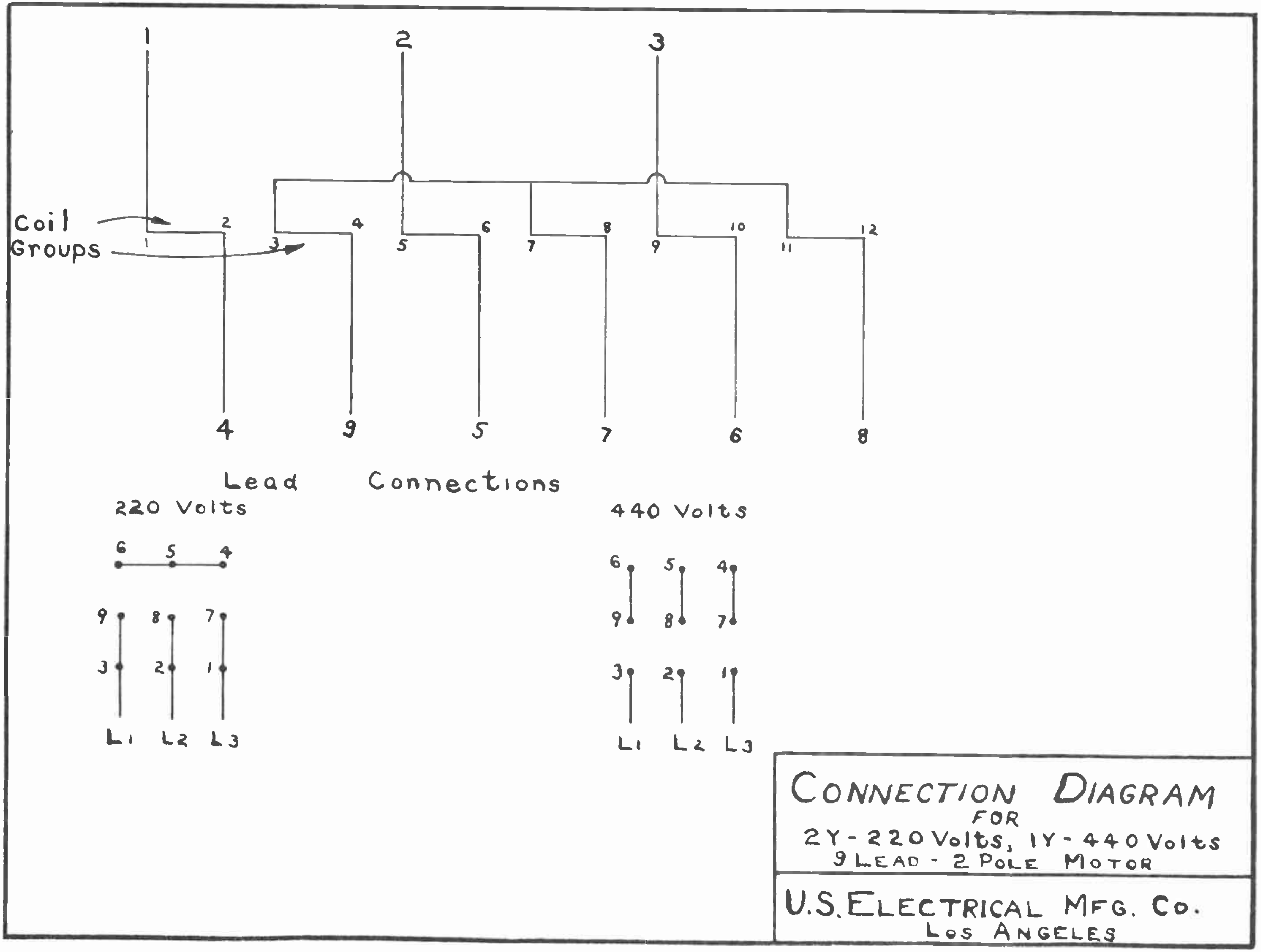
PEERLESS ELECTRIC A 16488

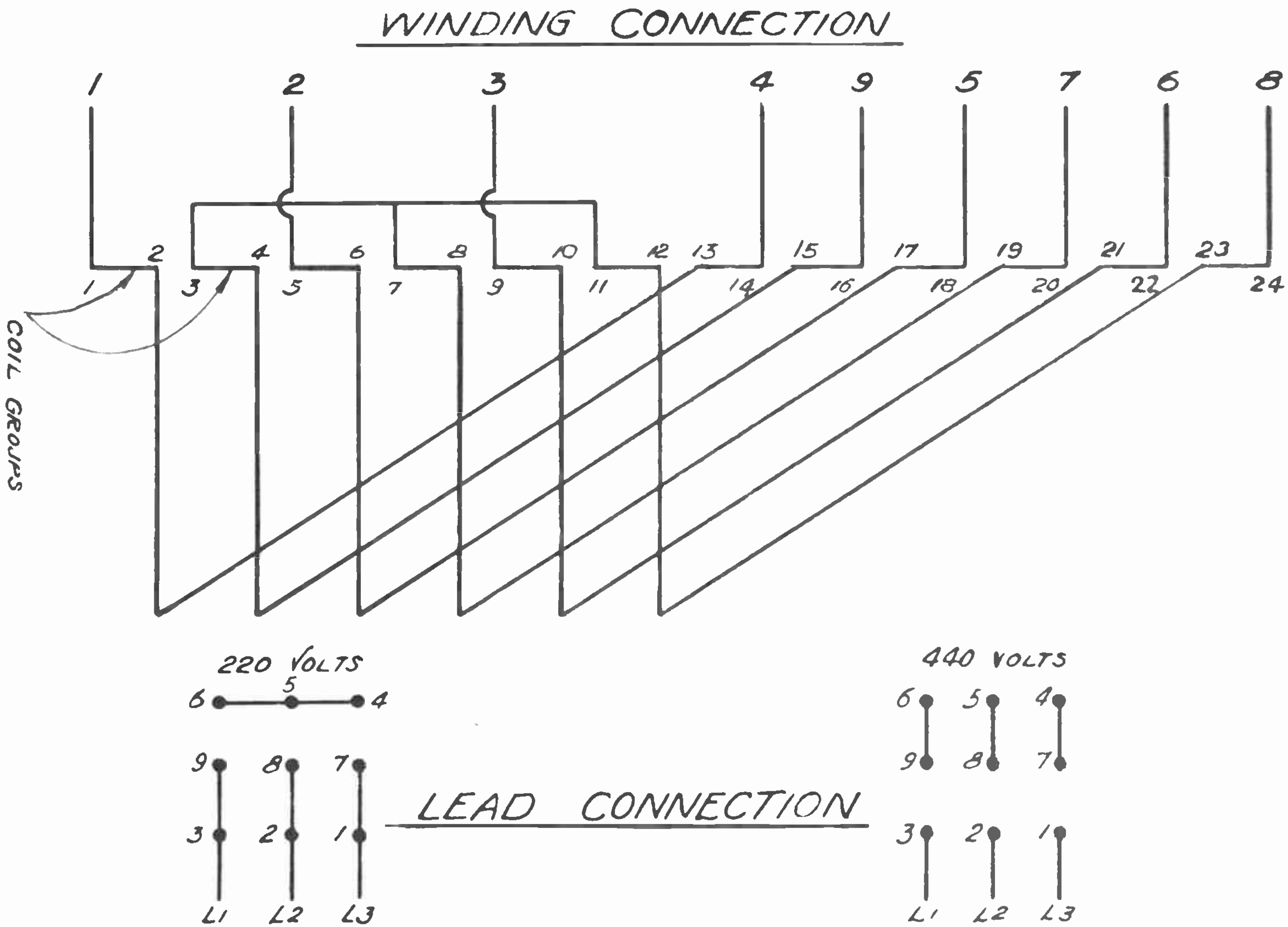

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
A
B
C
REYNOLDS ELECTRIC CO.
TIC 3 PHASE 4POLE SERIES-STAR CONN. DIAGRAM
DRAWING NO 2257



CONNECTION DIAGRAM
FOR
3 PHASE 2 Y
3 LEAD 4 POLE MOTOR

U.S. ELECTRICAL MFG. CO. LOS ANGELES	DRN. CHK.


1
2
3
Coil Groups
1 2 3 4 5 6 7 8 9 10 11 12
4 9 5 7 6 8
Lead Connections
220 Volts
6 5 4
9 8 7
3 2 1
L1 L2 L3
440 Volts
6 5 4
9 8 7
3 2 1
L1 L2 L3
CONNECTION DIAGRAM
FOR
2Y - 220 Volts, 1Y - 440 Volts
9 LEAD - 2 POLE MOTOR
U.S. ELECTRICAL MFG. CO.
LOS ANGELES

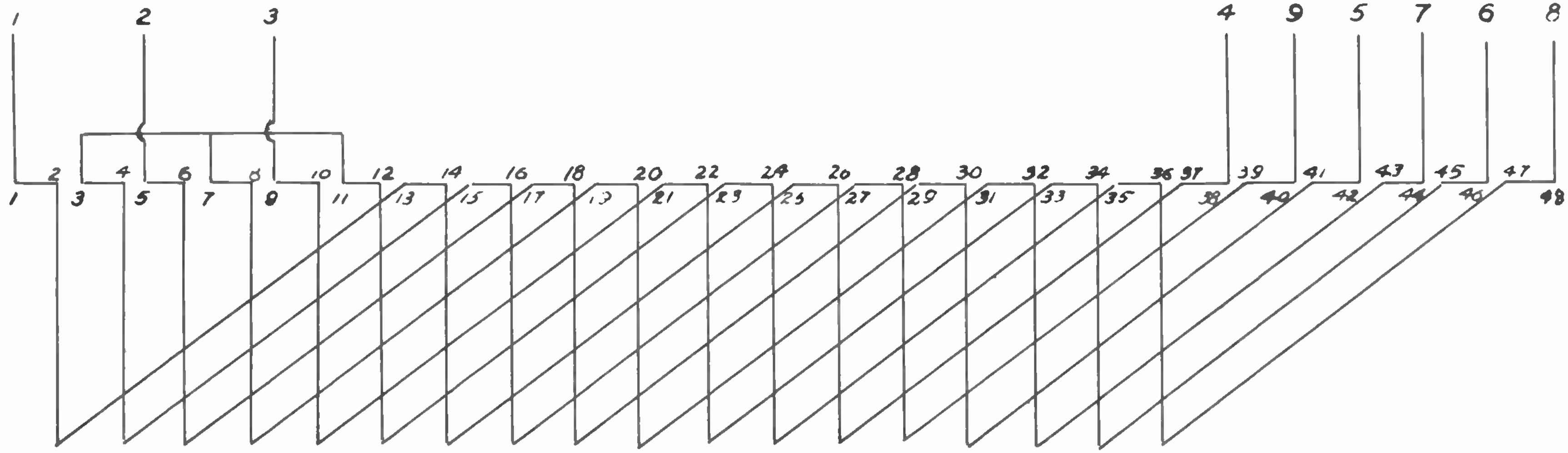


CONNECTION DIAGRAM
FOR
2Y-220 VOLTS 1Y-440 VOLTS
9 LEAD - 4 POLE MOTOR

U.S. ELECTRICAL MFG CO
LOS ANGELES

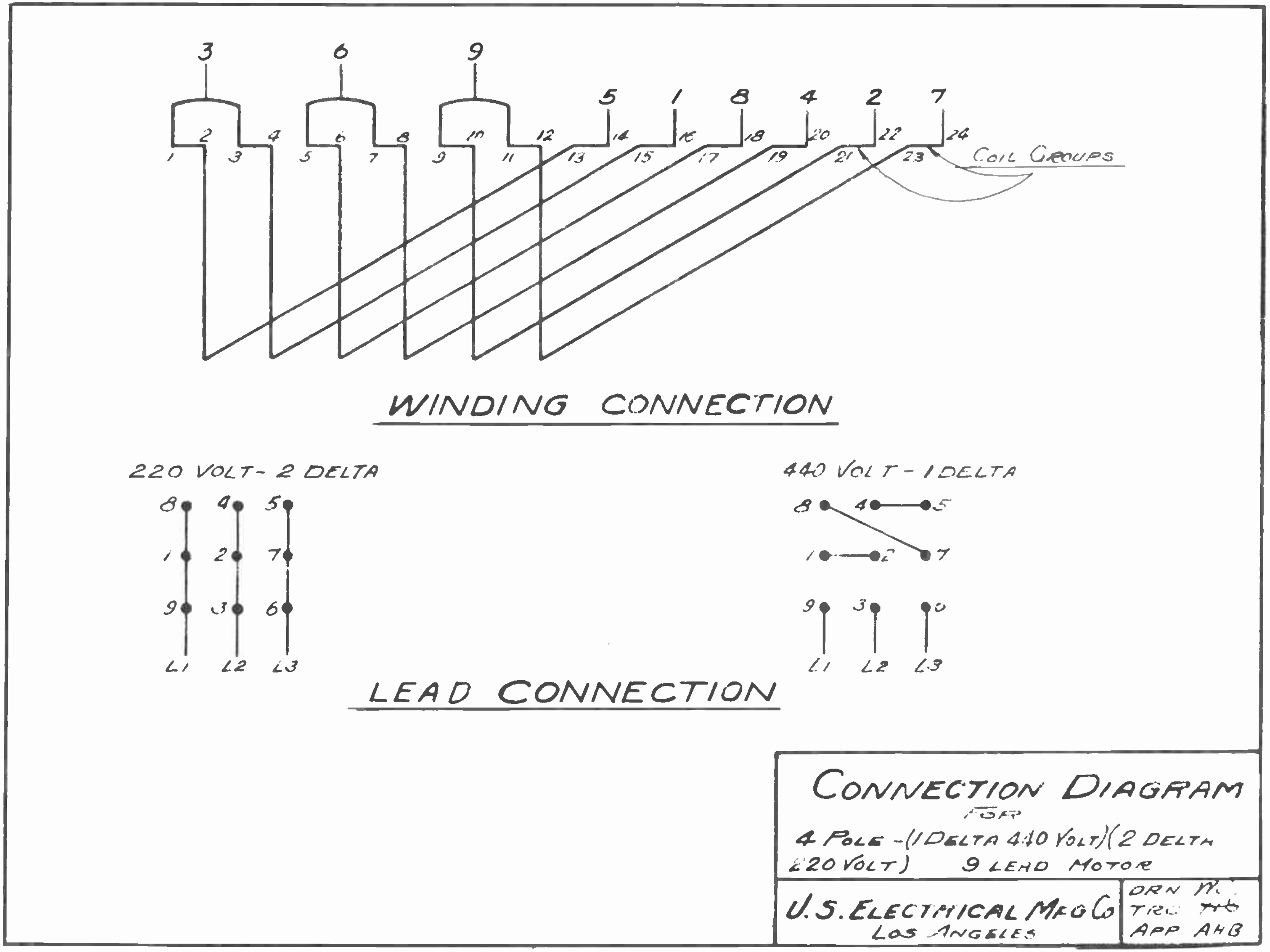
DRN-WJ
TRC-
APP-AHB

CD-50-28



U. S. ELECTRICAL MFG. CO.

Connection Diagram
For
2Y-220 Volts 1Y-440 Volts
9 Lead 8 Pole Motor
CD-50-28


3
6
9
5
1
8
4
2
7
COIL GROUPS
WINDING CONNECTION
220 VOLT - 2 DELTA
L1
L2
L3
440 VOLT - 1 DELTA
L1
L2
L3
LEAD CONNECTION
CONNECTION DIAGRAM
FOR
4 POLE - (1 DELTA 440 VOLT) (2 DELTA 220 VOLT) 9 LEAD MOTOR
U.S. ELECTRICAL MFG CO
LOS ANGELES
DRN
TRC
APP AHB

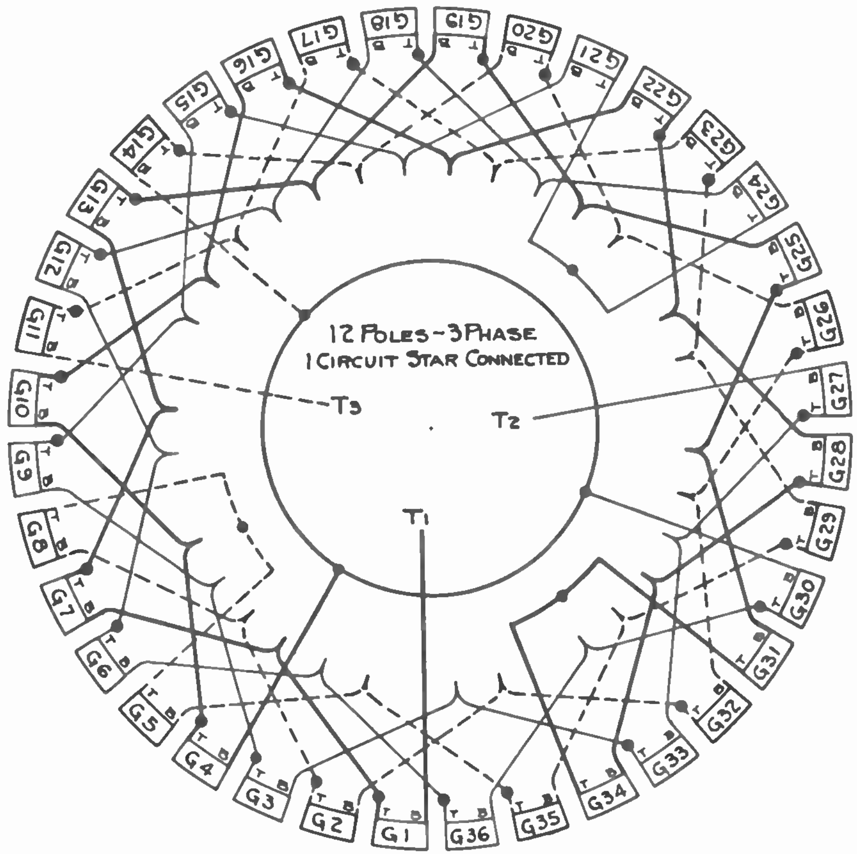
RS1231Y

"Phase wound rotor connection diagram. 12 poles, 3-phase, 1 circuit star"

RS1231Y

Dr. By:-
Ck. By:- Geo. B Pollard
Date:-

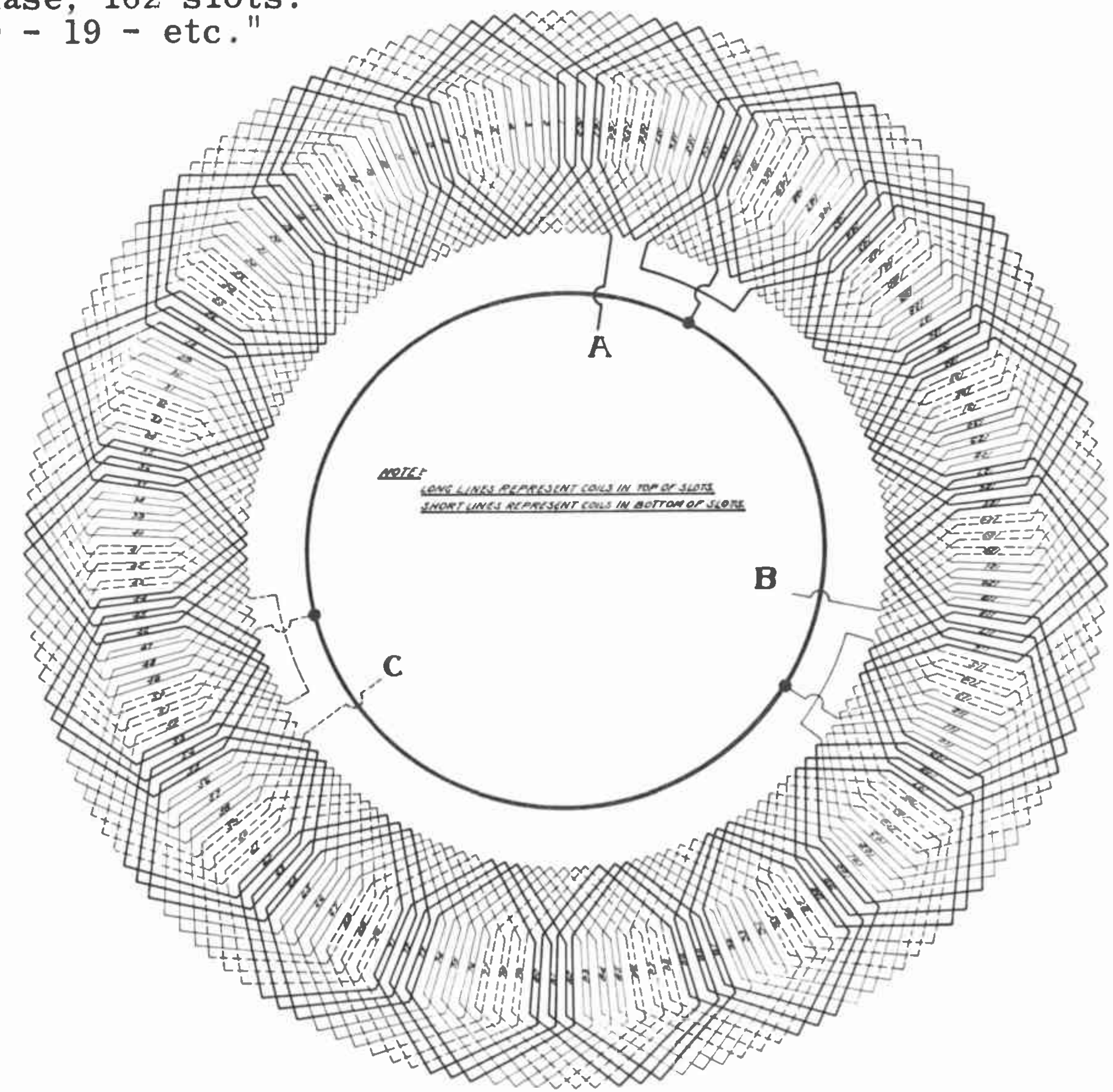
This Diagram Can Be Used For Connecting A Rotor Of Any Number Of Slots For G1, G2, Etc., Represent Any Number Of Coils In Series Per Pole Per Phase.



Connection Diagram

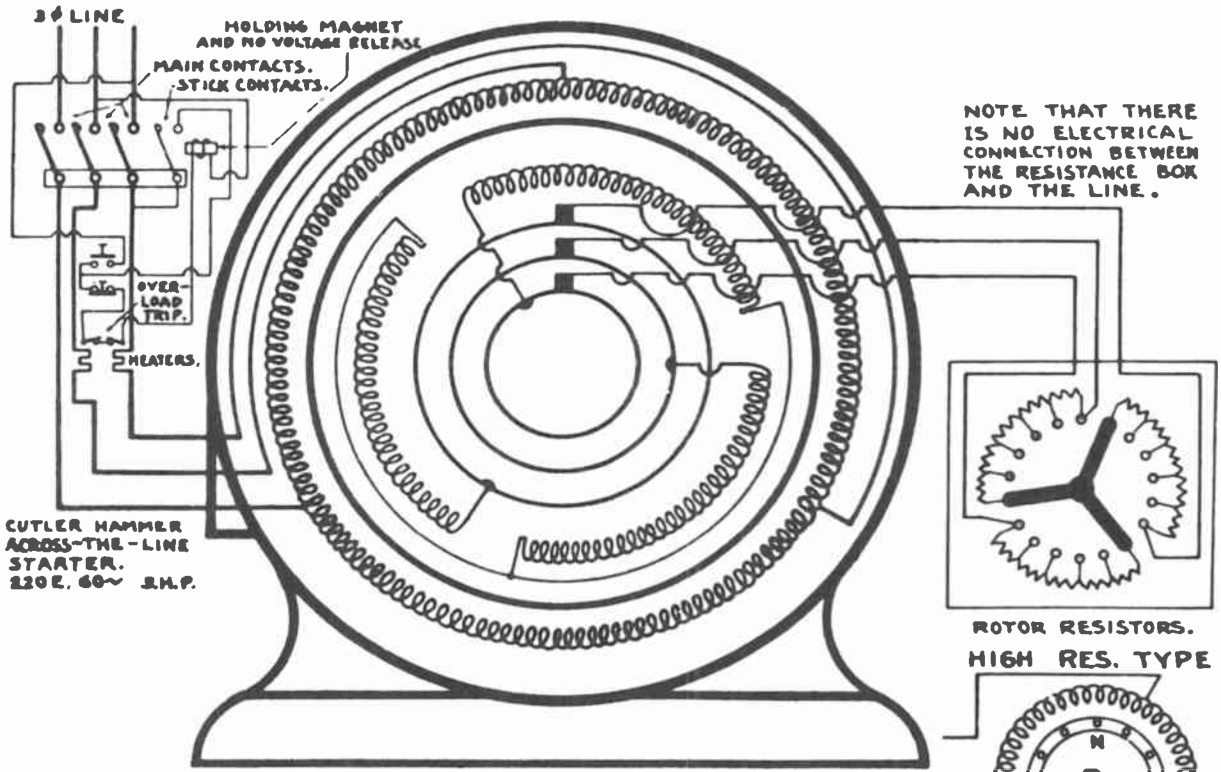
Fairbanks, Morse & Co.
Electrical Department
Beloit, Wisconsin

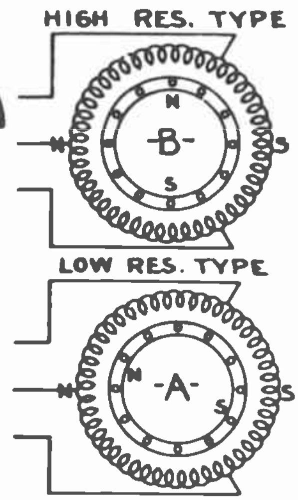
"Rotor connection diagram (wave winding)
18 poles, 3-phase, 162 slots.
Throw - 1 - 10 - 19 - etc."



Drawn by: Checked by: Date: Approved	SERIES STAR DIAGRAM 18 POLE - 162 SLOTS - 3 PHASE WAVE WINDING - THROW 1-10-19 etc.	A-1249

SLIP RING INDUCTION MOTOR Job *7





Diagrams A and B are used to show that an increase in rotor resistance causes the rotor poles to move into a more favorable position with respect to the stator poles thereby increasing the starting torque. If the rotor resistance is increased above a certain critical value, the torque will be reduced as indicated by the curves in the diagram below.

The slip ring induction motor operates on the same principle as the squirrel cage type, the revolving magnetic field set up by the stator winding reacting with the induced rotor poles to produce rotation. Insertion of resistance in the rotor circuit produces the following advantages: 1. High starting torque 2. Low starting current 3. Smooth starting action 4. Adjustable speed.

CHARACTERISTICS

The average slip ring motor will produce 3 times normal full load torque with 2.5 times normal full load current.

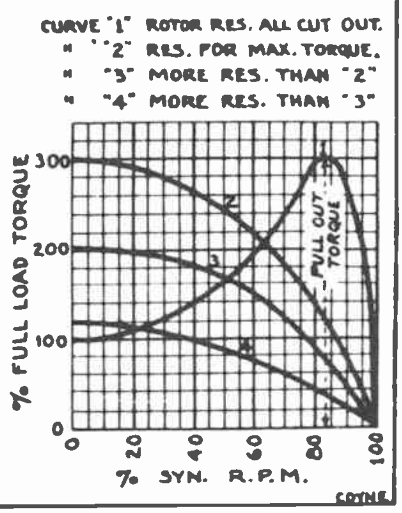
With all the external resistance cut out, the variation in speed from no load to full load will not exceed 5% of the full load speed. As resistance is inserted, the speed regulation becomes rapidly poorer

APPLICATION

Air compressors, large ventilating fans, conveyors, punch presses, printing presses, lathes, elevators, etc. may be used wherever a high starting torque, a smooth starting action, or adjustable speed is desired.

PRINCIPAL TROUBLES

Sliprings, brushes, brush holders, external rotor resistance, loose connections, bearings, insulation.



Synchronous Motors

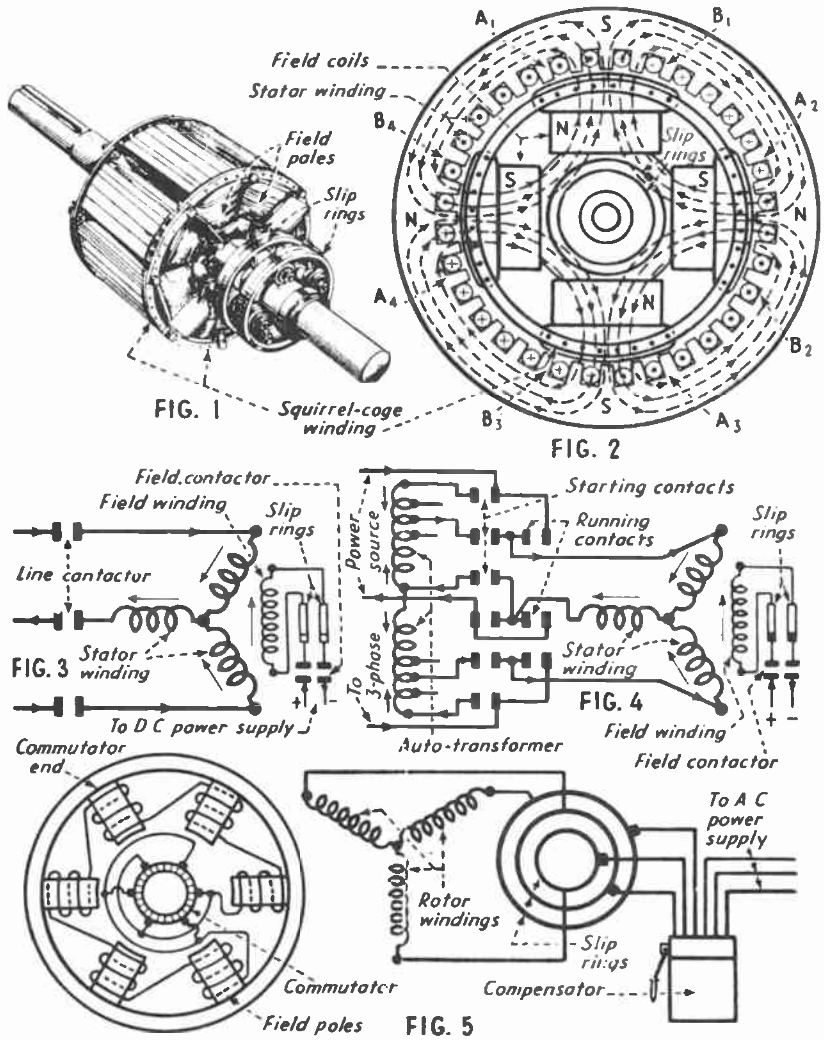


Fig. 1—Synchronous-motor rotor. Fig. 2—Diagram of synchronous-motor stator and rotor assembly. Fig. 3—Diagram of synchronous-motor connections for full-voltage starting. Fig. 4—Diagram of connections for reduced-voltage starting. Fig. 5—Diagrams of stator and rotor connections for self-synchronizing motor

How They Operate

Fig. 2 shows the rotor and stator assembly of a synchronous motor. When the stator winding is connected to a polyphase alternating-current source, it produces a rotating magnetic field as in an induction motor. When the rotor field coils are connected to direct current, their *N* and *S* field poles lock into step with *S* and *N* poles of the rotating magnetic field and both rotate at the same speed or in synchronism. This speed is fixed by line frequency and number of rotor poles.

Synchronous motors are designed for two standard full-load power factors: unity and 80% leading. Unity-power-factor motors, at full load and normal field current, have 100% power factor. At less than full load, their power factor is less than unity leading, but can be regulated by adjusting the field current.

ALTERNATING CURRENT DEPARTMENT

THE SYNCHRONOUS MOTOR

THE SYNCHRONOUS MOTOR is so named becuase the ROTOR revolves at the same speed s the REVOLVING MAGNETIC FIELD of the stator.

THREE WINDINGS ARE USED in this machine:

1. THE A.C. STATOR or armature winding, which prcduces a revolving magnetic field when polyphase A.C. is applied to it.
2. THE D.C. FIELD or rotor winding, which produces a fixed polarity. This winding must be excited from an outside source of D.C.
3. THE DAMPER or squirrel cage winding which consists of a few large copper bars imbedded in the D.C. field pole faces and shorted together by end rings. This winding serves 2 purposes: (a) It permits the motor to start as an induction tends to prevent hunting.

HUNTING is a periodical variation in the speed of the rotor with regard to the revolving magnetic field of the stator. It is caused by: (a) a sudden change in mechanical load. (b) a sudden change in A.C. line voltage. (c) a sudden change in D.C. field excitation. (d) hunting on the same system of other rotating electrical equipment.

THE FIELD DISCHARGE SWITCH and the field discharge resistor are arranged to protect the D.C. field from high transformer voltages induced by the stator field during the starting period, and also from high self-induced voltages generated by collapsing D.C. field flux when the field is disconnected from the source of excitation. The discharge resistor and switch form a closed circuit on the field when the switch is placed in the discharge position, and this greatly reduces the danger to the field insulation.

ADVANTAGES OF THE SYNCHRONOUS MOTOR: 1. Constant speed. 2. Variable power factor. The power factor may be varied by controlling the excitation current of of D.C. field. The P.F. will be UNITY of 100% at NORMAL excitation, LAGGING at UNDER excitation, LEADING at OVER excitation.

THE MOTOR WILL CORRECT POWER FACTOR because when the D.C. field is over excited the A.C. stator will draw a LEADING current which will neutralize a LAGGING current drawn by inductive apparatus connected to the same system. It will carry a mechanical load and correct P.F. of the system at the same time providing the full load current rating of the machine is not exceeded.

DISADVANTAGES OF SYNCHRONOUS MOTOR: Greater cost per H.P., low starting torque, subject to hunting, requires outside source of excitation, more auxiliary apparatus for control and indication, more intelligent handling, and may require some form of clutch to connect the load to it.

APPLICATIONS: Driving compressors for air conditioning and refrigeration, also for compressed air. Driving textile mill looms, cement grinding and rubber processing machines, paper pulp grinders, also M.G. sets, frequency changers, or in general any load of 25 H.P. or more not requiring heavy starting torque and which may be operated at a constant speed.

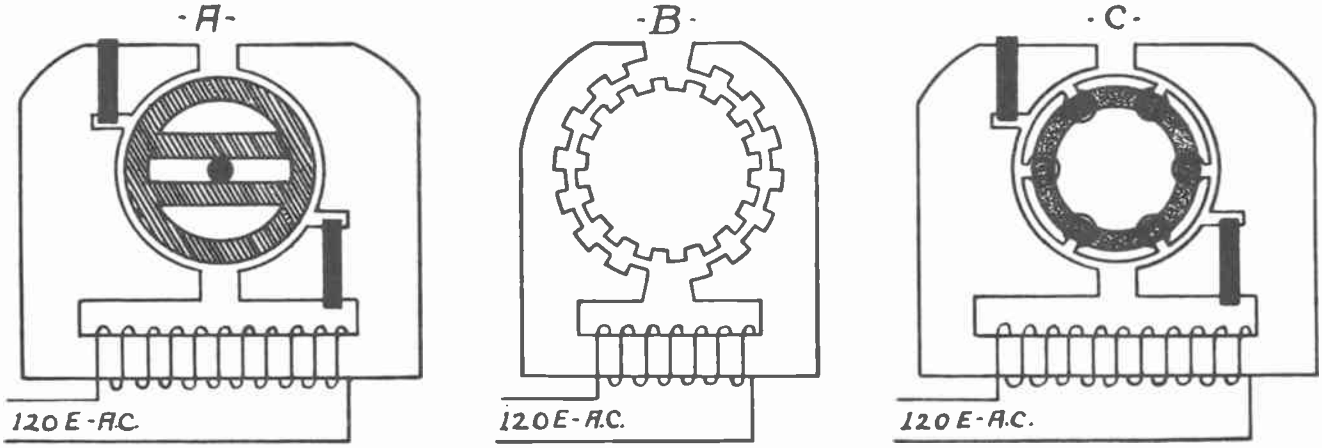
ROTATION may be reversed by changing any 2 of the 3 stator leads. The D.C. field polarity does not determine the direction of rotation.

PROCEDURE FOR STARTING THE MOTOR:

1. Reduce the exciter voltage to a minimum. (Turn field rheostat to right)
2. Place the field discharge switch in the discharge position.
3. Apply low voltage A.C. to the stator and allow motor to accelerate to almost full speed. (Watch AM. to note when starting current is reduced to a minimum.
4. Close the D.C. field switch to apply excitation current to the field.
5. Apply full voltage to the stator winding.
6. Adjust D.C. field excitation to obtain desired power factor.

PROCEDURE FOR STOPPING THE MOTOR: Remove the mechanical load if possible, then reduce field excitation and finally disconnect the stator from the A.C. supply.

SMALL SYNCHRONOUS MOTORS.



(A) Due to their constant speed characteristics, small synchronous motors are widely used in stroboscopes, mechanical rectifiers, electric clocks, recording devices, timing relays, demand meters, etc. These small motors operate similarly to the large power types except that the small units are not separately excited, the poles on the rotor being produced by magnetic induction from the stator. Turning at synchronous speed, the rotor is polarized and is in the position shown when the stator current is maximum. As the current diminishes, momentum carries the rotor to the vertical position just as the main poles reverse and, as the hard steel rotor still retains its poles, it is again attracted to the horizontal position and rotation continues. Shading coils are employed to make the unit self starting. Speed is determined by frequency; if frequency is constant, speed will not vary.

(B) SYBSYNCHRONOUS CLOCK MOTOR - Consists of a 2 pole stator and an iron rotor with 16 or more salient poles. The motor is not self starting, but when operating at synchronous speed, 2 diametrically opposite poles are attracted to the field poles as the flux of the field is increasing. Because of the inertia of the rotor, it continues to rotate while the flux is decreasing and passing through zero. The next pair of poles is then attracted by the field flux as it increases in the opposite direction. Although the stator has only 2 poles, the speed of the motor is the same as that of a motor having the same number of stator and rotor poles. EXAMPLE - At 60 cycles the speed is 450 R.P.M., corresponding to the 16 rotor poles. Because the rotor speed is much less than that corresponding to the 2 stator poles, the motor is said to operate at SUBSYNCHRONOUS speed.

(C) SELF-STARTING INDUCTION-REACTION SYBSYNCHRONOUS MOTOR - This motor is a 2 pole, single phase, combination induction and synchronous motor with a shaded pole field and a squirrel cage rotor. In this particular motor there are 6 rotor slots, so proportioned that they produce 6 salient poles on the rotor which give the synchronous (or reaction) motor effect. AT STARTING, the induction motor torque must be sufficient to overcome the tendency of the salient poles of the rotor to lock in with the stator poles, The motor operates as any induction motor, the rotor tending to accelerate to nearly synchronous speed. EXAMPLE - At 60 cycles, the induction motor torque tends to accelerate the rotor nearly to the 2 pole synchronous speed of 3600 R.P.M. The motor is so proportioned that at 1200 R.P.M., the 6 pole synchronous speed, the reaction torque due to the pulsating stator pole flux reacting with the 6 rotor poles, predominates over the induction motor torque developed at that speed. The rotor, therefore, locks in with the stator poles and runs synchronously at 1200 R.P.M. At its operating sybsynchronous speed, the motor developes simultaneously induction motor and synchronous motor torque. This type is used chiefly with timing devices.

Synchronous MOTORS

for Alternating Current Only

APPLICATION AND PERFORMANCE DATA

Application—Synchronous motors are generally employed for driving apparatus whose speed must be accurately maintained. They are used in large clocks, X-ray timers, recording instruments, and sound cameras and projectors. Bodine synchronous induction motors are regularly furnished with ratings from 1/2000 to 1/8 horsepower for single-phase or polyphase operation, at 1800 rpm, and 60 cycles.

Fig. 1—The Type NSY-34, one of a number of different sizes of small synchronous motors built By Bodine.

Characteristics—A typical set of synchronous motor performance curves is shown in Fig. 2. The predominant characteristic of all synchronous motors is that they maintain an absolutely constant speed. This speed is determined by the frequency of the alternating current to which they are connected. For 60-cycle current, the speed of four-pole motor is 1800 rpm. Synchronous speed will be maintained at all loads within the range of the motor, and will fall off only when a severe overload is applied or when the voltage drops appreciably below normal.

Synchronous motors have a fairly good starting torque. This varies with the position of the rotor. For certain positions (corresponding in number to the number of poles) the motor will develop a very high torque. The rating of Bodine synchronous motors is based upon their minimum starting torque, in order to insure proper starting at rated loads.

A synchronous motor performs as an induction motor in starting, but, as it nears synchronous speed, a critical point is reached where there is a sudden acceleration and the motor pulls into step. The torque which the motor will accelerate into synchronism, is called the "pull into synchronism torque." A synchronous motor may easily start a load which it cannot pull into synchronism, and the motor will operate as a pure induction motor with low efficiency, high slip, and a fair degree of noise. Care must therefore be taken in applying synchronous motors, to be certain that they will accelerate the load to synchronous speed under the most adverse load and voltage conditions. A motor which will easily pull into synchronism a load concentrated near its axis may not pull into synchronism a similar load having its weight some distance from the axis. In other words a heavy cylinder of small diameter can be accelerated more easily than a thin disc of large diameter.

Due to the magnetic relationships set up by the salient pole rotor, synchronous motors vibrate more than non-synchronous a-c motors. As the cause of this vibration is electrical rather than mechanical, it is present even though the rotor is both statically and dynamically balanced. Bodine synchronous motors have been carefully designed to reduce vibration to a minimum, but a small amount of vibration is inherent in the synchronous motor and must be expected.

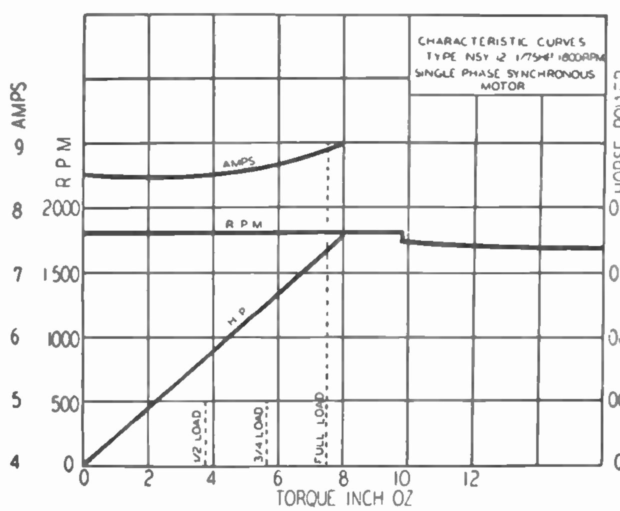


Fig. 2—Performance curves of a typical Bodine fractional horsepower synchronous motor.

Three Types—Bodine synchronous motors are available with three types of winding: split-phase, capacitor, and polyphase. The proper motor to use depends upon the particular application.

The split-phase synchronous motor, because of its low cost, high starting torque, and relatively high efficiency, is most commonly used on single phase applications. It is provided with a main winding and a starting winding similar to that of the split-phase induction motor. A starting switch or cutout disconnects the starting winding from the line when the motor has approached synchronous speed. The rotor is similar to that of the induction motor but the iron core has been modified so as to provide salient poles.

The capacitor synchronous motor is a single-phase induction motor without a starting switch or cutout, but it utilizes a capacitor unit to provide starting torque. The capacitor, which may be either rectangular or cylindrical in form, is considerably smaller than the motor, and is either mounted on the motor or at another point on the machine. As the capacitor motor has no centrifugal cutout, and its only moving part is the rotor core and shaft, it is extremely reliable and ideal for applications requiring frequent starting. Furthermore, like a non-synchronous capacitor motor, it is very quiet in operation and free from vibration. Hence, it is often specified in preference to the split-phase type of synchronous motor for applications in which vibration must be held to a minimum. However, as starting torque is sometimes less than full load torque, a careful check must be made to see that the motor will start the load.

Three phase synchronous motors are usually preferred where three phase current supply is available as they have a higher starting torque and a lower starting current than single-phase synchronous motors. Furthermore, like the capacitor motors, the three phase synchronous motor requires no centrifugal cutout switch. Hence, where frequent starting is required, this motor is preferred.

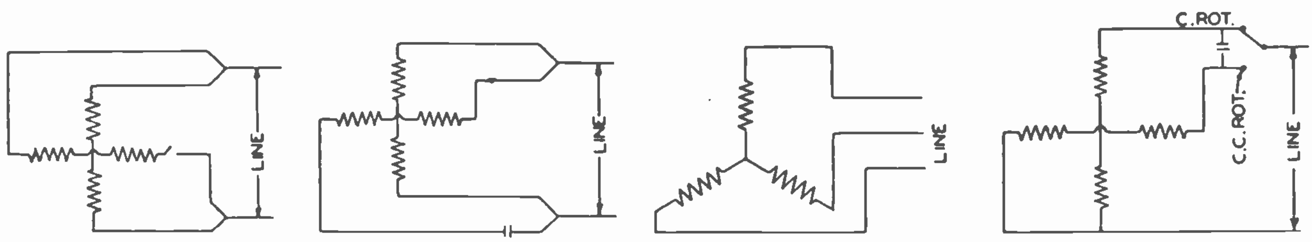
Construction—Bodine synchronous motors are available in a wide variety of frame sizes, ranging from a small but sturdy little unit less than two and a half inches high, to one 5⅝ inches in diameter. All are built for continuous duty, for jobs where reliability is important.

Careful design and long experience has enabled Bodine to build these synchronous motors compactly, securing maximum output for a given size. By specializing in small motors alone, Bodine Engineers are able to provide a wide choice of frames and exactly the electrical characteristic desired.

Synchronous motors may be obtained with either sleeve or ball bearings. Speed reducers to make the drive simpler can be made an integral part of each frame. Many other modifications desired by the industrial designer can easily be provided to order.

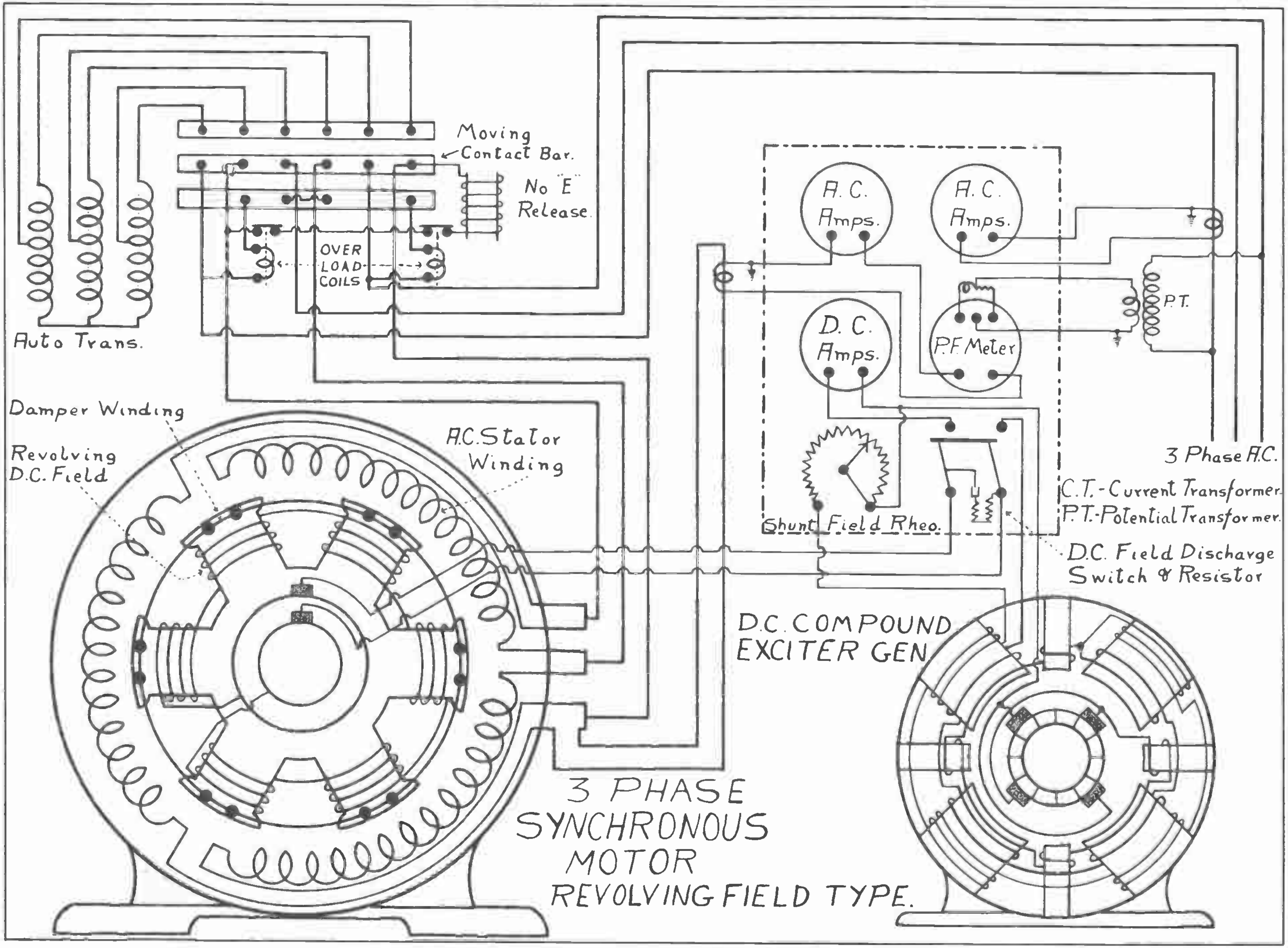
Like most alternating current motors, synchronous motors employ a squirrel carge rotor and a distributed stator. The split-phase start type is equipped with a cutout of the same construction used in split-phase induction motors. In fact the principal difference between synchronous and induction motor construction lies in the salient pole rotor employed in the former. This rotor modification for the synchronous motors has already been described.

Space limitations do not permit a more complete description here, but full details will be found in the Bulletins describing the construction of each frame type.



(a) SPLIT PHASE (b) 4 LEAD REVERSIBLE CAPACITOR (c) THREE PHASE (d) 3 LEAD REVERSIBLE CAPACITOR

Fig. 3—Arrangement of windings on popular types of synchronous motors.



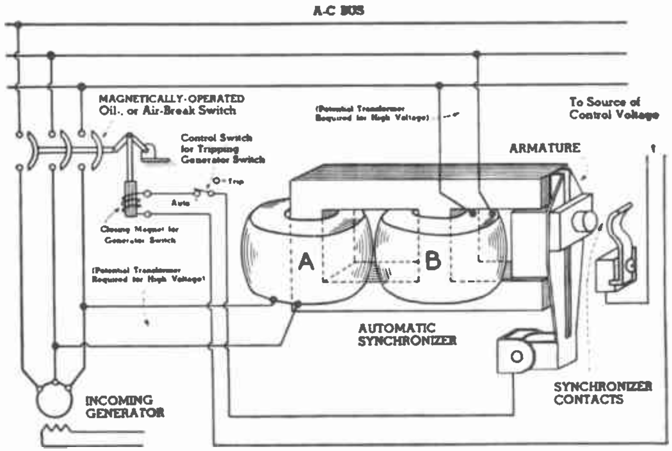
3 PHASE SYNCHRONOUS MOTOR REVOLVING FIELD TYPE.

HOW THE E-M AUTOMATIC SYNCHRONIZER WORKS

The laminated core of the Synchronizer (See Fig. 1, right) carries two voltage coils A and B. Coil A is connected to the incoming generator. Coil B is connected to the a-c bus which will ordinarily be alive, and the magnetic force due to the bus current in Coil B will keep the Armature of the Synchronizer closed, and the Synchronizer Contacts open, as shown in the figure.

The incoming generator is brought up to speed. The incoming generator voltage builds up, and coil A is thus also energized. The Automatic Synchronizer is so designed that coil A operates in conjunction with coil B to keep the Synchronizer Contacts open until the conditions are right for synchronizing.

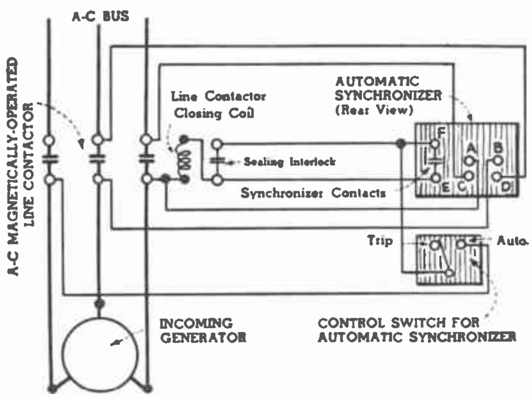
The Automatic Synchronizer is operative in the generator speed zone between 97% and 103% of synchronous speed, or closer depending on the speed setting of the Synchronizer. As soon as the incoming generator reaches proper speed, the Armature of the Synchronizer will drop open to close the Synchronizer Contacts at the first coincidence of similar phases between the incoming generator and the a-c bus, that is as soon as the incoming generator is "in step". The generator switch then closes connecting the generator to the bus, and it is ready to take load.



● *Fig. 1—Diagram showing construction and connections of the E-M Automatic Synchronizer.*

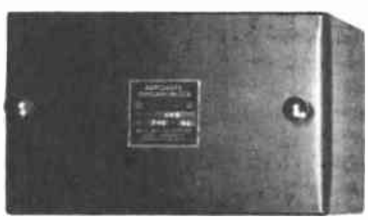
HOW THE E-M AUTOMATIC SYNCHRONIZER IS APPLIED

● SWITCHBOARD-MOUNTED AUTOMATIC SYNCHRONIZER



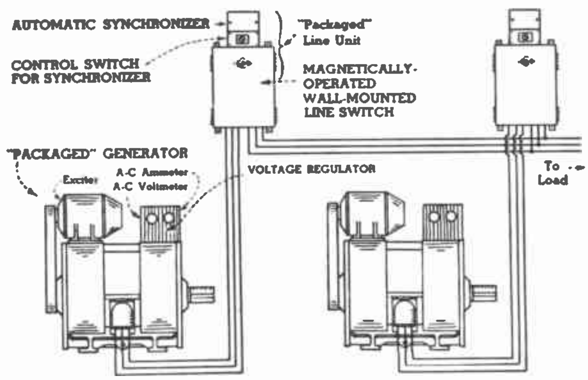
● Fig. 2—(Above) Connections for the E-M Automatic Synchronizer, and its Control Switch, for switchboard mounting are shown above. One Automatic Synchronizer and Control Switch are used for each generator.

Letters on the Automatic Synchronizer are terminal markings. As will be seen, only three sets of leads are required: one set to the a-c bus, one set to the incoming generator, and a set to connect the closing magnet (or closing magnet control relay) of the generator switch to the source of control voltage. For voltages higher than 575 volts, potential transformers are required. (Detailed instructions and connection diagram are supplied with each Automatic Synchronizer.)

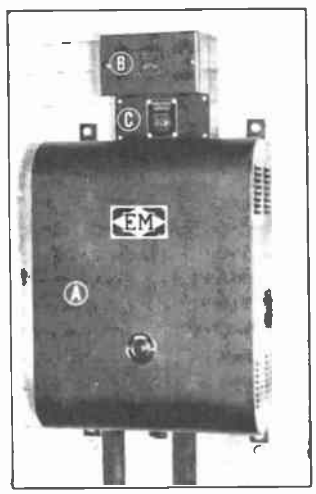


● *Fig. 3—(Left) E-M Automatic Synchronizer for panel, or bracket mounting. Synchronizer is enclosed in a case, with terminal studs in rear. Overall size of case: width 8 in., height 5 in., depth 3 5/16 in.*

● AUTOMATIC SYNCHRONIZER for "PACKAGED" GENERATORS



● Fig. 4—(Above) For use with E-M "Packaged" Generators, the Automatic Synchronizer and Control Switch (one each for each generator) are cabinet-mounted on top of the generator magnetic line switch, as shown above, and in Fig 5, right. This provides a compact, easily-installed, completely assembled, ready-to-use, wall-mounted arrangement. The Automatic Synchronizer and Control Switch are factory-wired to the generator switch.

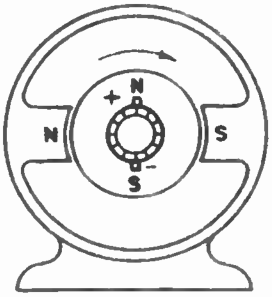


● *Fig. 5—(Right) Magnetic, Motor-Line Starter Type Generator Switch (A), Automatic Synchronizer (B), and Synchronizer Control Switch (C). A wall-mounted, completely assembled and wired combination for E-M "Packaged" Generator. Generator switch shown is for low voltage. For high voltage the switch is oil-break, floor-mounted type.*

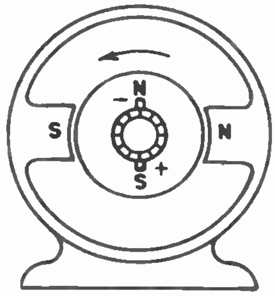
D.C. MOTORS AND GENERATORS.

OPERATION

A



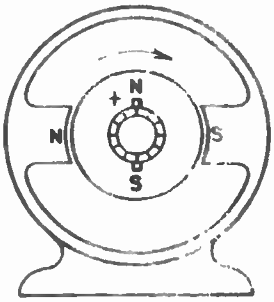
The D.C. motor operates on the first law of magnetism which states that like poles repel and unlike poles attract. Current flowing through the field coils produces the field poles, and current through the armature coils develops armature poles midway between the field poles. Attraction and repulsion between these two sets of poles produces rotation. Note that the armature poles remain stationary in space.



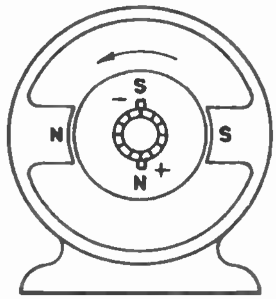
B

ROTATION

C



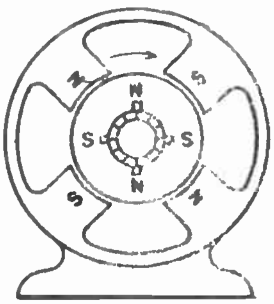
By reversing the direction of current flow through the fields or through the armature, the field poles or the armature poles will be reversed, and the direction of rotation changed. Compare A with B and C with D.



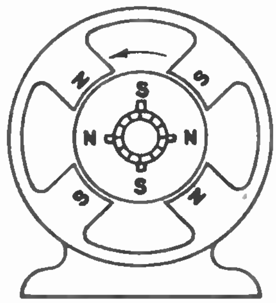
D

ARMATURE POLES

E



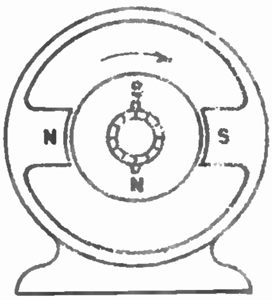
Diagrams E and F show a 4 pole motor. Note that the number of armature poles always equals the number of field poles, and that the armature poles are located midway between the field poles. From the above it is obvious that a 2 pole armature will not work in a 4 pole field. Note also that when the direction of current flow is reversed all poles are reversed.



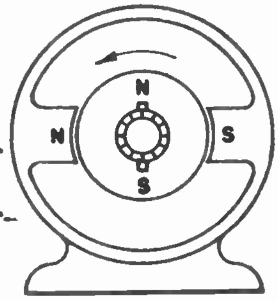
F

GENERATORS

G

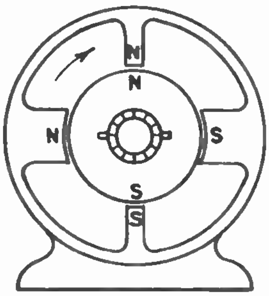


Diagrams G and H show two generators, one arranged for clockwise and the other for counter clockwise rotation. Note that poles are set up on generator armatures also, but that in this case the poles oppose rotation. As more current is drawn from the armature, these poles increase in strength; this explains why an electric generator is harder to drive as the armature current increases.



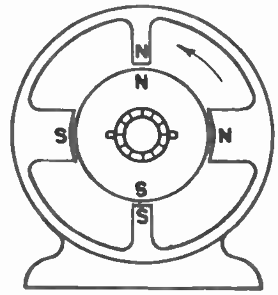
H

D.C. MOTORS AND GENERATORS.

A


INTERPOLES

To minimize sparking at the brushes, most D.C. motors are equipped with small poles placed midway between the main poles and called interpoles or commutating poles. For proper operation, these small poles must have the correct polarity. Reference to any of the diagrams will show that the polarity of the interpole is always the same as the armature pole adjacent to it.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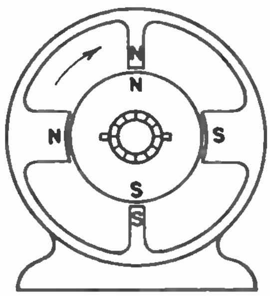
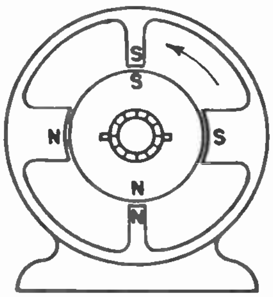
C


REVERSING ROTATION

The windings on the interpoles are always connected in series with the armature winding and are considered a part of the armature circuit. Therefore, when current through the armature is reversed, the interpole polarity is also reversed. This arrangement automatically preserves the proper relation between the armature poles and the interpoles when the armature current is reversed.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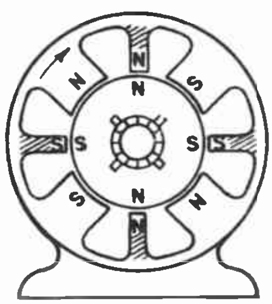
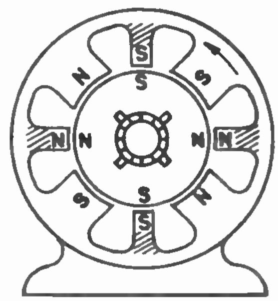
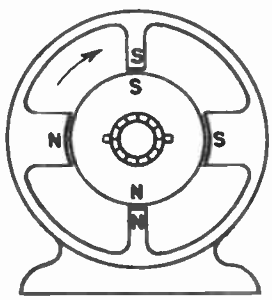
E


NUMBER OF INTERPOLES

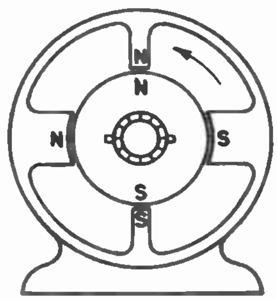
Machines equipped with interpoles may have as many interpoles as main poles or one-half as many interpoles as main poles. As the interpole winding is always connected in series with the armature, the interpole strength will vary with the value of armature current.


F

G


GENERATORS

Diagrams G and H show two generators equipped with interpoles. G is arranged for clockwise rotation and H for counter clockwise rotation. Note that the rule for the polarity of interpoles applies to generators as well as motors. Note too, that the armature poles oppose rotation and thus produce the force against which the prime mover must work to maintain rotation.


H

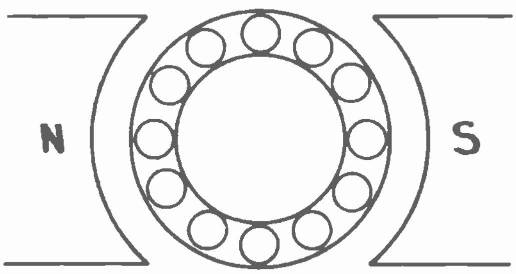
D. C. MOTOR PRINCIPLES

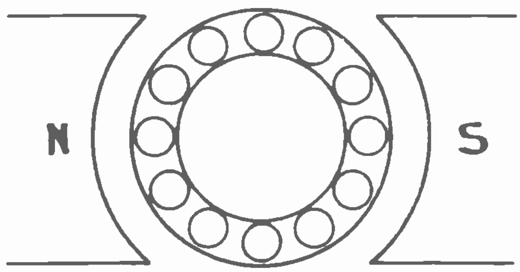
Electric motors are machines that change electrical energy into mechanical energy. They are rated in horse power. (H.P.)

The attraction and repulsion of the magnetic poles produced by sending current through the armature and field windings causes the armature to rotate. The armature rotating produces a twisting power called torque.

Fleming's Left Hand Rule For Motors

Place the thumb, first finger and remaining fingers at right angles to each other. Point the first finger in the direction of the field flux, remaining fingers in the direction of the armature current and the thumb will indicate the direction of rotation.

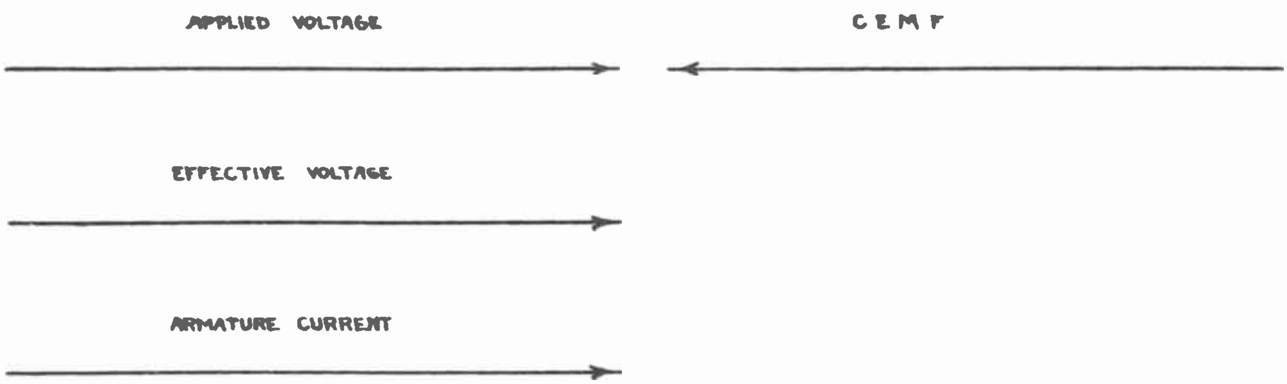




The direction of rotation can be reversed on any D.C. motor by reversing either the armature or field leads but not both. It is standard practice to reverse the armature leads to reverse the direction of rotation.

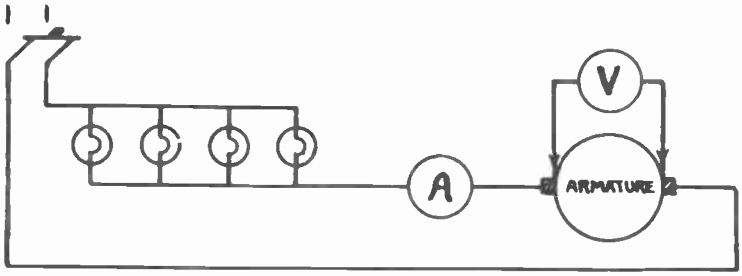
The amount of torque developed by a motor is proportional to the strength of the armature and field poles. Increasing the current in the armature or field winding will increase the torque of any motor.

The armature conductors rotating through the field flux has a voltage generated in them that opposes the applied voltage. This opposing voltage is called counter electro motove force, (C E M F) and serves as a governor for the D.C. motor. After a motor attains normal speed the current through the armature will be governed by the C E M F generated in the armature winding. This value will always be in proportion to the mechanical load on the motor.



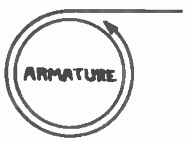
D.C. MOTOR PRINCIPLES (CONTINUED)

The applied voltage is the line voltage. The effective voltage is the voltage used to force the current through the resistance of the armature winding. This value can be determined by multiplying the resistance of the armature by the current flow through it. To find the resistance of the armature measure the voltage drop across the armature and the current flow through it and use ohm law formula. R equals E over I



The lamps are used to limit the current through the armature winding.

The revolutions per minute of a D.C. motor can be varied over a wide range. The maximum safe speed for the average D.C. machine is 6000 ft. per minute peripheral speed of the armature. D.C. motors can be designed to operate safely up to 15,000 peripheral ft. per minute. Periphery means outer surface.



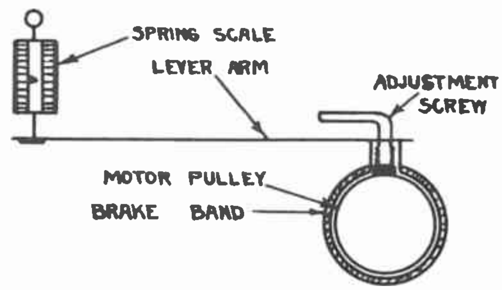
2 ft. circumference

$2\overline{)6000}$
3000 R.P.M. is the maximum safe speed for the average D.C. machine that has an armature that is 2 ft. in circumference

The H.P. rating of a motor refers to the rate of doing work. The amount of H.P. output is proportional to the speed and torque developed by the motor. The Prony Brake Test is used to determine the H.P. output of a motor.

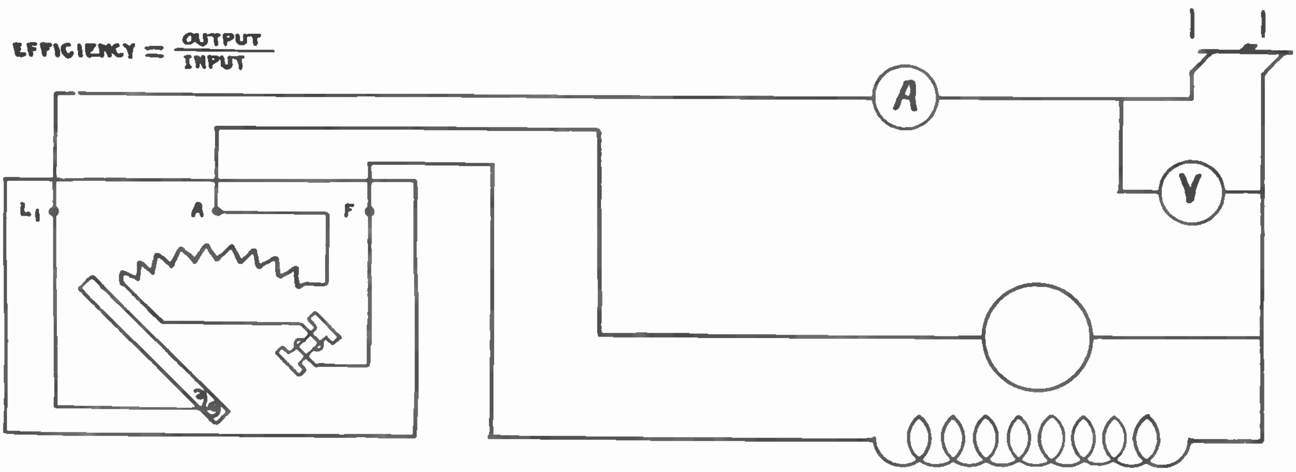
PRONY BRAKE FORMULA

$$H.P. = \frac{2\pi \times P \times L \times R.P.M.}{33{,}000}$$



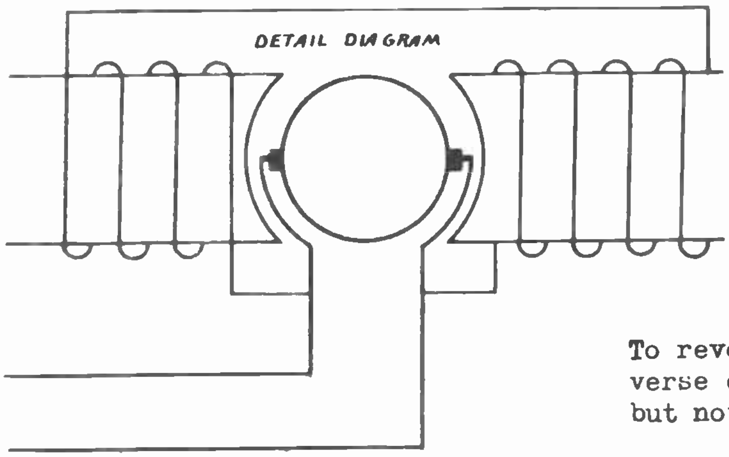
2π equals 6.28
P " Pull on the lever arm in lbs.
L " Length of the lever arm in ft.
R.P.M. equals Revolutions per minute.

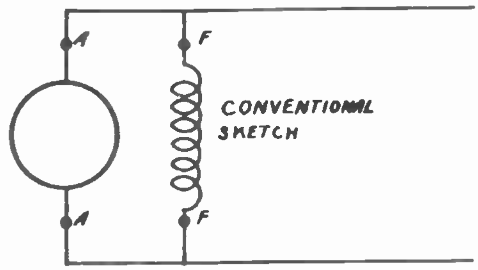
$$EFFICIENCY = \frac{OUTPUT}{INPUT}$$



SHUNT MOTOR

A shunt motor is a motor that maintains nearly constant speed from no load to full load. The shunt field winding consists of many turns of small wire and is connected parallel with the armature winding or across the line. The diagrams below show the proper connection for the armature and field.





To reverse the direction of rotation reverse either the armature or field leads but not both.

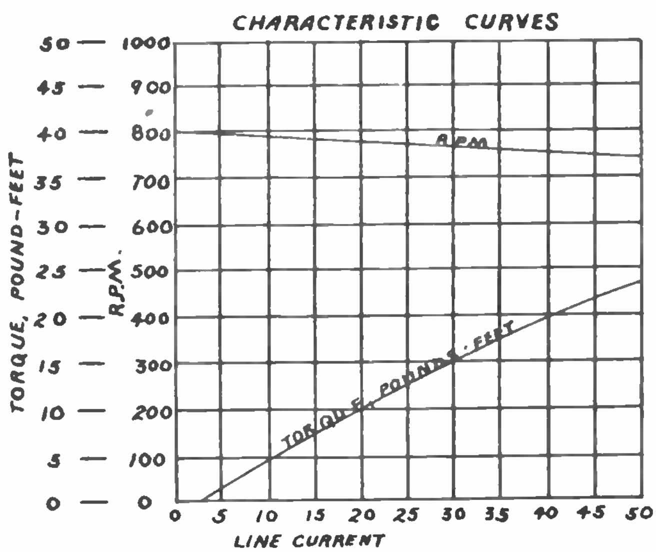
The characteristic curves below show that the torque developed by a shunt type motor varies with the armature current. This is true because the torque is proportional to the armature and field flux. The field maintains constant strength because it is connected across the line and the armature flux will vary with the armature current. The torque of a shunt motor is considered to be fair in comparison to other D.C. motors. It will start about 50% overload before being damaged by excessive current.

The shunt type motor maintains nearly constant speed from no load to full load because the shunt field strength is constant. The characteristic curve shows that the speed varies about 10% from no load to full load which gives this motor very good speed regulation.

This motor is widely used where it is desired to control the speed above and below normal speed. A shunt field rheostat connected in series with the shunt field will cause the motor to increase in speed. A resistor connected in series with the armature will cause the motor to decrease in speed.

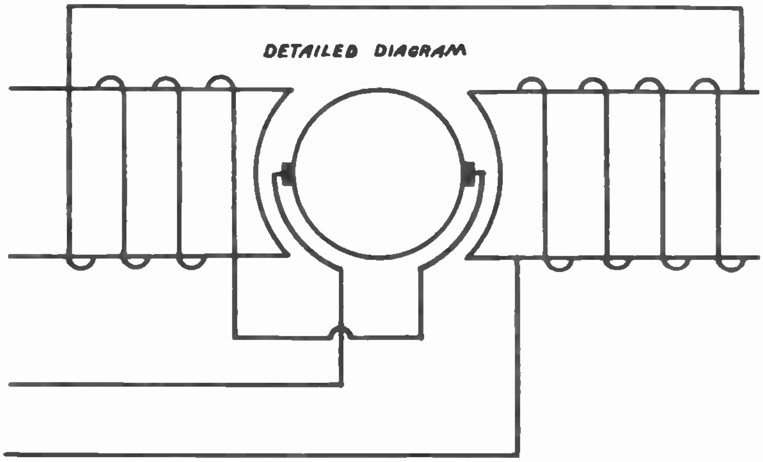
Shunt motors sometimes have a few turns of heavy wire wound on each field pole and connected in series with the armature. This winding produces the same polarity as the shunt field winding and produces a more stable operation when the motor is carrying a fluctuating load.

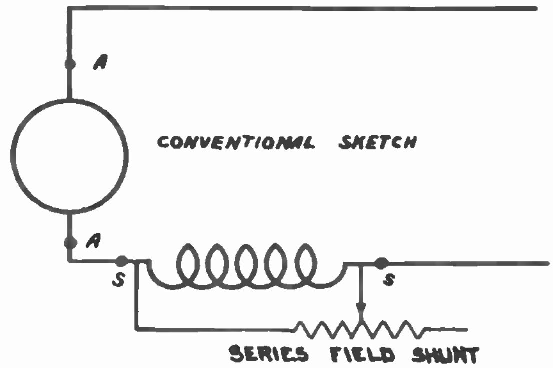
For applications of the shunt motor see Motor Application Chart Number 115.



SERIES MOTOR

A motor that has its field and armature connected in series with each other is a series type motor. The field is constructed of a few turns of heavy wire or strap conductor. The field strength will vary with the armature current under normal conditions.



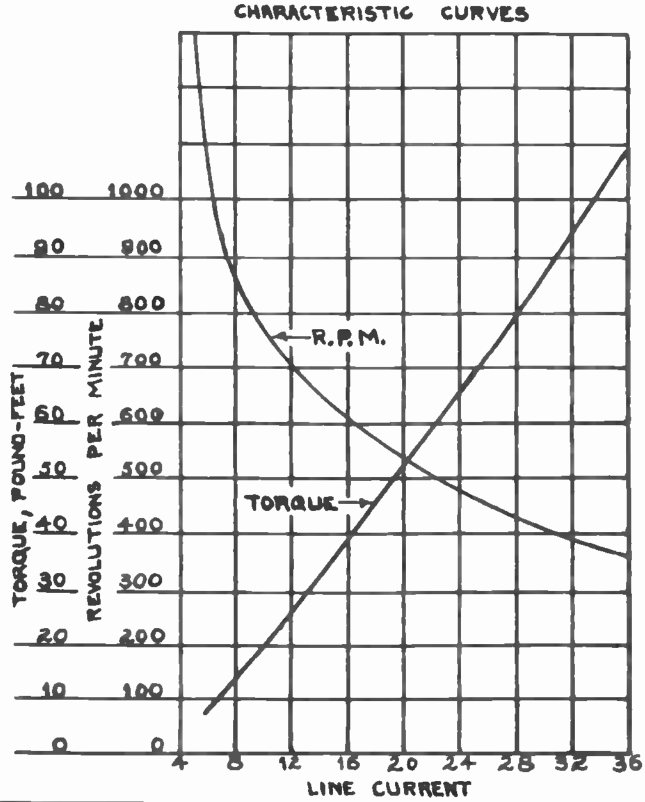


The starting and stalling torque is excellent. It will start or carry very heavy overloads. The torque of a series motor varies with the square of the armature current. This is true because the field strength varies with the armature current. Example - Doubling the armature current will likewise double the field strength and produce four times as much reaction between armature and field poles or produce four times as much torque.

The speed regulation is very poor. The speed varies inversely with the load which means more load less speed and less load more speed. Care must be taken to see that there will always be sufficient load on the motor to keep the speed within safe limits. If the load drop to zero the motor probably would run fast enough to destroy itself.

The series motor is limited in application because of its poor speed regulation. It is especially suitable for cranes, hoists, mine machines and electrical railway work. These loads can be handled more efficiently with a series motor because the speed will be slow if the load is heavy and a light load will be driven at a high speed.

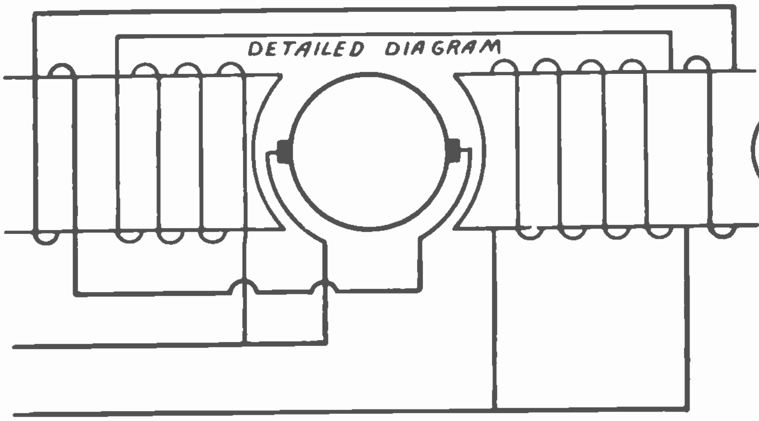
The speed of a series motor can be controlled above normal speed by connecting a series field shunt parallel to the series field. The speed will vary inversely with the field strength. Controlling the speed above normal decreases the possible torque output but does not affect the H.P. output.

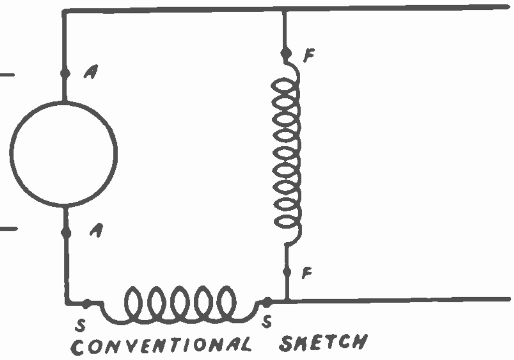


COYNE

COMPOUND MOTOR

The field of a compound motor is made up of shunt and series coils placed on each field pole. The shunt winding is the main field winding. The series is the compound winding and its strength varies with the load current. If the shunt and series coils produce the same polarity at each field pole the connection is known as CUMULATIVE COMPOUND.





COMPOUND MOTOR CONNECTED CUMULATIVE

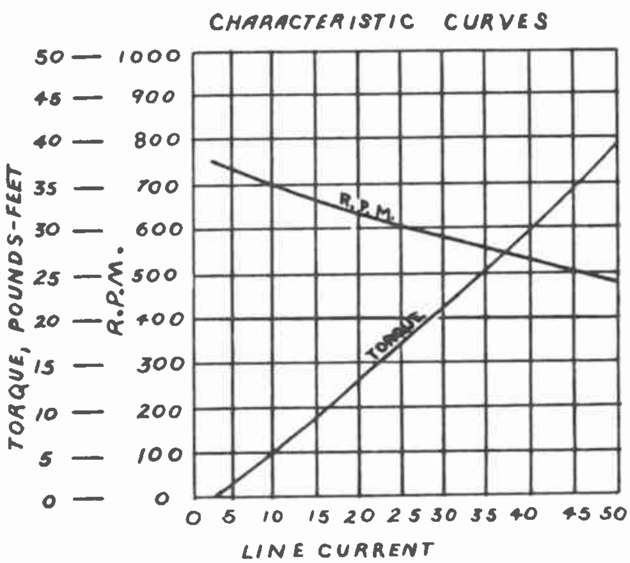
The TORQUE is very good. It will start to carry heavy overloads. The cumulative connected compound motor produces a better torque than the shunt motor but not as good as the series motor.
The SPEED REGULATION is fair. The speed will vary from 15 to 25% from no load to full load. The per cent variation in speed from no load to full load will be governed by the comparative strength of the shunt and series field.
The CUMULATIVE CONNECTED COMPOUND MOTOR is suitable for jobs, such as, compressors, crushers, steel mill roll, etc. For a complete list of applications see chart #115.

DIFFERENTIAL CONNECTED COMPOUND MOTOR

If the polarity of the series field oppose the shunt field the connection is known as differential compound.
The SPEED REGULATION of a differential connected compound motor is very good up to approximately 75% of full load rating. It is apt to slow down or stall if loaded beyond that point.
The TORQUE is very poor. It is apt to start and then reverse its rotation when starting a load.
There is very little use for the differential compound motor.

TESTS TO USE TO DETERMINE CONNECTION MADE FOR COMPOUND MOTOR.

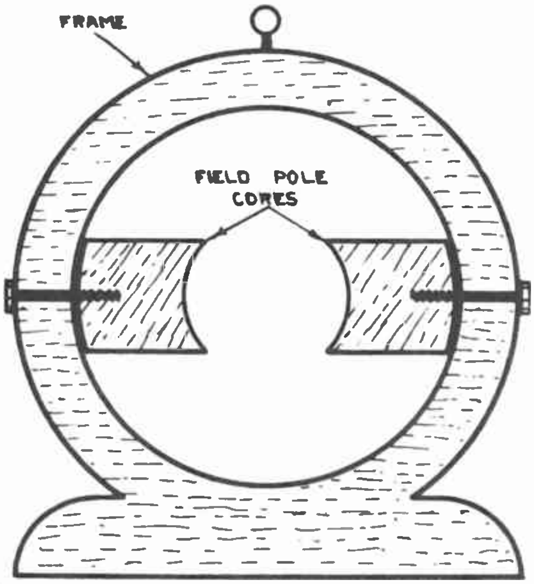
1. Test the speed as connected. Reverse the series field leads and retest the speed. The connection producing the higher speed will be differential compound.
2. Operate the motor as a shunt motor. (series field disconnected) Observe the direction of rotation. Next operate the motor as a series motor. (shunt field disconnected) Again observe the direction of rotation. If each field connection produces the same direction of rotation. If each field connection produces the same direction of rotation, reconnect the fields the same as when testing and the motor will be cumulative compound.



D.C. MOTOR & GENERATOR CONSTRUCTION

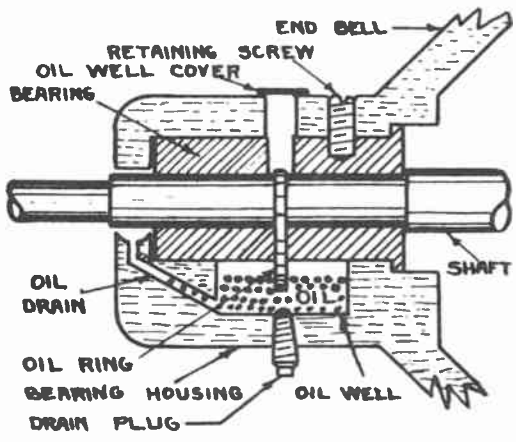
D.C. power is widely used in the industrial field. This type of power must be used for telephones, field excitation, lifting magnets and electro plating work. The characteristics of D.C. Motors make them especially suitable for loads that are difficult to start, where the speed must be varied over a wide range, and where the load must be started and stopped often; such as, traction work, milling machines, mine work, lathes, pumps, steel mill work, printing presses, elevators, etc.

Any D.C. machine may be used as a motor or generator. This construction information applies to both machines.



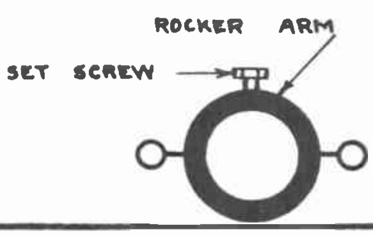
The frame is made of iron because it is used to complete the magnetic circuit for the field poles. Frames are made in three types; open, semi-enclosed and closed types. The open frame has the end plates or bells open so the air can freely circulate through the machine. The semi enclosed frame has a wire netting or small holes in the end bells so that air can enter but will prevent any foreign material entering the machine. The enclosed type frame has the end bells completely closed and the machine is air tight. Some machines are water tight which makes it possible to operate them under water. The closed type frame is used in cement plants, flour mills, etc. where the air is filled with dust particles that damage machine insulation.

The field poles are made of iron, either in solid form or built of thin strips called laminations. The iron field poles support the field windings and complete the magnetic circuit between the frame and armature core.



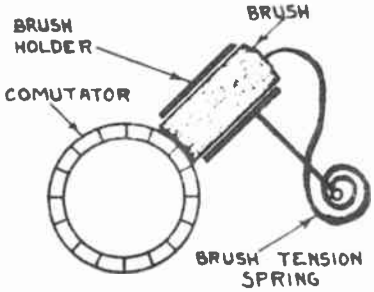
The bearings are the parts of the machine that fit around the armature shaft and support the weight of the armature. They are made in three general types; sleeve, roller, and ball bearings. Bearings will be discussed in detail later in the course.

The oil rings are small rings used with sleeve type bearings. They carry the oil from the oil well to the shaft. The oil ring must turn when the machine is operating otherwise the bearing will burn out.



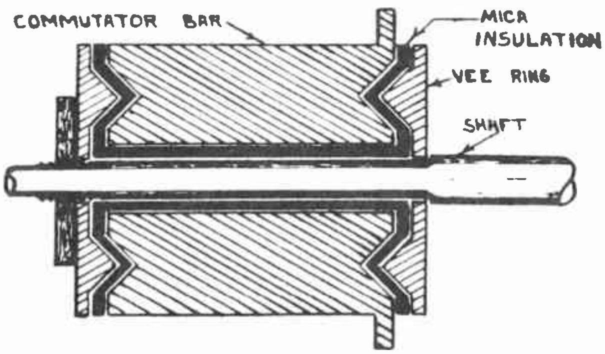
The rocker arm supports the brush holders. This arm is usually adjustable to make it possible to shift the brushes to obtain best operation. When the brushes are rigidly fastened to the end bell the entire end bell assembly is shifted to obtain best operation.

D.C. MOTOR & GENERATOR CONSTRUCTION (CONTINUED)

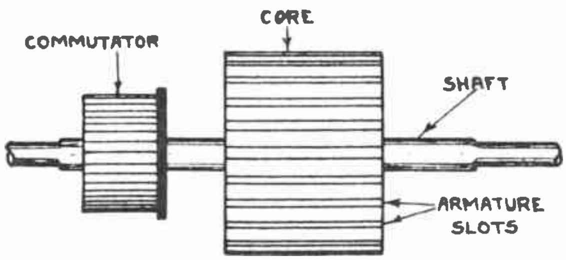


The brush holders support the brushes and hold them in the proper position on the commutator. The brushes should be spaced equi-distantly on the commutator when more than two sets of brushes are used. When only two sets are used they will be spaced the same distance as a pair of adjacent field poles.
The brush tension spring applies enough pressure on the brush to make a good electrical connection between the commutator and brush.

Brushes used on electrical machines are made of copper, graphite, carbon or a mixture of these materials. The purpose of the brushes is to complete the electrical connection between the line circuit and the armature winding.

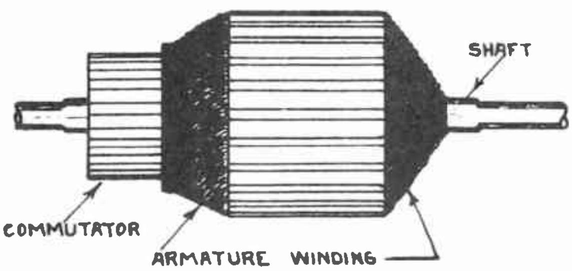


Commutators are constructed by placing copper bars or segments in a cylindrical form around the shaft. The copper bars are insulated from each other and from the shaft by mica insulation. An insulating compound is used instead of mica on small commutators. The commutator bars are soldered to and complete the connection between the armature coils.



The armature core is made of laminated iron (thin sheets) pressed tightly together. The laminated construction is used to prevent induced currents (eddy currents) from circulating in the iron core when the machine is in operation. The iron armature core is also a part of the magnetic circuit for the field, and has a number of slots around its entire surface, in which the armature coils are wound.

COMPLETE ARMATURE



The armature winding is a series of coils wound in the armature slots and the ends of the coils connect to the commutator bars. The number of turns and the size of wire is determined by the size speed and operating voltage of the machine. The purpose of the armature winding is to set up magnetic poles on the surface of the armature core.

The field windings are made in three different types: shunt, series and compound wound fields. Shunt fields have many turns of small wire and series fields have a few turns of heavy wire. The compound field is a combination of the two windings. The name of the field winding depends on the connection with respect to the armature winding. The purpose of the field winding is to produce magnetic poles that react with the armature poles to produce rotation.

Constant Speed D.C. MOTORS

Shunt and Compound Wound

APPLICATION AND PERFORMANCE DATA

Application—Most equipment which is built to operate on direct current can be successfully operated with constant speed motors. They are regularly furnished for all devices which, on alternating current, would be driven by split-phase or capacitor motors. Railroad and marine equipment, machine tools and control apparatus are a few of the many fields where these motors are often specified, even in preference to alternating current motors.

Bodine constant speed direct current motors are designed for use as companion motors to the split-phase units used on alternating current, and for general direct current operation. The frames are similar to those used on a-c, and are mechanically interchangeable with them. Ratings range from 1/70 to 1/6 hp at 1725 rpm but other ratings can also be furnished at standard speeds at 1125 and 3450 rpm.

Fig. 1—The Type NSH-54 motor. This is one of a number of D.C. motor frames.

Standard motors are built for operation on 115 or 230 volts, but motors for other voltages can be furnished to order. Bodine regularly supplies its customers with motors for 6, 12 and 32 volts, and for more unusual inputs as well. Large motors cannot be furnished for operation on very low voltages because of the physical limitations arising from the high currents which result.

Characteristics — The principal characteristics of shunt and compound wound constant speed motors are:

1. **Practically constant speed under load.** The speed varies from about 2000 rpm at no load to 1725 rpm at full load for a 1725 rpm motor. This is somewhat more than the variation of the usual alternating current motor, and the variation is somewhat greater for very small sizes, and less for the larger sizes.
2. **No racing or running away at no load.** Top speeds are but little above load speeds.
3. **Good starting torque.** Starting torque is approximately 150% of full load torque.
4. **Generally satisfactory communtation.** Brushes and springs have been carefully chosen, and the motor itself designed, for long brush life.
5. **Speed adjustability.** Through the use of suitable resistance the motor speed may be increased or decreased.

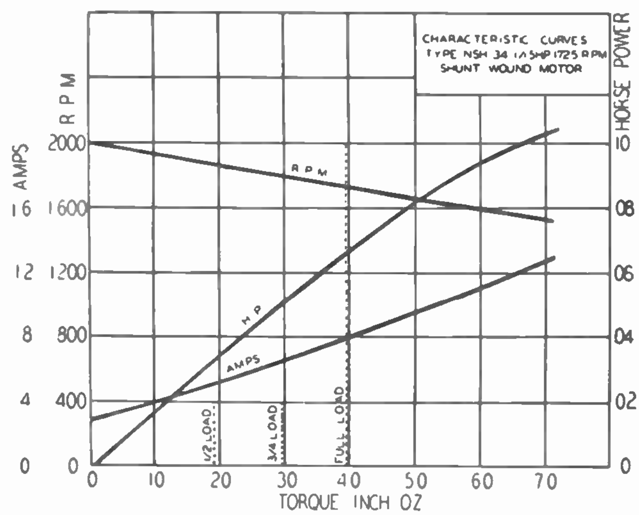


Fig. 2—Typical shunt wound motor performance curves.

CONSTANT SPEED D.C. MOTORS - Continued

6. Reversibility.

Motor connections may be interchanged for reverse rotation while the motor is either standing still or rotating.

Shunt and compound motors are the two principal types of d-c motors. They are very similar in construction and in performance. Characteristic curves for the shunt motor are shown in Fig. 2. The compound windings are generally used for the larger motors, and have a few series field turns in addition to the shunt winding to provide the higher starting torque needed, and lower the inrush current at starting.

A small change in speed with load (as compared with series motors, for example) is characteristic of these constant speed d-c motors. Since the no load speed is low, they are desirable for driving fluctuating loads, and will run relatively quiet under such conditions.

Much work has been done to determine the design factors necessary for long brush life and Bodine constant speed direct current motors will be found to have given an excellent account of themselves in this respect. There are, of course, certain adverse applications, such as those requiring frequent reversal or dynamic braking while the motor is running under load. Decreased brush life must sometimes be accepted under such conditions.

The speed of these motors may be adjusted through the use of suitable rheostats or resistances. If resistance is placed in the armature circuit, the motor speed will be decreased; if in the field circuit, it will be increased. Generally a change of speed approximately 50% above or below the rated motor speed may be secured by this means. If conditions are favorable and particularly if starting torque requirements are low, a wider range may be obtainable. For very wide speed ranges it is often better, however, to use a series motor. The constant speed d-c motor provides a speed which, at any setting of the rheostat, does not change widely with load. Speed changes with changes in load are characteristic of series motors, but not of shunt motors.

Construction—Constant speed d-c motors are available in a wide choice of frame sizes, and like all Bodine motors are designed for exacting applications. They will be found reliable as well as attractive in appearance.

The designer may secure sleeve or ball bearings for most frames. and many special modifications can be obtained at little expense, especially if a quantity of motors are needed.

The internal construction of Bodine d-c motors has been carefully designed to provide compactness without sacrifice of reliability. The field structure, of laminated steel, has two salient poles, around which the field coils are placed. The armature, rotating in diamond bored bearings, is connected through brushes and commutator, across the field as in the diagrams below.

The details of these parts, and of the other mechanical features, are completely covered in Bulletins describing the construction of each of the several frame types in which d-c motors are built.

Speed reducer motors are obtainable for all constant speed d-c motor frames. They afford the means of simplifying complicated power transmissions and eliminating belts, chains, and exposed gears.

(a) 4 LEAD REVERSIBLE SHUNT WOUND, Type NSH

(b) 5 LEAD REVERSIBLE COMPOUND WOUND Type NCO

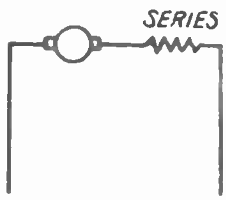
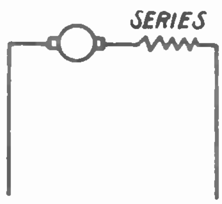
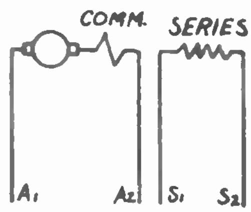
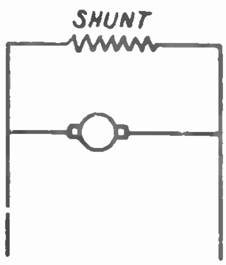
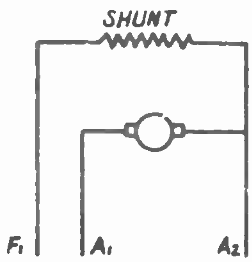
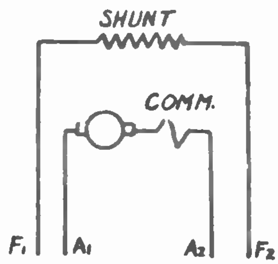
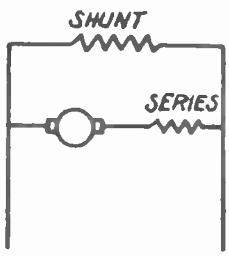
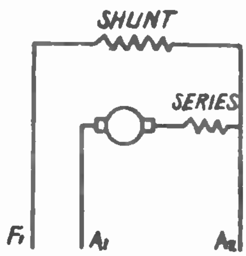
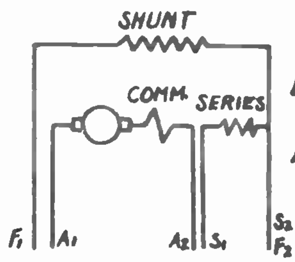
Fig. 3—Diagrams of connections for standard shunt and compound wound motors.

Century

ENGINEERING INFORMATION

CONNECTION DIAGRAMS FOR DIRECT CURRENT MOTORS

SINGLE VOLTAGE, REVERSIBLE, WITHOUT OVERLOAD PROTECTION

TYPE OF WINDING	TYPE DM 1/3 HP & SMALLER 60-70-80 FRAME, NO INTERPOLE	TYPE DM 1/2 & 3/4 HP, 70-80 FRAME, NO INTERPOLE	TYPE DN ANY HP, 90 & LARGER FRAMES WITH INTERPOLES	* - CONNECTIONS CCW (FACING END OPPOSITE SHAFT)	CW
SERIES	 FIG. 1	 FIG. 2	 FIG. 3	L_1 TO A_1 A_2 TO S_1 L_2 TO S_2	L_1 TO A_2 A_1 TO S_1 L_2 TO S_2
SHUNT	 FIG. 4	 FIG. 5	 FIG. 6	L_1 TO F_1; A_1 L_2 TO F_2; A_2	L_1 TO F_1; A_2 L_2 TO F_2; A_1
COMPOUND	 FIG. 7	 FIG. 8	 FIG. 9	L_1 TO F_1; A_1 A_2 TO S_1 L_2 TO S_2F_2	L_1 TO F_1; A_2 A_1 TO S_1 L_2 TO S_2F_2

TO REVERSE ROTATION INTERCHANGE LEADS AT BRUSH HOLDER; STANDARD ROTATION IS C.C.W. FACING END OPPOSITE SHAFT

TAG 882-A IS FURNISHED WITH THESE MOTORS.

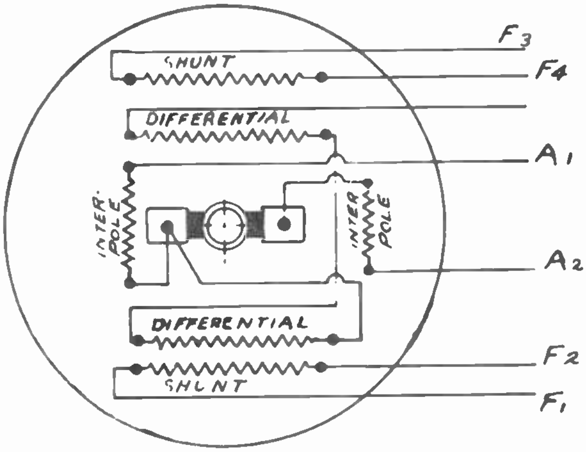
* - CONTROL NOT COVERED - CONSULT CONTROL MANUFACTURERS DIAGRAMS.

TAG 882-A AND CONNECTION DIAGRAM IS FURNISHED WITH THESE MOTORS.

Revisions	Material	Pat. Mld. Die	V-5835197
	Drawn By TEdoll		EXTERNAL DIAGRAM
	Inspected Hern. hrung		First Made For BC GENERATOR

First Called For On CPRW-740834-89

Prints To: B8, B44(2), B45, B57, B74:2



THIRD ANGLE PROJECTION V

GENERAL ELECTRIC FORT WAYNE WORKS

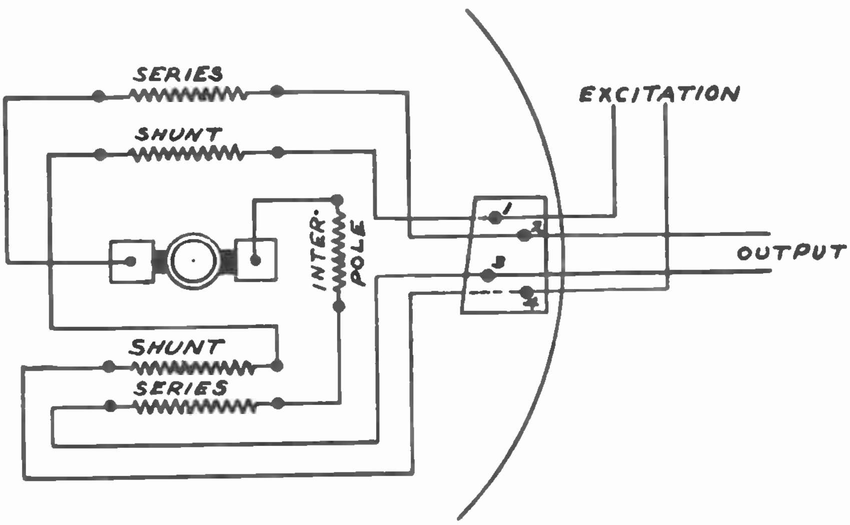
V-5835197

Revisions	Material	Pat. Mld. Die	V-5837239
	Drawn By TEdoll		EXTERNAL DIAGRAM
	Inspected [illegible]		First Made For BC MOTORS- (CUMULATIVE COMPOUND GEN.)

First Called For On STL-84280

Prints To: B8, B44:2, B45, B57, B14:2

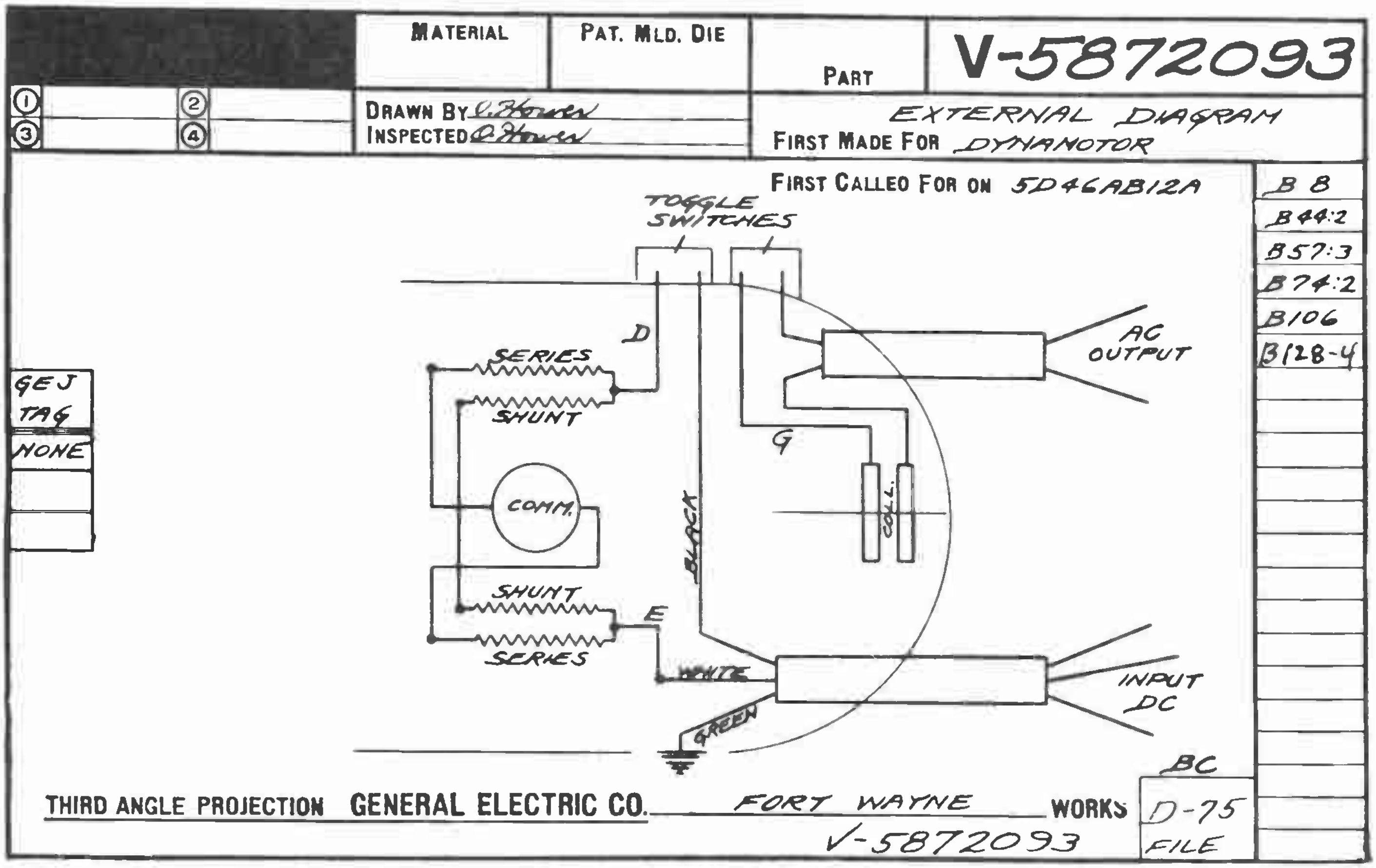
G.E.J. TAG NONE

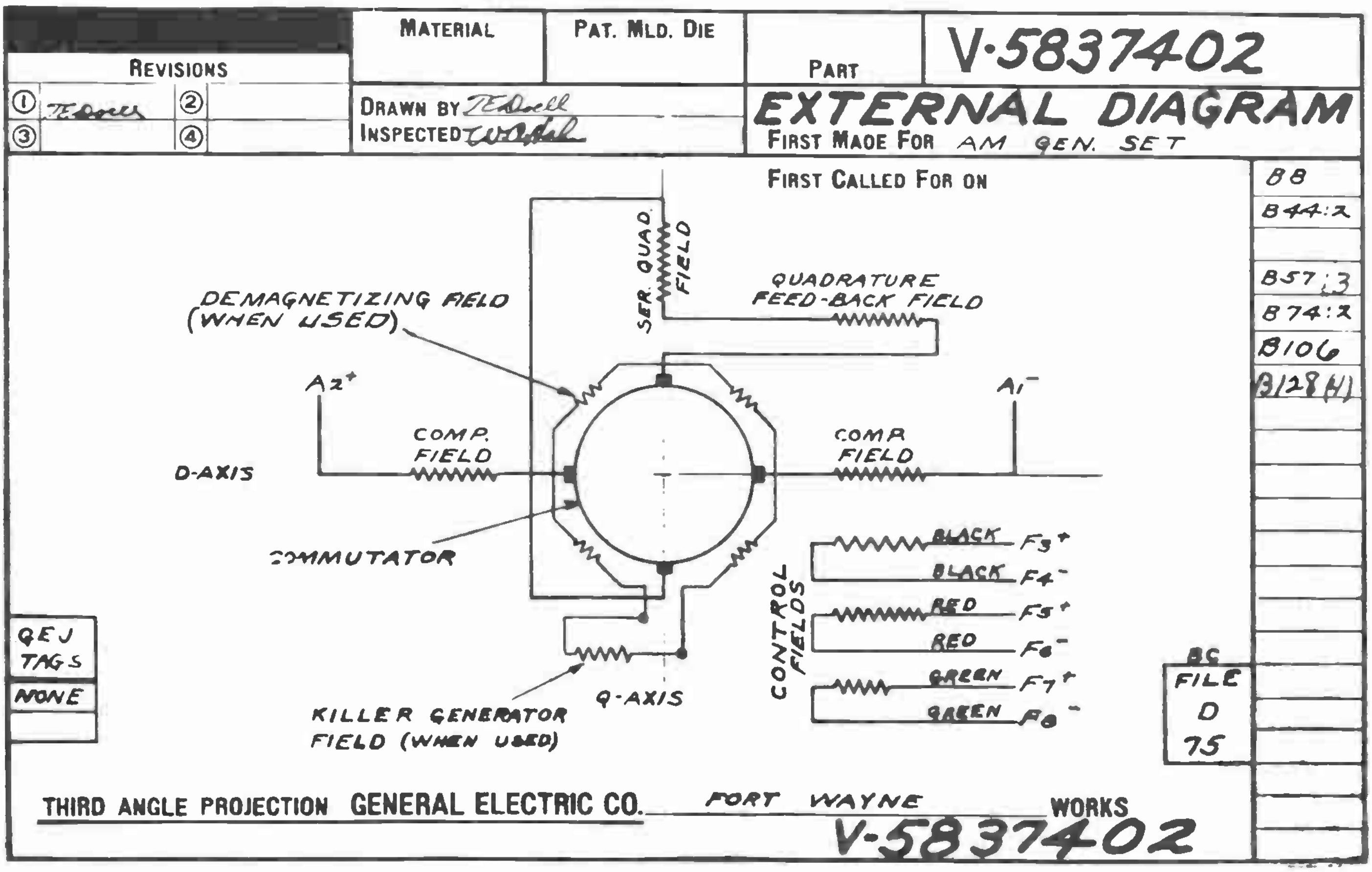


THIRD ANGLE PROJECTION V

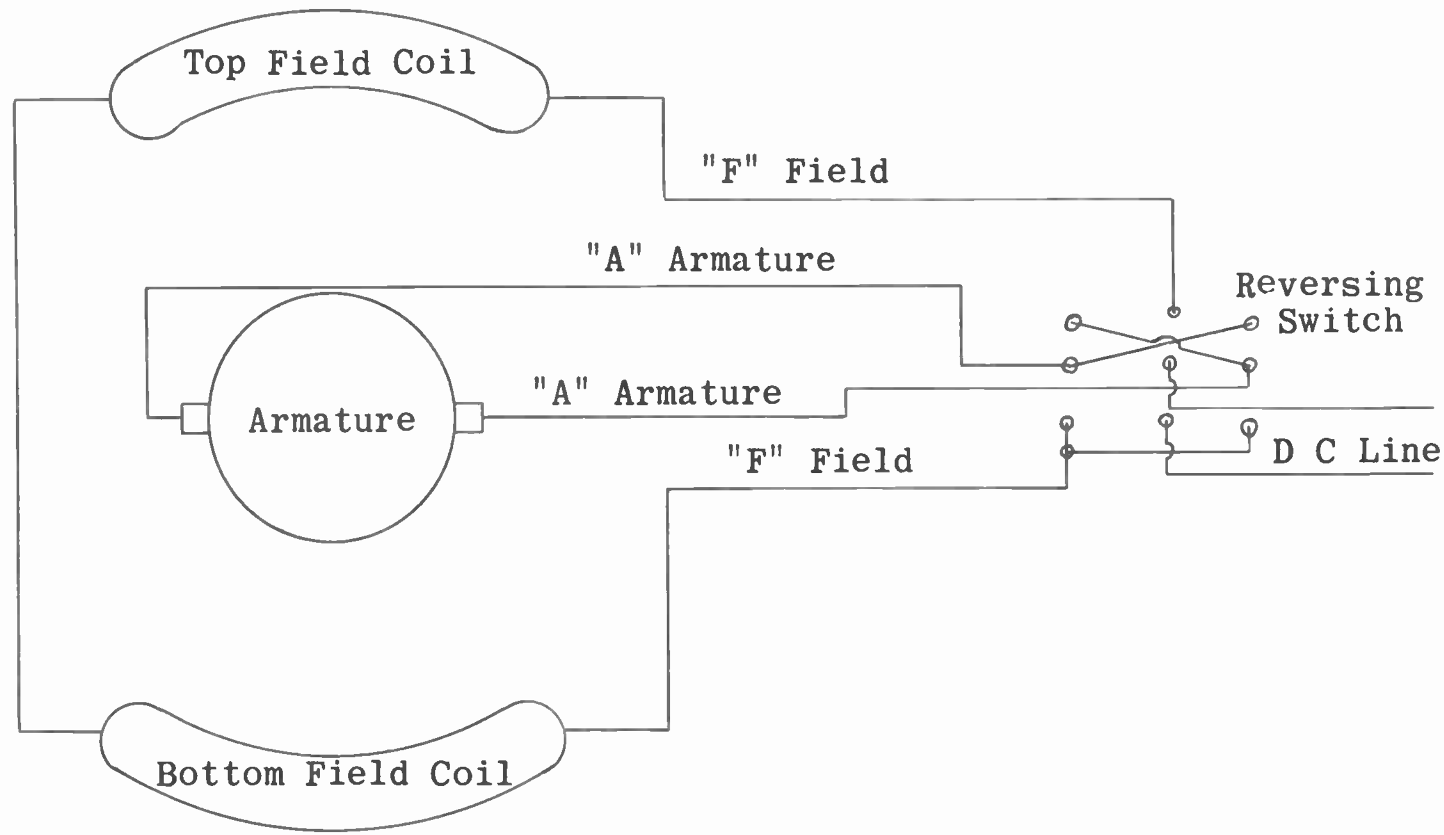
GENERAL ELECTRIC FORT WAYNE WORKS

V-5837239


MATERIAL
PAT. MLD. DIE
PART
V-5872093
DRAWN BY
INSPECTED
EXTERNAL DIAGRAM
FIRST MADE FOR DYNAMOTOR
FIRST CALLED FOR ON 5D46AB12A
B 8
B44:2
B57:3
B74:2
B106
B128-4
TOGGLE SWITCHES
D
SERIES
SHUNT
COMM.
SHUNT
SERIES
E
BLACK
WHITE
GREEN
G
COLL.
AC OUTPUT
INPUT DC
GEJ TAG
NONE
BC
THIRD ANGLE PROJECTION GENERAL ELECTRIC CO. FORT WAYNE WORKS
D-75
FILE
V-5872093


MATERIAL
PAT. MLD. DIE
PART
V-5837402
REVISIONS
DRAWN BY
INSPECTED
EXTERNAL DIAGRAM
FIRST MADE FOR AM GEN. SET
FIRST CALLED FOR ON
B8
B44:2
B57:3
B74:2
B106
B128(4)
SER. QUAD. FIELD
QUADRATURE FEED-BACK FIELD
DEMAGNETIZING FIELD (WHEN USED)
A2+
A1−
COMP. FIELD
COMP. FIELD
D-AXIS
COMMUTATOR
CONTROL FIELDS
BLACK F3+
BLACK F4−
RED F5+
RED F6−
GREEN F7+
GREEN F8−
Q-AXIS
KILLER GENERATOR FIELD (WHEN USED)
GEJ TAGS
NONE
BC
FILE
D
75
THIRD ANGLE PROJECTION GENERAL ELECTRIC CO. FORT WAYNE WORKS
V-5837402

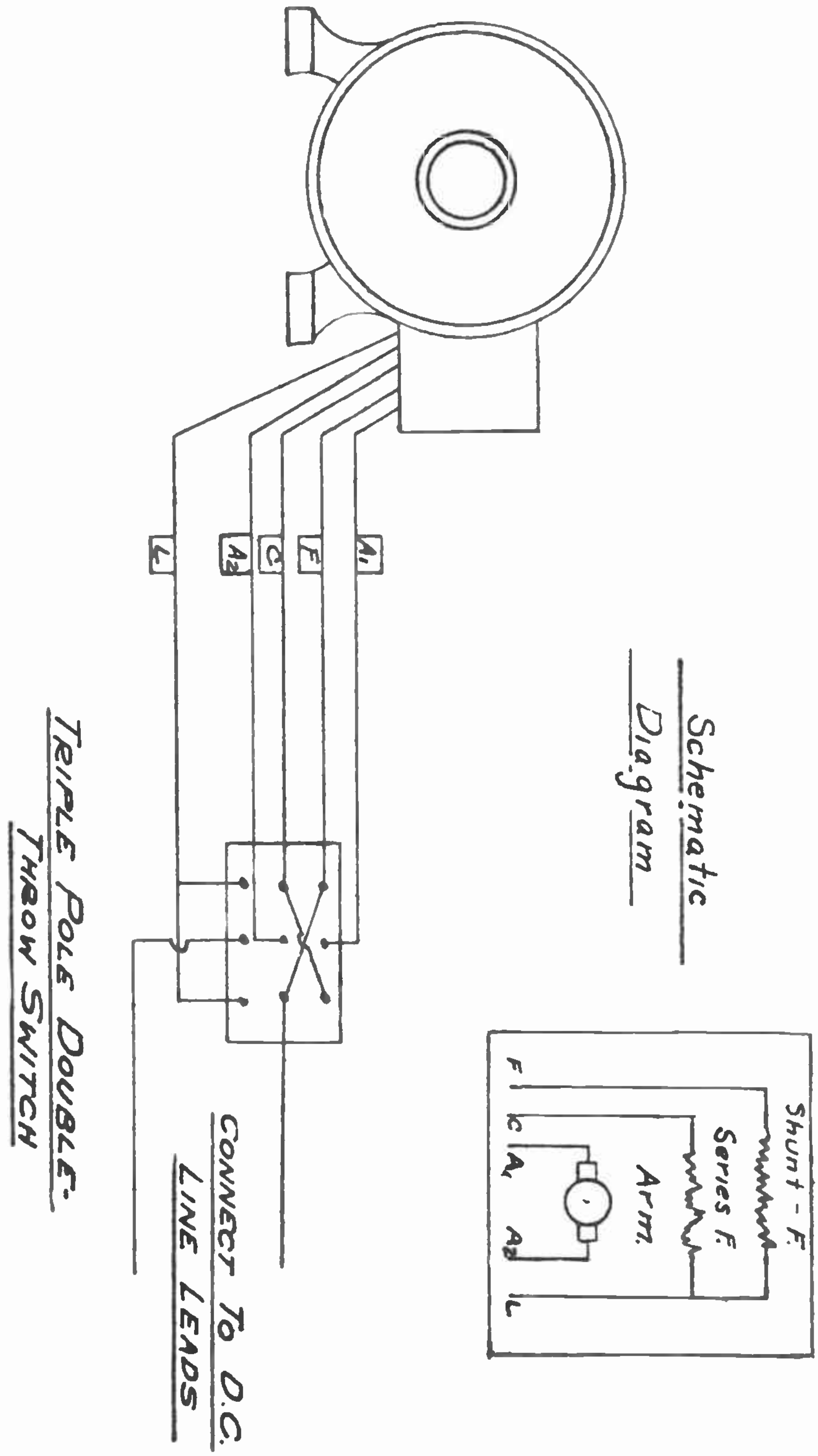
CONNECTIONS - 4 Wire Reversing Series Motor



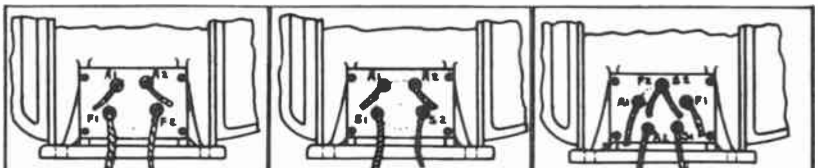
Janette Mfg.Co.
Chicago, Ill.

WIRING DIAGRAM OF D-C COMPOUND WOUND MOTOR
WITH REVERSING SWITCH

JANETTE MFG. CO.



TERMINAL MARKING & CONNECTIONS



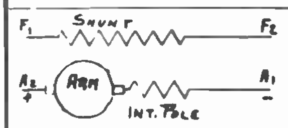
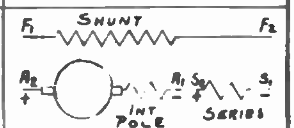
Shunt	Series	Compound
Counter Clockwise Rotation, A1-F1 To One Side Of Line, A2-F2 To Other Side Of Line.	Counter Clockwise Rotation, A1 To One Side Of Line, S2 To Other Side Of Line. A2-S1 Jumped Together.	Counter Clockwise Rotation. A1-F1 To One Side Of Line, F2-S2 To Other Side Of Line. A2-S1 Jumped Together.
Clockwise Rotation A2-F1 To One Side Of Line A1-F2 To Other Side Of Line	Clockwise Rotation A2 To One Side Of Line S2 To Other Side Of Line A1-S1 Jumped Together.	Clockwise Rotation A2-F1 To One Side Of Line F2-S2 To Other Side Of Line A1-S1 Jumped Together.

Caution! Check Brushes In Holder To Insure They Do Not Bind Or Stick In Holders. Note Three Marks On Brush Holder Yoke ≡—And One Mark On End Shield On All Non Inter Pole Motors. Shift Yoke To Corresponding Mark When Changing Rotation.

Top Line ≡— Clockwise	Center Line ≡— Neutral or Reversible	Bottom Line ≡— Counter Clockwise

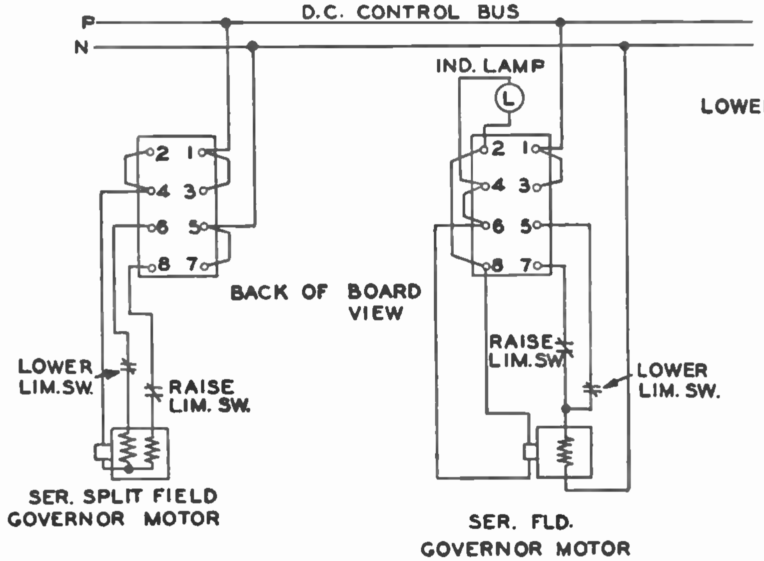
D.C. MOTORS

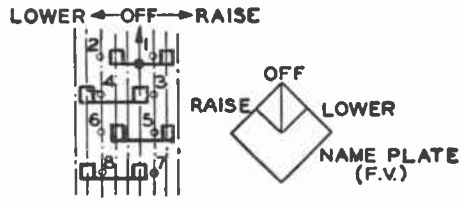
D.C. GENERATORS (Two Wire)

Shunt Wound.	Compound Wound.
	
Clockwise Rotation (Standard)	
A_2-For one side of line. F_1-Through rheostat to A_2. A_1 & F_2-For other side of line.	A_2-For one side of line. F_1-Through rheostat to A_2. F_2, A_1 & S_2-Jumped together. S_1-For other side of line.
Counter-clockwise Rotation.	
A_1-For one side of line. F_1-Through rheostat to A_1. A_2 & F_2-For other side of line.	A_1-For one side of line. F_1-Through rheostat to A_1. F_2, A_2 & S_2-Jumped together. S_1-For other side of line.

NOTE-Commutating Pole Machines, have the brushes set on neutral and pinned in place. Brushes should never be shifted away from neutral. Non-commutating Pole Machines have three marks on the brush yoke and one on the end shield. When changing direction of rotation shift yoke to corresponding mark as shown below.

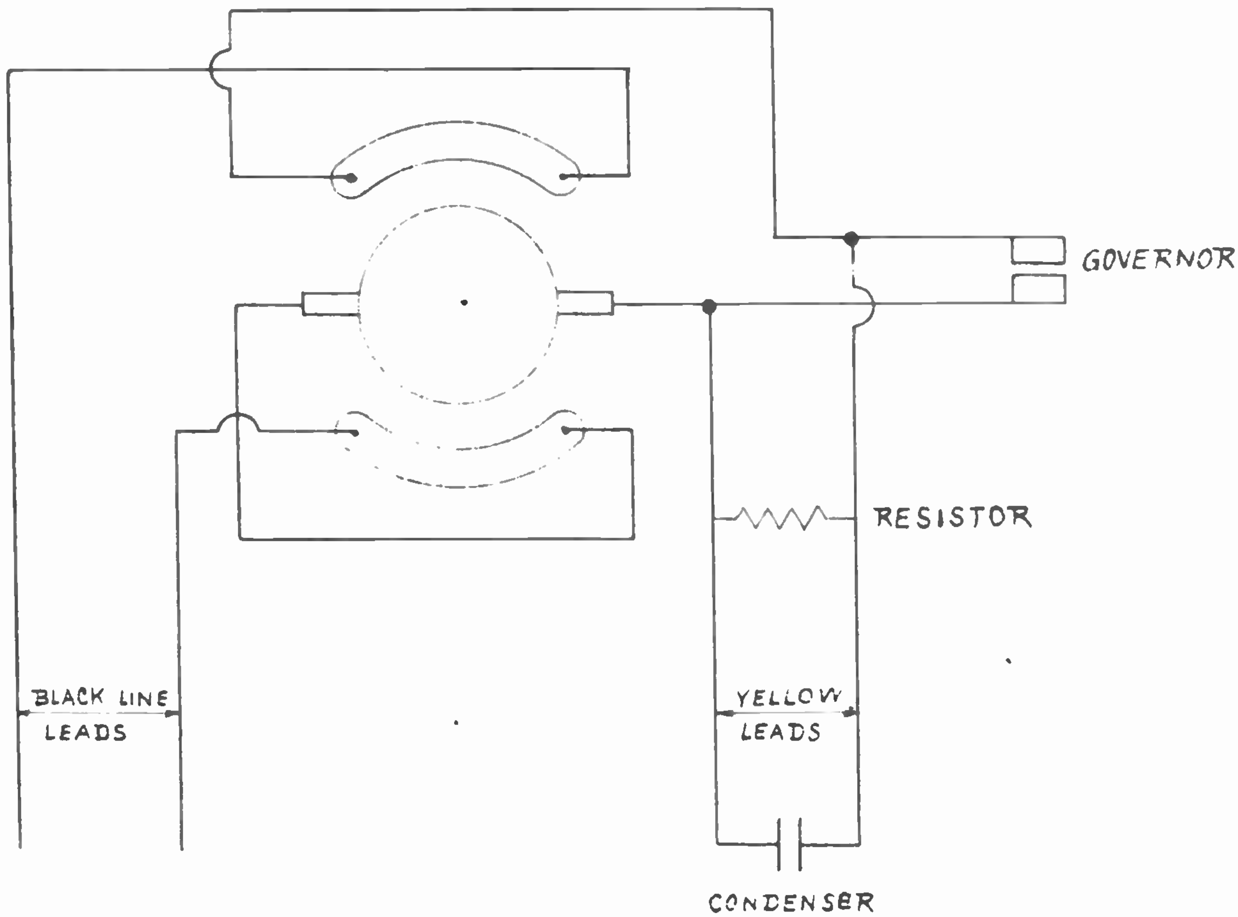
GOVERNOR MOTOR SPEED CONTROL SWITCH - ALLIS-CHALMERS TYPE 153 ROTARY





CONTACTS	POSITIONS		
	RAISE	OFF	LOWER
1-2			X
3-4	X		
5-6			X
7-8	X		

DRUM DEVELOPMENT
(SPRING RETURN)



SERIES WOUND MOTOR - GOVERNOR SPEED CONTROL
WISCONSIN ELECTRIC CO., RACINE, WIS.

AMERICAN STANDARD

3.2 D-c MOTORS

3.205 Connections and Terminal Markings—D-c Motors, Shunt-Wound

Standard direction of shaft rotation for non-reversing motors is counter-clockwise facing the end opposite the drive.

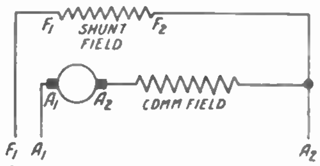


FIG. 1 NON-REVERSING COMMUTATING-POLE TYPE

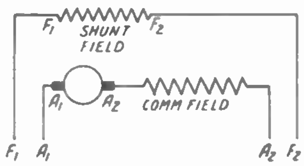


FIG. 2 REVERSING COMMUTATINC-POLE TYPE

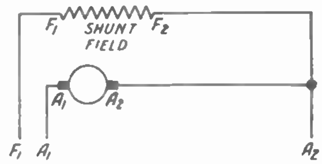


FIG 3 NON-REVERSING NON-COMMUTATING-POLE TYPE

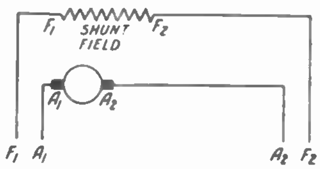


FIG. 4 REVERSING NON-COMMUTATING-POLE TYPE

NOTE I—See 1.510 for terminal letters assigned to different types of windings, and 1.130 for the significance of the subscript numerals.

NOTE II—Connections shown in these diagrams will give standard counter-clockwise shaft rotation facing the end opposite the drive. To obtain clockwise shaft rotation the armature or main field leads must be reversed.

NOTE III—Commutating field windings are shown on the A_2 side of the armature, but this location, while preferred, is not standardized. If sound engineering, sound economics or convenience so dictates, this winding may be connected in on either side of the armature or may be divided part on one side and part on the other.

3.210 Connections and Terminal Markings—D-c Motors, Series-Wound

Standard direction of shaft rotation for non-reversing motors is counter-clockwise facing the end opposite the drive.

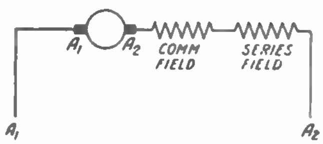


FIG. 1 NON-REVERSING COMMUTATING-POLE TYPE

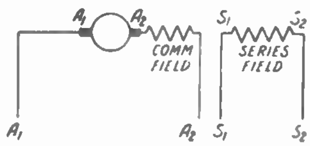


FIG 2 REVERSING COMMUTATING-POLE TYPE

FIG 3 NON-REVERSING NON-COMMUTATING-POLE TYPE

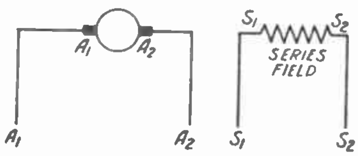


FIG. 4 REVERSING NON-COMMUTATING-POLE TYPE

NOTE I—See 1.510 for terminal letters assigned to different types of windings, and 1.130 for the significance of the subscript numerals.

NOTE II—Connections shown in these diagrams will give standard counter-clockwise shaft rotation facing the end opposite the drive. To obtain clockwise shaft rotation the armature or main field leads must be reversed.

NOTE III—Commutating and series field windings are shown on the A_2 side of the armature, but this location, while preferred, is not standardized. If sound engineering, sound economics or convenience so dictates, these windings may be connected on either side of the armature or may be divided part on one side and part on the other.

3.215 Connections and Terminal Markings—D-c Motors, Compound-Wound

Standard direction of shaft rotation for non-reversing motors is counter-clockwise facing the end opposite the drive.

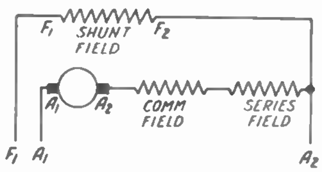


FIG 1 NON-REVERSING COMMUTATING-POLE TYPE

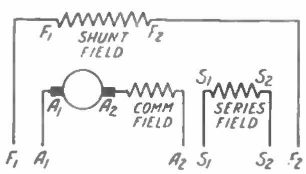


FIG. 2 REVERSING COMMUTATING-POLE TYPE

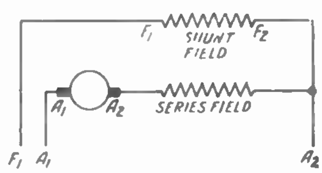


FIG 3 NON-REVERSING NON-COMMUTATING POLE TYPE

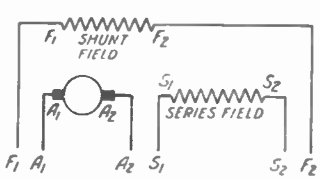


FIG 4 REVERSING NON-COMMUTATING-POLE TYPE

NOTE I—See 1.510 for terminal letters assigned to different types of windings, and 1.130 for the significance of the subscript numerals.

NOTE II—Connections shown in these diagrams will give standard counter-clockwise shaft rotation facing the end opposite the drive. To obtain clockwise shaft rotation the armature or main field leads must be reversed.

NOTE III—Commutating and series field windings are shown on the A_2 side of the armature but this location, while preferred, is not standardized. If sound engineering, sound economics or convenience so dictates, these windings may be connected on either side of the armature or may be divided part on one side and part on the other.

NOTE IV—For differential connection of the series fields no change should be made on the field leads or terminal markings on the machine, but the connection of the series field to the armature should be shown reversed.

LAP WINDING AND ARMATURE CONNECTIONS

An armature winding is an electro-magnet having a number of coils connected to commutator bars. There must be at least one start and one finish lead connected to each commutator bar. There are two types of armature windings, LAP & WAVE wound. The coil leads of a lap wound armature connects to commutator bars that are near each other and the coil leads of a wave wound armature connects to commutator bars that are widely separated. See Fig. 1 & 2.

When current flows through the coil in a clockwise direction a south pole will be produced on the surface of the armature. Fig. 3. If the current flows in a counter clockwise direction a north pole will be produced on the surface of the armature. Fig. 4. A large number of coils are used to produce a strong magnetic pole and a smoother twisting action.

FIG. 1

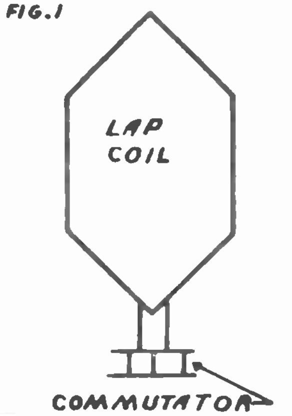


FIG. 2

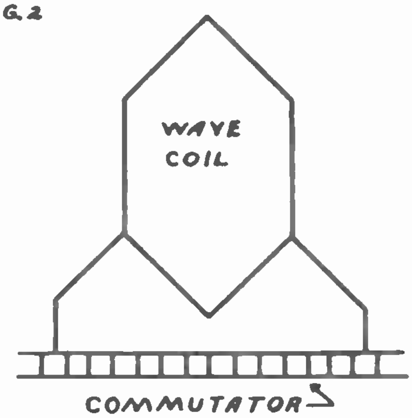


FIG. 3

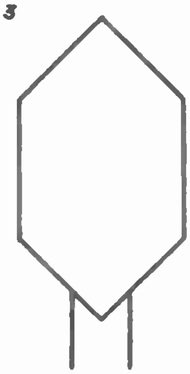
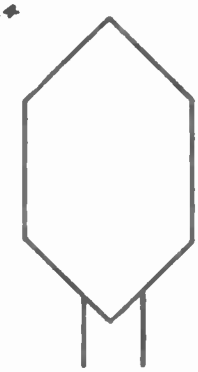


FIG. 4



ARMATURE WINDING CONNECTIONS

Although there are only two types of D.C. armature windings there are a number of winding connections that apply to either a lap or a wave wound armature.

SYMMETRICAL & NON-SYMMETRICAL CONNECTIONS. If the coil leads connect to commutator bars that are on a line with the center of the coil the connection is symmetrical. Fig. 5. If the coil leads connect to commutator bars that are not on a line with the center of the coil the connection is non-symmetrical. Fig. 6.

The brushes must always short the coil when it is in the neutral plane which means that the brushes be located on a line with the center of the field pole if the coil is connected symmetrical and located between the field poles if connected non-symmetrical.

FIG. 5 SYMMETRICAL

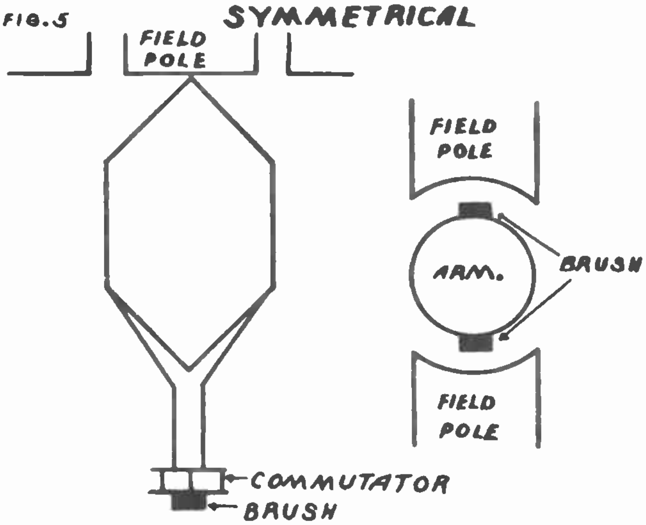
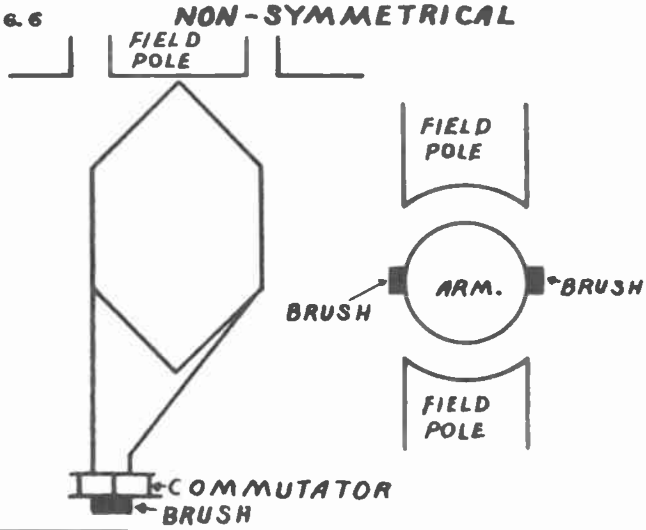


FIG. 6 NON-SYMMETRICAL



LAP WINDING AND ARMATURE CONNECTIONS (CONTINUED)

PROGRESSIVE & RETROGRESSIVE CONNECTIONS. If the start and finish leads of a coil, or the element of a coil, do not cross the connection is known as progressive. Fig. 7. If the start and finish leads of a coil, or the element of a coil, cross the winding is connected retrogressive. Fig. 8.

If a winding is changed from progressive to retrogressive, or vise versa, the effect will be reversed rotation on a motor and reversed brush polarity on a generator. Lap wound armatures are usually connected progressive and wave wound armatures retrogressive.

FIG. 7 PROGRESSIVE

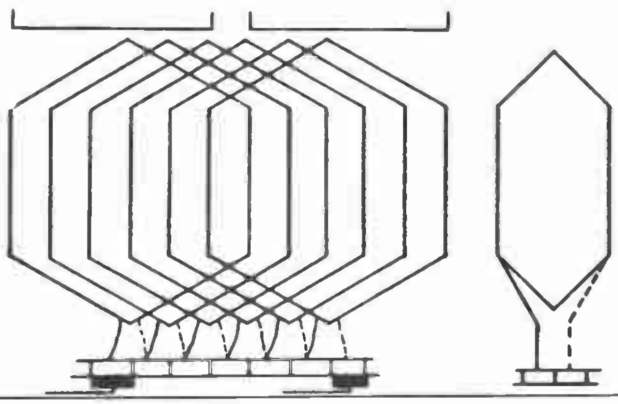
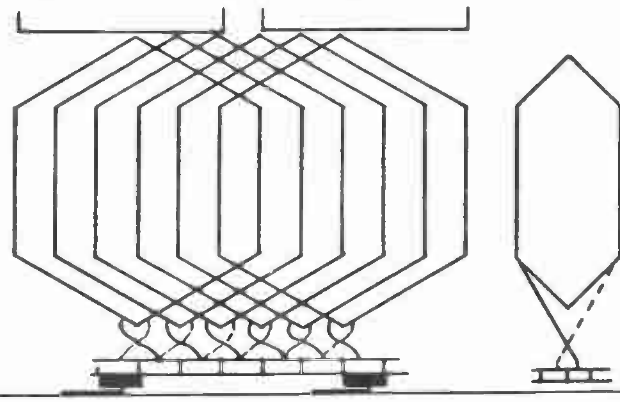


FIG. 8 RETROGRESSIVE



ELEMENT WINDINGS are used to reduce the voltage across adjacent commutator bars and decrease the tendency of brush sparking. Example - An armature has 30 turns per coil and the voltage per turn is 1 volt or 30 E per coil. If the coil were wound in one section and connected to adjacent commutator bars the voltage across the bars will be 30 E. Such a coil would have one start and one finish lead and there would be as many bars as slots. This would be a single element winding. Fig. 9.

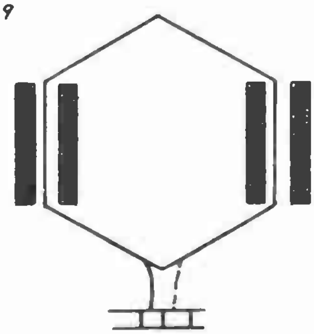
If this coil were divided in two sections (15 turns per section) and each section connected to adjacent bars the voltage across adjacent bars would be 15 E. Such a coil would have two start and two finish leads and there would be twice as many bars as slots. This would be known as a two element winding. Fig. 10.

If the coil were divided in three sections (10 turns per section) and each section connected to adjacent bars the voltage across adjacent bars would be 10 E. Such a coil would have three start and three finish leads and there would be three times as many bars as slots. This would be known as a three element winding. Fig. 11.

Element windings are particularly desirable for high voltage machines. The practical limit is usually three or four elements.

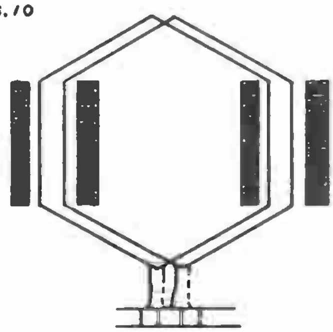
SINGLE ELEMENT

FIG. 9



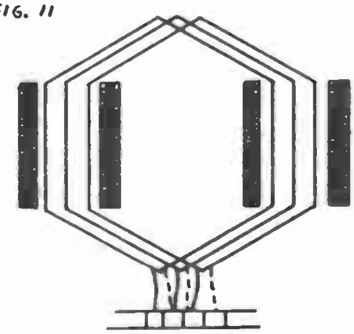
TWO ELEMENT

FIG. 10



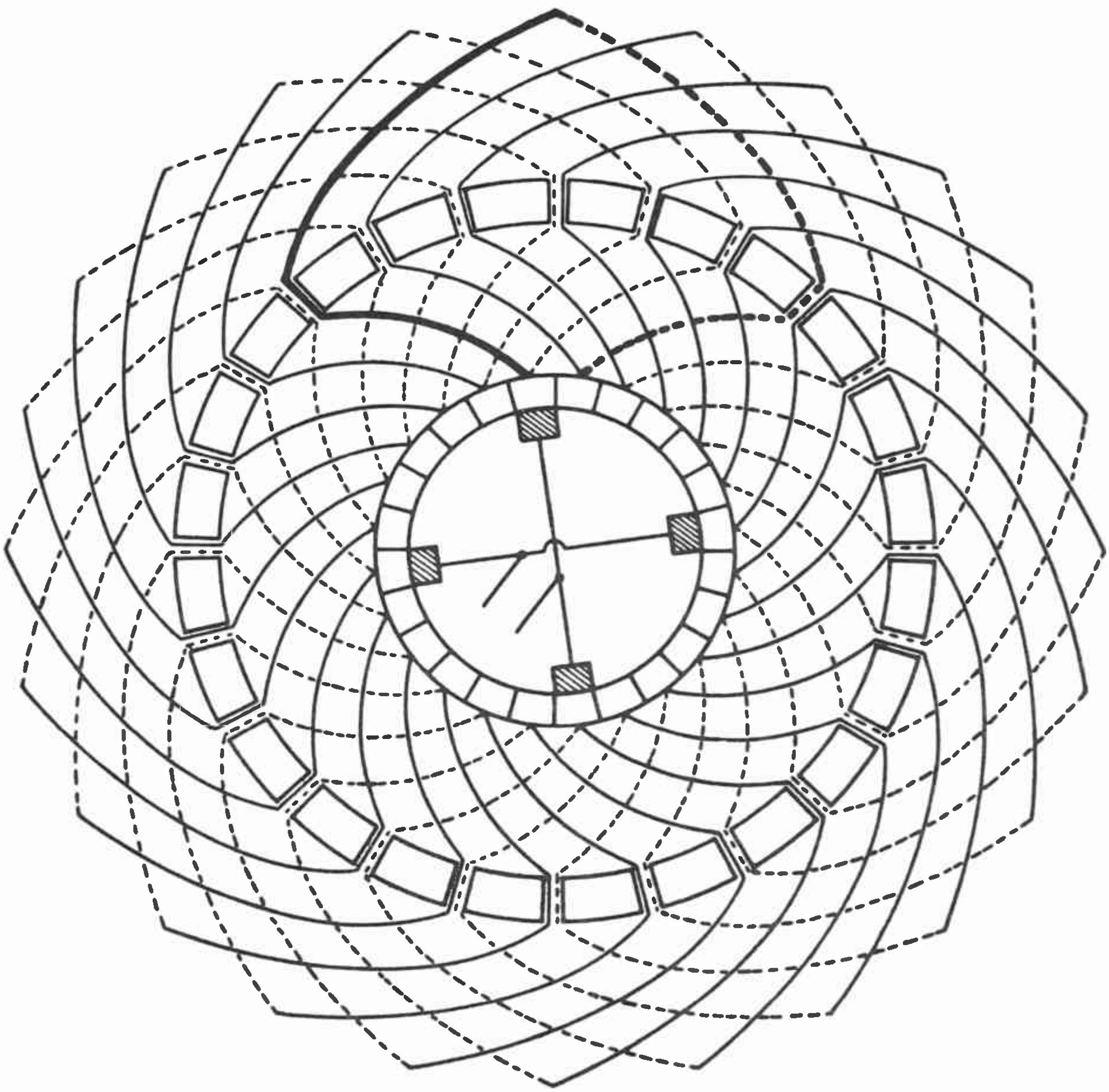
THREE ELEMENT

FIG. 11



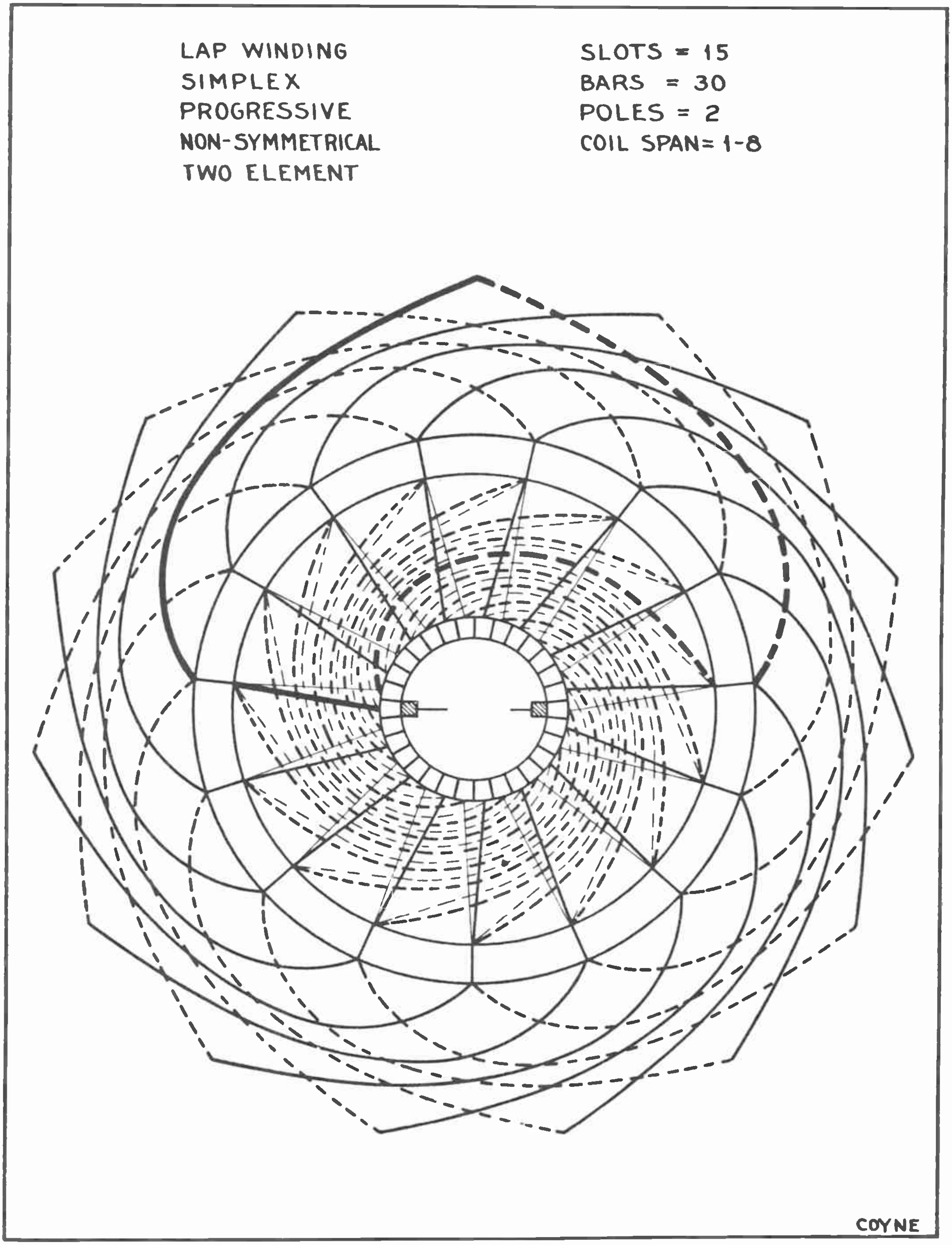
LAP WINDING
SIMPLEX
PROGRESSIVE
SYMMETRICAL
SINGLE ELEMENT

SLOTS = 24
BARS = 24
POLES = 4
COIL SPAN = 1-7



COIL SPAN = THE NEXT WHOLE NUMBER ABOVE SLOTS ÷ POLES

COYNE


LAP WINDING
SIMPLEX
PROGRESSIVE
NON-SYMMETRICAL
TWO ELEMENT
SLOTS = 15
BARS = 30
POLES = 2
COIL SPAN= 1-8
COYNE

PRINCIPLES OF LAP AND WAVE WINDINGS

The lap winding is usually used on a circuit where the operating voltage is 220 E or less in value. This type of winding is desirable for general factory work. It is possible to design an armature for a higher ampere capacity by having it lap wound. The higher ampere capacity is obtained because there will be a greater number of parallel paths in the armature which increases its ability to carry current.

Fig. 1

SECTION OF A 4 POLE PROGRESSIVE LAP WINDING.

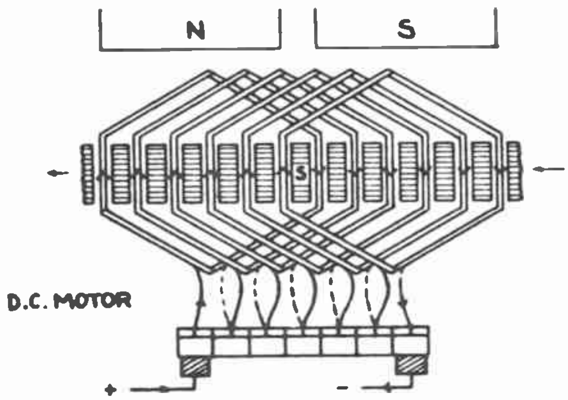
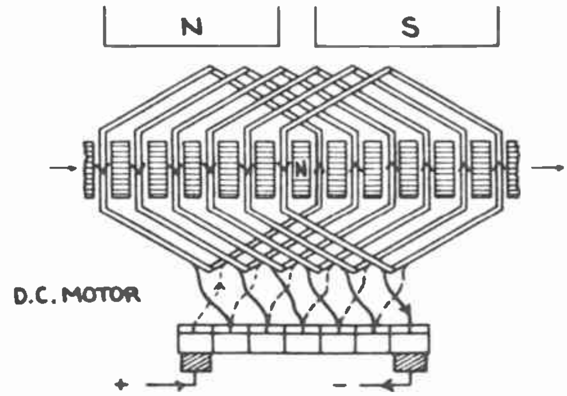


Fig. 2

SECTION OF A 4 POLE RETROGRESSIVE LAP WINDING.



The name wave wound is derived from the way the current circulates or waves through the armature. The wave type winding is usually used on a circuit where the operating voltage is 250 E or more in value. This type winding is desirable for traction work, steel mills & mine work. It is possible to design an armature for a higher operating voltage by having it wave wound. The higher operating voltage is obtained because there will be a greater number of armature coils in series between the brushes which increases the operating voltage.

Fig. 3

4 pole progressive wave winding.

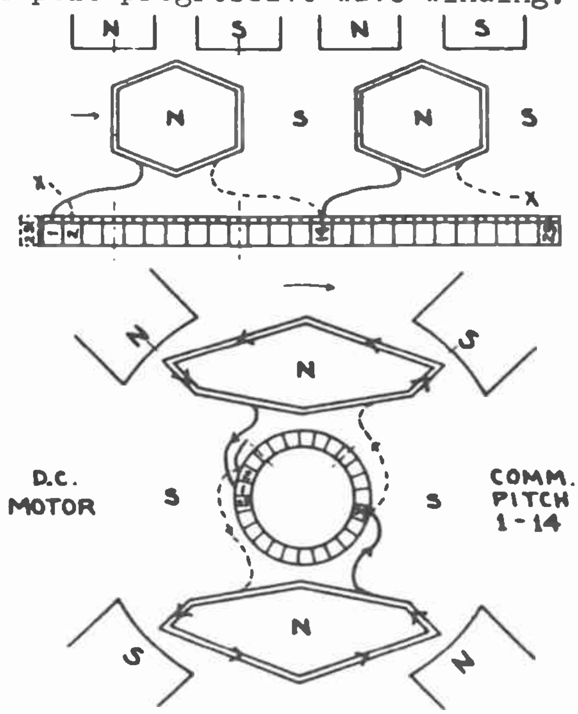
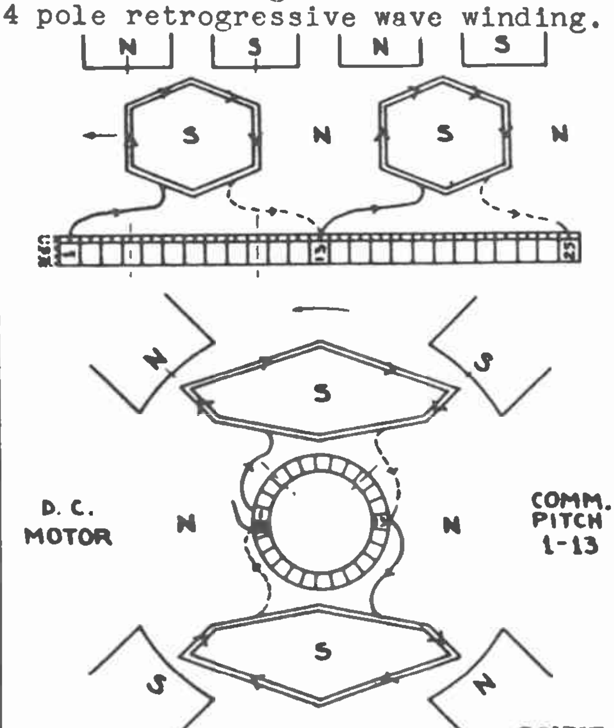
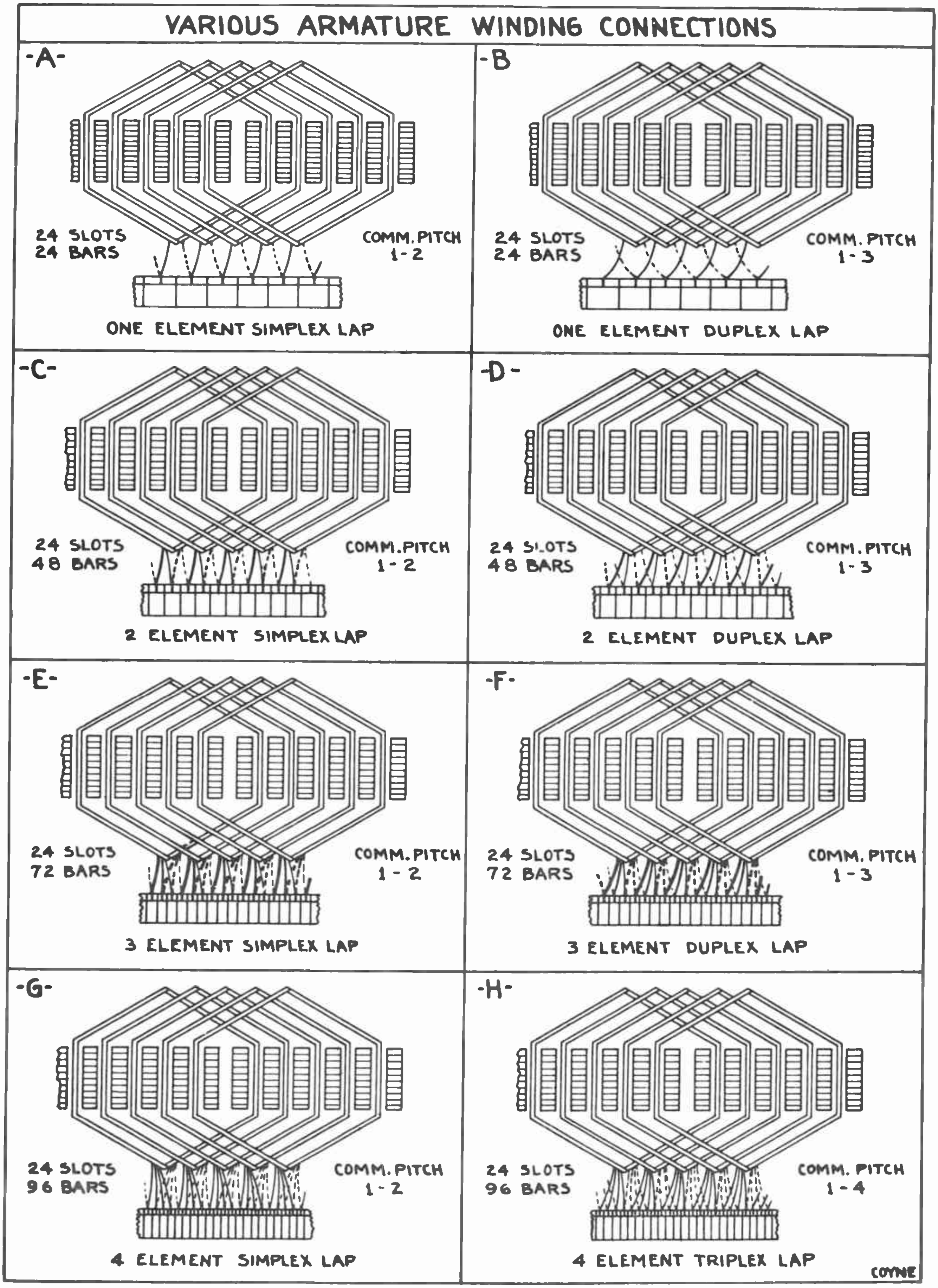


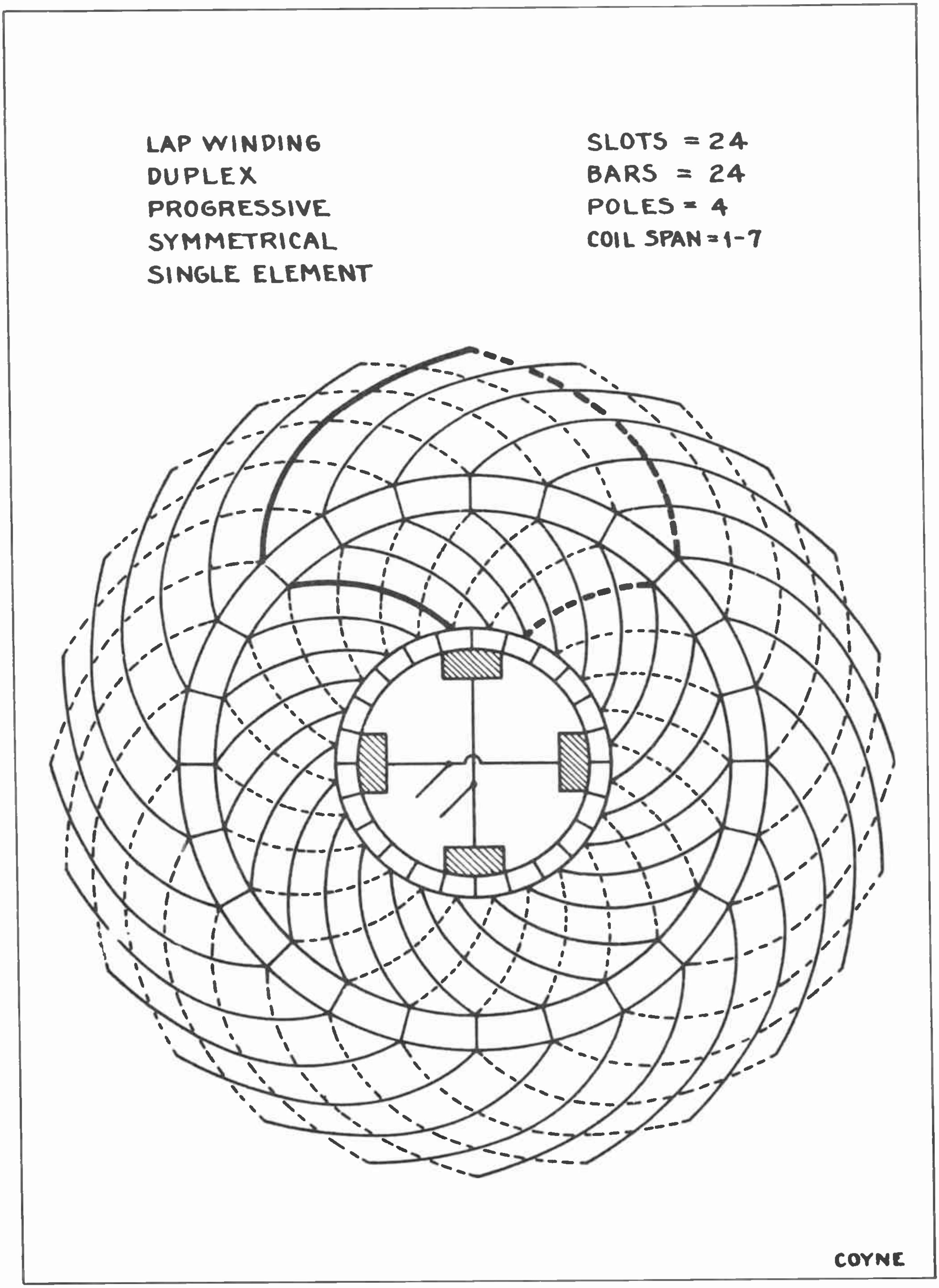
Fig. 4

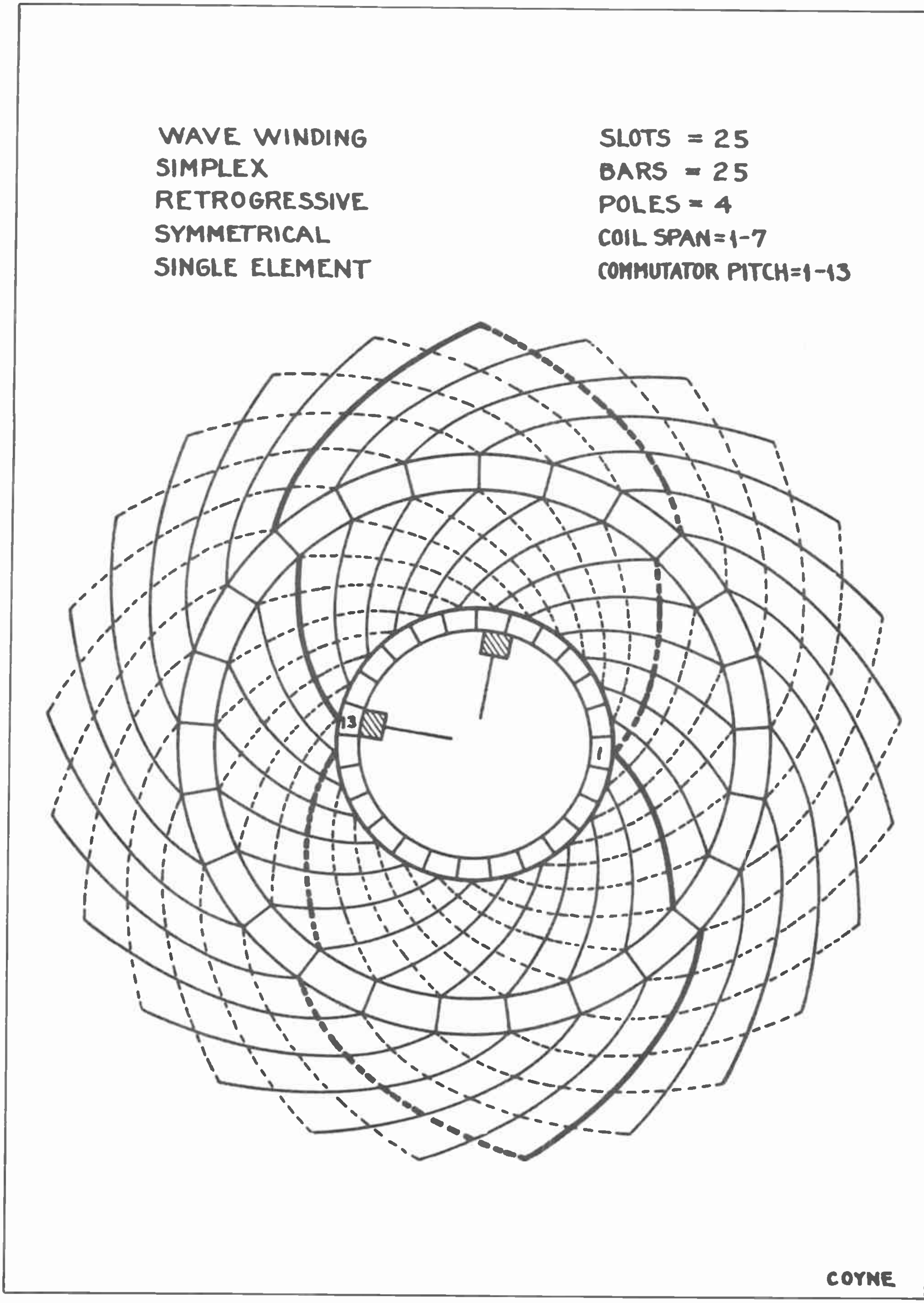
4 pole retrogressive wave winding.

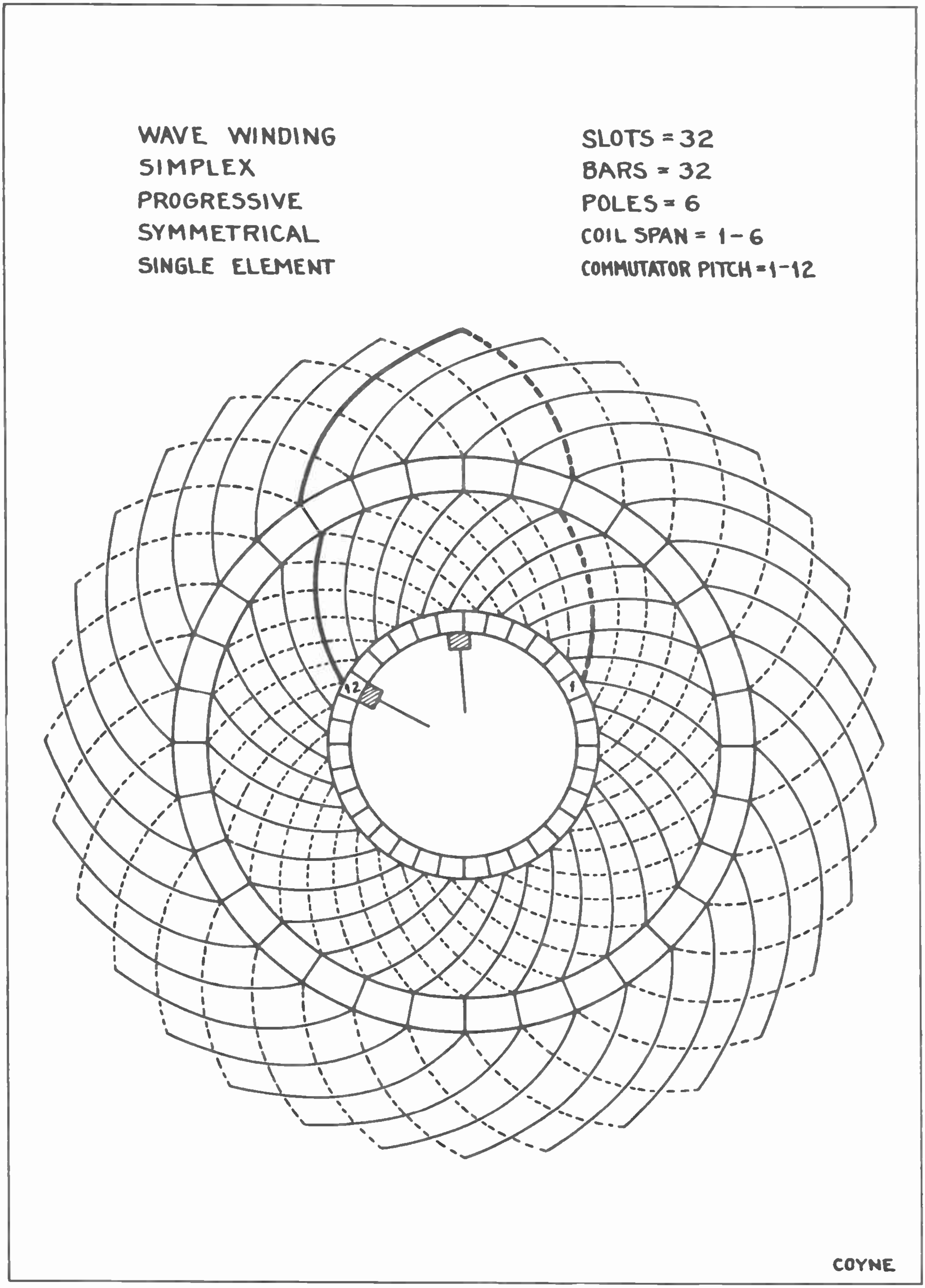


COYNE


VARIOUS ARMATURE WINDING CONNECTIONS
-A-
24 SLOTS
24 BARS
COMM. PITCH
1 - 2
ONE ELEMENT SIMPLEX LAP
-B
24 SLOTS
24 BARS
COMM. PITCH
1 - 3
ONE ELEMENT DUPLEX LAP
-C-
24 SLOTS
48 BARS
COMM. PITCH
1 - 2
2 ELEMENT SIMPLEX LAP
-D-
24 SLOTS
48 BARS
COMM. PITCH
1 - 3
2 ELEMENT DUPLEX LAP
-E-
24 SLOTS
72 BARS
COMM. PITCH
1 - 2
3 ELEMENT SIMPLEX LAP
-F-
24 SLOTS
72 BARS
COMM. PITCH
1 - 3
3 ELEMENT DUPLEX LAP
-G-
24 SLOTS
96 BARS
COMM. PITCH
1 - 2
4 ELEMENT SIMPLEX LAP
-H-
24 SLOTS
96 BARS
COMM. PITCH
1 - 4
4 ELEMENT TRIPLEX LAP
COYNE

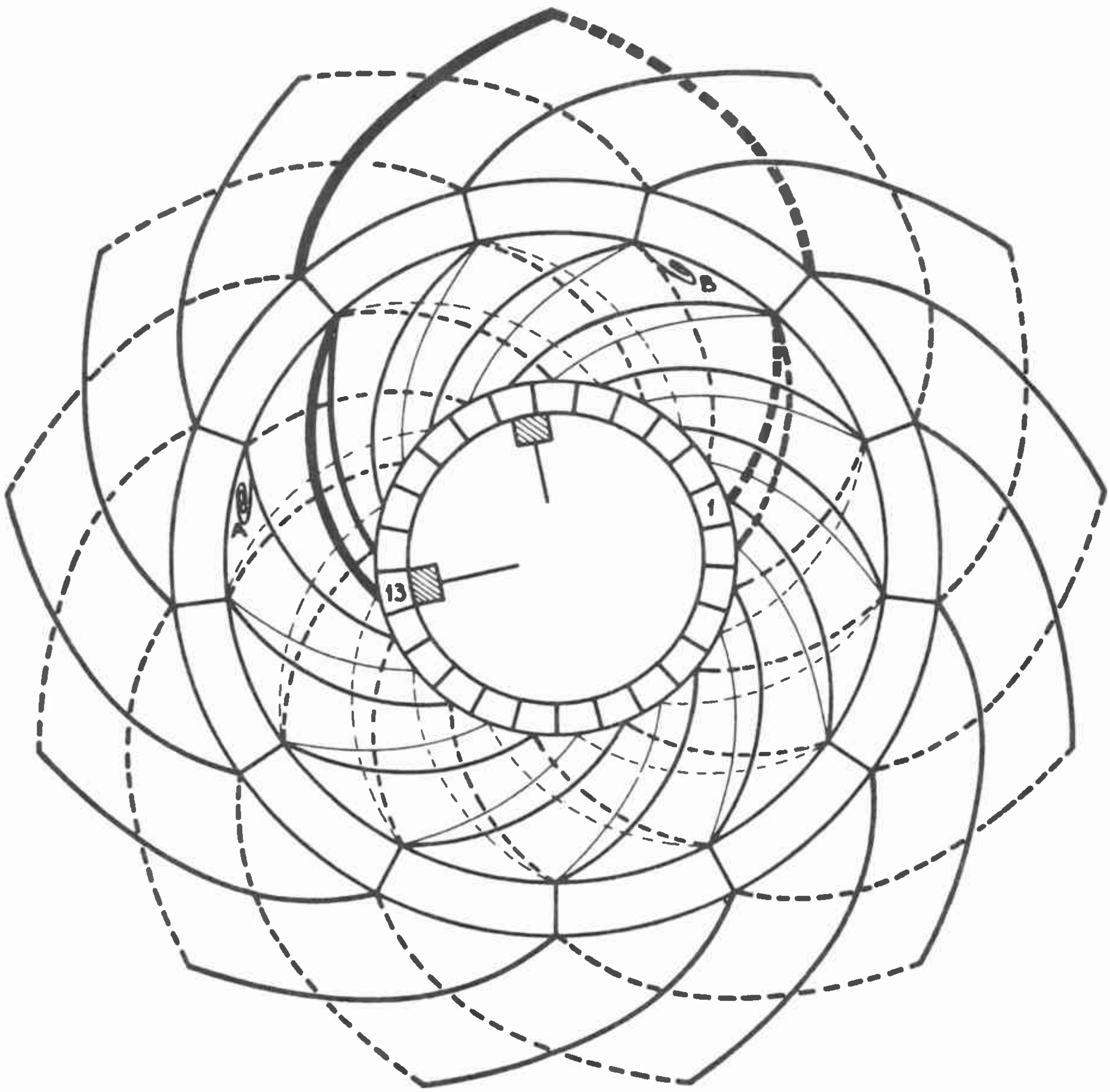

LAP WINDING
DUPLEX
PROGRESSIVE
SYMMETRICAL
SINGLE ELEMENT
SLOTS = 24
BARS = 24
POLES = 4
COIL SPAN = 1-7
COYNE


WAVE WINDING
SIMPLEX
RETROGRESSIVE
SYMMETRICAL
SINGLE ELEMENT
SLOTS = 25
BARS = 25
POLES = 4
COIL SPAN=1-7
COMMUTATOR PITCH=1-13
13
1
COYNE


WAVE WINDING
SIMPLEX
PROGRESSIVE
SYMMETRICAL
SINGLE ELEMENT
SLOTS = 32
BARS = 32
POLES = 6
COIL SPAN = 1-6
COMMUTATOR PITCH = 1-12
12
1
COYNE

WAVE WINDING
SIMPLEX
RETROGRESSIVE
SYMMETRICAL
TWO ELEMENT

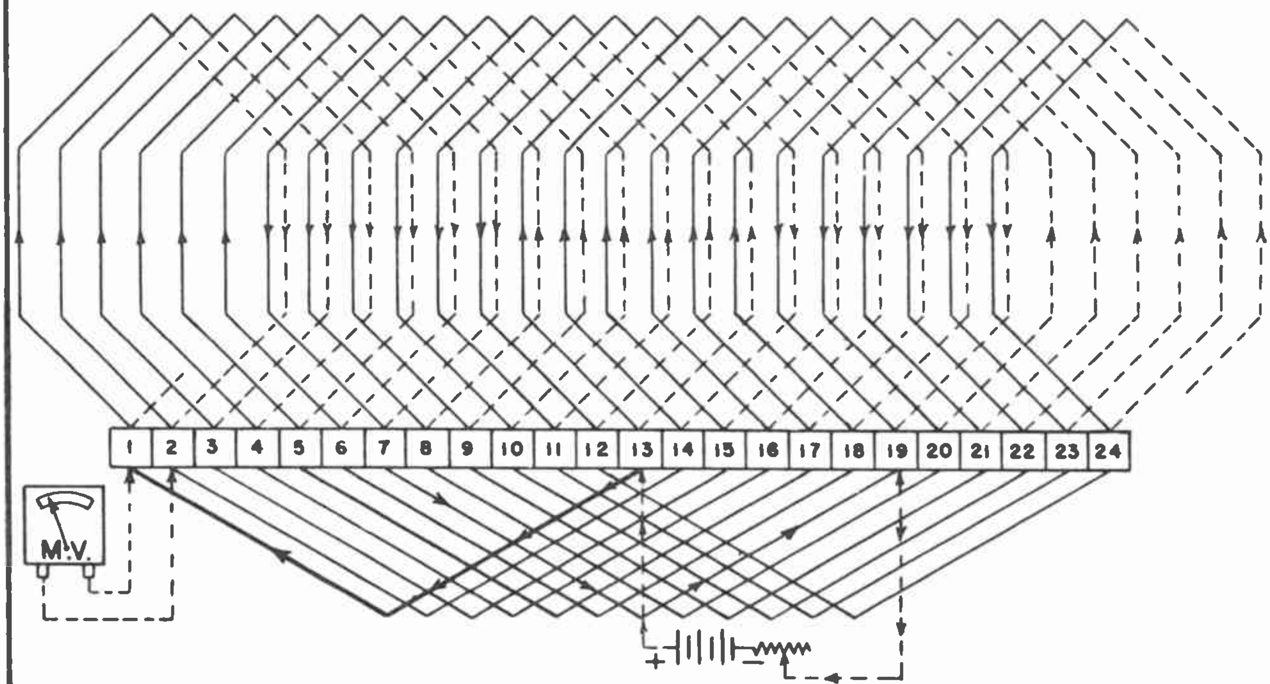
SLOTS = 13
BARS = 25
POLES = 4
COIL SPAN = 1-4
COMMUTATOR PITCH = 1-13



A - B ENDS OF DEAD COIL.

COYNE

ARMATURE EQUALIZER CONNECTIONS.



Although equalizers have been used on large armatures for many years, the application of these connections to small machines is a comparatively recent innovation that has raised questions regarding the advantages of such connections, and the method of testing such windings for faults.

Briefly, equalizer connections provide better commutation, make possible one-half the number of brushes usually used on the lap-wound machine, and provide the manufacturer with a means of avoiding the special slot and commutator bar relationships demanded by wave-type windings. Inasmuch as the equalizers here referred to are permanently connected to the commutator, and inasmuch as they make testing of the armature impossible by the regular procedure, the testing method and other information about these connections should prove of value to maintenance electricians and armature shop men.

The principal purpose of equalizers is to connect together on the armature those points which have the same polarity and which should have equal potential. For a four-pole winding this means commutator bars 180 degrees apart; for a six-pole armature, bars 120 degrees apart; for an eight-pole machine, bars 90 degrees apart. The number of bars spanned by the equalizer will equal bars ÷ pairs of poles. For the armature shown in the diagram, each equalizer will span 24÷2, or 12 bars, thereby making the connection 1 and 13, 2 and 14, etc. The pitch for any other number of bars or poles would be determined by the same method.

To test such an armature, current must be fed to the armature from an external low voltage D.C. supply, such as a battery, the leads being connected to commutator segments one-half the equalizer pitch apart. Since the equalizer pitch is 12 segments in this case, the leads will be spaced six bars apart or 1 and 7. Any pair of bars so spaced may be used, in a fully equalized armature; bars 13 and 15 being employed in the diagram.

The value of the test current is adjusted to give satisfactory deflection on the millivoltmeter, and volt drop readings are taken between all adjacent pairs of segments. These readings are interpreted in the usual manner, low readings indicating shorts, high readings showing high resistance connections or opens. Tracing the winding and also by actual test, it will be noted that if the readings from bars 13 and 19 are forward, then the readings from 19 to 1 will be backward. 1 to 7 will be forward, and 1 to 13 backward. This is a normal indication obtained in all windings.

If the factors mentioned are kept in mind, the procedure given will produce consistently accurate results. It is to be noted such an armature will, when tested on a growler, give a shorted indication on all coils, even though the winding is in perfect condition. The reason for this can be seen by tracing from bar 1 through the coil to bar 2, through the equalizer to bar 14, through the coil to bar 13 and back through the equalizer to bar 2. Thus every coil on the armature is apparently short circuited by having another coil placed in series with it through the equalizer connections. This explains the need for a special testing procedure.

DATA SHEET FOR MOTOR AND GENERATOR REWINDING

Job No. ________ Customer ____________________

Address ____________________

Date received ________ Date promised ________

How delivered ________ Send ________ Will call ________

Terms of payment ________ Estimate ________

Cost of materials used ________ Total hrs. labor ________

WORK TO BE DONE

Write out in detail ____________________

____

____

REWIND DATA

H.P. ________ Volts ________ Amps. ________ R.P.M. ________ Type ________

Serial No. ________ Make ________

No. of slots ________ Coil span ________ Turns per coil ________

Size and kind of wire ________ Wdg. conn. ________

No. of wires in parallel ________ Lbs. of scrap wire removed ________

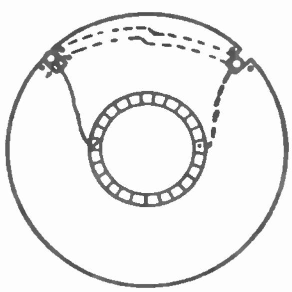
Slot insulation ________

No. of comm. bars. ________ Comm. pitch ________

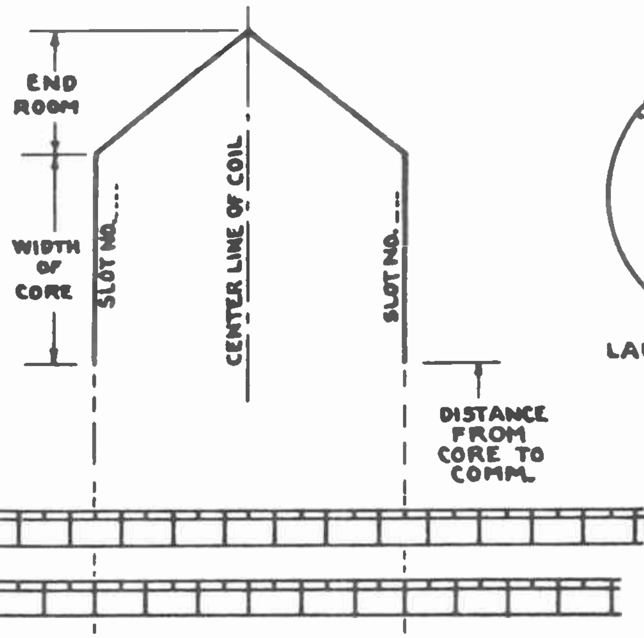
Dead coils ________ Dead bars ________ Wires per bar ________

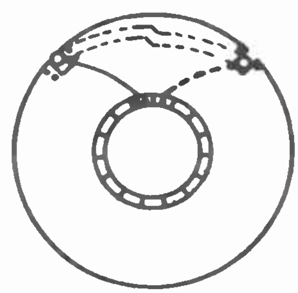
Dia. of core ________ Length of core ________ End room ________

Band wires ________ Size ________ No. of turns ________ Solder balance weights ________

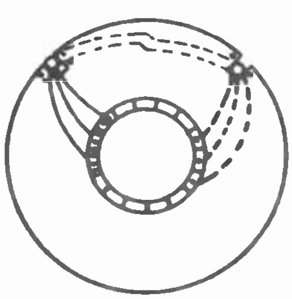


WAVE SIMPLEX SYM.

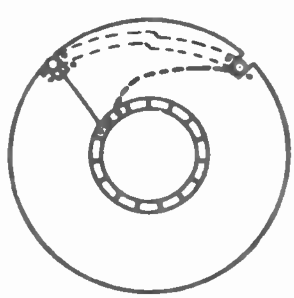




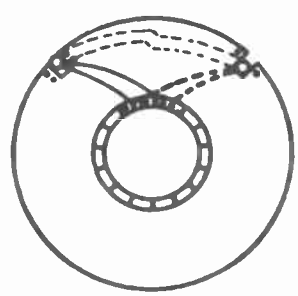
LAP SIMPLEX SYM.



WAVE SIMPLEX SYM. 3 ELEMENT



LAP SIMPLEX NON-SYM.



LAP SIMPLEX SYM. 2 ELEMENT.

Coil Forming

The sketches show the method of making the right size coils for an armature winding.

The first step is to count the number of slots and commutator segments for determining the coil span and what element it is. After the coil span is found measurements should be according to Fig. 3 which shows the size a coil should be in relation to the average size armature. Notice particularly that the coil end extends 1/2" beyond the slot, 1/4" before spanning over to another slot. It can also be noticed that the twist (or curl) made in each end of the coil must be made at the exact center, otherwise the coils will not fit in properly.

Using a ruler, measure from a point 1/2" from the commutator in the exact center of the coil, (using a coil span of 1-7, slot #4, counting from #1 would be the center) to within 1/4" of slot #7. Referring to the armature in Fig. 3 this would be from C to D or 2-1/4". Measuring from C to B would be 6-1/2", and from A to B would be another 2-1/4" making a total of 11 inches for the length of the coil.

Set the coil winder (Fig. 1) at 11" and if the armature has twice as many segments as slots, or is two element, wind the two element coils with two wires in parallel, making both of the small coils in the two element coil in one operation. After the coils are wound on the winder they should be taped with cotton tape.

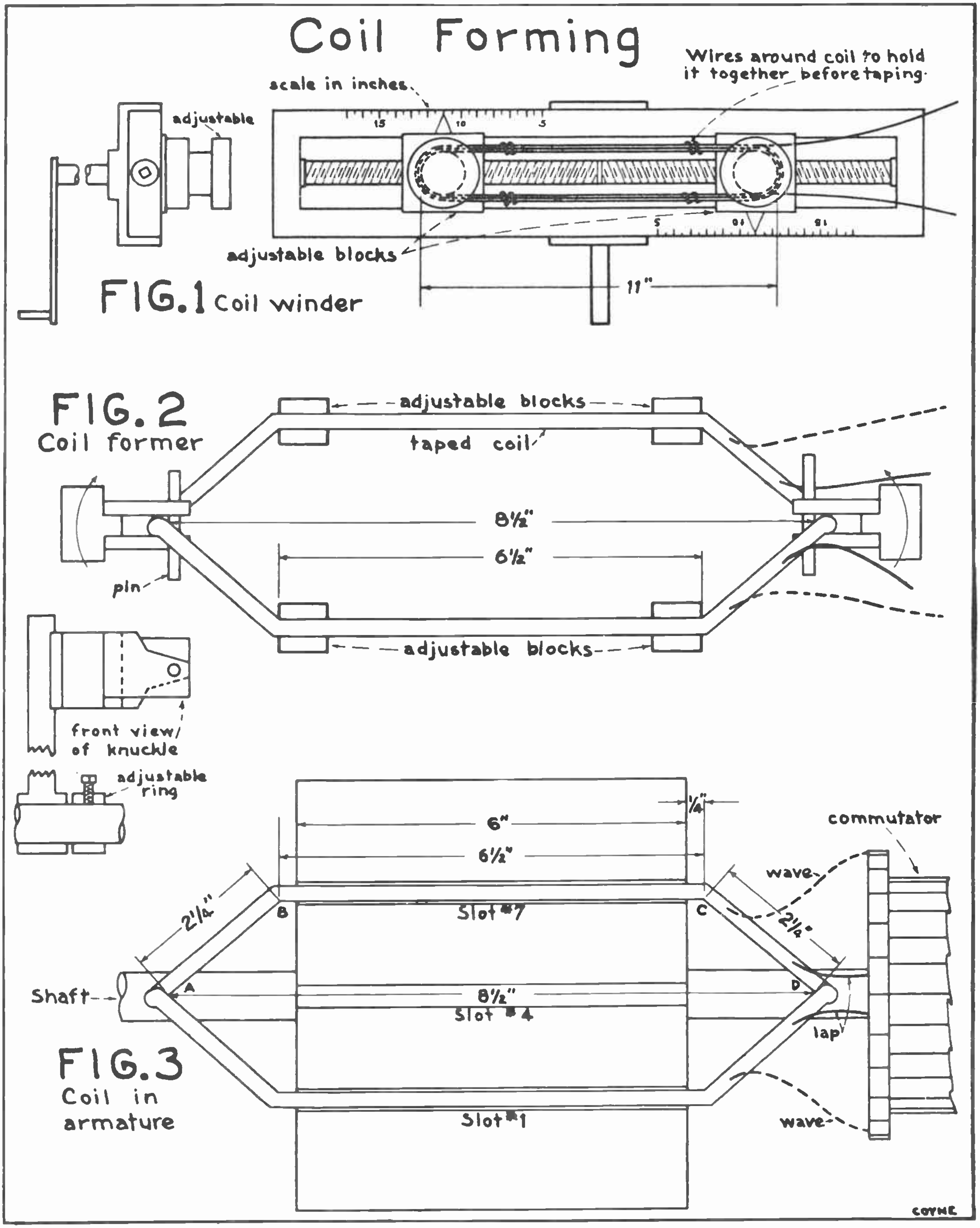
Referring to Fig. 2 which shows the method to use in forming the coil and bringing out the leads for both lap and wave wound coils note that coil should be taped before forming, assuming the approximate point where the lead should come out.

Extreme care must be taken in taping the coils to overlap exactly 1/2 its width pulling each turn firmly against the wires of the coil (start taping the coil 1" from the end at which the leads are to be brought out).

The next step is shaping the coil. The slots in the coil former that will hold the coil while it is being shaped should be set 6-1/2" on the scale (the slot on the pull arm should also be the same width and height). To get the length of the coil from one point to the other, measure from the center of the coil along the 4th slot (starting within 3/4" of the commutator and letting the ruler extend out at the other end) to a point the same distance at the opposite side. Referring to Fig. 3 this would be from D to A or 8-1/2". The adjustable rings on the shaft of the coil former will slide out so the holes in the knuckles will be held this distance (8-1/2") apart. Too much pressure should not be exerted in pulling the coil into position, as there is danger of breaking the insulation. When the coil has been stretched out the knuckles should be turned in the direction shown in Fig. 2, being very careful to see that the holes that the pins go through, to hold the coils in place, are exactly in the center of the coil.

Note:- The leads that extend from the coil when winding should be only long enough to reach to the end of the commutator bar opposite the riser. These ends should never be used to wind around the coil. Short lengths of wire may be used for this purpose, removing them as the coil is taped.

Note:- It is always good practice to make but one coil, shape it and try it on the armature to see if it is the exact size desired. Then if any alterations must be made only one coil will be wasted.


Coil Forming
Wires around coil to hold it together before taping.
scale in inches
adjustable
adjustable blocks
FIG. 1 Coil winder
11"
FIG. 2
Coil former
adjustable blocks
taped coil
8½"
6½"
pin
adjustable blocks
front view of knuckle
adjustable ring
¼"
6"
6½"
commutator
wave
2¼"
2½"
B
C
Slot #7
Shaft
A
D
8½"
Slot #4
lap
FIG. 3
Coil in armature
Slot #1
wave
COYNE

DC - ARMATURE WINDING TOOLS AND MATERIALS

To test and rewind armature stators efficiently, certain tools and testing equipment are necessary. The list given below indicates the tools and testing devices that should be available to the winder if his work is to be done effectively.

ARMATURE AND STATOR TOOLS

1 - 16 oz. machinists hammer	1 - Pair tin shears	1 - Pair of scissors
1 - 12 oz. machinists hammer	1 - Knife	1 - Set wedge drivers
1 - Large screwdriver 6"	1 - Flat file	1 - Coil lifter and shaper
1 - Small screwdriver 3"	1 - Cold chisel	1 - Long nose plier
1 - #1 Rawhide mallet	1 - Lead scraper	1 - Diagonal plier
1 - #2 Rawhide mallet	1 - Armature spoon	1 - Set coil tamping tools
1 - Outside growler	1 - 6" Parallel plier	1 - 8" side cutting plier
1 - Inside growler	1 - Set soldering irons	1 - Universal test meter

The proper insulation of a stator or armature means the insulation of the slots as well as the coils, the former serving the dual purpose of insulating and mechanically protecting the coils at the same time. These insulations may be divided into groups which indicate the purpose for which they are most suitable. In the first group may be listed the purely electrical insulations: cotton tape, oiled cloth of cotton muslin or linen, varnished cambric, varnished muslin, varnished silk, and empire cloth. In the second group the materials which afford the greatest mechanical protection: pressboard, presspahn, hard fiber, vulcanized fiber, and fish paper. In the third group those especially adapted to high temperatures such as: mica, micanite, mica paper, glass tape, and mica cloth. From this it may be seen that there is an insulation for practically every purpose, and that a certain degree of care must be exercised in choosing the insulation for any particular job. The most widely used slot insulations with their various thicknesses are given below.

SLOT INSULATIONS

Black varnished cambric	.012" thick	Fullerboard	.007 - .015"
Yellow varnished cambric	.007 - .015	Oiled asbestos paper	.006 - .015"
Yellow varnished silk	.003	Varnished " "	.006 - .015
Fish paper	.004 - .023	Mica paper	.005 - up
Duro	.007 - .015	Micanite	.005 - up

INSULATING TAPES

Friction) Taping
Rubber) splices

Cotton)
Linen) Taping
Silk) Coils
Glass)

Oiled muslin)
Varnished cambric) Used for
Duro) taping
Mica) coils.
Black varnished cloth)

SLOT WEDGES OR SLOT STICKS

Fiber - usually rawhide fiber

Wood - generally maple

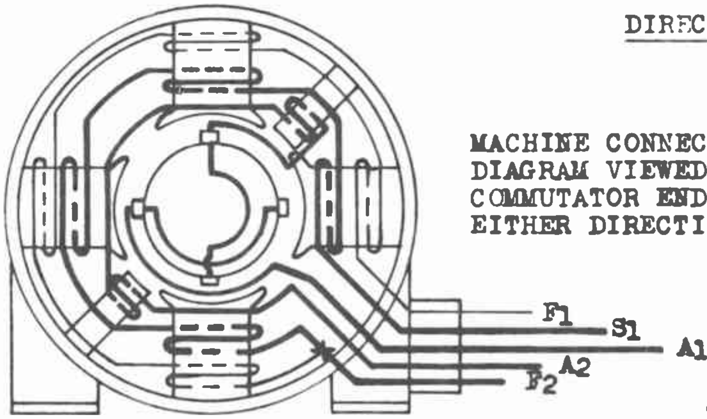
INSULATING COMPOUNDS

Air dry) Baking not
Shellac) essential

Clear baking varnish) Requires
Black baking varnish) baking

DIRECT CURRENT WINDING AND CONNECTION DATA.

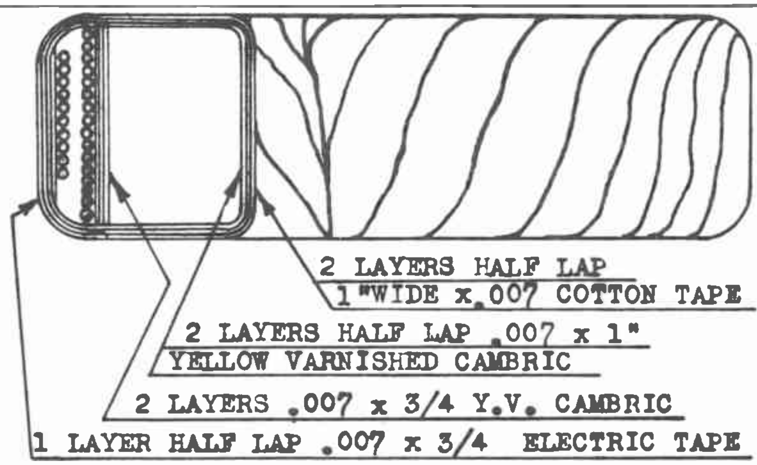
B-4781



MACHINE CONNECTION DIAGRAM VIEWED FROM COMMUTATOR END
EITHER DIRECTION OF ROTATION

THESE SYMBOLS STAMPED ON TERMINALS

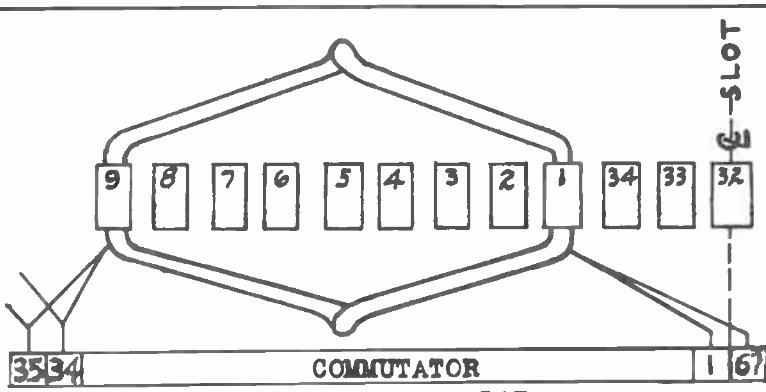
THE PEERLESS ELECTRIC CO.



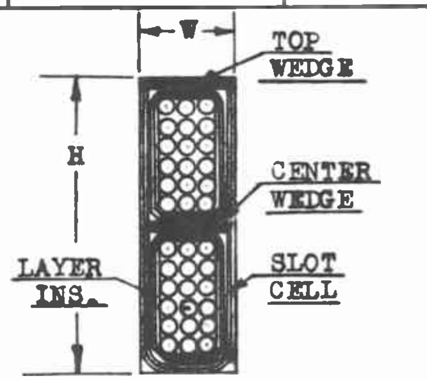
MAIN POLE COIL

COMMUTATING POLE COIL INSULATION SAME AS MAIN POLE COIL

TREATMENT OF COMPLETED COILS	
MAIN FIELD	COM. FIELD
DIP IN BB 52V13 VARNISH & BAKE 6 HOURS. AGAIN DIP IN CB 52V13 VARNISH & BAKE 4 HOURS. AFTER ASSEMBLY IN SHELL, BRUSH WITH AIR DRYING VARNISH.	SAME AS MAIN FIELD



2 COILS PER SLOT



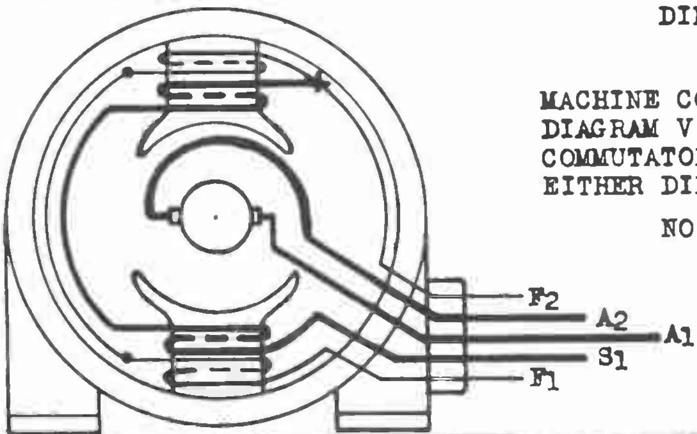
SECTION OF ARMATURE SLOT

TREATMENT OF COMPLETED ARMATURE
1. DIP IN BB 52V13 VARNISH.
2. BAKE 4 HOURS AT 260°F.
3. REPEAT 3 TIMES.

INSULATION MATERIALS	NAVY SPEC.
SLOT CELL-.020 COPAREX	17-1-10
CENTER WEDGE-.020 COPAREX	17-1-10
TOP WEDGE- .020 COPAREX	17-1-10
COIL LAYER INSULATION .007 COTTON TAPE 1/2 LAP	27-T-11

B-4803

DIRECT CURRENT WINDING AND CONNECTION DATA

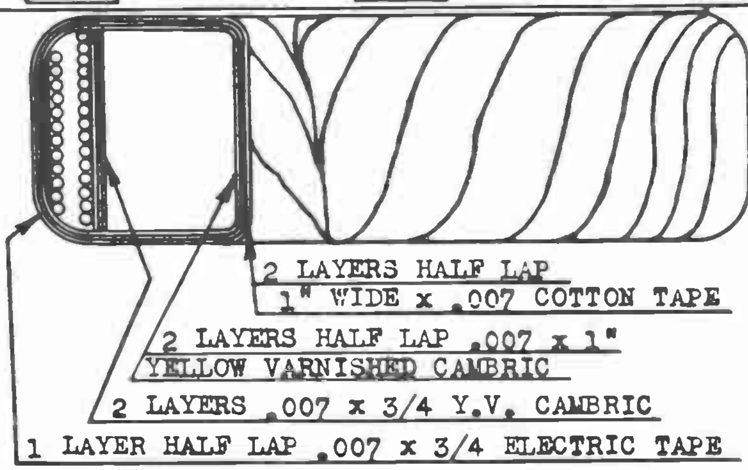


MACHINE CONNECTION DIAGRAM VIEWED FROM COMMUTATOR END
EITHER DIRECTION OF ROTATION.

NO INTERPOLE.

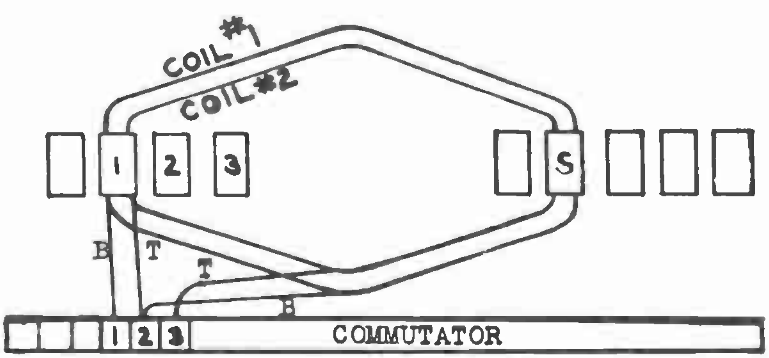
THE PEERLESS ELECTRIC CO.

THESE SYMBOLS MUST BE STAMPED ON TERMINALS.

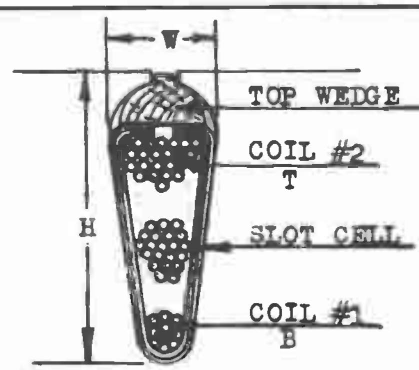


MAIN POLE COIL

TREATMENT OF COMPLETED COILS.
FIELD
DIP IN BB 52V13 VARNISH & BAKE 6 HOURS. AGAIN DIP IN CB 52V13 VARNISH & BAKE 4 HOURS. AFTER ASSEMBLY IN SHELL, BRUSH WITH AIR DRYING VARNISH.



2 COILS PER SLOT



SECTION OF ARMATURE SLOT

TREATMENT OF COMPLETED ARMATURE	INSULATION MATERIALS	NAVY SPEC.
1. DIP IN BB 52V13 VARNISH. 2. BAKE 4 HOURS AT 260°F. 3. REPEAT 3 TIMES.	SLOT CELL--.020 Tufelec TOP WEDGE--MAPLE	

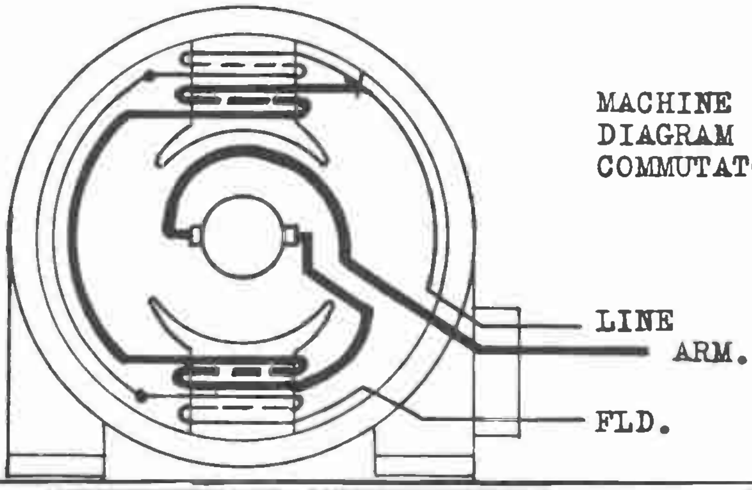
B-4803

DIRECT CURRENT WINDING AND CONNECTION DATA.

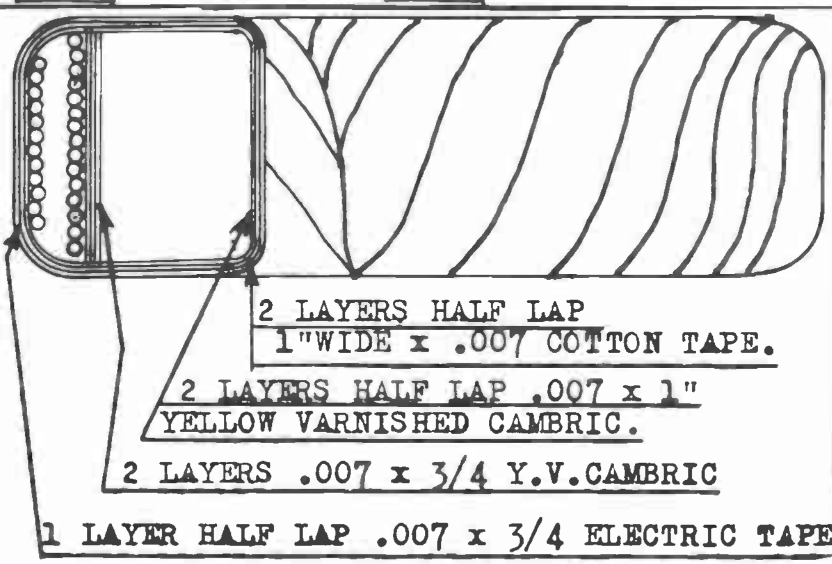
B-4847

MACHINE CONNECTION DIAGRAM VIEWED FROM COMMUTATOR END, CLOCKWISE ROTATION.

THE PEERLESS ELECTRIC CO.

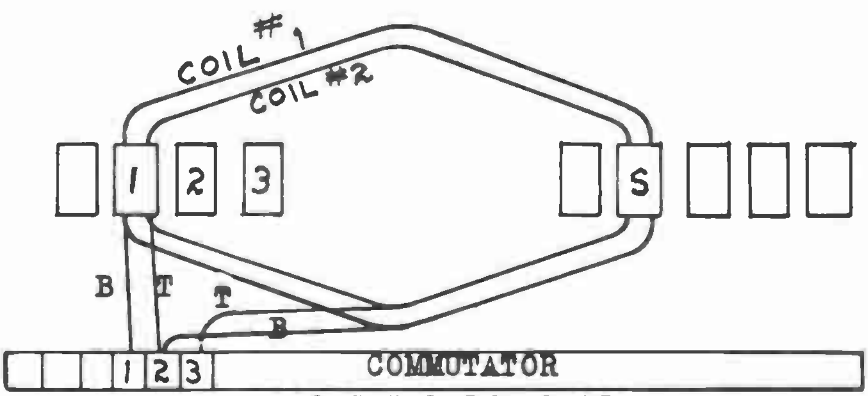


THESE SYMBOLS STAMPED ON TERMINALS.

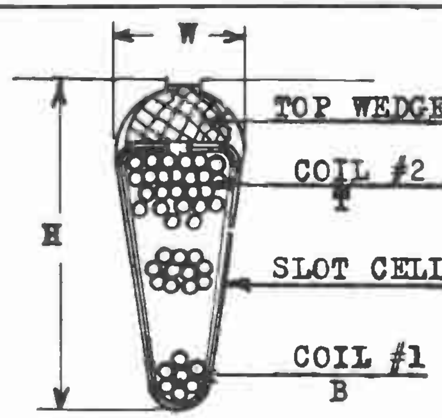


MAIN POLE COIL

TREATMENT OF COMPLETED COILS.
FIELD
DIP IN BB 52V13 VARNISH & BAKE 6 HOURS. AGAIN DIP IN CB 52V13 VARNISH & BAKE 4 HOURS. AFTER ASSEMBLY IN SHELL, BRUSH WITH AIR DRYING VARNISH.



2 COILS PER SLOT.



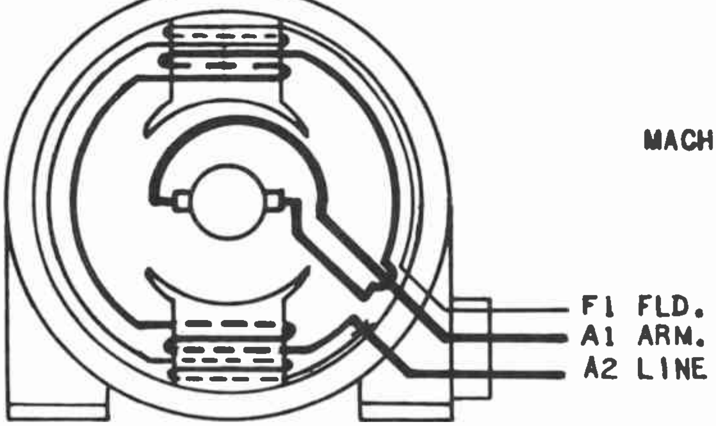
SECTION OF ARMATURE SLOT

TREATMENT OF COMPLETED ARMATURE	INSULATION MATERIALS	NAVY SPEC.
1. DIP IN BB 52V13 VARNISH. 2. BAKE 4 HOURS at 260 F 3. REPEAT 3 TIMES.	SLOT CELL--.020 Tufelec TOP WEDGE---MAPLE	

DIRECT CURRENT
MOTOR
CONNECTION AND WINDING DATA

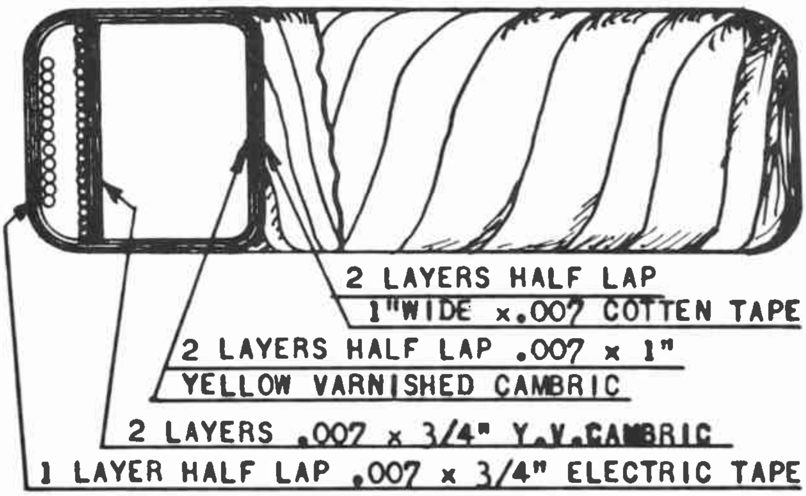
B-5136

CONNECTION DIAGRAM
MACHINE VIEWED FROM COMMUTATOR END
ROTATION COUNTER CLOCKWISE



THESE SYMBOLS ARE
STAMPED ON TERMINALS

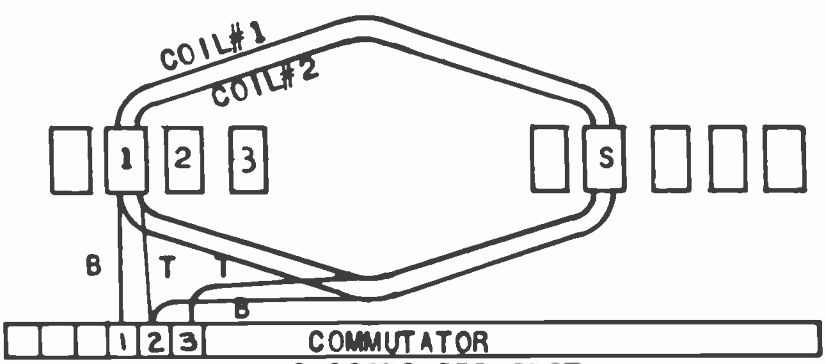
THE PEERLESS ELECTRIC CO.,
WARREN OHIO.



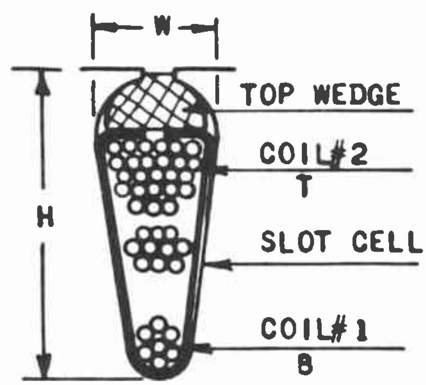
MAIN POLE COIL

TREATMENT OF COMPLETED COIL	
MAIN FIELD	
DIP IN BB 52V13 VARNISH & BAKE 6 HOURS. AGAIN DIP IN CB 52V13 VARNISH & BAKE 4 HOURS. AFTER ASSEMBLY IN SHELL, BRUSH WITH AIR DRYING VARNISH.	

B-5136



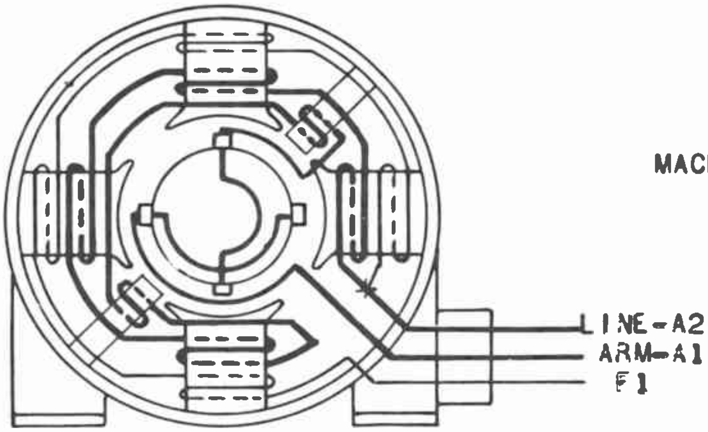
2 COILS PER SLOT



SECTION OF ARMATURE SLOT

TREATMENT OF COMPLETED ARMATURE
1.DIP IN BB 52V13 VARNISH 2.BAKE 4 HOURS AT 260 F. 3.REPEAT 3 TIMES.

INSULATION MATERIAL		
MATERIALS		NAVY. SPEC.
SLOT CELL	.002 COPAREX	17-1-10
TOP WEDGE	MAPLE	



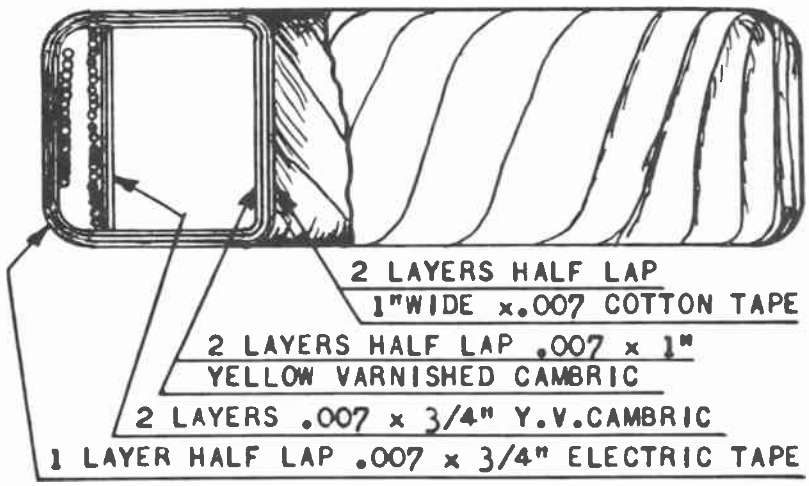
DIRECT CURRENT
MOTOR
CONNECTION AND WINDING DATA

B-5231

CONNECTION DIAGRAM
MACHINE VIEWED FROM COMMUTATOR END
ROTATION COUNTER CLOCKWISE
COMPOUND INTERPOLE

THESE SYMBOLS ARE
STAMPED ON TERMINALS

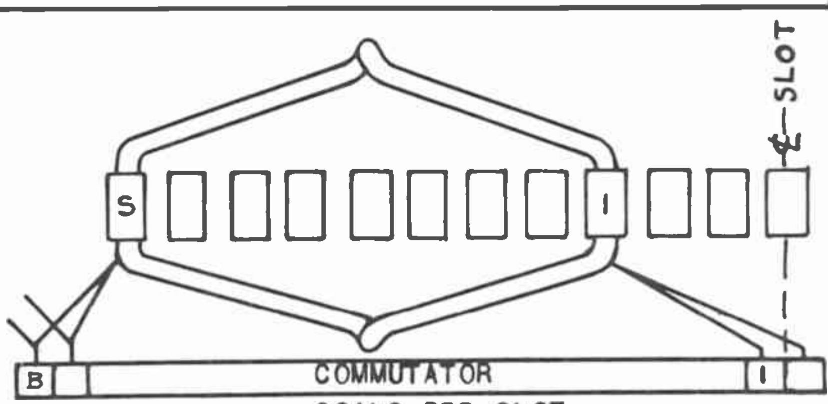
THE PEERLESS ELECTRIC CO.,
WARREN OHIO.



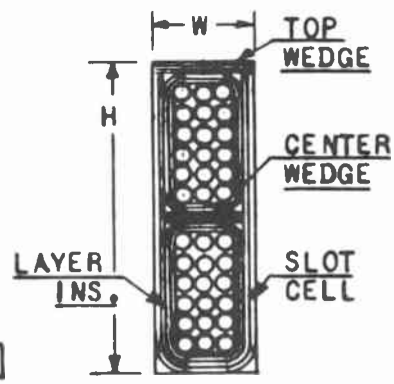
MAIN POLE COIL
COMMUTATING POLE COIL INSULATION
SAME AS MAIN POLE COIL

TREATMENT OF COMPLETED COIL	
MAIN FIELD	COM.FIELD
DIP IN BB 52V13 VARNISH & BAKE 6 HOURS. AGAIN DIP IN CB 52V13 VARNISH & BAKE 4 HOURS. AFTER ASSEMBLY IN SHELL,BRUSH WITH AIR DRYING VARNISH.	SAME AS MAIN FIELD

B-5231



COILS PER SLOT

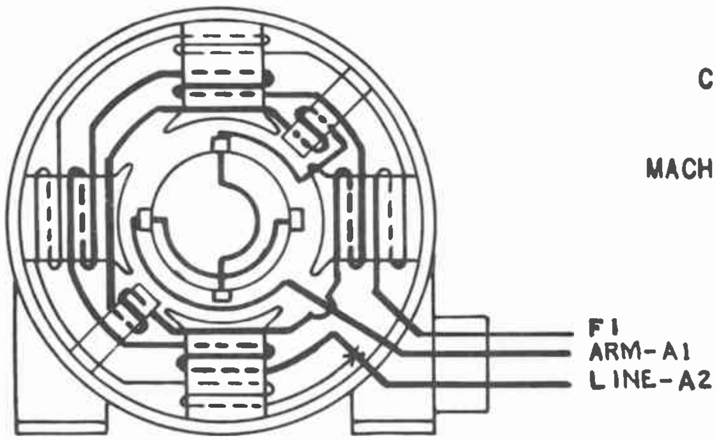


SECTION OF ARMATURE SLOT

TREATMENT OF COMPLETED ARMATURE

1. DIP IN BB 52V13 VARNISH
2. BAKE 4 HOURS AT 260 F.
3. REPEAT 3 TIMES.

INSULATION MATERIALS	
MATERIALS	NAVY SPEC.
SLOT CELL .002 COPAREX	17-1-10
CENTER WEDGE .020 COPAREX	17-1-10
TOP WEDGE .020 COPAREX	17-1-10
COIL LAYER INSULATION, .007 COTTON TAPE 1/2 LAP.	27-T-11



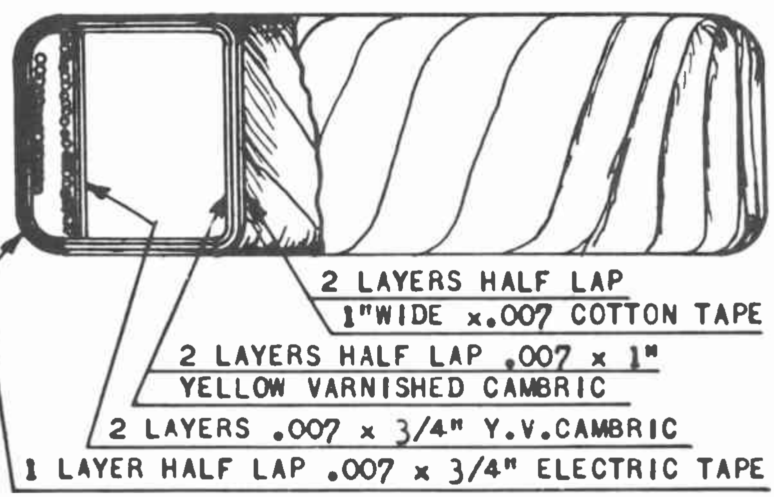
DIRECT CURRENT
MOTOR
CONNECTION AND WINDING DATA

B-5232

CONNECTION DIAGRAM
MACHINE VIEWED FROM COMMUTATOR END
ROTATION CLOCKWISE
COMPOUND INTERPOLE

THESE SYMBOLS ARE
STAMPED ON TERMINALS

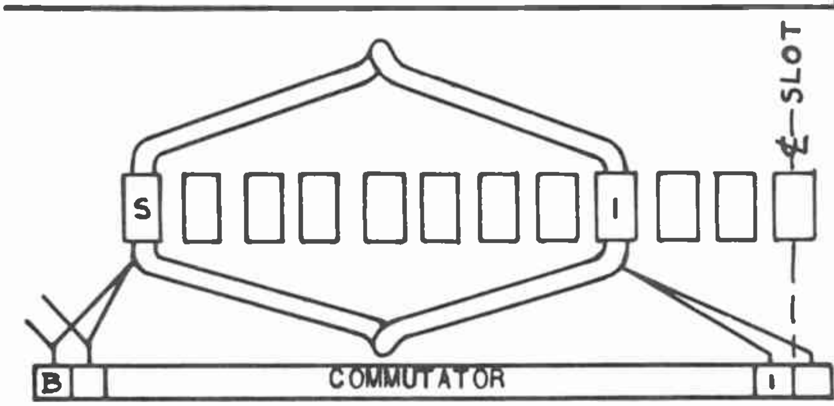
THE PEERLESS ELECTRIC CO.,
WARREN OHIO.



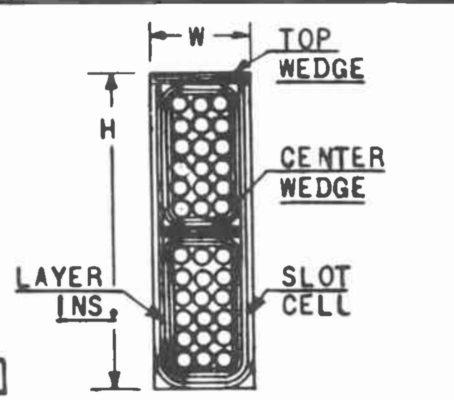
MAIN POLE COIL
COMMUTATING POLE COIL INSULATION
SAME AS MAIN POLE COIL

TREATMENT OF COMPLETED COIL	
MAIN FIELD	COM.FIELD
DIP IN BB 52V13 VARNISH & BAKE 6 HOURS. AGAIN DIP IN CB 52V13 VARNISH & BAKE 4 HOURS. AFTER ASSEMBLY IN SHELL, BRUSH WITH AIR DRYING VARNISH.	SAME AS MAIN FIELD

B-5232



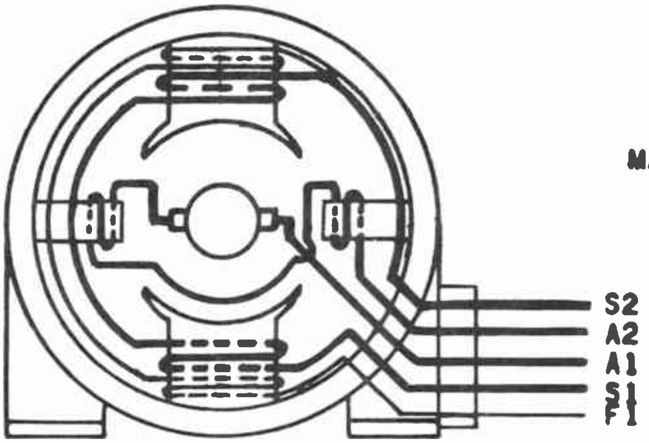
COILS PER SLOT



SECTION OF ARMATURE SLOT

TREATMENT OF COMPLETED ARMATURE
1.DIP IN BB 52V13 VARNISH 2.BAKE 4 HOURS AT 260 F. 3.REPEAT 3 TIMES.

INSULATION MATERIALS	
MATERIALS	NAVY SPEC.
SLOT CELL .002 COPAREX	17-I-10
CENTER WEDGE .020 COPAREX	17-I-10
TOP WEDGE .020 COPAREX	17-I-10
COIL LAYER INSULATION, .007 COTTON TAPE 1/2 LAP.	27-T-11



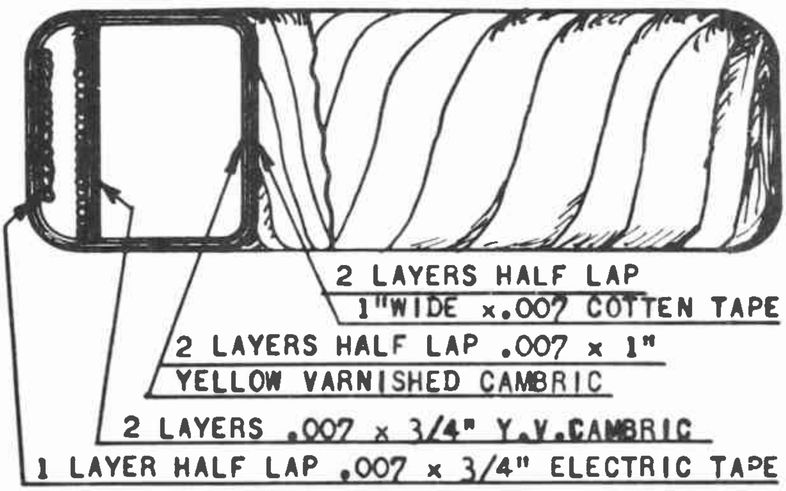
DIRECT CURRENT
MOTOR
CONNECTION AND WINDING DATA

B-5386

CONNECTION DIAGRAM
MACHINE VIEWED FROM COMMUTATOR END
ROTATION REVERSIBLE
COMPOUND INTERPOLE

THESE SYMBOLS ARE
STAMPED ON TERMINALS

THE PEERLESS ELECTRIC CO.,
WARREN OHIO.

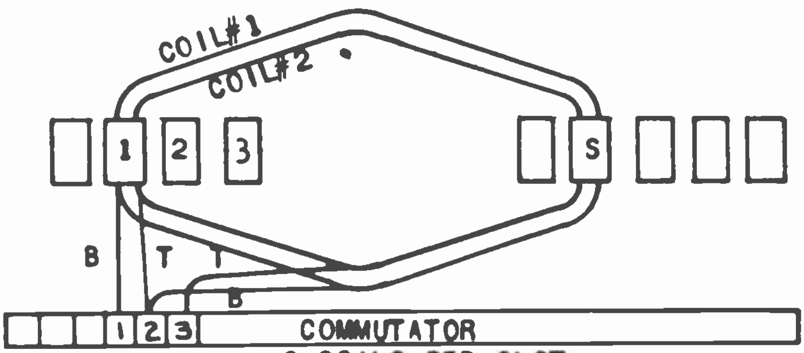


MAIN POLE COIL

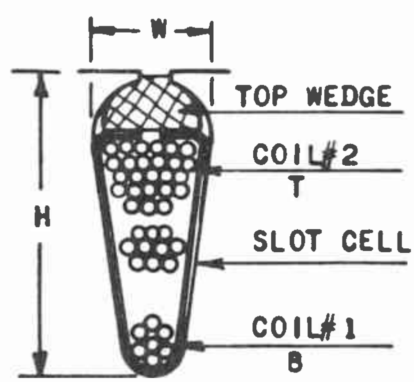
COMMUTATING POLE COIL INSULATION
SAME AS MAIN POLE COIL

TREATMENT OF COMPLETED COIL	
MAIN FIELD	COM.FIELD
DIP IN BB 52V13 VARNISH & BAKE 6 HOURS. AGAIN DIP IN CB 52V13 VARNISH & BAKE 4 HOURS. AFTER ASSEMBLY IN SHELL, BRUSH WITH AIR DRYING VARNISH.	SAME AS MAIN FIELD

B-5386



2 COILS PER SLOT

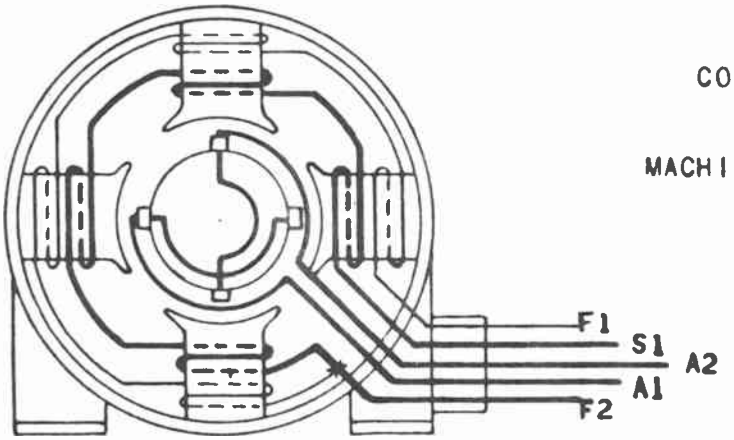


SECTION OF ARMATURE SLOT

TREATMENT OF COMPLETED ARMATURE

1. DIP IN BB 52V13 VARNISH
2. BAKE 4 HOURS AT 260 F.
3. REPEAT 3 TIMES.

INSULATION MATERIAL		
MATERIALS		NAVY. SPEC.
SLOT CELL	.002 COPAREX	17-1-10
TOP WEDGE	MAPLE	

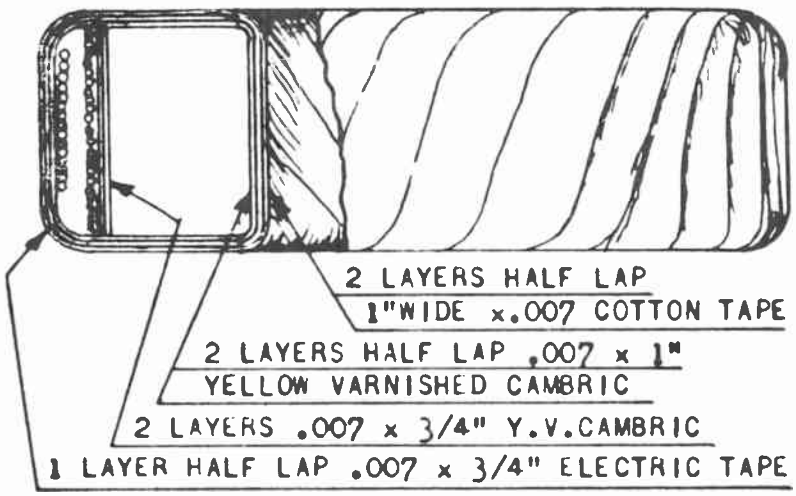


DIRECT CURRENT
MOTOR
CONNECTION AND WINDING DATA

CONNECTION DIAGRAM
MACHINE VIEWED FROM COMMUTATOR END
ROTATION REVERSIBLE
COMPOUND NON INTERPOLE

THESE SYMBOLS ARE
STAMPED ON TERMINALS

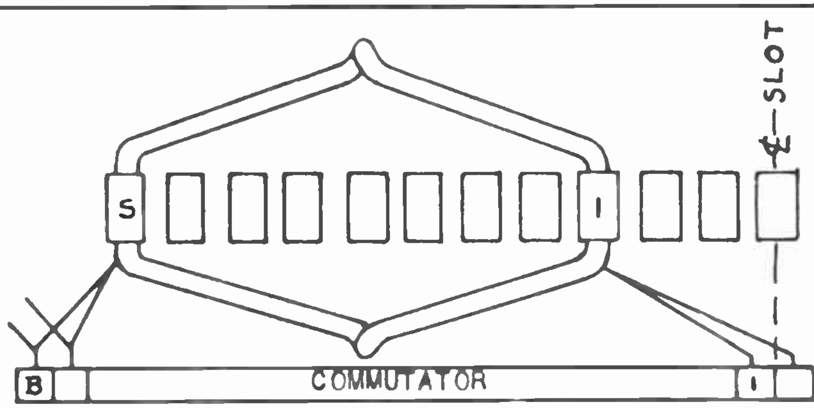
THE PEERLESS ELECTRIC CO.,
WARREN OHIO.



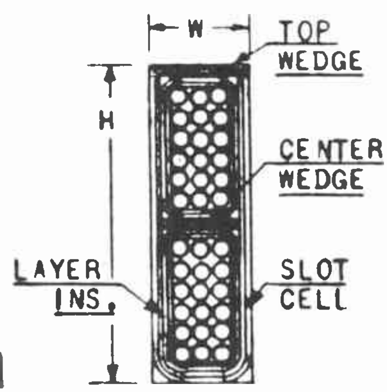
MAIN POLE COIL

TREATMENT OF COMPLETED COIL	
MAIN FIELD	COM.FIELD
DIP IN BB 52V13 VARNISH & BAKE 6 HOURS. AGAIN DIP IN CB 52V13 VARNISH & BAKE 4 HOURS. AFTER ASSEMBLY IN SHELL, BRUSH WITH AIR DRYING VARNISH.	NONE

B-5445



COILS PER SLOT

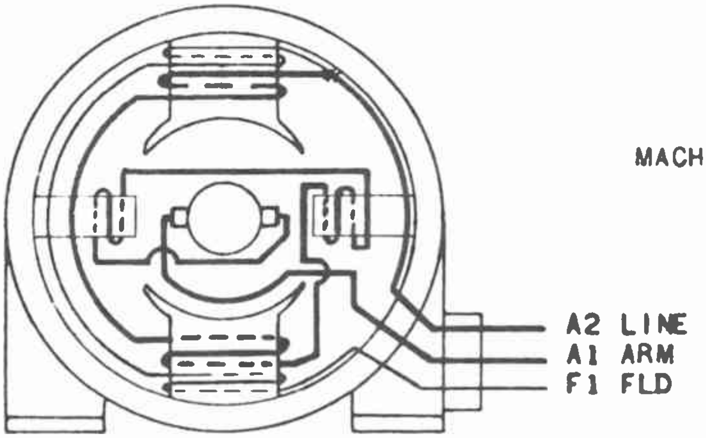


SECTION OF ARMATURE SLOT

TREATMENT OF COMPLETED ARMATURE

1. DIP IN BB 52V13 VARNISH
2. BAKE 4 HOURS AT 260 F.
3. REPEAT 3 TIMES.

INSULATION MATERIALS	
MATERIALS	NAVY SPEC.
SLOT CELL .002 COPAREX	17-1-10
CENTER WEDGE .020 COPAREX	17-1-10
TOP WEDGE .020 COPAREX	17-1-10
COIL LAYER INSULATION, .007 COTTON TAPE 1/2 LAP.	27-T-11



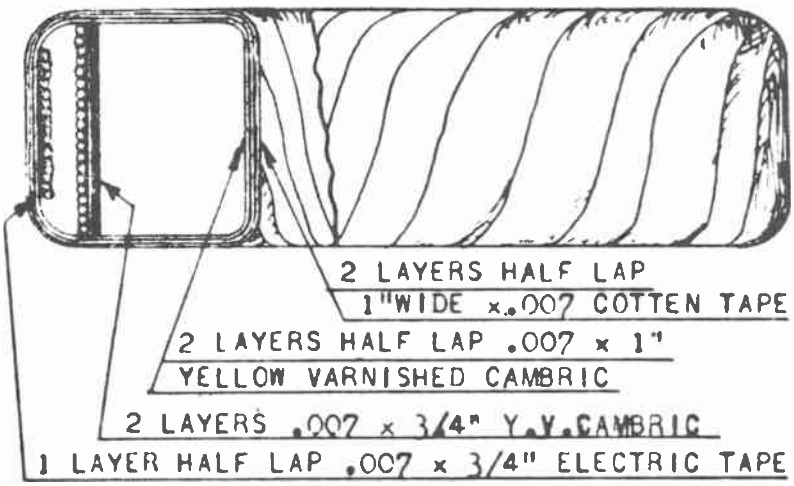
DIRECT CURRENT
MOTOR
CONNECTION AND WINDING DATA

B-5555

CONNECTION DIAGRAM
MACHINE VIEWED FROM COMMUTATOR END
ROTATION CLOCKWISE

THESE SYMBOLS ARE
STAMPED ON TERMINALS

THE PEERLESS ELECTRIC CO.,
WARREN OHIO.

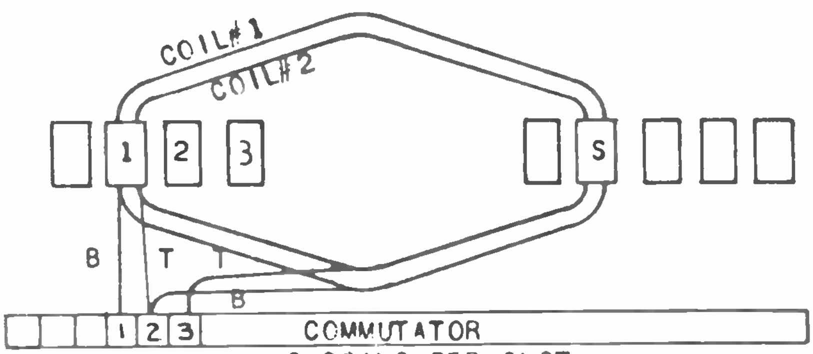


MAIN POLE COIL

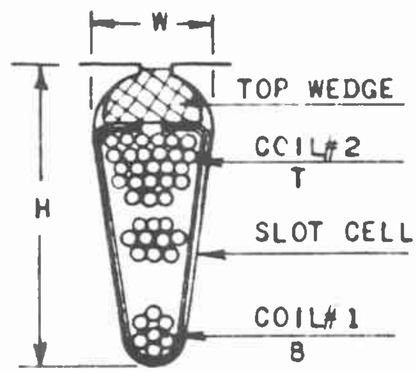
COMMUTATING POLE COIL INSULATION SAME AS MAIN POLE COIL

TREATMENT OF COMPLETED COIL	
MAIN FIELD	COM. FIELD
DIP IN BB 52V13 VARNISH & BAKE 6 HOURS. AGAIN DIP IN CB 52V13 VARNISH & BAKE 4 HOURS. AFTER ASSEMBLY IN SHELL, BRUSH WITH AIR DRYING VARNISH.	SAME AS MAIN FIELD

B-5555



2 COILS PER SLOT



SECTION OF ARMATURE SLOT

TREATMENT OF COMPLETED ARMATURE

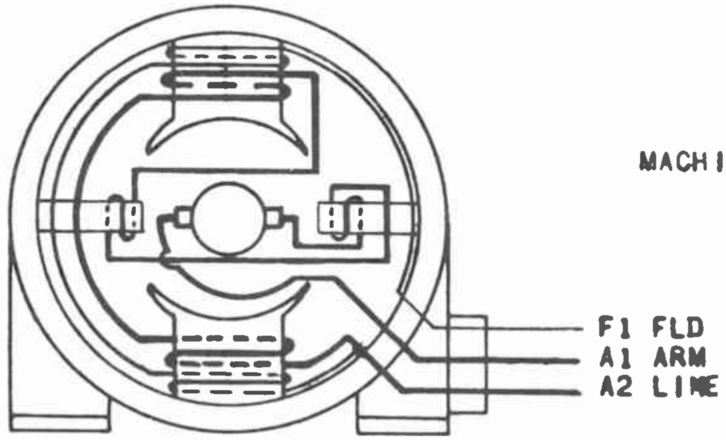
1. DIP IN BB 52V13 VARNISH
2. BAKE 4 HOURS AT 260 F.
3. REPEAT 3 TIMES.

INSULATION MATERIAL		
MATERIALS		NAVY. SPEC.
SLOT CELL	.002 COPAREX	17-1-10
TOP WEDGE	MAPLE	

DIRECT CURRENT
MOTOR
CONNECTION AND WINDING DATA

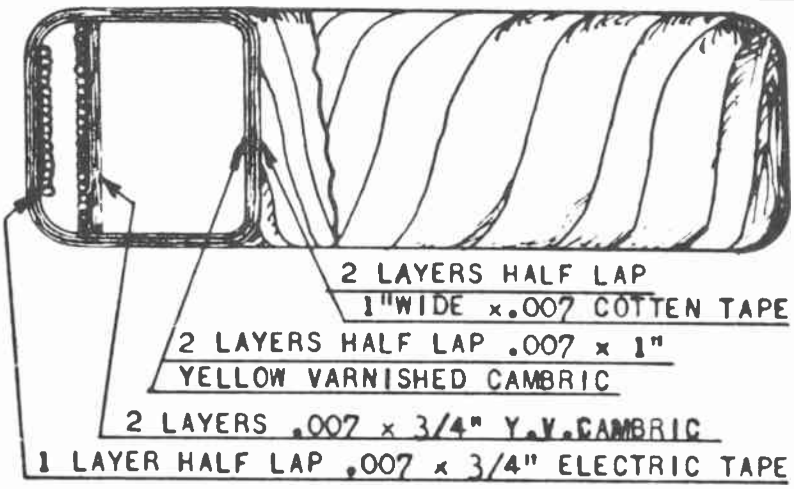
B-5556

CONNECTION DIAGRAM
MACHINE VIEWED FROM COMMUTATOR END
ROTATION COUNTER CLOCKWISE



THESE SYMBOLS ARE
STAMPED ON TERMINALS

THE PEERLESS ELECTRIC CO.,
WARREN OHIO.

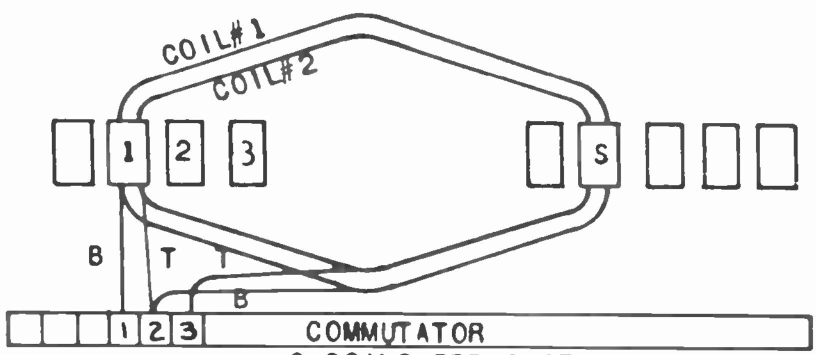


MAIN POLE COIL

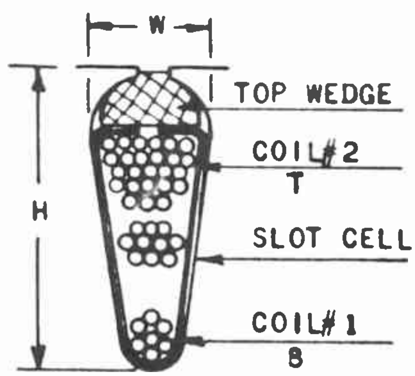
COMMUTATING POLE COIL INSULATION
SAME AS MAIN POLE COIL

TREATMENT OF COMPLETED COIL	
MAIN FIELD	COM.FIELD
DIP IN 88 52V13 VARNISH & BAKE 6 HOURS. AGAIN DIP IN CB 52V13 VARNISH & BAKE 4 HOURS. AFTER ASSEMBLY IN SHELL, BRUSH WITH AIR DRYING VARNISH.	SAME AS FIELD FIELD

B-5556



2 COILS PER SLOT

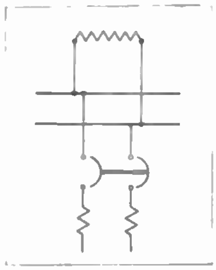


SECTION OF ARMATURE SLOT

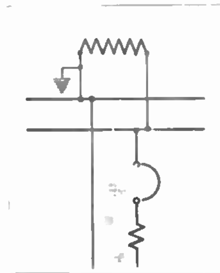
TREATMENT OF COMPLETED ARMATURE
1.DIP IN 88 52V13 VARNISH 2.BAKE 4 HOURS AT 260 F. 3.REPEAT 3 TIMES.

INSULATION MATERIAL		
MATERIALS		NAVY. SPEC.
SLOT CELL	.002 COPAREX	17-1-10
TOP WEDGE	MAPLE	

CIRCUIT BREAKERS

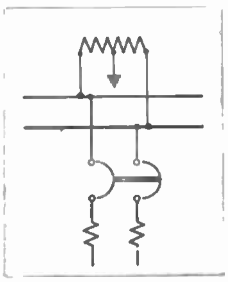


SINGLE-PHASE TWO-WIRE



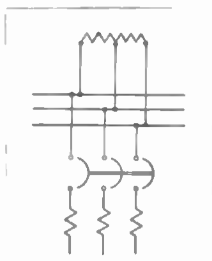
SINGLE-PHASE TWO-WIRE GROUNDED

Coil must be connected in ungrounded conductor to protect against a fault to the ground.

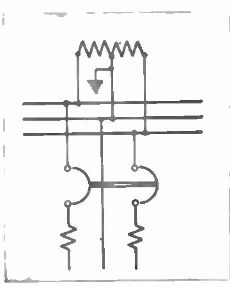


SINGLE-PHASE TWO-WIRE GROUNDED NEUTRAL

One coil alone will not protect circuit against phase-to-ground faults and two coils are therefore necessary

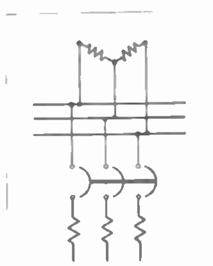


SINGLE-PHASE THREE-WIRE UNGROUNDED

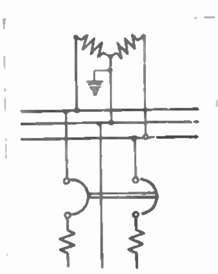


SINGLE-PHASE THREE WIRE GROUNDED NEUTRAL

Unprotected conductors must always be connected to neutral.

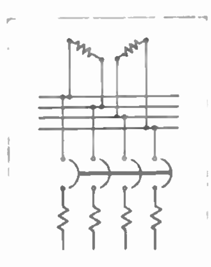


TWO-PHASE, THREE-WIRE UNGROUNDED

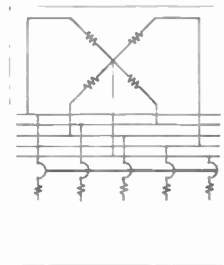


TWO-PHASE, THREE-WIRE GROUNDED

Unprotected conductors must always be connected to grounded bus bar.

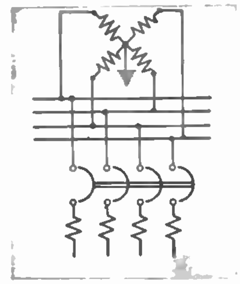


TWO-PHASE, FOUR-WIRE UNGROUNDED



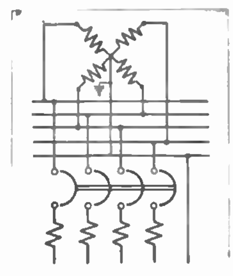
TWO-PHASE, FIVE-WIRE UNGROUNDED

All conductors must have overcurrent coils.



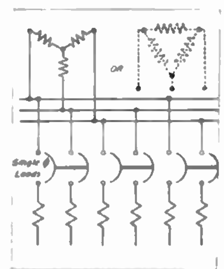
TWO-PHASE, FOUR-WIRE GROUNDED

All conductors must have overcurrent coils.

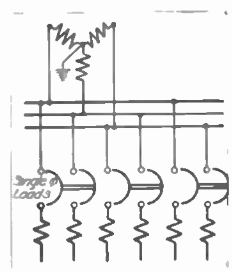


TWO-PHASE, FIVE-WIRE GROUNDED

All conductors except neutral must have overcurrent coils

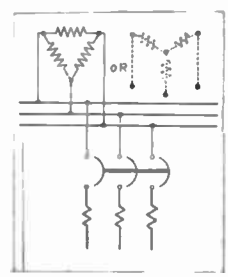


THREE-PHASE, THREE-WIRE UNGROUNDED

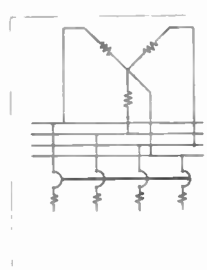


THREE-PHASE, THREE-WIRE TRANSFORMER NEUTRAL GROUNDED

All conductors must have overcurrent coils.

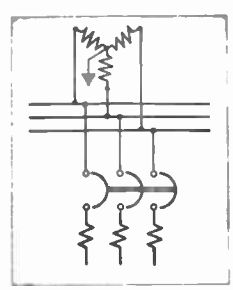


THREE-PHASE, THREE-WIRE UNGROUNDED



THREE-PHASE, FOUR-WIRE UNGROUNDED

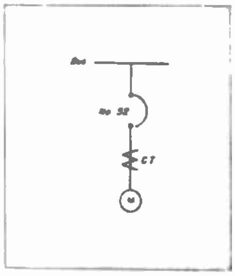
All conductors must have overcurrent coils.



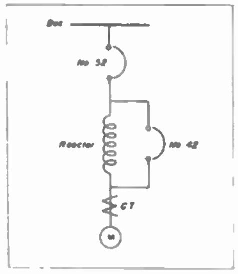
THREE-PHASE, THREE-WIRE NEUTRAL GROUNDED

All conductors must have overcurrent coils.

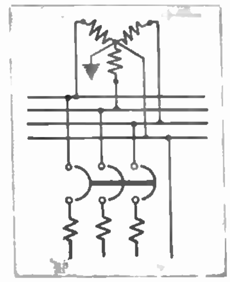
I-T-E CIRCUIT BREAKERS



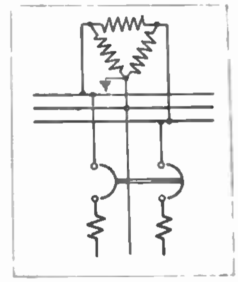
Full voltage



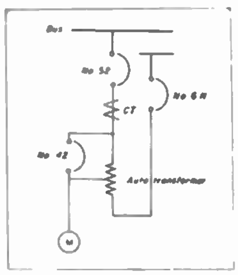
Series reacto



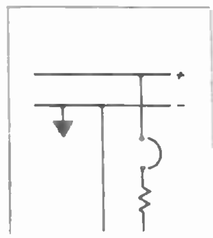
THREE-PHASE, FOUR-WIRE GROUNDED NEUTRAL



THREE-PHASE, THREE-WIRE GROUNDED

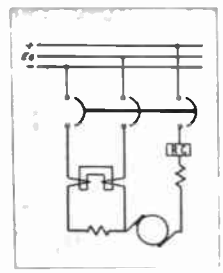


Autotransformer

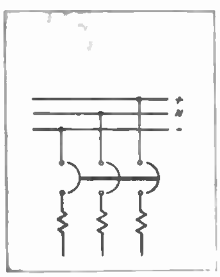


D-C TWO-WIRE GROUNDED

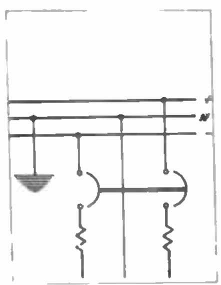
Coil and breaker contact must be connected in ungrounded conductor to protect against a fault to the ground.



D-C TWO-WIRE PARALLEL OPERATION

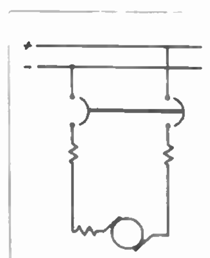


D-C THREE-WIRE UNGROUNDED

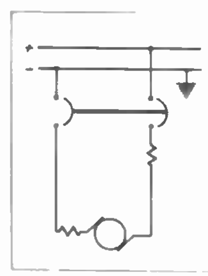


D-C THREE-WIRE GROUNDED NEUTRAL

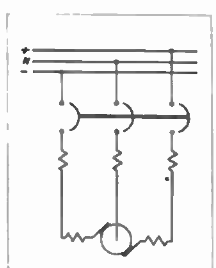
Unprotected conductors must always be connected to neutral.



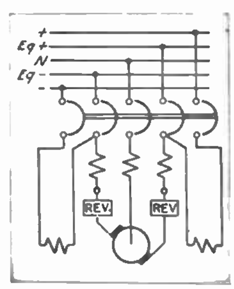
D-C TWO-WIRE UNGROUNDED



D-C TWO-WIRE GROUNDED NEGATIVE



D-C THREE-WIRE GROUNDED or UNGROUNDED NEUTRAL

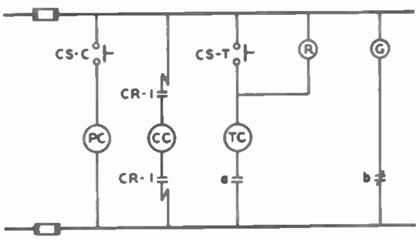


D-C GENERATOR, THREE-WIRE and EQUALIZERS

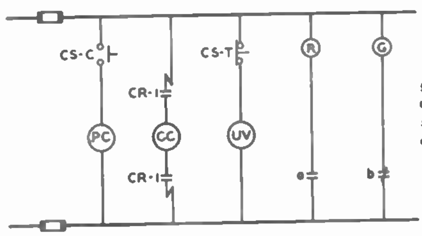
Overcurrent coils measure total armature current and give correct protection.

I-T-E CIRCUIT BREAKERS

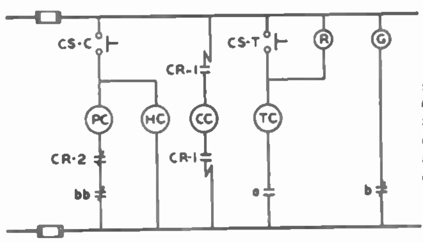
The following schematic diagrams give the various means of controlling electrically operated air circuit breakers.



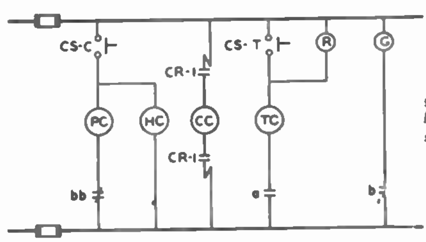
Schematic diagram showing relay, and shunt trip. Control switch with momentary contacts.



Schematic diagram showing relay, and undervoltage trip. Control switch with momentary closing contact and maintained trip contact.

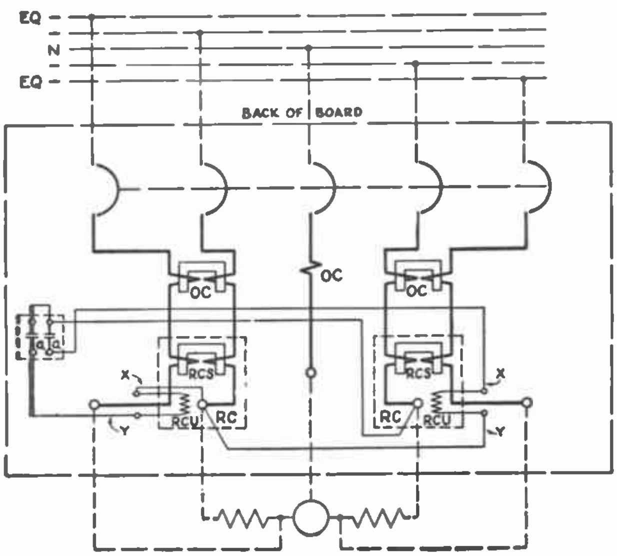


Schematic diagram showing anti pump relay and shunt trip. Control switch with contacts either maintained or momentary. Omit one CR-1 contact when used for KA.



Schematic diagram showing trip free relay and shunt trip. Control switch with momentary contacts.

F—Fuse
CS-C—Control switch—close
CS-T—Control switch—trip
CR—Control relay
CR 1—Control relay contacts, closed when pick up coil is energized
CR 2—Control relay contacts, open only when pick up coil is deenergised and holding coil is energized
HC—Control relay, holding coil
PC—Control relay, pick up coil
a—Contact closed when circuit breaker is closed
b—Contact closed when circuit breaker is open
bb—Contact closed when closing solenoid is in nonoperated position
CC—Circuit breaker closing coil
TC—Circuit breaker trip coil
UV—Circuit breaker undervoltage trip coil
G—Green indicating lamp
R—Red indicating lamp



Typical connection diagram for algebraic overcurrent and reverse current tripping devices used on 5-pole d-c generator circuit breakers.

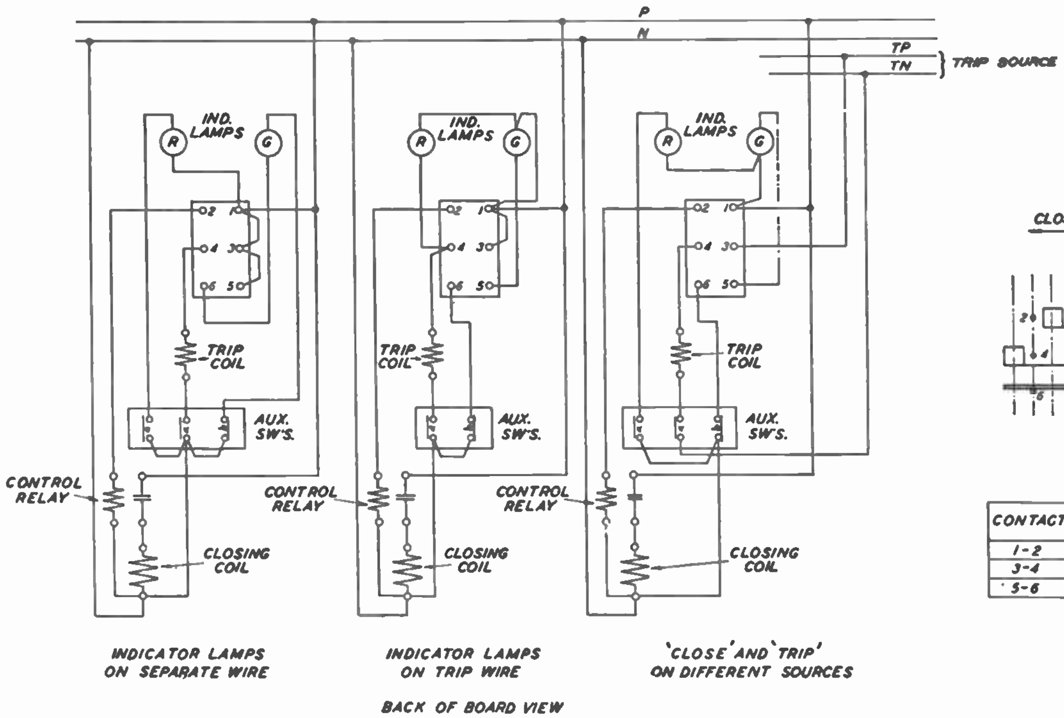
This device consists of laminated iron stacked together so as to surround the equalizer and one main lead of the circuit breaker. A pivoted armature cooperates with the electromagnet, and the distance between it and the magnet is governed by a movable stop. A time delay feature is usually added to the device. A calibrated scale is provided to indicate various tripping current values corresponding to armature position.

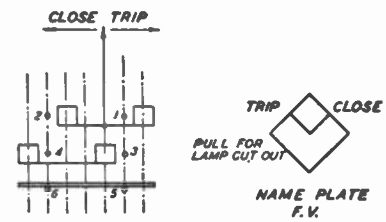
The magnetism produced is at all times proportional to the algebraic sum of the currents carried by both the main and the equalizer lead and, there fore, accurately represents the armature current. In other words, the algebraic overload device takes due account of the direction of flow of the equalizer current. If the equalizer current is flowing in the same direction as the current in the main lead its effect on the overcurrent device is added to that produced by the current in the main. On the other hand, if the current in the equalizer lead is flowing in the opposite direction to that in the main, its effect on the overload magnet is to counteract, in proportion to its magnitude, the magnetism produced by the current in the main.

It is apparent that this special overload device is subjected at all times to the algebraic sum of the current in the main and the equalizer. This algebraic sum represents the true armature current. Therefore, with overcurrent devices actuated by the true armature current, complete protection and immediate disconnection without damage are assured.

ALLIS-CHALMERS CIRCUIT BREAKER CONTROL SWITCHES

ROTARY — TYPE 153 — CONNECTION DIAGRAMS

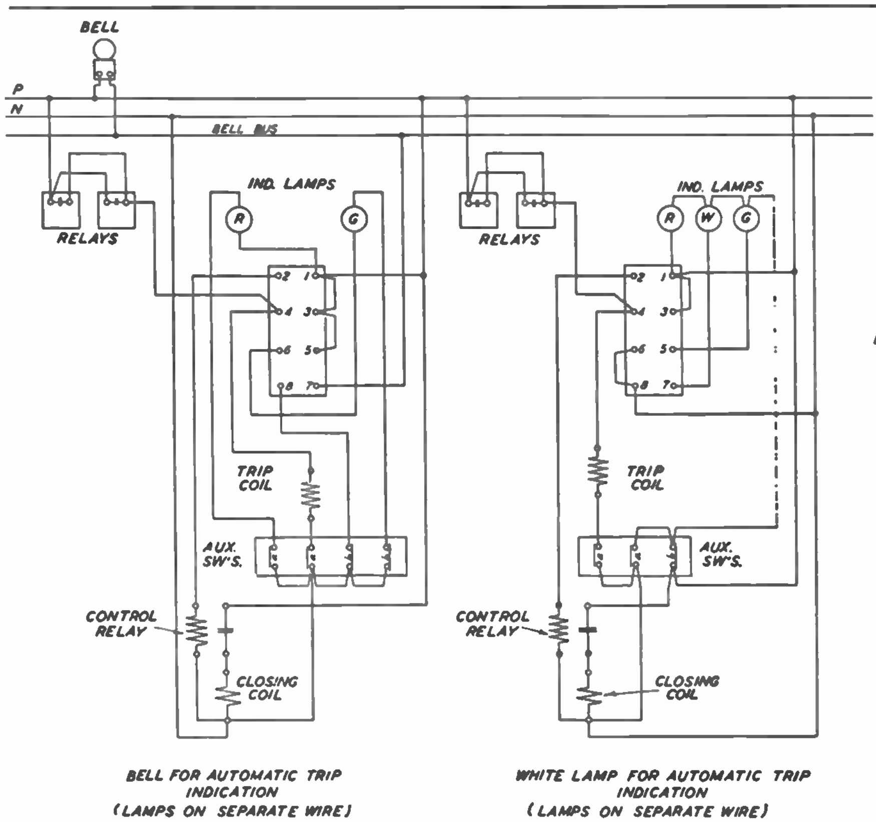


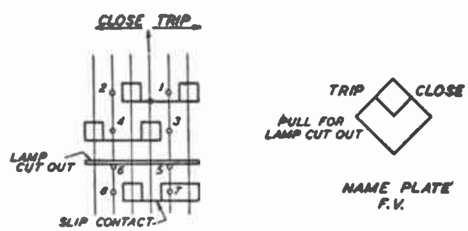


CONTACTS	POSITIONS			
	CLOSE	NORMAL	TRIP	PULLOUT
1-2	X			
3-4			X	X
5-6	X	X	X	

DRUM DEVELOPMENT (SPRING RETURN)

Circuit Breaker Control Switch, with lamp cut-out.





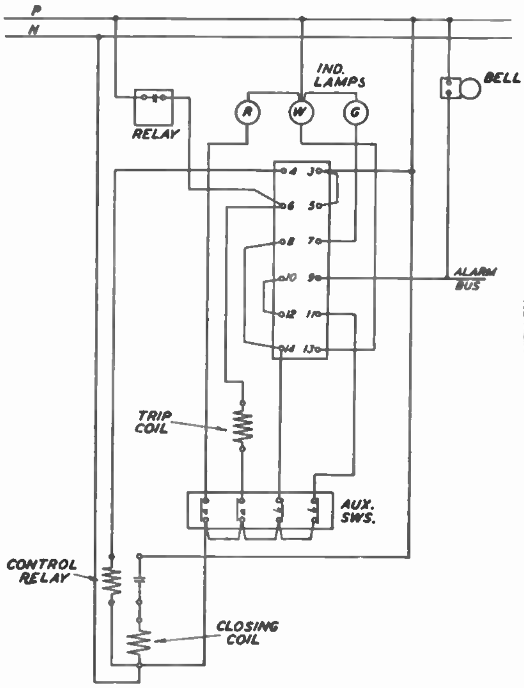
CONTACTS	POSITIONS				
	CLOSE	NORMAL AFTER CLOSE	TRIP	NORMAL AFTER TRIP	PULLOUT
1-2	X				
3-4			X		X
5-6	X	X	X	X	
7-8	X	X			

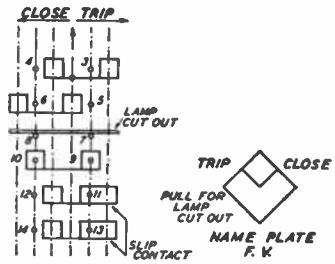
DRUM DEVELOPMENT (SPRING RETURN)

Circuit Breaker Control Switch, with automatic trip indicator

ALLIS-CHALMERS CIRCUIT BREAKER CONTROL SWITCHES

ROTARY — TYPE 153 — CONNECTION DIAGRAMS

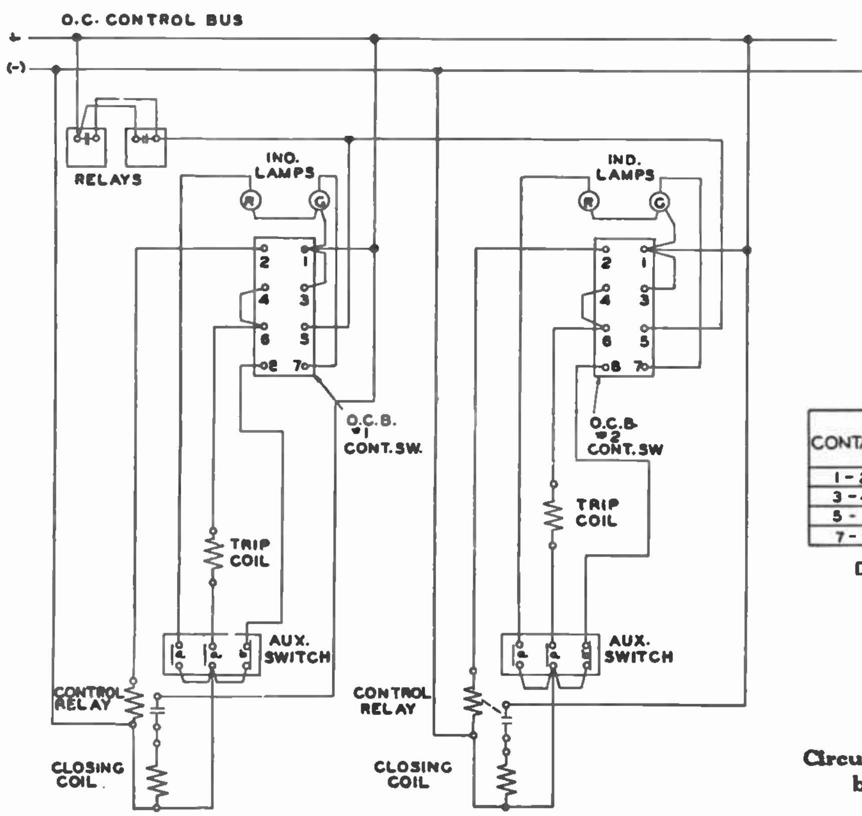


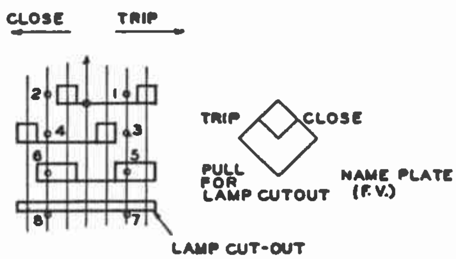


CONTACTS	POSITIONS: CLOSE	NORMAL AFTER CLOSE	TRIP	NORMAL AFTER TRIP	PULLOUT
3-4	X				
5-6			X		X
7-8	X	X	X	X	
9-10		X		X	
11-12	X	X			
13-14	X	X			

DRUM DEVELOPMENT
(SPRING RETURN)

Circuit Breaker Control Switch, with lamp cutout and two automatic trip indicators





CONTACTS	POSITIONS: TRIP	NORM	CLOSE	PULL OUT
1-2			X	
3-4	X			X
5-6		X	X	
7-8	X	X	X	

DRUM DEVELOPMENT
SPRING RETURN

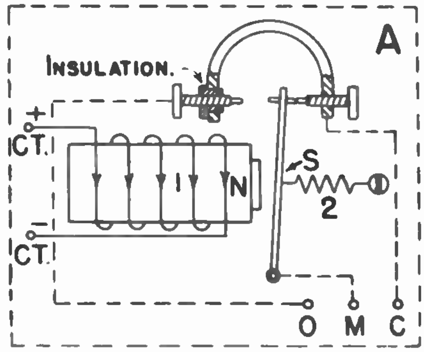
Circuit Breaker Control Switch, for double bus system

RELAYS.

A RELAY IS A MAGNETICALLY OPERATED SWITCH that can be used to:

1. Control circuits distant from the operating point.
2. Control a relatively high voltage or high wattage circuit by means of a low power, low voltage circuit.
3. Obtain a variety of control operations not possible with ordinary switches.

Whether the circuits controlled will be closed or opened when the relay coil is energized will depend upon the arrangement and connection of the relay contacts.



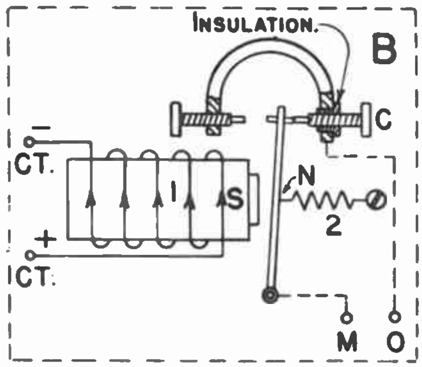
WESTERN UNION RELAY.

C=NORMALLY CLOSED CONTACT.
O= " OPEN "
M=MOVING CONTACT.
1= MAGNET COIL WITH TERMINALS CT.
2= SPRING.

ACTION

When current flows through the relay coil, it magnetizes the iron core with a polarity that depends upon the connection of the coil to the source. This pole induces in the iron section of the movable assembly, a pole of opposite sign, and the attraction between these operates the relay switch. If the current through the coil is reversed, both poles are reversed; therefore attraction always occurs. From above it is obvious that relays can be designed to operate on either direct or alternating current.

It is important to note that while relays may vary widely in mechanical construction, they all operate on the same principle. The sketches on this sheet show some of the differences in design.



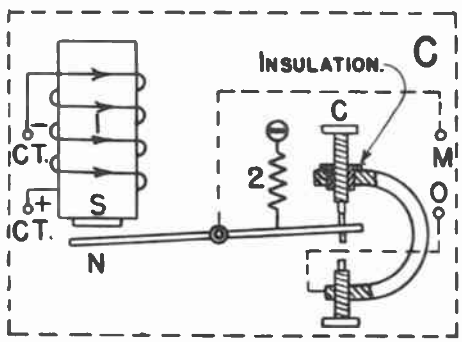
PONY RELAY.

TESTING

Before any attempt is made to connect a relay in a circuit:

1. Make a sketch of the terminal locations
2. Test and identify all terminals
3. Make sure the relay is operating

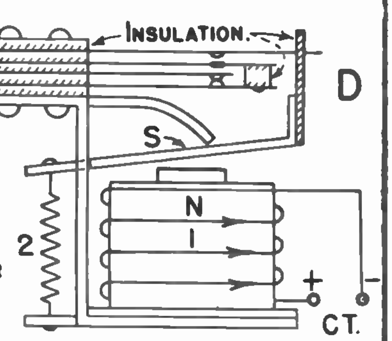
Using an ordinary test lamp circuit, first find the pair of terminals that, when the test leads are placed on them, causes the relay to operate. These are the coil terminals. Identify them on the terminal sketch with the symbols CT. Next locate by test, inspection, or both, the open, moving, and closed contact terminals. Mark them on the terminal sketch with the symbols O, M, and C respectively.



DIXIE RELAY.

After the terminals have been identified, check the operation. The relay should pull the movable section up as soon as the coil is energized, and drop it out as soon as the coil is deenergized. The moving section should not touch the core, and the tension on the spring should not be too low or too high. The relay switch contacts must be clean.

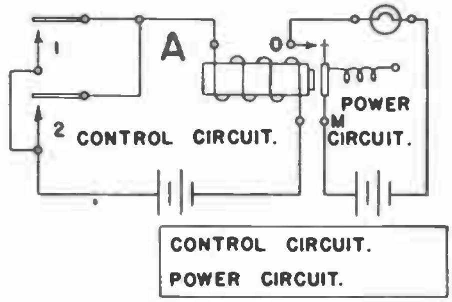
Connecting a relay in a circuit without first making the above tests is, in the general case, an inefficient and time wasting procedure.



CLAPPER TYPE RELAY.

RELAY CIRCUITS.

Diagram A shows an application in which a relay and a low voltage control circuit are used to operate a circuit carrying more power at a higher voltage.



To wire this circuit:

1. Make a note of the apparatus required. 2 open circuit switches; 1 relay; 1 lamp; 2 batteries.

2. Test all apparatus involved and select and use only that equipment that is in operating condition.

3. Wire each circuit one step at a time, and check each step before wiring the next.

4. Trace the circuits according to the method previously outlined.

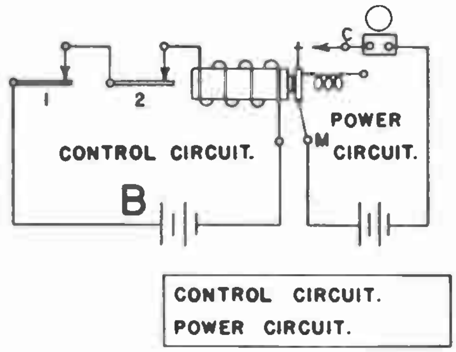


Diagram B shows a relay application similar to that indicated in A. In this case, however, the control circuit is normally closed, whereas in A the control circuit is normally open. The switches used are the closed circuit type. Note also that in diagram A the open contact of the relay switch is used in the power circuit, but that in B the closed contact is employed. The list of apparatus for this circuit will therefore be somewhat different than in the previous case. The procedure for wiring will be the same as before.

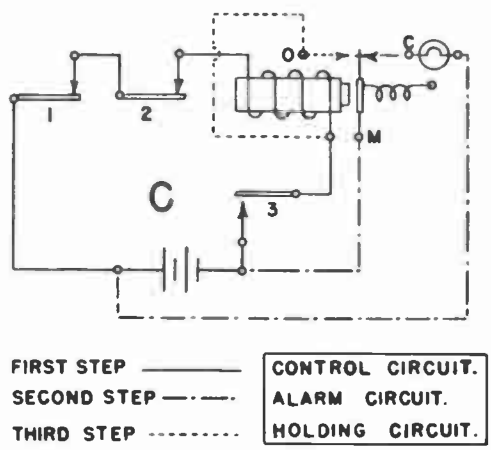


Diagram C shows relay applications in which a type of control not obtainable with ordinary switches is achieved. When switch 1 or 2 is pressed the relay switch closes the indicating circuit and the lamp lights and remains alight until switch 3 is pressed, when the relay is energized and stays that way until some other switch is operated.

Wire the circuit in 3 steps and test each before going on to the next. The first step is shown in solid lines, the second in dashed lines, and the third in dotted lines. Trace the circuits and show the color used in the boxed section.

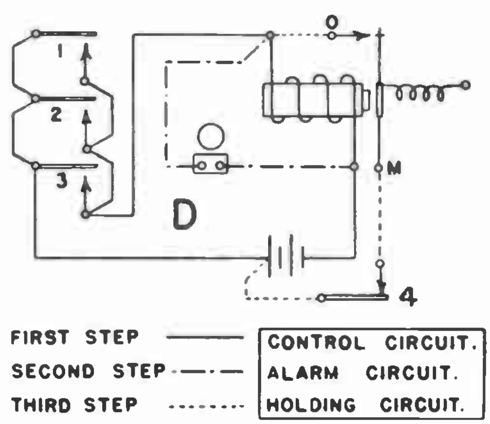
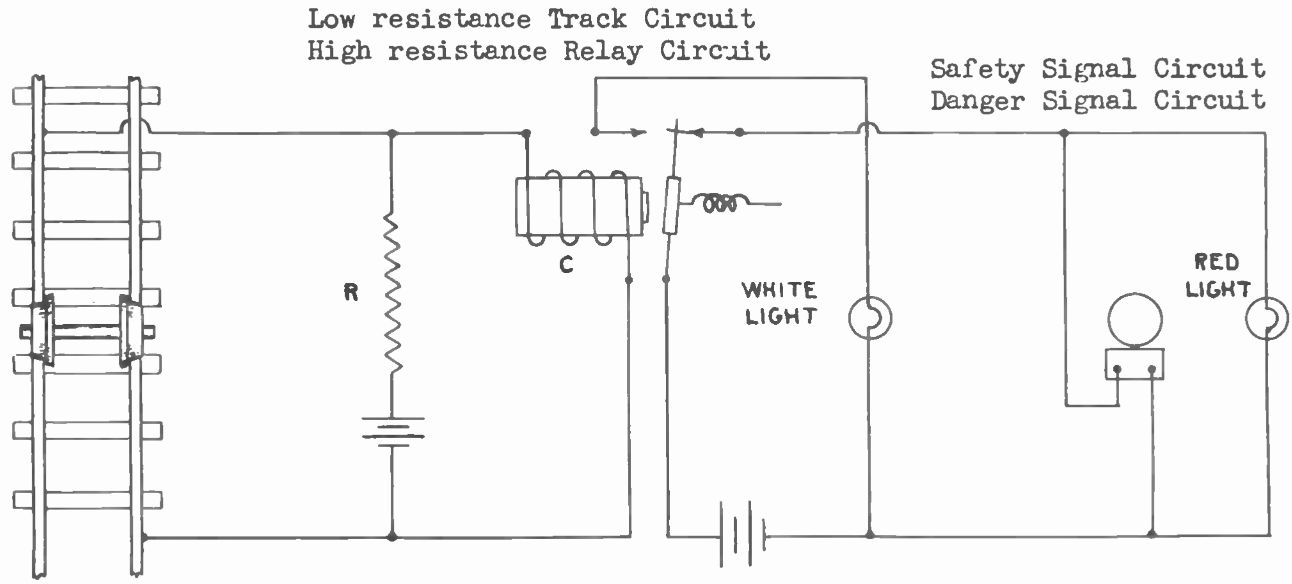


Diagram D shows another relay being used to obtain a special type of control. Switches 1, 2, or 3 energize the relay and close the bell circuit through the relay switch. The bell rings continuously until switch 4 is pressed to reset the relay.

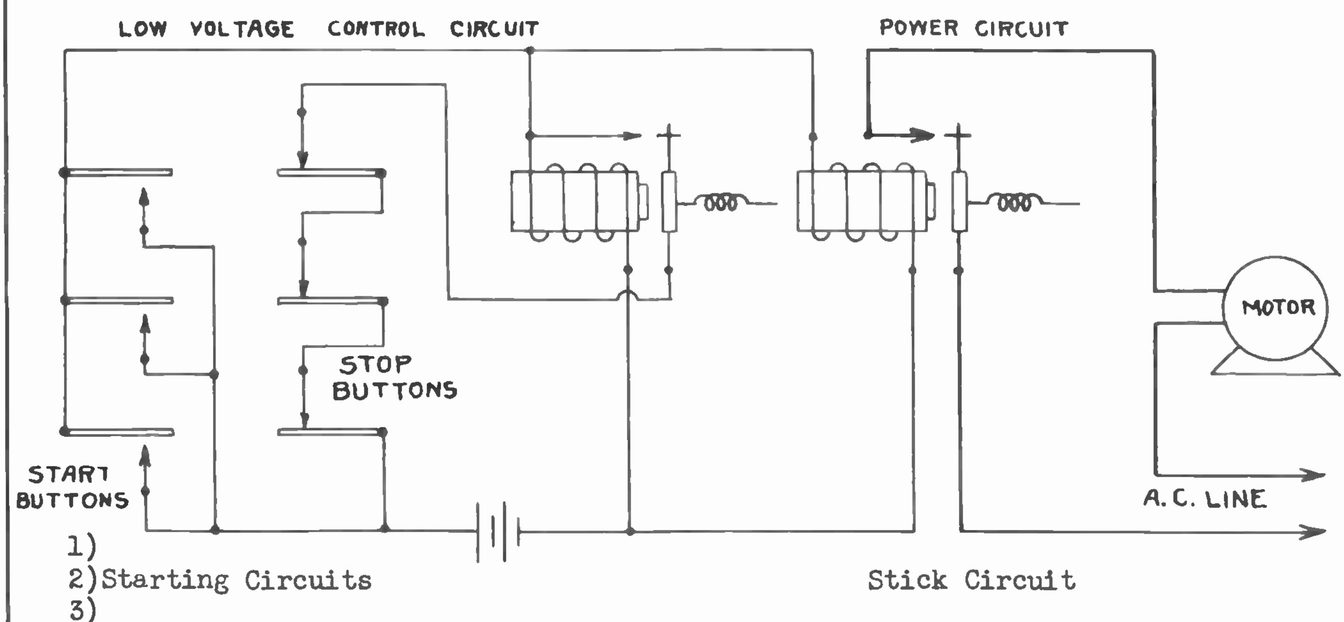
Wire a step at a time as directed in diagram C then trace the circuits and show colors used.

RELAY APPLICATIONS



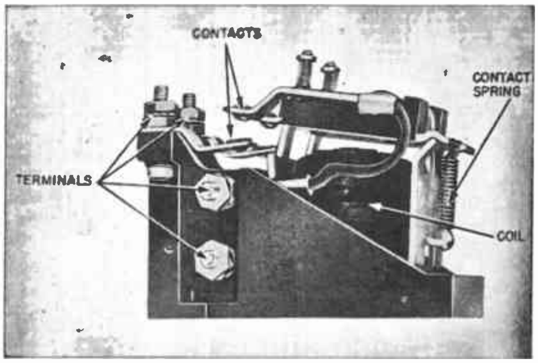
Railway crossing alarm system. When no train is on this section of the track, current will flow through the resistance "R" and the coil "C" of the high resistance relay. This will attract the relay armature, and complete a circuit through the open bridge contact and the white lamp, (clear signal.) When this section of track is shorted by the train wheels and axle, most of the current will flow through this lower resistance path, thereby greatly reducing the current through "C" and releasing the armature, closing the circuit to red lamp and bell, (danger signal.) An open circuit switch may be used in place of track on this job.

JOB 35



This diagram shows how a motor may be operated from several different places. Control systems similar to the above are often used to operate motors driving conveyors, printing presses, lathes, multiple drilling machines, and so on.

RELAY MAINTENANCE



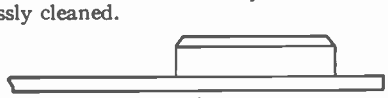
Typical Relay

RELAYS

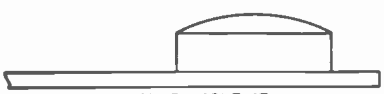
In electronic apparatus, relays are used for the following functions:

1. As contactor relays to close power circuits. Their contacts are designed to carry large amounts of current.
2. As interlock relays to associate two different components or circuits in such a way that one will not operate unless certain conditions are fulfilled by the other.
3. As overload or underload relays to operate when the current or voltage in the circuit exceeds or drops below the predetermined value. They are generally used to protect the equipment.
4. As time delay relays to protect equipment. In general, this type of relay can be adjusted to operate after a period of a few seconds, or action can be delayed as long as 50 minutes. The time delay relay is usually used to allow a certain component to heat up before other potentials or components are turned on.
5. Telephone type relays used in high speed sequence circuits and time delay circuits. Adjustments and cleaning of most relays of this type should not be attempted by the maintenance man unless the adjusting tools and instructions recommended by the manufacturer are available. It is usually better to stock spare relays and return defective relays to the factory.
6. Special applications such as, when contact galvanometers are used to measure and control various things like temperature, carbon monoxide gas, or many other applications.

Relay contacts are usually of two kinds—hard surface or soft surface types. Hard surface contacts are made of various alloys. The soft surface contacts are of two kinds: Solid silver and silver-plated. Knowledge of the kind of material used in the contacts is important. Improper cleaning of silver plated contacts will soon remove the plating. The care of solid silver contacts deserves special attention as they are made of soft metal which will wear away at an excessive rate if carelessly cleaned.



FLAT CONTACT



CONVEX CONTACT

Relay Contacts

Relay contacts are of various shapes, depending upon their size and application. In some instances both contacts are flat; while in other cases, one contact is convex and its mate is flat. The original shape of a contact must be retained during cleaning. If burning or pitting has distorted the contact so that it must be reshaped, the original shape must be restored. It is essential that maintenance men familiarize themselves with all details of relays by examining them while they are in good condition. In this way they will be prepared to do their work well.

Relays enclosed in glass, bakelite or metal cases require the removal of the cover for maintenance. Some relays are not covered but must be partially disassembled in order to inspect contacts and completely disassembled in order to clean the contacts. Some relays can be inspected and cleaned without being removed from their mountings or taken apart. Although specific instructions for removing relays are given under the individual maintenance items in the instruction book supplied with the apparatus, a few details apply to all relays and are presented here for general guidance. Before removing a relay, take these steps:

Removing Relays

1. Examine the base of the relay to determine the location of the mounting screws. If possible, examine the other side of the panel and determine how the screws are fastened in place. Panels, covers or other parts often must be removed prior to the removal of the relay. Determine what must be done before attempting to remove it. This will save time and prevent damage to equipment.
2. Attach a tag to each relay terminal, with a number or letter on it; and attach a tag with the same identification mark to the associated connecting lead.
3. Remove each lead from its terminal and bend it carefully out of the way. When the leads are reconnected, match terminals and leads that have corresponding numbers or letters.

Inspecting Relays

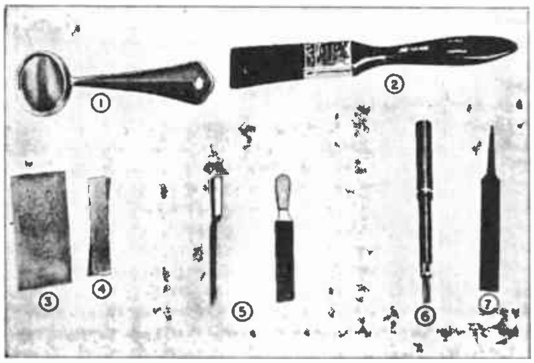
Inspect the relay to detect abnormal conditions. If the contacts are not readily accessible, they should be inspected with the aid of a flashlight and a mirror. The mechanical action of the relays should be checked to make certain that when moving and stationary contacts come together they make positive contact and are directly in line with each other. The contacts must have the required "wipe" and "gap" for the particular relay. If an A.C. relay is excessively noisy, it is due to one of two reasons. First, the armature may not make a mechanically perfect union. Since it is usually a ground fit, any attempt to file it may make it worse. This requires expert care or a new armature. The other cause is that the shading coil or short circuited copper winding embedded in the armature face has open circuited. A new coil or new armature is required. The armature or plunger mechanism should move freely, without binding or dragging. Do not damage or misalign the relay mechanism. A relay is considered normal if it meets all of the following requirements:

1. The assembly is free from dirt, dust and other foreign matter.
2. The contacts are not burned, pitted or corroded.
3. The contacts are lined up and correctly spaced.
4. The contact springs are in good condition.
5. The contact moving parts travel freely and function in a satisfactory manner. (The solenoids of plunger type relays must be free from obstruction.)
6. The connections to the relay are tight.
7. The wire insulation is not frayed or worn.
8. The relay assembly is securely mounted.
9. The coil shows no sign of overheating.
10. The relay is not abnormally noisy.

RELAY MAINTENANCE

Tighten all loose connections and mounting screws, but do not apply enough force to damage the screw or break the parts it holds. Do not start a screw with its threads crossed. If a screw does not turn easily, remove it and start over again.

Clean the exterior of the relay with a dry cloth. If it is very dirty, clean it with a cloth (or brush dipped in cleaning fluid) and wipe the surface with a dry cloth to remove the film left by the fluid. If connections are dirty and corroded, remove, clean and replace them carefully.



Relay Cleaning Tools

1. Dental Mirror, Non-magnifying.
2. Paint Brush.
3. Lint-free Cloth.
4. #0000 Sandpaper strip ¾" x 6".
5. Sandpaper on stick, see Fig. 11 for constructional details.
6. Burnishing Tool.
7. Fine-cut file.

MAINTENANCE RELAY CONTACTS

Hard alloy contacts will require the following maintenance: Clean dirty contacts by drawing a strip of thin, clean cloth or paper between them while they are held together. In some cases, it may be necessary to moisten the cloth with cleaning fluid. Use a dry cloth or paper strip for polishing.

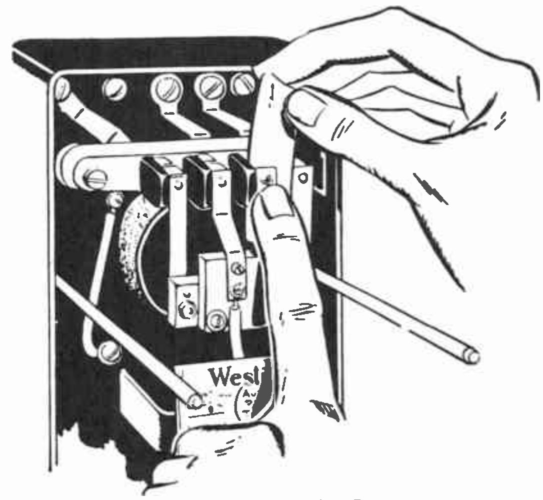
Clean corroded, burned or pitted contacts with a burnishing tool. This tool is not a file and is used on relays with extremely hard contacts. A contact should not be burnished unless it is found to be pitted or oxidized, and then not any more than is necessary to restore a smooth, clean surface. The original shape of the contact must be retained.

Solid silver contacts may be cleaned with a cloth or brush dipped in cleaning fluid. After cleaning, polish contacts with a dry cloth. The brown discoloration that is found on silver and silver-plated relay contacts is silver oxide, which is a good conductor. It should be left alone unless the contacts must be cleaned for some other reason. It may be removed with a cloth moistened in cleaning fluid.

Deeply pitted solid silver contacts will require shaping with a fine file or #0000 sandpaper.

In cleaning solid silver contacts, insert fine sandpaper between the contacts and draw it through them while the contacts are gently pressed together with the fingers, or, use sandpaper glued to a piece of wood

NOTE—After using sandpaper, small particles of abrasive may remain on the contact surfaces and must be removed to assure good contact.



Cleaning Relay Contacts

When the corrosion has been removed, wipe the contacts with a clean cloth moistened with cleaning fluid. The final operation in cleaning should be polishing with a dry cloth, so as to make sure that all of the grains of sand from the sandpaper are removed from the contact surface. Make certain that the shape of the contacts has not been altered from the original.

Burned or pitted solid silver contacts should be resurfaced, if necessary, with #0000 sandpaper. The original shape of the contact should be retained. After a high polish has been obtained, wipe thoroughly with a clean cloth, using a cleaning fluid when required.

Very badly burned or pitted contacts should be replaced, if possible. If a replacement is not available use a fine-cut file to remove the pit. The original shape of the contact must be preserved. After filing, apply #0000 sandpaper, and finally a clean dry cloth.

Silver-plated contacts are cleaned with a cloth or brush dipped in cleaning fluid. After being cleaned, the contacts are polished with a dry cloth. When corroded, contacts should be cleaned with sandpaper. This must be done very carefully so as not to remove too much of the silver plating. When the corrosion has been removed, polish the contacts with a clean, dry cloth, making certain that the shape of the contact has not been changed.

Silver-plated contacts that are badly burned or pitted should be replaced. If a replacement is not immediately available, the contacts may be dressed with sandpaper until the burned or pitted spots are removed. If you find that the sandpaper does not remove the burns or pits, then use a burnishing tool very carefully.

The use of a file on silver-plated contacts is recommended for only extreme emergencies.

Highly abrasive materials such as emery cloth, heavy sandpaper or carborundum paper should never be used for surfacing relay contacts as these materials will damage the contact surfaces.

Adjust contact arms to the correct positions if they have been moved during cleaning. Take care not to change the settings of adjustable relays. The correct settings and proper means of adjustment for the contactors and relays of a specific equipment will be found in the instruction book supplied with the equipment.

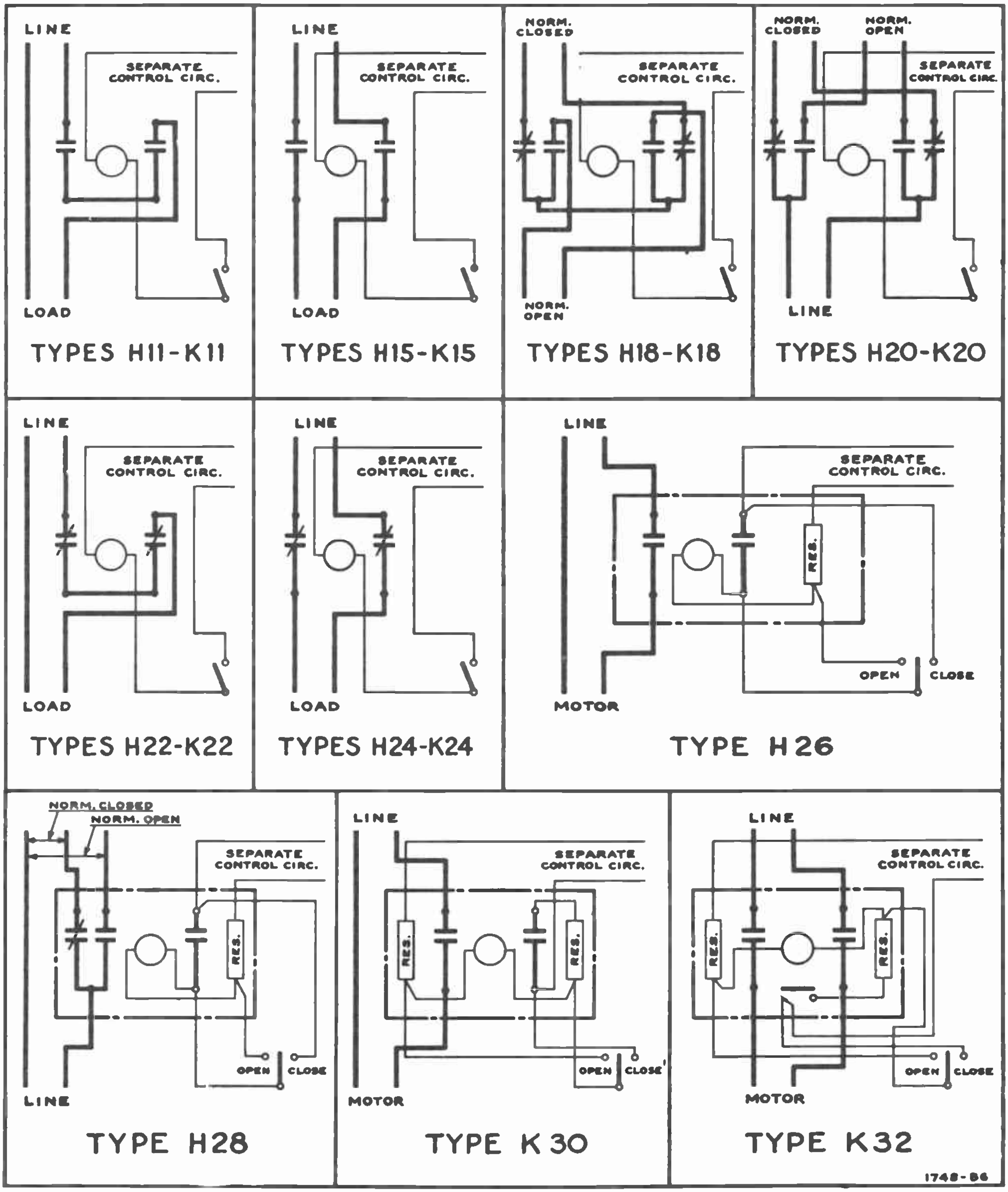
Maintenance Sales Department

Westinghouse Electric Corporation

Wiring Diagrams

CLASS 8501

A. C. MAGNETIC RELAYS

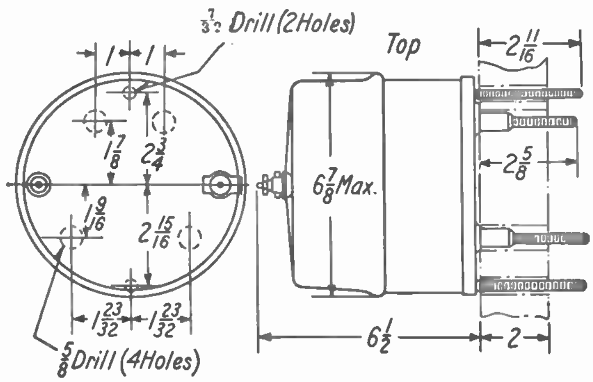


WESTINGHOUSE RELAYS

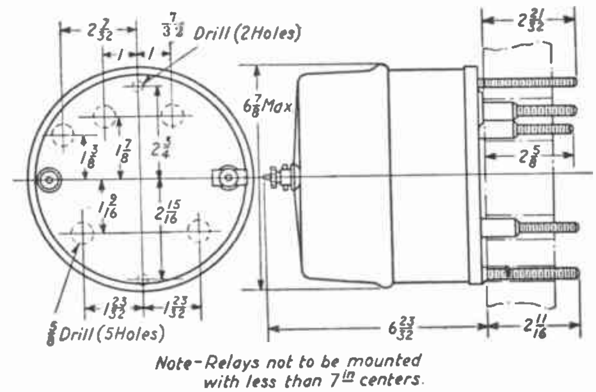
TYPE CV VOLTAGE RELAYS—Continued

Round Case Relays

OUTLINE DIMENSIONS IN INCHES

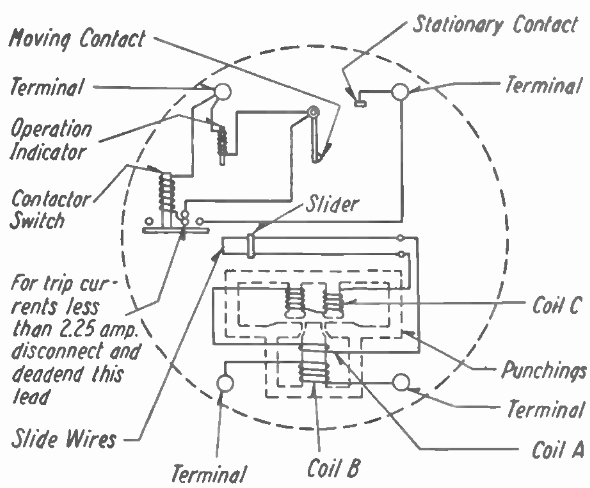


—TYPE CV RELAY, OVER OR UNDERVOLTAGE, NON-GEARED OR GEARED, SINGLE-CIRCUIT CLOSING

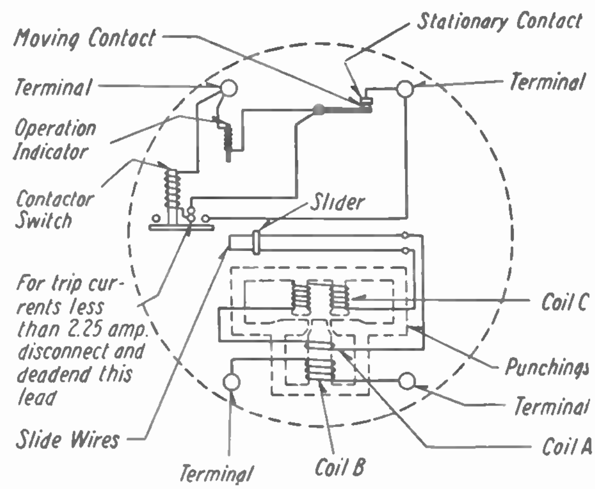


—TYPE CV RELAY, OVER OR UNDERVOLTAGE, TWO-CIRCUIT CLOSING, NON-GEARED OR GEARED DOUBLE-THROW CONTACT, ONE-CIRCUIT OPENING, ONE-CIRCUIT CLOSING

WIRING DIAGRAMS



—SINGLE-TRIP, OVERVOLTAGE, TYPE CV RELAY REAR VIEW

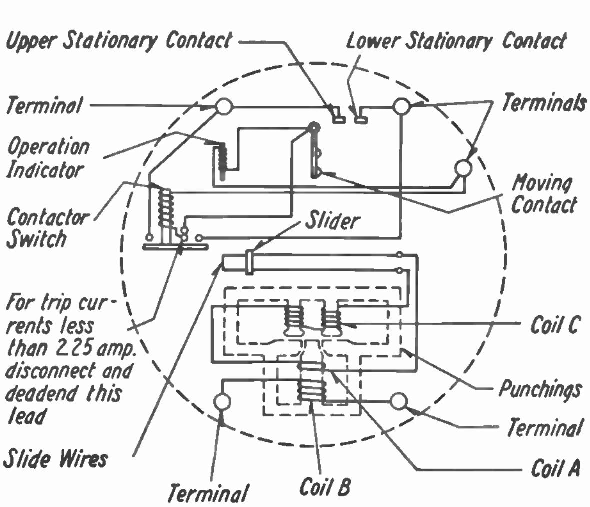


—SINGLE-TRIP, UNDERVOLTAGE, TYPE CV RELAY REAR VIEW

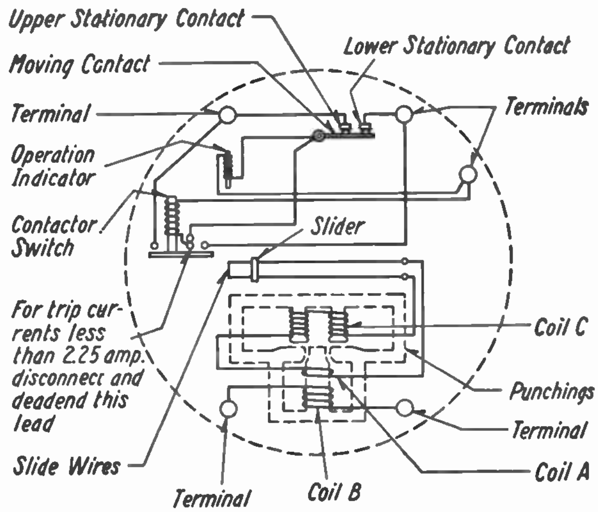
Westinghouse Relays

TYPE CV VOLTAGE RELAYS—Continued

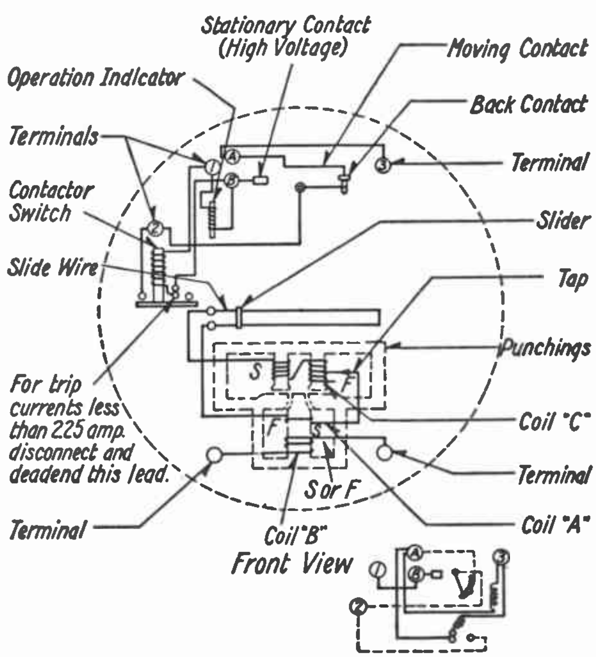
WIRING DIAGRAMS—Continued



—Double-Trip, Overvoltage, Type CV Relay—Rear View



—Double-Trip, Undervoltage, Type CV Relay—Rear View



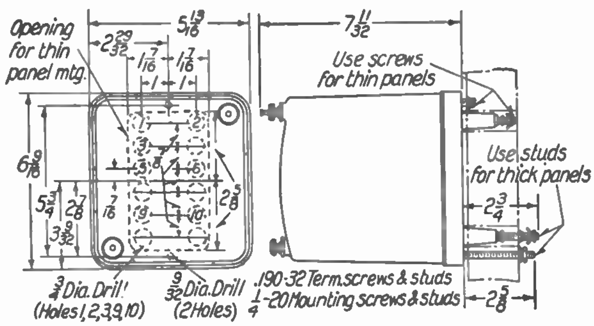
This is the standard conn. with the ind. & contactor switch in the high voltage contact circuit. To put these in the low voltage, circuit interchange the lead between A & 3 with the circuit between B & 1 as shown in small diagram above.

—Single-Pole Double-Throw, Type CV Relay

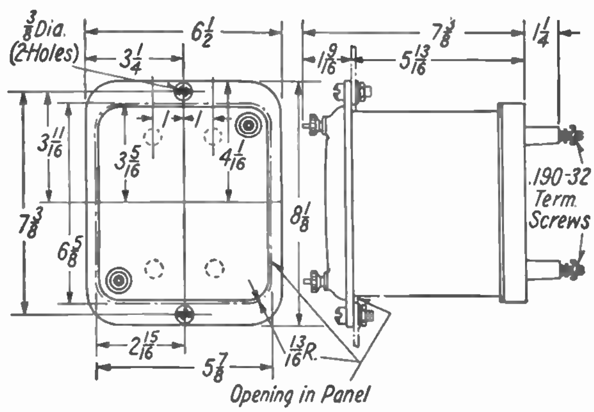
TYPE CV VOLTAGE RELAYS—Continued

Rectangular Relays

OUTLINE DIMENSIONS IN INCHES



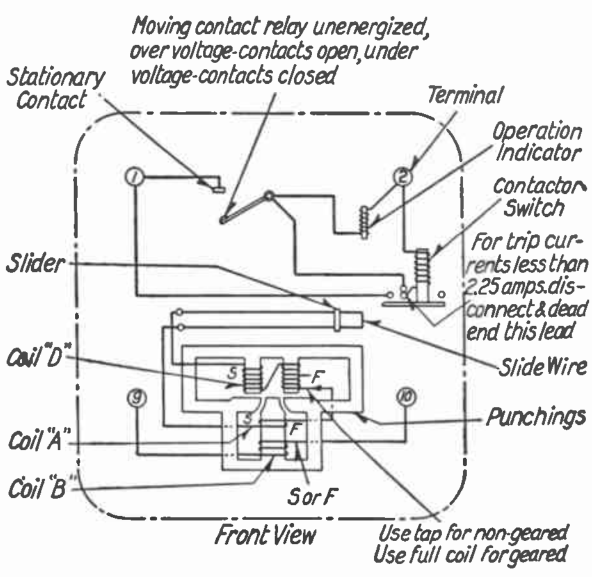
—Type CV Relay, Projection Type Outline and Drilling Plan



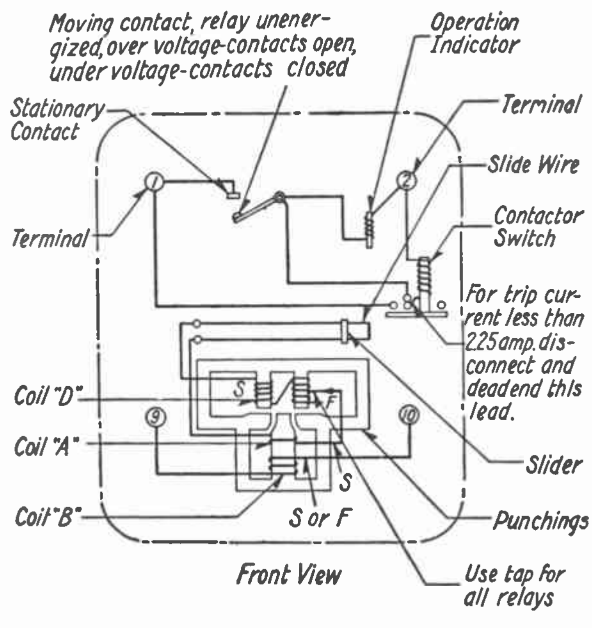
—Type CV Relay, Flush Type Front Mounting Outline

NOTE—Use terminals 1, 2, 9, and 10 for single trip relays. For double trip relays use 1, 2, 3, 9, and 10.

WIRING DIAGRAMS



—Standard Undervoltage or Long Time Overvoltage Single Trip CV Relay

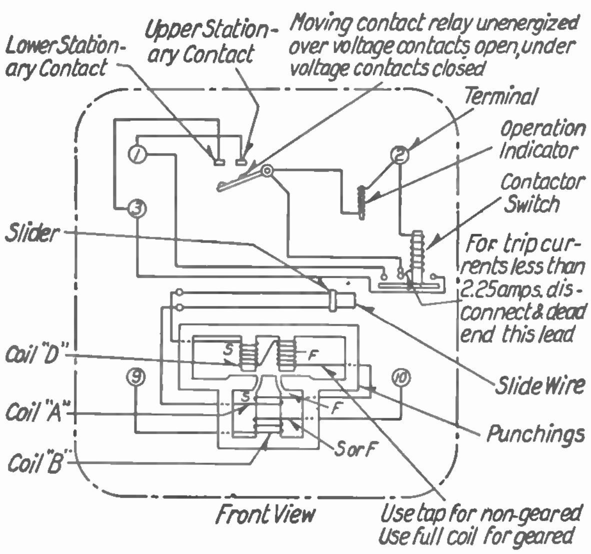


—Standard Overvoltage or Long Time Undervoltage Single Trip Relay

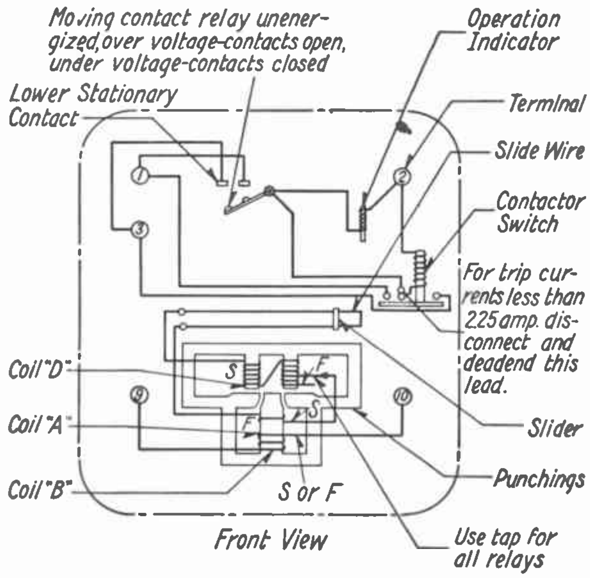
Westinghouse Relays

TYPE CV VOLTAGE RELAYS—Continued

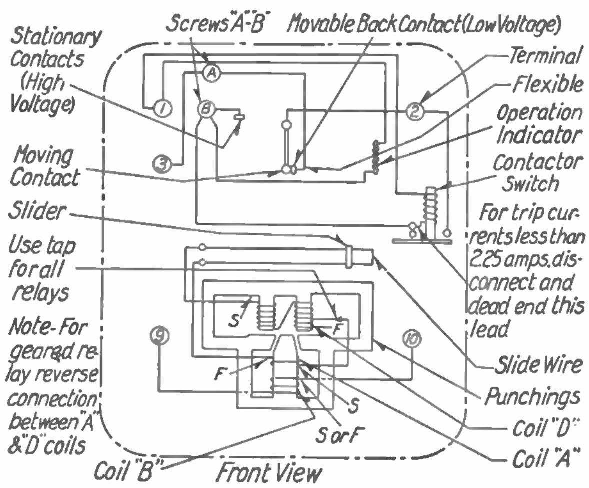
WIRING DIAGRAMS—Continued



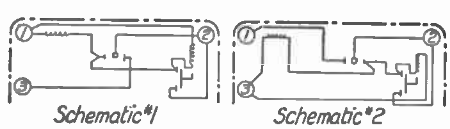
—Standard Undervoltage or Long Time Overvoltage Double Trip CV Relay



—Standard Overvoltage or Long Time Undervoltage Double Trip CV Relay



This is the standard arrangement with indicator and contactor switch in series with the high voltage contacts (See Schematic #1). To put the indicator in the low voltage circuit, interchange the lead between A and 3 with the circuit between B and 1 as shown in Schematic #2.

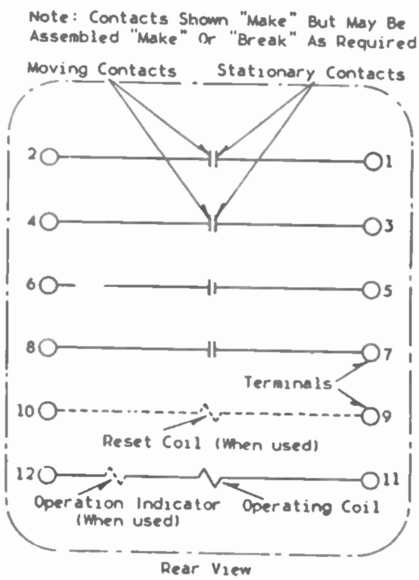


—Single-Pole Double Throw CV Relays

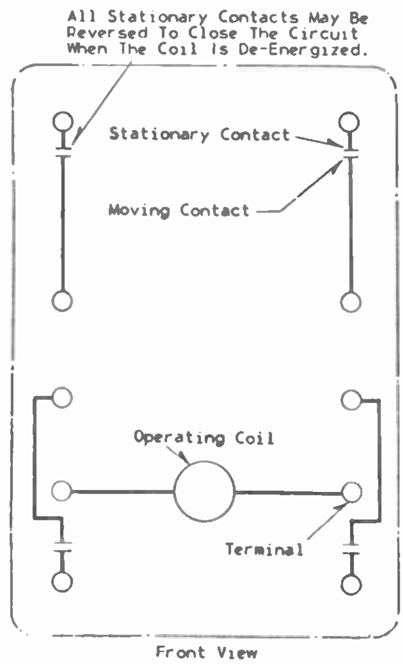
Westinghouse Relays

TYPES MG-4 AND MG-6 MULTI-CONTACT AUXILIARY RELAYS—Continued

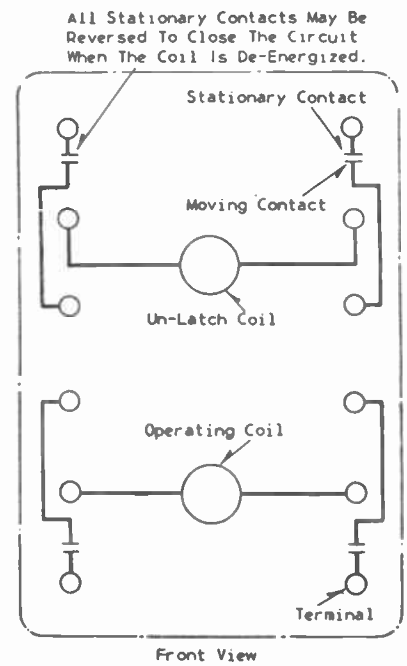
WIRING DIAGRAMS



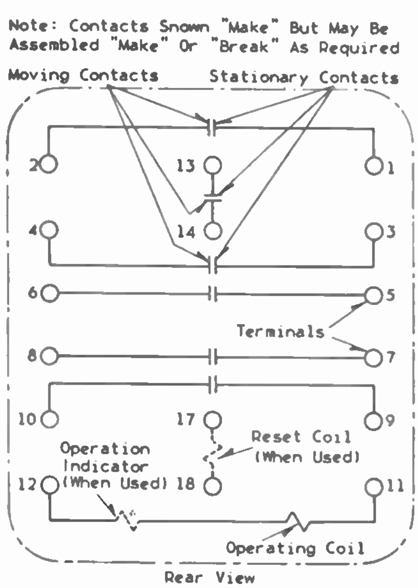
—Wiring Diagram of Type MG Relay, Four Contacts in Standard Case



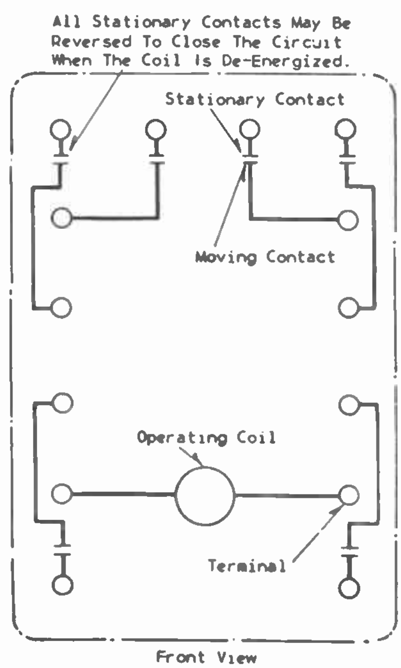
—Wiring Diagram of Type MG Relay, Four Contacts with or without Contact Latch and Hand Reset



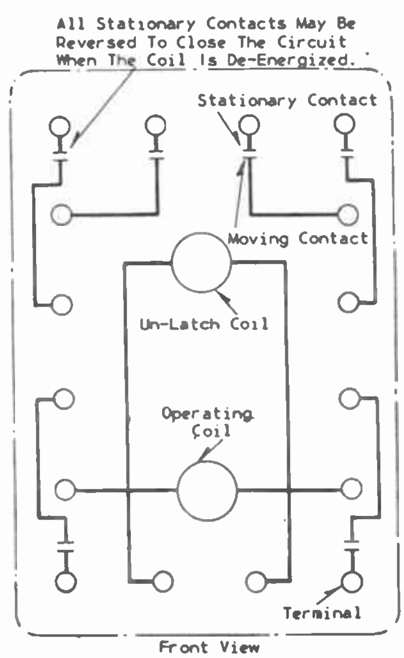
—Wiring Diagram of Type MG Relay, Four Contacts, Contact Latch with Electrical Reset and Hand Reset



—Wiring Diagram of Type MG Relay Six Contacts, in Standard Case



—Wiring Diagram of Type MG Relay, Six Contacts, with or without Contact Latch and Hand Reset

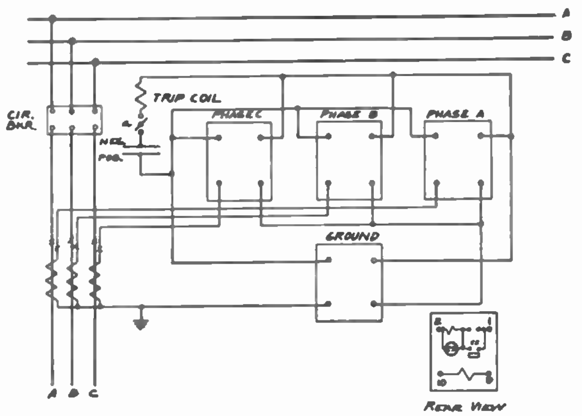


—Wiring Diagram of Type MG Relay, Six Contacts, Contact Latch, with Electrical Reset and Hand Reset

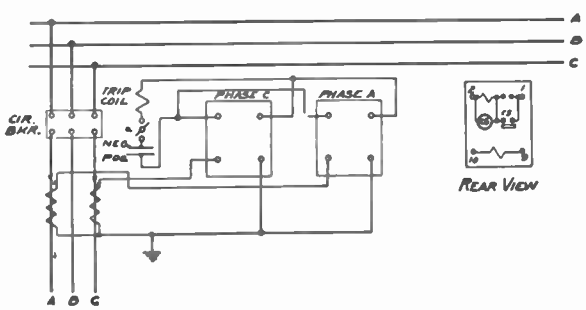
Westinghouse Relays

TYPES CO AND COH OVERCURRENT RELAYS—Continued

CONNECTION DIAGRAMS—Continued



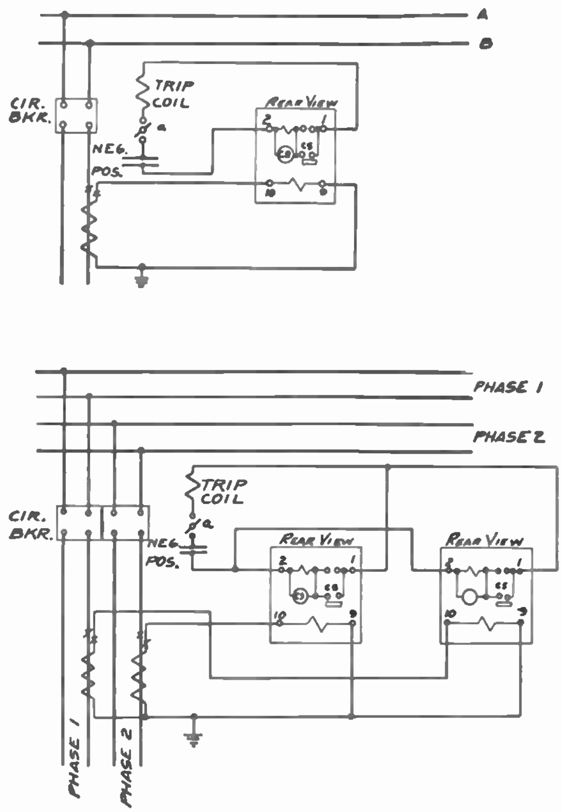
With Grounded Neutral System for Complete Phase and Ground Protection.



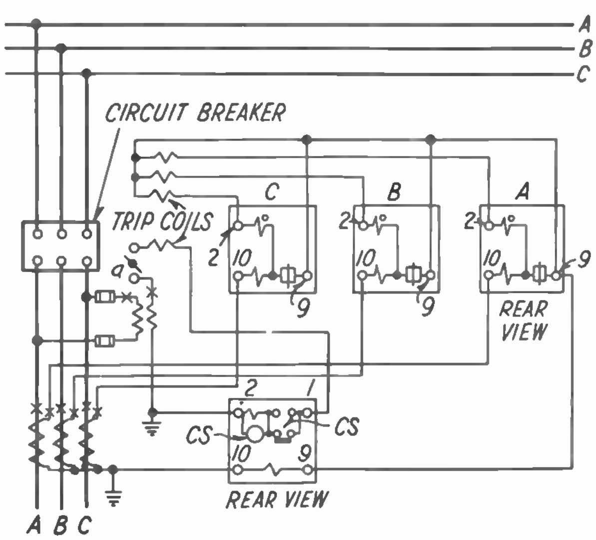
With Ungrounded Neutral

Note: No Protection for Simultaneous Ground Fault on Phase B and in Generator.

—External Connections Using Circuit Closing CO Relays on 3 Phase Systems



—External Connections for Single and Two Phase Systems



Rear View

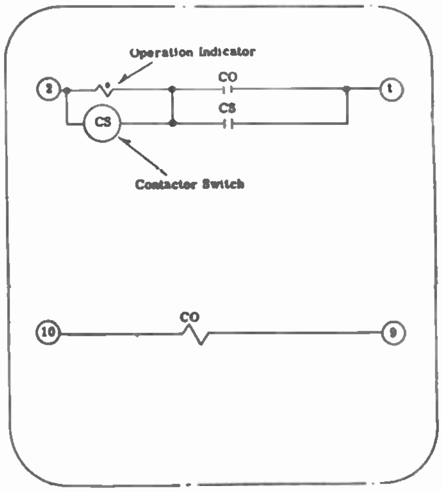
—External Connections Using Circuit Opening CO Relays for Phase Overload Protection and Circuit Closing CO for Ground Protection

Westinghouse Relays

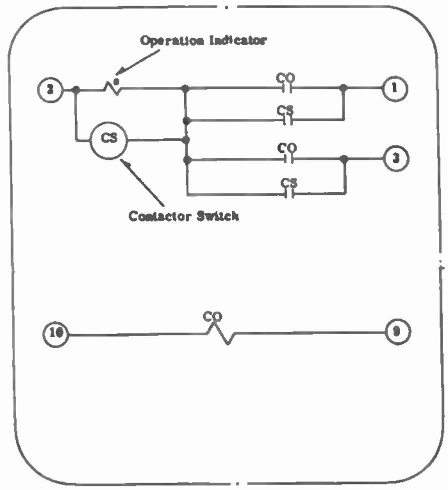
TYPES CO AND COH OVERCURRENT RELAYS—Continued

WIRING DIAGRAMS

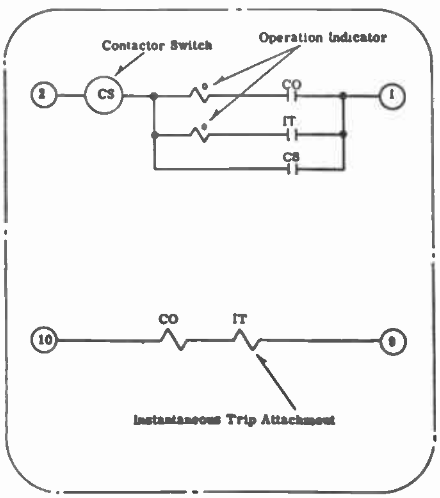
Standard Case—(Rear Views)



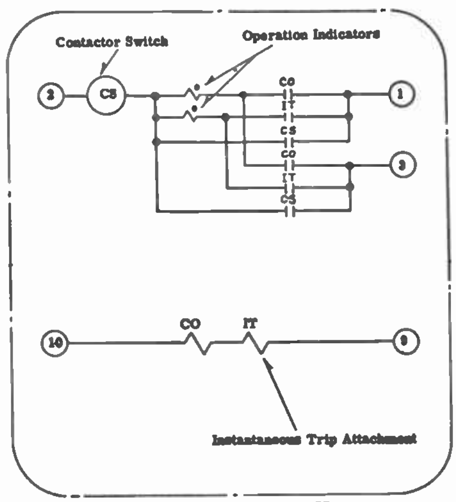
—Single Trip CO and COH Relays



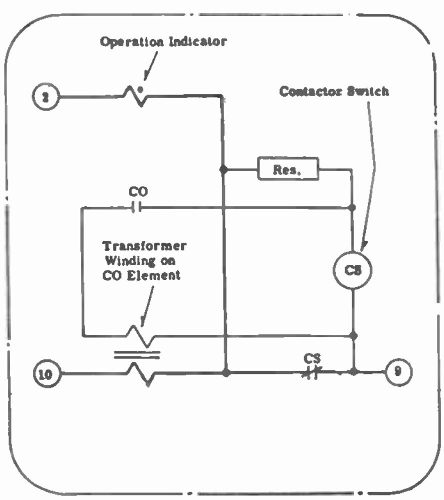
—Double Trip CO and COH Relays



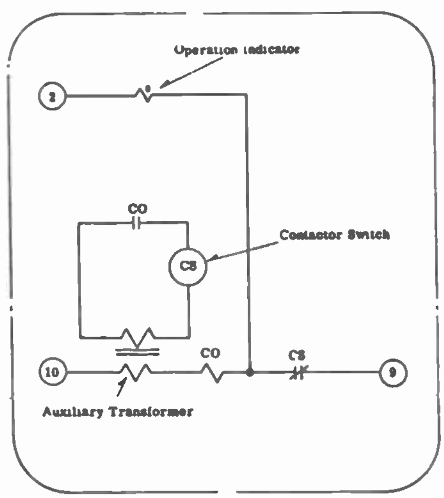
—Single Trip CO and COH Relays with Instantaneous Trip Attachment



Double Trip CO and COH Relays with Instantaneous Trip Attachment



—Circuit Opening Definite Time CO Relay



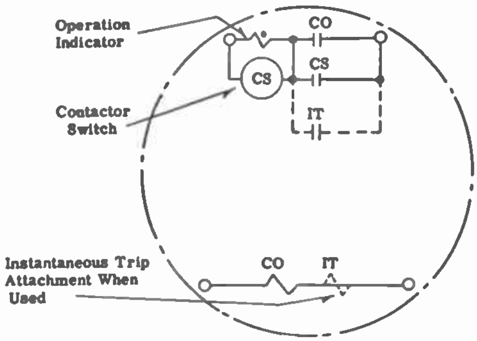
—Circuit Opening Inverse and Very Inverse CO Relay

Westinghouse Relays

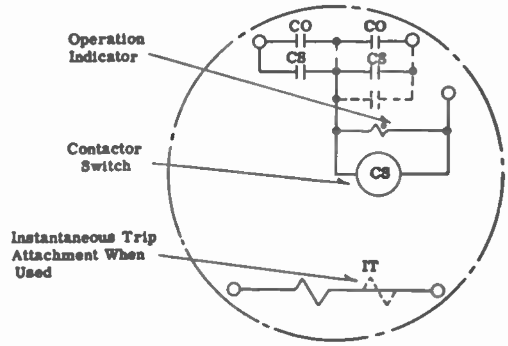
TYPES CO AND COH OVERCURRENT RELAYS—Continued

WIRING DIAGRAMS—Continued

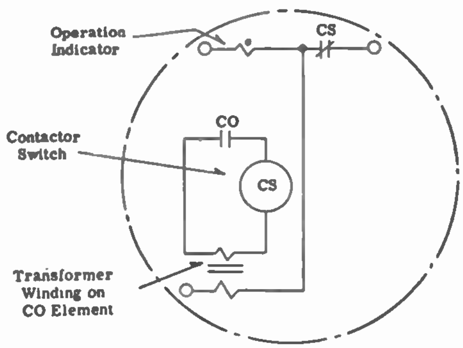
(Rear Views)



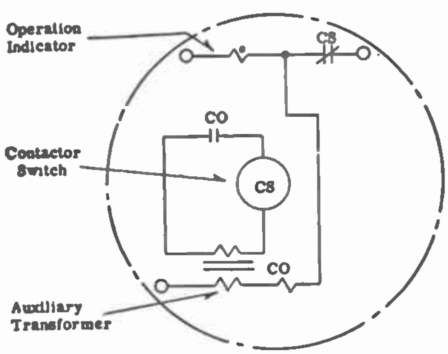
—Single Trip CO and COH Relays in Round Case



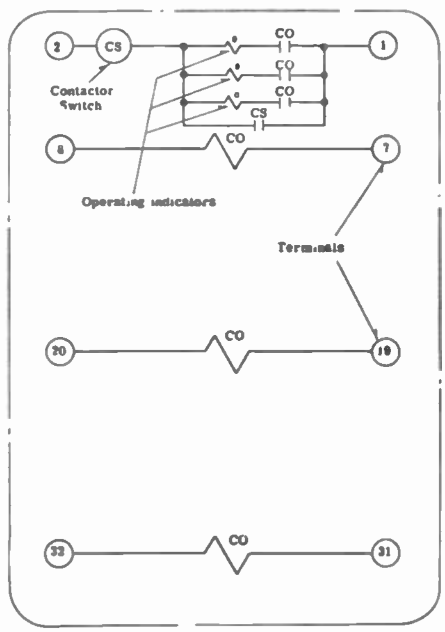
—Double Trip CO and COH Relays in Round Case



—Circuit Opening Definite Time CO Relay in Round Case

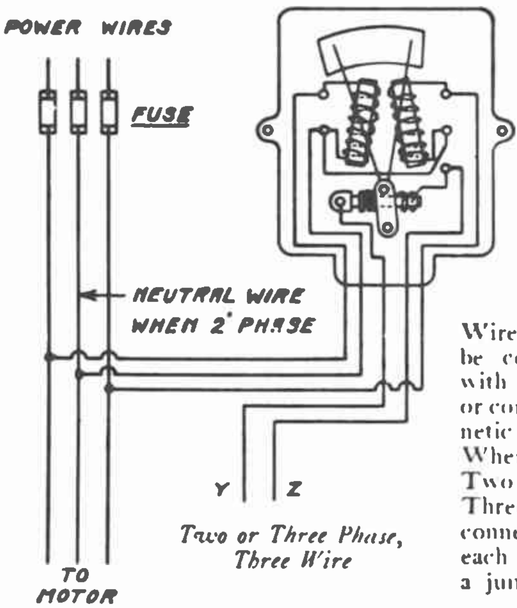


—Circuit Opening Inverse and Very Inverse CO Relays in Round Case



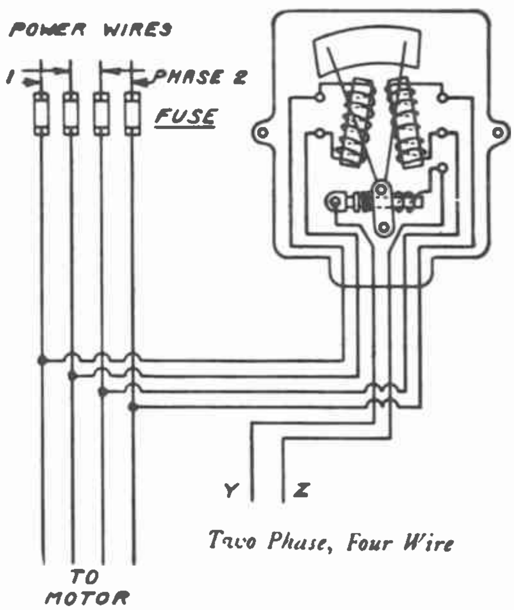
—Three Element CO Relay in Standard Case

Reverse Phase Relay



Two or Three Phase, Three Wire

Wires Y and Z are to be connected in series with line contactor coil or common wire of magnetic reversing switches. When connecting to a Two or Three Phase Three Wire circuit, connect one terminal of each coil together with a jumper as illustrated



Two Phase, Four Wire

PHASE REVERSAL

It is a well known fact that the reversal of one phase of a polyphase circuit will cause the motor to rotate in the reverse direction. In the case of elevators, hoists and cranes a reversal of motor rotation is almost certain to result in either injury to persons, or damage to product or property, with the probability that all will occur.

In addition to elevators, hoists and cranes, motor driven machinery of any kind is liable to serious damage or destruction on account of motor reversal which is caused by phase reversal, and the use of the Reverse Phase Relay is therefore, desirable for even continuously running motors.

If a phase reversal occurs while the motor is running the ES Reverse Phase Relay acts to open the main motor circuit which stops the motor. Or if the motor is not running it acts to prevent it being started until the phases are restored to their normal order.

PHASE FAILURE

The ES Reverse Phase Relay also provides protection against phase failure of the power which otherwise might result in motor burn out.

If the load is approximately the full load capacity of the motor, the motor will stall if a phase failure occurs, and the Reverse Phase Relay will open the magnetic switch control circuit which will prevent the motor burning out or being started again until the phases are restored.

LOW VOLTAGE

If there is an appreciable drop in voltage the motor will stall and the ES Reverse Phase Relay will open the control circuit of the magnetic switches thereby preventing the burning out of the motor.

When there is an appreciable drop in voltage, the torque developed in the Reverse Phase Relay is not sufficient to keep the contacts in the closed position and the Relay acts to open the main motor circuit.

A spring is used only to maintain good contact. In case of phase failure the contacts are opened by the force of gravity, but in the case of reversal of one phase the force of gravity is augmented by the force exerted by the coils turning the aluminum vane to the right.

POSITION INDICATORS.

Position indicators are employed to transmit motion by electrical means between points which cannot be readily connected mechanically. In Figure A rotation of the arm on the sender rheostat varies the current through the receiver which is used as a receiver. When properly calibrated, the meter needle motion will be proportional to the motion at the sender. Thus the amount of gasoline in the tank may be indicated on the instrument panel of a car.

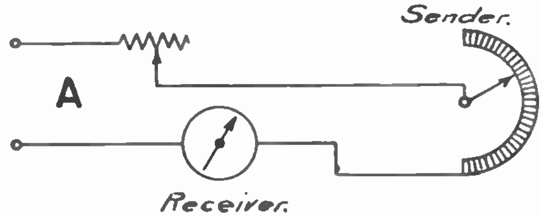


Figure B shows a similar arramgement except that clockwise rotation of the sender increases the voltage applied to the receiver and the deflection is in proportion to it.

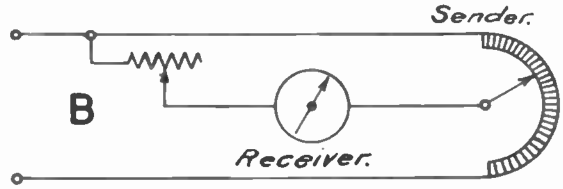
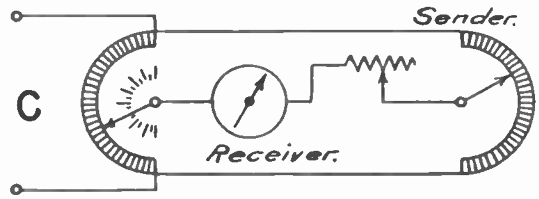
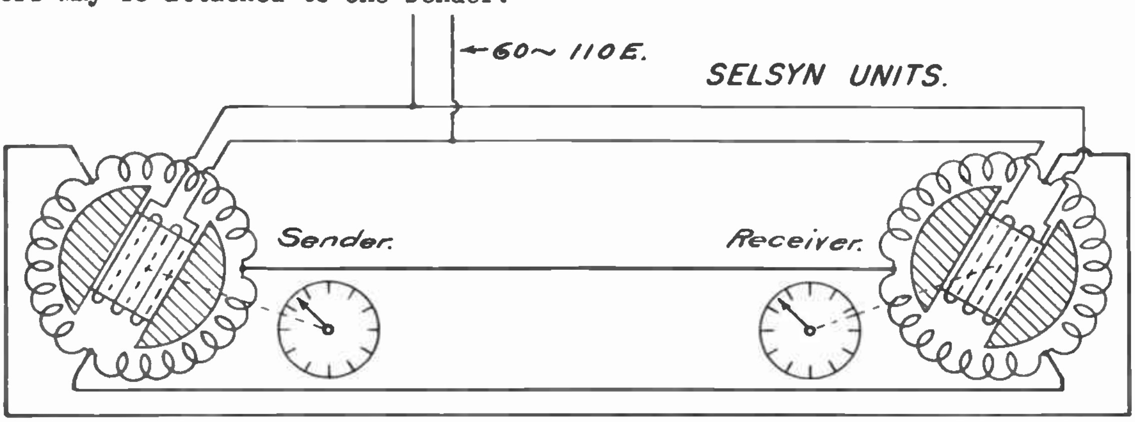


Diagram C shows a bridge type circuit in which the meter needle is returned to zero by manipulating a rheostat at the receiving end. When balanced, both rheostat arms are in identical positions.



There are many other circuit arrangements but the basic operating principle is the same. The electrical method is particularly suited to most applications because the units may be any distance apart, and several receivers may be attached to one sender.



If two small motors of the type shown above are connected together and the rotors are energized from a single phase A.C. source, the varying flux produced by the rotors will induce voltages in the stator windings. If the rotors are in identical positions, the induced stator voltages will be in direct opposition and no current will flow in the leads connecting the stators together. Should one rotor be moved, this voltage balance is disturbed and current will flow through the other stator winding in such a direction as to cause its rotor to move to a corresponding position. This self synchronizing action which is characteristic of many types of A.C. motors is utilized in the Selsyn position indicator.

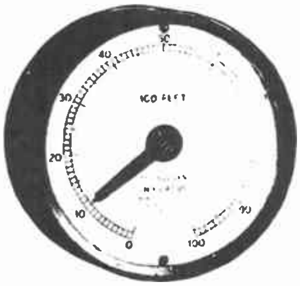
With the indicators arranged as shown, movement of the sender rotor is duplicated by the receiver and, whether the sender is rotated through a small angle or several revolutions, the receiver follows the motion exactly. Where several indications are required, several receivers may be attached to the same sender. In this way motion of the sender may be reproduced at any number of remote points.

Coyne.

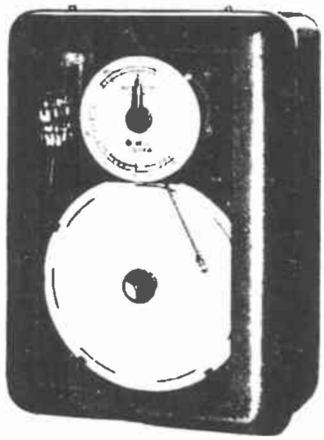
SELSYNS*

For Remote Signaling, Control, and Indication

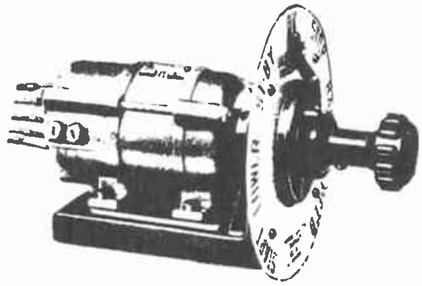
SELSYN DEVICES



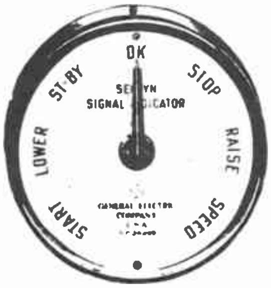
Standard-type level indicator



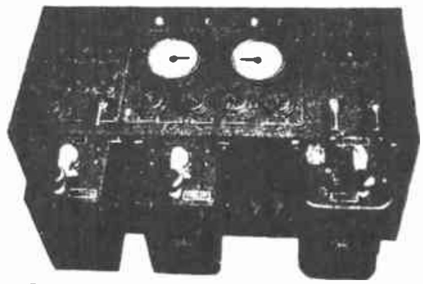
Combined indicator and recorder



Selsyn transmitter



Standard-type signal indicator



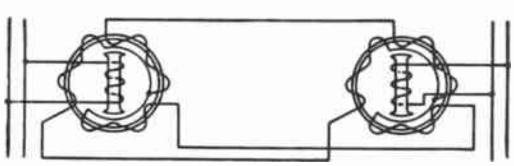
Control bench, with Selsyn indicators for double-bascule bridge

DESCRIPTION AND OPERATION

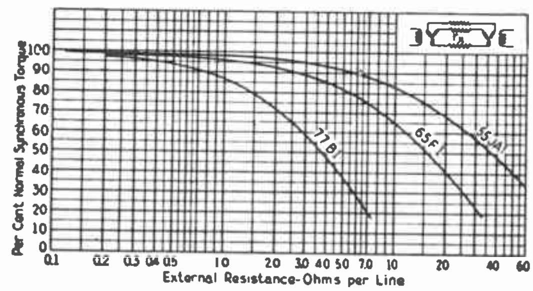
"SELSYN" is a General Electric trademark for self-synchronous devices. These devices are similar to 3-phase induction motors, but have two definite field poles, the windings of which are connected to a single-phase, alternating-current source of excitation. Two of these units are used in a simple Selsyn system. One is operated at the sending point as a generator and is called the transmitter; the other is operated at the receiving point as a motor and is known as the receiver. The secondary windings of the transmitter are connected to those of the receiver, as shown in the diagram below.

When the primary excitation circuit is closed, an alternating-current voltage is impressed on the primary of both the transmitter and the receiver. Since the receiver rotor is free to turn, it assumes a position similar to that of the transmitter rotor. As the transmitter is turned (either manually or mechanically), the receiver rotor follows at the same speed and in the same direction.

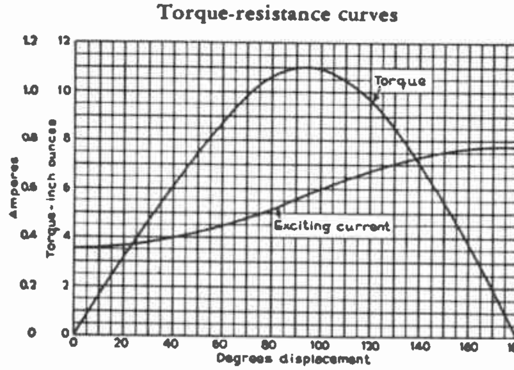
The reason for this self-synchronous action is because the single-phase current in the primary induces voltages in the three legs of each secondary. These three voltages are not equal in magnitude, and vary with the position of the rotor. When the two rotors are in exactly corresponding positions, the voltages induced in the transmitter secondary are equal and opposite to those induced in the receiver secondary; that is, they are balanced, so that no current flows in the secondary windings.



Connection diagram showing interconnected stator windings and rotor windings connected to source of excitation



Torque-resistance curves



Type 2J55 Selsyn torque curve

If, however, the transmitter rotor is moved from the original position, the induced voltages are no longer equal and opposite, and current flows in the secondary windings. This current flow sets up a torque which tends to return the rotors to the synchronous position. This position corresponds to the new position of the transmitter.

SELSYNS

FEATURES

Selsyns are strong and compact. There is no complicated assembly of parts that requires adjustment and there are no delicate parts to get out of order. An important characteristic of the Selsyn is its comparatively high torque, which prevents the indicator pointer from oscillating when it swings into position. An internal mechanical damper is furnished with the Selsyn receiver in order to prevent oscillation when synchronizing, and to overcome any tendency of the receiver to run as a motor. Features which make this system desirable for the service to which it is applicable are:

Reliability. All parts are designed for long life. High-grade ball bearings are used in the rotors to insure accuracy and to reduce maintenance. Collector rings and brushes are used to assure an uninterrupted flow of current.

Accuracy. Selsyns are exceptionally accurate because of a careful balance of electric and mechanical parts, and the use of low-friction bearings.

Continuous Indication. Operation of the indicator (motor) is definite and at all times in agreement with the transmitter (generator). The movement is smooth and continuous.

Instantaneous Response. The indicator responds immediately to the changes of position of the transmitter. There is no hesitation in starting. The transmitter moves, and the indicator follows instantly.

Self-synchronous. If power fails, the indicator is automatically reset in agreement with the transmitter on resumption of power. Necessity of removing the cover and resetting the rotor by hand and then checking back and forth with the transmitter is obviated.

Convenient Location. The indicator may be located wherever desired. It is small and compact, and may be mounted on a panel, pedestal, wall or desk, in brief, in the most advantageous position.

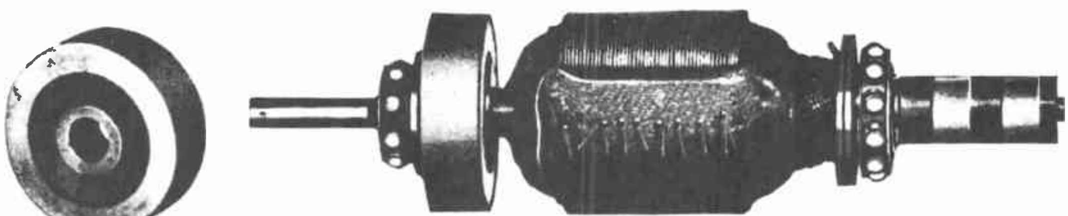
Ease of Installation. It is necessary only to bolt the devices in place and run a few wires.

Multiple Indication. When used for indication, one transmitter may be used with several properly sized indicators so that indication and signals can be made simultaneously at several places.

Selective Operation. For indication and signaling, one transmitter, if desired, can send to a number of indicators, one at a time. This is accomplished by a selector switch mounted with the transmitter.

Scope. Selsyns can be used to indicate either linear or angular movement. They can also be used to control, from a distant point, the motion of a device by controlling its actuating element.

Serviceability. The Selsyn system installed on the control boards of the Panama Canal locks is operating as efficiently today as when it was first operated in 1914.



Wound rotor, with damper for Selsyn Model 2JD55JA1. *Left:* View of damper removed

TWO CLASSES OF SELSYNS

There are two general classes of requirements which Selsyns must meet: in some cases, it must be an exceptionally quiet unit of very high accuracy; but for general-purpose applications, an inexpensive, fairly accurate unit not having to meet stringent noise requirements may be acceptable. To meet the first requirement, the following Selsyns have been developed:

Instrument High Accuracy Type

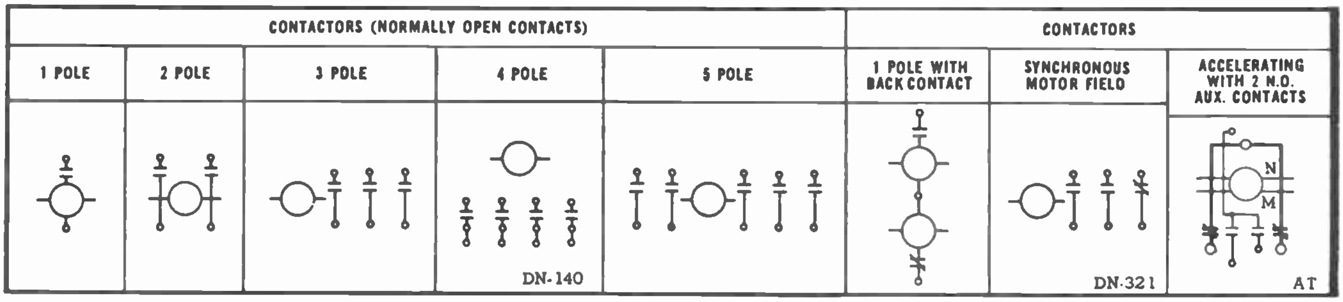
2J55JA1. This model develops a maximum safe continuous operating torque of 2.7 in-oz., which occurs at 20 degrees displacement. This unit has a primary winding suitable for 110-volt excitation and a secondary winding developing 55 volts. The accuracy of this unit is tested at the factory and must be within the limits of ± 1 degree. The bearings are high-quality ball bearings, lubricated at the factory, and require but little attention in the field. The unit is totally enclosed, dustproof, and very compact, although extremely sturdy.

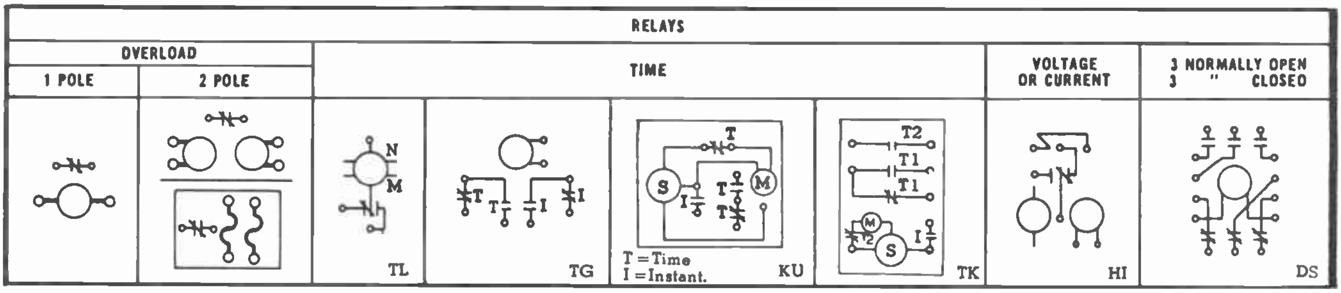
2JD55JA1. This model is identical with the 2J55JA1 except that it is equipped wtih an oscillation damper. This oscillation damper has a braking effect on the oscillations which may develop as a result of overshooting.

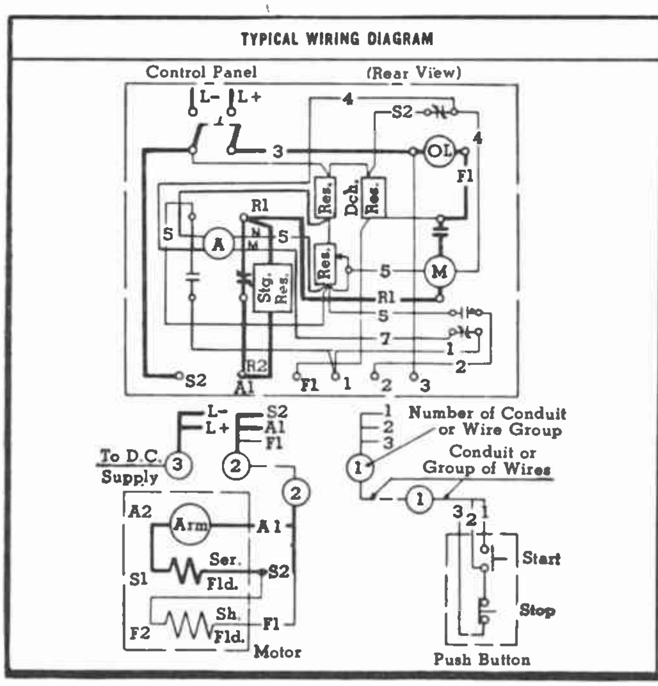
N.E.M.A. INDUSTRIAL CONTROL STANDARD DEVICE MARKINGS

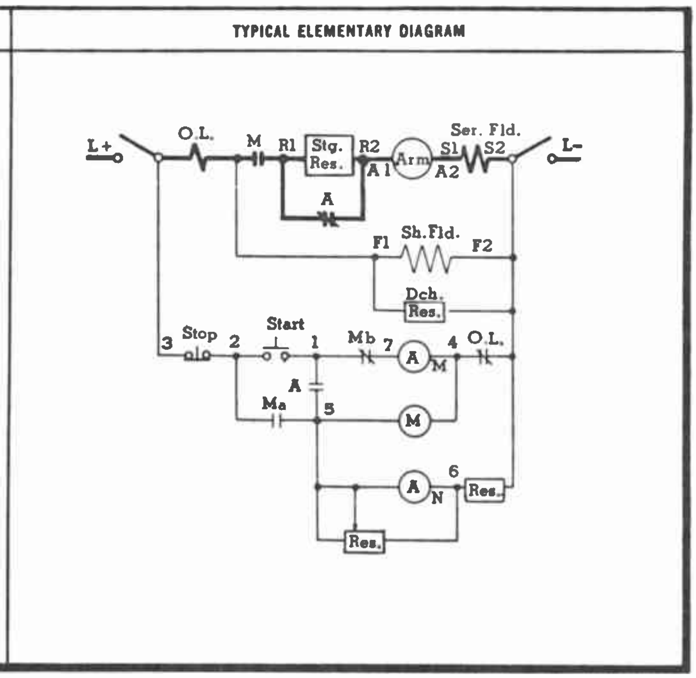
THE MARKINGS GIVEN BELOW ARE INTENDED FOR USE ON DIAGRAMS IN CONNECTION WITH SYMBOLS TO INDICATE THE FUNCTION OR USE OF THE PARTICULAR DEVICE

Armature Acceleration	A	Field Discharge	FD	Final Limit—Up	FLU	Maximum Torque	MT
Armature Shunt	AS	Field Dynamic Braking	DF	Final Limit—Down	FLD	Middle Landing	MLD
Aux. Sw. (Breaker) Normally Open	"a"	Field Failure (Loss of Field)	FL	Forward	F	Main or Line	M
Aux. Sw. (Breaker) Normally Closed	"b"	Field Forcing (Decreasing on Variable Voltage)	DF	Full Field	FF	Motor Field	MF
Balanced Voltage	BV	Field Forcing (Increasing on Variable Voltage)	CF	Generator Field	GF	Overload	OL
Brake	BR	Field Protective (Field Weakened at Standstill)	FP	High Speed	HS	Pilot Motor	PM
Compensator—Running	MR	Field Reversing	FR	Hoist	H	Plug	P
Compensator—Starting	MS	Field Weakening	FW	Jam	J	Reverse	R
Control	CR	Final Limit—Forward	FLF	Kick Off	KO	Series Relay	SR
Door Switch	DS	Final Limit—Reverse	FLR	Landing	LD	Slow Down	SD
Down	D	Final Limit—Hoist	FLH	Limit Switch	LS	Thermostat	TS
Dynamic Braking	DB	Final Limit—Lower	FLL	Lowering	L	Time	T
Field Acceleration	FA			Low Speed	LS	Up	U
Field Deceleration	FD			Low Torque	LT	Undervoltage	UV
				Low Voltage	LV	Voltage Relay	VR
				Master Switch	MS		





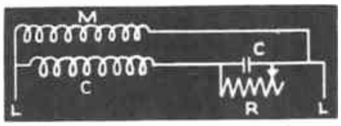




Speed Control Characteristics of Fractional Horsepower Motors

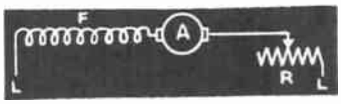
For some types of motors, such as standard, synchronous, or induction motors, it is impractical to obtain speed control. In fact, it is their fixed or steady speed under varying loads which makes synchronous and induction motors so ideal for many applications. Their speed can be controlled, of course, by changing the frequency of the applied current, but this method is not commonly used for fractional horsepower motors.

Shaded pole and split-phase motors with high-resistance rotors may be operated with some reduction in speed by inserting resistance in the stator circuit. The speed of capacitor motors may be controlled by employing a high-resistance rotor and shunting an adjustable resistor across the capacitor.

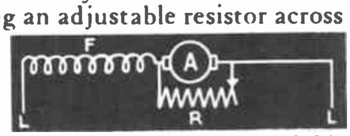


There are two general types of speed control: *stepless control* with all possible intermediate speeds over a required range; and *step-by-step control* which limits control to two or more definite speeds.

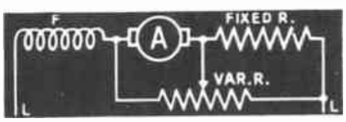
SERIES MOTORS. The simplest method of controlling the speed of a series motor is to connect an adjustable resistor in series with the motor. The speed for a given load decreases as the control resistance is increased. If enough resistance is added, the motor can be decreased to a standstill, but a reduction in speed of 50% is usually considered the practical limit. In all cases, the speed is highly sensitive to load changes. The slightest increase or decrease in load, due to friction in bearings, belts, gears, and other parts, causes a change in motor speed. This is a characteristic of all series motors, and nothing can be done to prevent it except to use governor control, discussed later. There are many applications, however, in which load conditions are quite uniform at all speeds, and for such applications, the series motor is very satisfactory. A series motor can also be controlled by shunting an adjustable resistor across the armature.

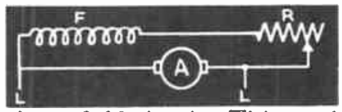


Although the control range is somewhat less, the speed is likely to be more stable, and the starting torque is better because of the stronger field.

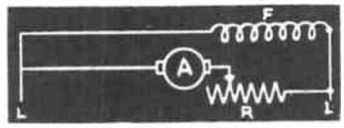


Another way to get series motor speed control over a wide range, and still retain reasonable stability at low speeds is to connect a fixed resistor in series with the armature and use a variable resistor across armature. This combination, however, requires an actual test with the proper load to determine the necessary resistance values and wattage ratings of the resistors. If this is not done carefully, the resistors may burn out. Such testing is also needed to assure maximum speed stability.

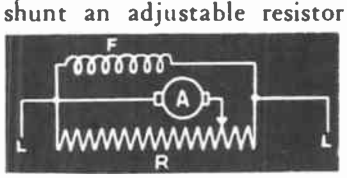




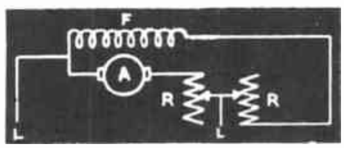
SHUNT MOTORS. It is common practice to regulate the speed of shunt motors by inserting resistance in the shunt field circuit. This weakens the magnetic field which, in turn, speeds up the motor. Such field control provides stable motor speeds at light loads provided the magnetic field is not appreciably weakened. To reduce the speed of a shunt motor, resistance must be added to the armature circuit.



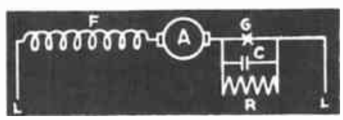
Another way to reduce the speed of a shunt motor is to shunt an adjustable resistor (potentiometer or voltage divider) across the line, with one armature lead connected to the movable contactor of the resistor. The movement of the contactor lowers the voltage applied to the armature. By this method, the speed can be brought down fairly low without sacrificing good starting performance. This method, however, dissipates energy continuously in the adjustable resistor and therefore is suited only for small motors and comparatively light loads.



When speed regulation of shunt motor is required over a wide range, adjustable resistors must be inserted in both the shunt field and armature circuits. Weakening the shunt field reduces its starting torque, shortens the brush life, and disturbs speed stability. When resistance is used on the armature, circuit starting torque and speed stability are affected in direct proportion to the added resistance.



GOVERNOR-CONTROLLED MOTORS. For certain fractional horsepower motor applications usually on series motors, but occasionally shunt motors, electric governors offer the best solution to speed control problems. The electric governor is a centrifugally operated switch which automatically reduces the current through the motor when it runs faster than the speed for which the governor is set, and restores the full line voltage when the speed falls below the setting.



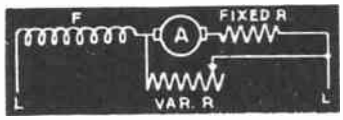
Form S governors (adjustable during standstill only) are recommended where utmost accuracy in speed adjustment is desired. If a narrow speed range suffices for a job, the adjusted speed can often be held within 1%.

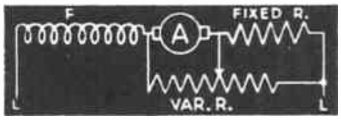
Form R governors (adjustable during running) provide wide control with speed stability under widely varying loads.

Both types require a small resistor and capacitor across the governor contacts to minimize sparking at contacts.

Single Step Control of Fractional Horsepower Motors

In the January issue of the Motorgram, we presented a brief discussion of the gradual or stepless speed control characteristics of fractional horsepower motors. We suggested several methods for obtaining intermediate speeds over a required range. One method, which was described in the last Motorgram, will control the speed of a series motor over a wide range and still retain stability at low speeds. A fixed resistor is connected in series with the armature and a variable resistor is connected across both armature and fixed resistor.

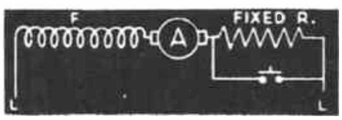


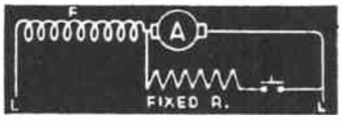


A modification of this method, which gives better results, is to connect a fixed resistor in series with the armature, and use a variable resistor, which is shunted like a potentiometer across both armature and fixed resistor, to apply a variable voltage to the armature. As shown in the second diagram, the movable arm of the variable resistor is connected between the armature and the fixed series resistor.

In both of the above methods an actual test under normal load is needed to determine the resistance values and wattage ratings of the necessary resistors. If this test is not done carefully the resistors may be underrated and burn out. Such testing is also needed to assure maximum speed stability.

SINGLE STEP SPEED CONTROL. It is sometimes sufficient to change the speed of a series motor in one fairly large step. Such control can be accomplished by connecting a fixed resistor in series with the motor, and then using a switch or automatic contactor for short circuiting the resistor when full speed is desired. When the switch or contactor is open, the fixed resistor is cut into the motor circuit and the motor speed drops. The higher the resistance of the fixed resistor, the slower will be the speed of the motor for a given load. The motor speed will remain constant only if the motor torque is not changed. With this arrangement the starting torque is likely to be low if the motor is started with the fixed resistor in the circuit.

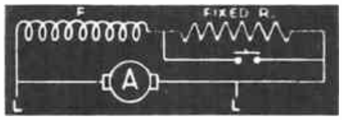




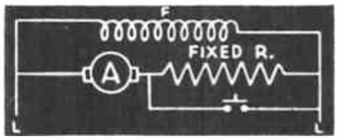
Step speed control for a series motor can also be obtained by shunting a fixed resistor across the armature. The speed is likely to be more stable and the starting torque better than if the resistor is in series with the motor, because of the stronger field. The shunt resistor circuit must be provided with a switch or automatic contactor to open the resistor circuit when full speed is desired. The switch is closed during the starting period or whenever the lower speed is desired.

On alternating current variable or fixed transformers may be substituted in place of resistors, thereby eliminating most of the voltage change due to current variation in the resistors.

SHUNT MOTORS. Single step control of shunt motors is obtained by inserting a fixed resistor in the shunt field circuit, using a switch or automatic contactor to short circuit the resistor for low speed operation. The resistor weakens the magnetic field which in turn speeds up the motor. Such field control provides stable motor speeds at light loads provided the magnetic field is not weakened too much.

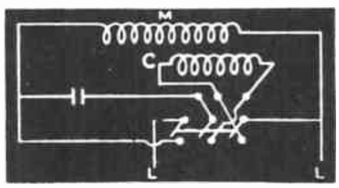


To reduce the speed of a shunt motor in a single step, a fixed resistor must be added to the armature circuit. A switch or automatic contactor must be provided to short circuit the resistor for full speed operation.



INDUCTION TYPE MOTORS. Multispeed stator windings that will provide two speeds such as 2:1, 3:1, 3:2, etc., can be provided for induction type motors. The horsepower ratings of multispeed motors are usually somewhat less than single speed motors due to the more complicated stator windings. Since a portion of the stator winding lies idle for either one of the speed ranges, the starting and pull-in torque of multispeed motors is often lower than for standard motors.

CAPACITOR MOTORS. There are many methods for step control or multispeed control of capacitor motors. An auto-transformer may be employed to provide the necessary step-down of stator voltage. A simple method of achieving a two-speed control is to shift the capacitor from the capacitor winding to the main winding by using a three pole, double throw switch. This method will not work for a 3-wire reversible capacitor with identical main and capacitor windings.



Summarizing briefly, the speed control characteristics of the various fractional horsepower motors fall into two classes. The first, comprising mostly brush type motors, can be subjected to speed control without requiring any special winding. The other class, consisting mainly of induction type motors, usually requires special windings if some suitable degree of speed control is desired. It should be borne in mind, however, that if the utmost in speed range and stability is desired, special windings are required even for brush type motors.

Blowout

Arc boxes are sometimes used without magnetic blowouts, but a blowout is never employed without some form of arc box. Although blowout coils may be shunt wound for connection across the supply voltage, they are usually current carrying coils and are mounted as part of the stationary contact support assembly and connected in series with the contacts. In either case they set up a magnetic field at right angles to the flow of current through the contacts. When the contacts open, this magnetic field forces the resulting arc out into the arc box where it is elongated and cooled until extinguished. Without the arc box to confine and to direct the arc, the latter might spread to adjacent poles of the switch or to ground. Blowout assemblies usually include iron cores and pole pieces. The core passes through the blowout coil and makes contact with the two pole pieces, one on each side of the arc box. On a-c contactors, these parts are laminated. On small and medium sized switches, the pole pieces are often parts of the arc box itself, but on large switches they are rigidly mounted and attached to the blowout core so the arc box slides conveniently in between them.

Resistance of a series wound blowout coil is usually so low and the voltage drop between turns so small that little insulation is required. On large strap wound coils, a thin separator of asbestos composition, or similar material, is used between turns.

Blowout coils require practically no attention. They have no moving parts, and mechanical injury is not likely to occur. Connections and mountings should be kept tight. Short-circuited turns will reduce the blowout effect, and on a-c coils the induced current through the short-circuited turns may result in overheating and roasting out of the coil. When blowout coils are installed and connected, the polarity should be such that the arc is blown away from and not back into the contacts and switch structure. Reversed polarity will burn up the contacts and other parts in the path of the arc. This is sometimes experienced with wire wound coils, the leads of which are long enough for either right or wrong connections and in which the direction of winding is not apparent. This is rarely possible with strap wound coils as the two ends are usually different and just right for connecting in their proper places.

CAUSES AND CURES IN CONTROLLER MAINTENANCE

Part	What to Look For	What to Do about It
Thermal Overload Relay	Trips at wrong current value	Check rating against load and replace with coil or heater of proper rating
	Local heating due to loose heater connections	Clean contact surfaces and tighten binding screws or bolts
	Contacts and springs	Dress up contacts, check springs and adjust relay mechanically
Dash Pots	Operation too quick or too slow	Adjust setting. Fill with proper liquid to proper level
	sticking	Clean out dirt and adjust mechanically
Resistors	Overheating in general	Check ventilation. Check load and frequency of operation against rating
	Local heating at terminal	Clean contact surfaces and tighten
	Open circuits	Check connections and replace broken units
Rectifiers	D-c output voltage	Check and adjust impressed a-c voltage. If open-circuited or shorted, replace defective units. If aging too rapidly check load and ambient temperature. Clean off dust to aid ventilation
Transformers	Overheating	Check load and frequency of operation against rating
	Open circuits	Rewind or replace. Check and tighten connections
Connections and Wiring	Defective insulation	Repair or replace
	Loose connections	Tighten
	General appearance	Keep neat and avoid temporary wiring. Clean off dust and rubbish
Panels and Insulation	Dirt, grease, moisture, mechanical injury, burning due to arcing, overheating, creepage, etc. Broken arc boxes, panels and molded parts	Clean, varnish, replace and repair as required
Switch Oil	Check oil level, and condition of oil	Replace with oil of correct grade, as recommended by manufacturer, when it becomes very dirty. Clean out oil tanks and wipe off carbon deposits from control parts with dry rag. Keep oil at proper level
Springs	Pressure and tension	Check against manufacturers recommendations. Adjust or replace
Bearings	Alignment and general condition	Line up properly. Clean corroded surfaces. If damaged or badly worn, replace. Do not lubricate contactor bearings, but lubricate other bearings as recommended.
Mechanical Interlocks and other Mechanical Parts	Broken or damaged parts	Repair or replace broken parts
	Improper adjustment	Adjust for ease of operation
	Frictions at bearings	Lubricate where recommended
Failure to Start and to Operate Properly	Overload relay contact open Voltage too low or failed completely	Locate cause of trouble and repair as recommended
	Blown fuses Open-circuits Burned out coils Broken wires Loose connections Burned out resistors or transformers Corroded, burned, or worn contacts on main switches, auxiliary switches, accessories, or master switches	Check circuits with magneto or lamp
Failure to Stop	Shorted connections Grounds Sneak circuits Bad wiring in conduits Contacts welding, or for other reason, failing to open Damaged limit switches or other accessories Open circuited, breaking resistors or failure of brakes.	If no other available provision for emergency stop, open main line switch Locate trouble and repair

CAUSES AND CURES IN CONTROLLER MAINTENANCE

Part	What to Look for	What to Do about It
Accessories	Worn out or badly burned contacts	Dress with sandpaper or fine file
	Defective or missing springs	Adjust or replace
	Damaged or poorly adjusted mechanical parts	Repair, replace or adjust; lubricate where necessary
	Dirt or tailings interfering with operation	Clean out
	Water in case	Clean and dry. Repair gasket and secure cover
	Defective insulation and loose connections	Repair insulation and tighten connections
Arc Box	Broken or damaged parts	Repair or replace
	Loose bolts and screws	Tighten
	Badly burned	Clean and repair or replace
	Interferes with moving parts	Adjust
	Creepage or voltage breakdown over or through arc walls	Clean, dry out in oven, or replace
	Adjustment	See that arc is fully in place
Blowout	Ineffective blowout and overheating	Check ampere rating and if improperly applied, replace with different coil. Check polarity and reverse if necessary. Check for open circuited shunt coil or shorted turns in series coils.
Contacts	Badly burned or pitted contacts	Dress up contacts with sandpaper, or fine file
	Badly oxidized copper contacts	Replace if necessary
	Overheating	Tighten hardware
	Welding	Check spring pressure. Replace spring if necessary. Check rating against load. Adjust switch mechanically. If conditions too severe for open type contactors, replace with oil immersed or dust-tight equipment. Instruct operator in proper manipulation of manually operated devices.
Shunts	Worn, frayed, or partially broken	Replace
	Interference with or in contact with other parts of controller	Straighten, adjust, or replace with shunt of proper length and width
	Overheating	Check capacity against load and see that correct shunt is being used
Electrical Interlocks	Contact condition	Dress as for any contacts
	Mechanical operation and adjustment	Adjust for correct movement, ease of operation, proper opening or closing with respect to main contacts. Adjust or replace springs.
Magnets and Coils	Sluggish operation	Clean and adjust mechanically. Align bearings and free up the movement.
	Overheating	Check voltage and coil rating. Check for shorted turns. See that magnet, if a-c, is closing properly.
	Sticking in	Clean, if due to grease. Check air gap and if shim is used, see that it is in place.
	Noisy a-c magnets	See that it closes properly. Look for broken shading coil and replace if necessary. Clean magnet faces.
	Abnormally short coil life	Check supply voltage and coil rating

Contacts

Electric circuits are opened and closed with contacts. Except for static controller units such as transformers and resistors, all other controller parts serve merely to open and close contacts in their proper sequence. Contacts are made in a variety of types and forms. Copper, silver, and special alloys to meet unusual conditions are used. Carbon contacts, which were formerly utilized to a great extent, have become almost extinct. Carbon contacts do not weld but they are mechanically weak. Copper contacts become coated with a non-conducting oxide, which in normal operation is burned off or broken by mechanical action of the contacts as they close or by burning action of the arc as the contacts open. Silver contacts are coming into wide use particularly where operation is infrequent or where spring pressure is light. Silver oxide does not increase contact resistance.

Contacts are designed so that in closing they pound, slide, scrub, and/or roll, and therefore they are to a considerable extent self cleaning. They may be closed manually, magnetically, pneumatically, by pilot motor through gears or cams, or automatically by floats, pressures, or temperatures. Large contacts are often provided with smaller and separate tips, called arcing contacts, or arcing tips, which touch first in closing and separate last in opening. Their function is to take most of the punishment and thus save the main contacts. Arcing tips do not have to be smooth and will perform satisfactorily even when badly worn and pitted. They can be replaced at a fraction of the cost of the main contacts.

Arcing horns serve as extensions to the contacts themselves to lead the arc away from the contacts and out into the arc box. Arc horns are usually part of or are attached to the contact supports, though they are sometimes built into the arc box.

When contacts become badly pitted and burned they should be touched up or replaced. They may be buffed, sandpapered, or dressed with a fine file. Coarse filing wastes copper and may alter the shape of the contact. Do not use emery as particles of emery may stick to contact surface and encourage welding or excessive wear, or may get into bearings. Contacts need not be smooth but they should seat squarely. Heavy films of oxide should be removed from copper contacts but oxide on silver contacts should be left alone.

A-C AND D-C

HEAVY DUTY PUSHBUTTONS

CLASS 15-010—TYPE HD

INCHING BY PUSHBUTTON (Figs. 6, 7, 8)

Incning or jogging by Pushbutton is most frequently accomplished by one of the following three methods:

(a) A three-button "Start-Inch-Stop" Station

(b) A "Start-Stop" Station with latch on Pushbutton to hold button partially depressed while machine is inched with start button.

(c) A maintained position Selector Switch.

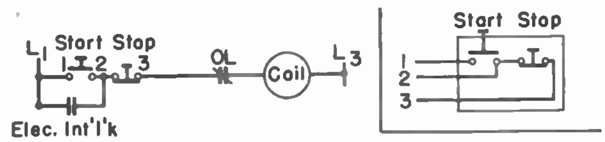
Method (a) is the most desirable, since each button has an independent function. However, it requires a separate inching relay in the circuit (see Figure 8). The three-button station should never be used without the inching relay.

TYPICAL PUSHBUTTON CONNECTION DIAGRAMS

On all figures below, the left-hand sketches represent schematic control circuit wiring diagrams. The right-hand sketches represent Pushbutton station wiring.

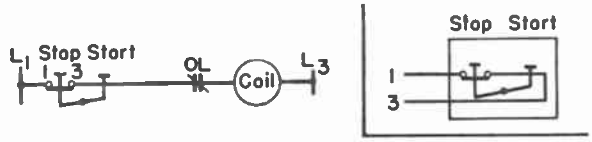
On the right-hand sketches, the numbers on line leads correspond to those marked on all Standard Westinghouse Class 11-200 Non-Reversing Linestarters, and Class 11-210 Reversing Linestarters—but the letters marked on the leads are reference points only, corresponding to letters shown in these schematic diagrams.

START—STOP



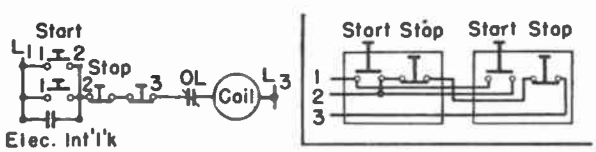
(Fig. 1)

Buttons: Two momentary-contact, one closed, one open. **Circuit:** Low-voltage Protection, Single-Station.



(Fig. 2)

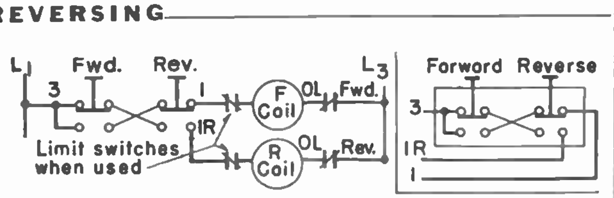
Buttons: Two maintained-contact. **Circuit:** Low-Voltage Release Single-Station.



(Fig. 3)

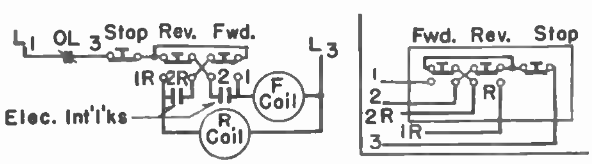
Buttons: Four momentary-contact, two closed, two open. **Circuit:** Low-voltage protection, two stations.

REVERSING



(Fig. 4)

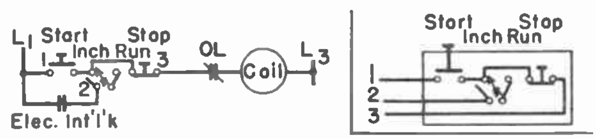
Buttons: Two momentary contacts, both normally open. **Circuit:** Inching only, interlocked through buttons motor runs only as long as button is held down.



(Fig. 5)

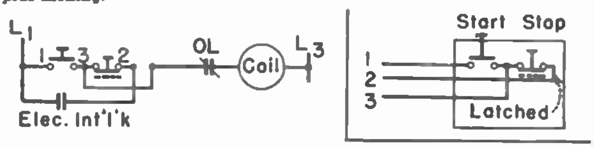
Buttons: Three momentary contact, two open, one closed. **Circuit:** Low-voltage protection, interlocked through buttons.

START—STOP—INCHING



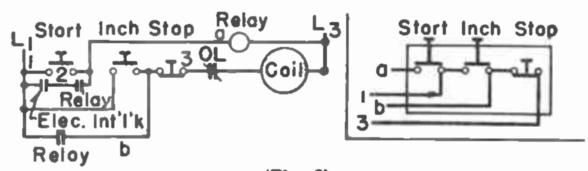
(Fig. 6)

Buttons: Two momentary-contact and one Rotary Switch for manual selection of inching or running circuit. **Circuit:** Low-voltage protection plus inching.



(Fig. 7)

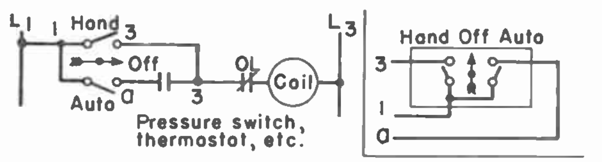
Buttons: Two momentary-contact, one open, one closed, with safety latch for manual selection of inching or running circuit. **Circuit:** Low-voltage protection plus inching.



(Fig. 8)

Buttons: Three momentary-contact and inching relay. No manual selection required for inching or running circuit. **Circuit:** Low-voltage protection plus fool-proof inching.

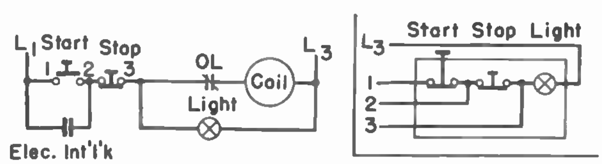
HAND—OFF—AUTOMATIC



(Fig. 9)

Rotary Selector Switch: Two maintained-contact, one closed in right-hand, other in left-hand positions, both open in middle position. **Circuit:** Automatic control in AUTO position makes pressure switch, thermostat, etc. open and close circuit. Manual control in HAND position, permits closing circuit at any time for test or emergency. When handle is in OFF position all operation ceases.

INDICATING LIGHTS



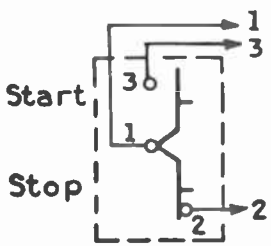
(Fig. 10)

Buttons: Two momentary-contact, one indicating light. **Circuit:** Low-voltage protection.

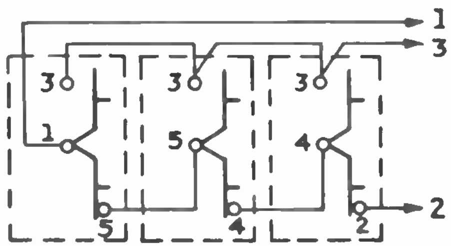
WITH LINE CONTACTORS HAVING NON-INSULATED HOLDING-CIRCUIT INTERLOCK. Internal wiring shown in each station is made when station is installed. Then connect the arrow terminals to like numbered terminals on the panel as follows: Connect 1 to the line contactor interlock, 2 to the line contactor coil, 3 to the line.

With connections for diagram "Three BS-79-J", is "start" and "stop" buttons on different stations are pressed at the same time the motor may not stop. Preferable are connections shown by diagram "Three BS-207-J", with which any stop button will stop the motor.

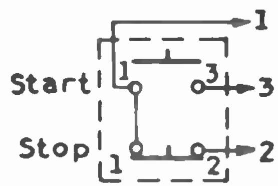
For two, four, or more stations omit or insert stations between the outer stations shown in the diagrams "Three BS-79-J", "Three BS-207-J", "Three CR2940-2A1", and "Three CR2940-3".



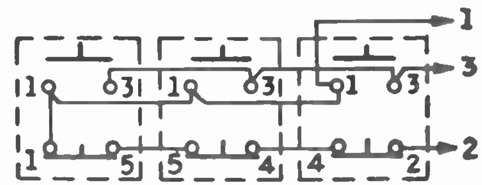
BS-79-J



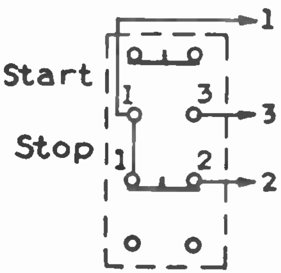
Three BS-79-J



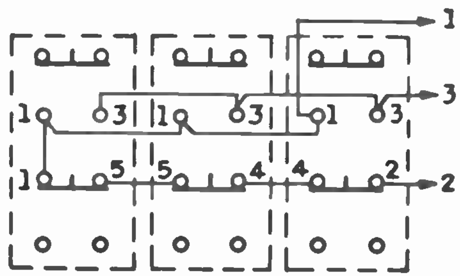
BS-207-J



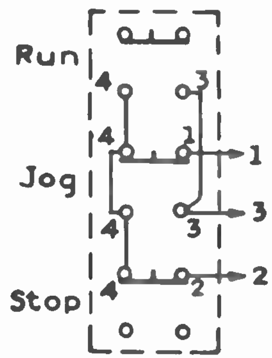
Three BS-207-J



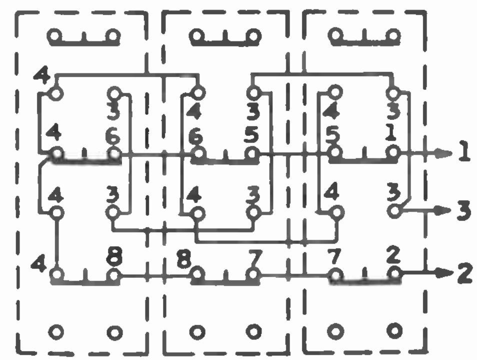
CR2940-2A1



Three CR2940-2A1



CR2940-3

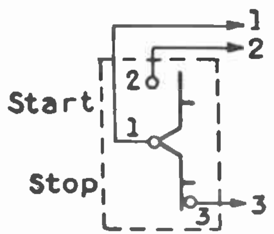


Three CR2940-3

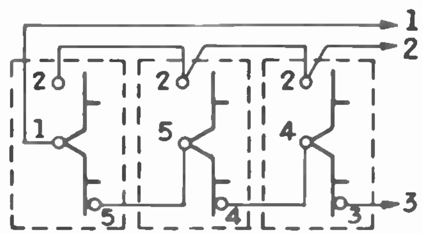
WITH LINE CONTACTORS HAVING INSULATED HOLDING-CIRCUIT INTERLOCKS. Internal wiring shown in each station is made when station is installed. Then connect arrow terminals to like numbered terminals on panel as follows: Non-reversing panels; connect 1 to line contactor interlock, 2 to the line contactor coil, 3 to line. On reversing panels; connect 1 to the "forward" contactor interlock, 2 to the "forward contactor coil, 3 to the "reverse" contactor coil, 4 to the reverse contactor interlock, 5 to the line.

With connections for diagram "Three BS-79-J", if "start" and "stop" buttons on different stations are pressed at the same time the motor may not stop. Preferable are connections shown by diagram "Three BS-207-J", as any "stop" button will stop the motor.

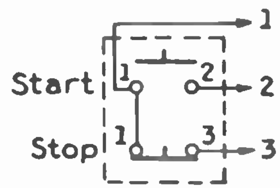
For two, four, or more stations omit or insert stations between the outer stations shown in the diagrams "Three BS-79-J", "Three BS-207-J", "Three CR2940-2A1", and "Three CR2940-3".



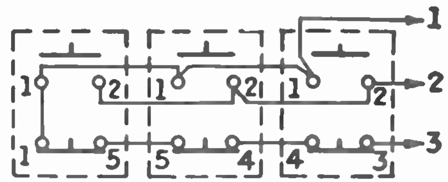
BS-79-J



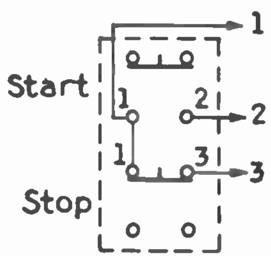
Three BS-79-J



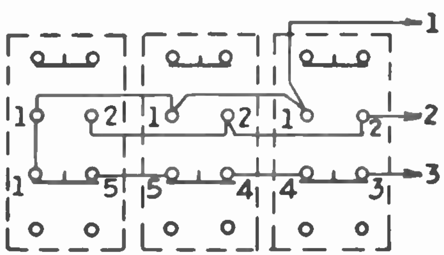
BS-207-J



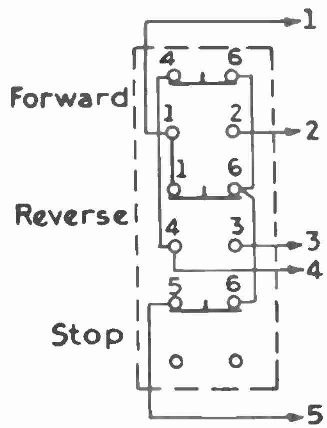
Three BS-207-J



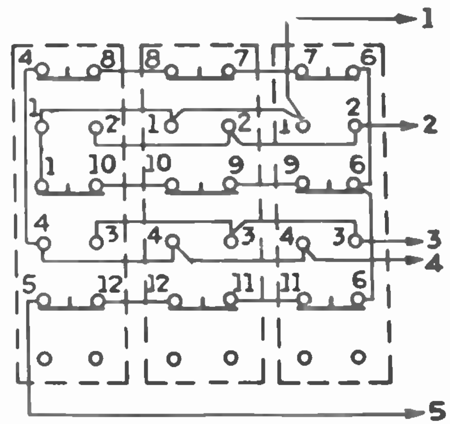
CR2940-2A1



Three CR2940-2A1

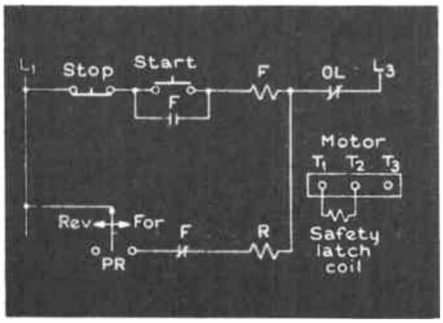


CR2940-3

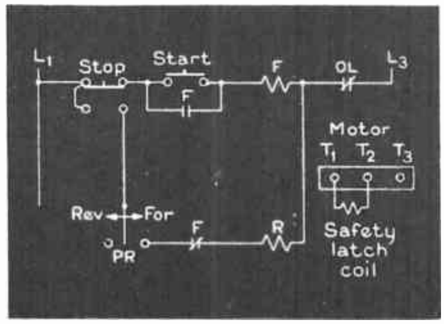


Three CR2940-3

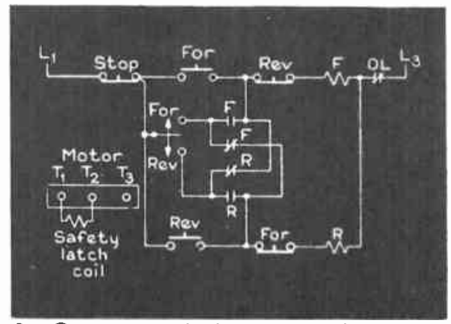
8 WAYS TO APPLY THE PLUGGING SWITCH



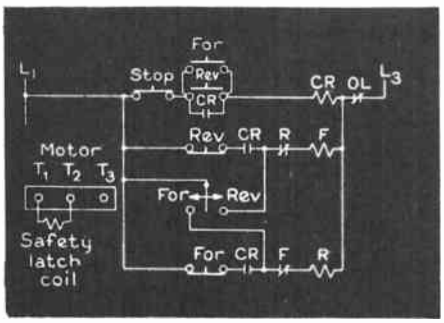
1. Operation in one direction. Pressing Stop button plugs motor to stop.



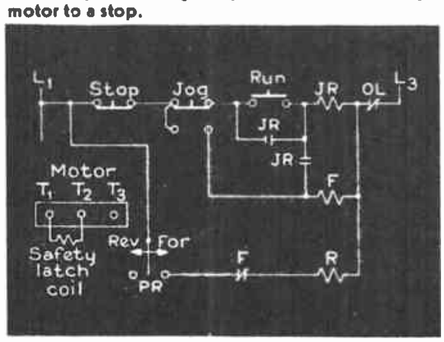
2. Operation in one direction. Pressing Stop button and immediately releasing it permits coast-stop. Holding Stop button down plugs motor to a stop.



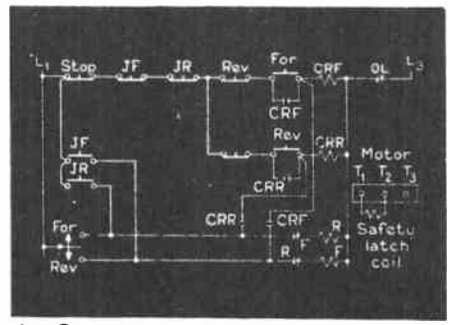
3. Operation in both directions. In starting, direction button must be held down until motor starts. Coast to stop if Stop button is held down—plug to Stop if button is released.



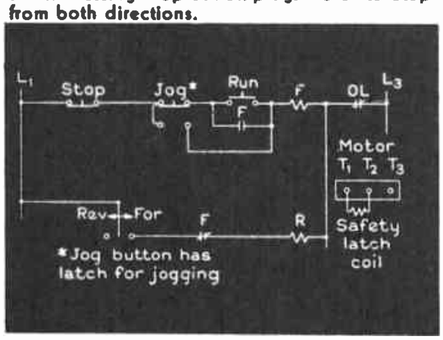
4. Same as number three except direction button need not be held down until motor starts. Pressing Stop button plugs motor to Stop from both directions.



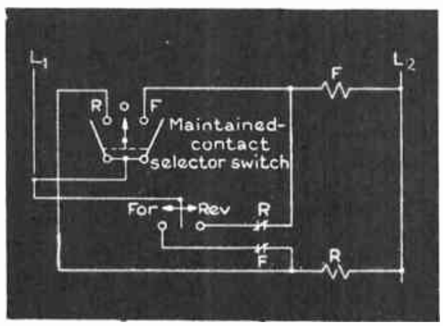
5. Operation in one direction. Plug-stop when Stop button is pressed. Jogging with auxiliary jogging relay.



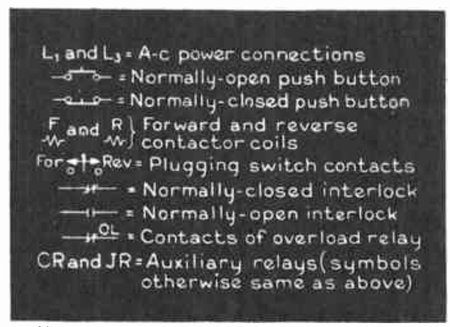
6. Operation in either direction. Jogging forward and reverse provided by auxiliary jogging relays. Plug-stop from both directions.



7. Operation in one direction. Jogging provided without auxiliary jogging relay by means of push-button station with latch for jogging. Plug to stop from either direction.



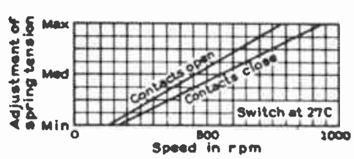
8. Operation in either direction from maintained-contact station. Plug to stop from either direction when switch is turned to Off. No undervoltage protection.

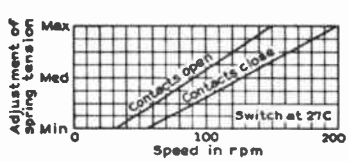


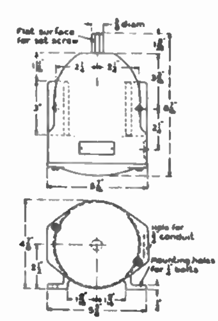
Key to symbols in elementary diagrams

For other circuits to fill special requirements, consult your G-E office.

Contact Arrangement Single-pole, Double-throw	Rotation to Operate Contacts (Facing Shaft)	Lockout Coil	CR2962 Form For Adjustment Range 40–140 Rpm	CR2962 Form For Adjustment Range 140–750 Rpm
Both throws normally open	Clockwise or counterclockwise	Yes	A1A	A1D
		No	A2A	A2D
One throw normally open, one throw normally closed	Clockwise	Yes	A1B	A1E
		No	A2B	A2E
One throw normally open, one throw normally closed	Counterclockwise	Yes	A1C	A1F
		No	A2C	A2F

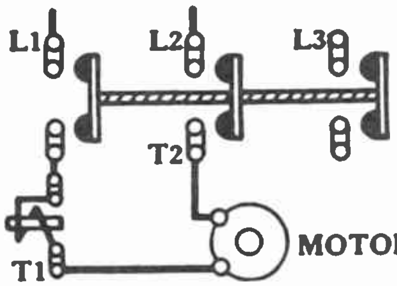




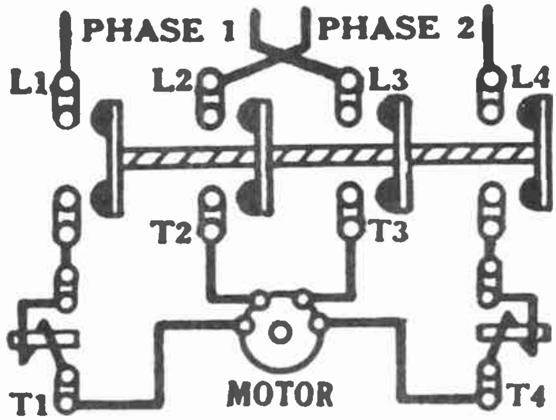


MANUAL LINE VOLTAGE A-C STARTERS - ALLEN-BRADLEY

SINGLE PHASE LINES

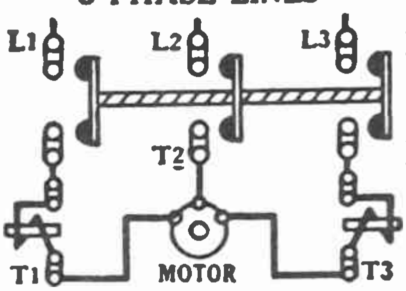


2 PHASE, 4 WIRE LINES



MOTOR LEADS
Phase 1
T 1 and T 3
Phase 2
T 2 and T 4

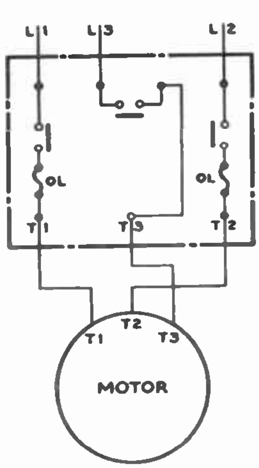
3 PHASE LINES

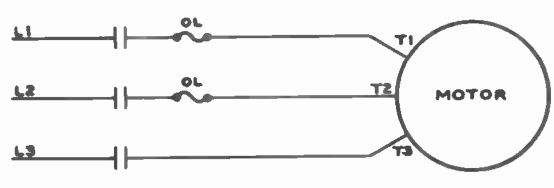


For Single Phase Terminals L2 and T2 are not used.

For Two Phase 3 Wire Terminals L2 and T2 are common.

CLASS 2510 SQUARE D A. C. MANUAL LINE VOLTAGE STARTERS





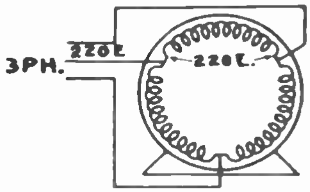
CLASS 2510, TYPE W10

STAR-DELTA STARTERS

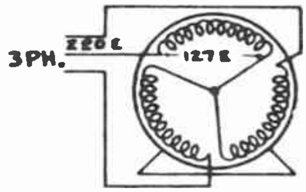
This job is used to demonstrate the difference between the ends of each phase on a 3 phase winding, and to show that this difference must be taken into account when the phases are connected together.

Proper connection of the windings on any 3 phase motor, generator, or transformer, must be preceded by identification of the phase ends as starts and finishes, just as the proper connection of a battery to others must be preceded by the finding of the positive and negative terminals.

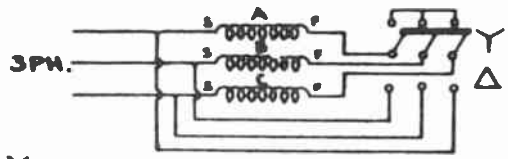
The simplest method of finding the starts and finishes of the phases in a three phase motor is given below. Follow each step carefully. With the windings connected star, a test will show unequal voltage per phase with an incorrect connection. This explains why the motor hums when the phases are improperly arranged.



DELTA CONNECTION
SYMBOL-Δ
PH.E = LINE E

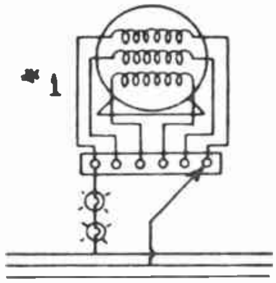


STAR CONNECTION. SYMBOL-Y
PHASE E = .58 x LINE E
LINE E = 1.73 x PHASE E



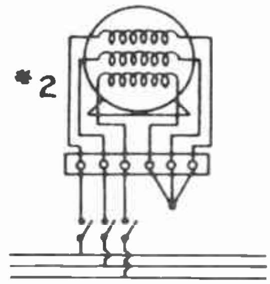
SIMPLE DIAGRAM OF A STAR-DELTA STARTER

#1



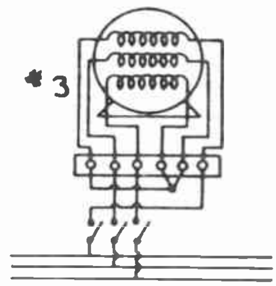
TESTING TO FIND THE ENDS OF THE PHASES.

#2



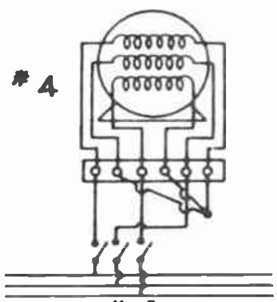
ASSUME 3 ENDS TO BE FINISHES AND CONNECT TOGETHER. CONNECT 3 STARTS TO LINE.

#3



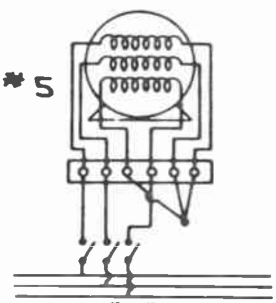
IF MOTOR IS NOISY REVERSE LEADS CONNECTED TO PHASE "A" IF NO IMPROVEMENT SEE #4.

#4



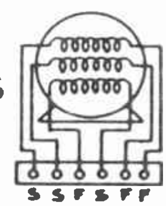
REPLACE "A" LEADS AND REVERSE LEADS OF "B" PHASE. IF NO IMPROVEMENT SEE #5.

#5

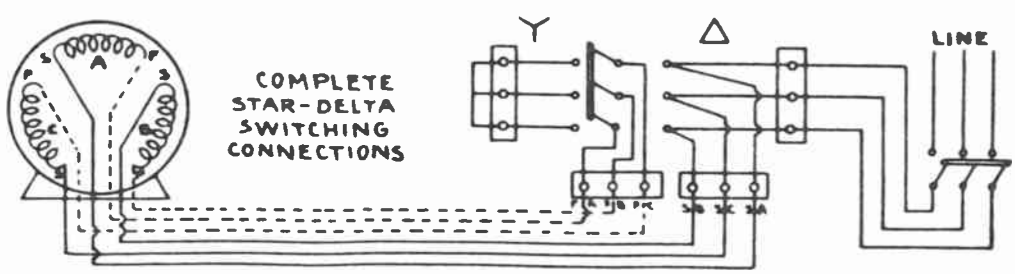


REPLACE "B" LEADS AND REVERSE LEADS OF PHASE "C". MOTOR SHOULD NOW OPERATE.

#6

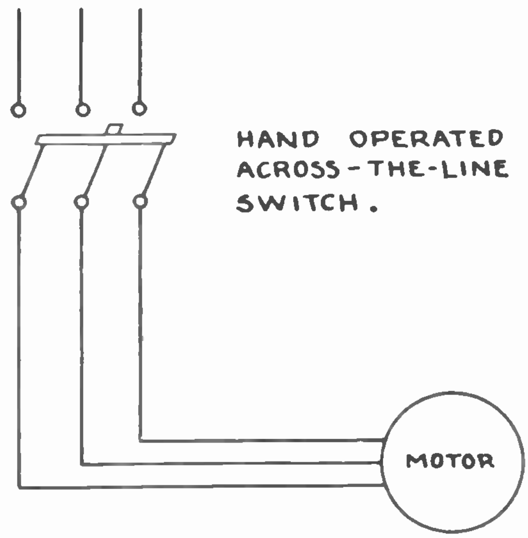


WHEN MOTOR OPERATES MARK PHASES AS SHOWN ABOVE

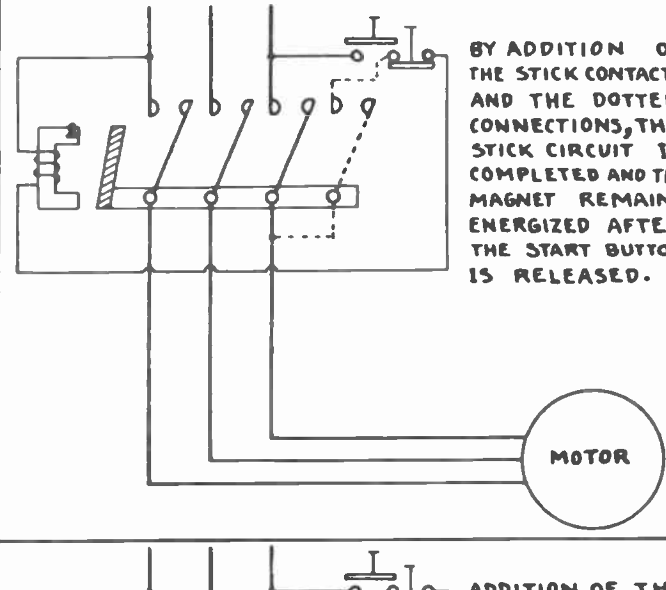


COMPLETE STAR-DELTA SWITCHING CONNECTIONS

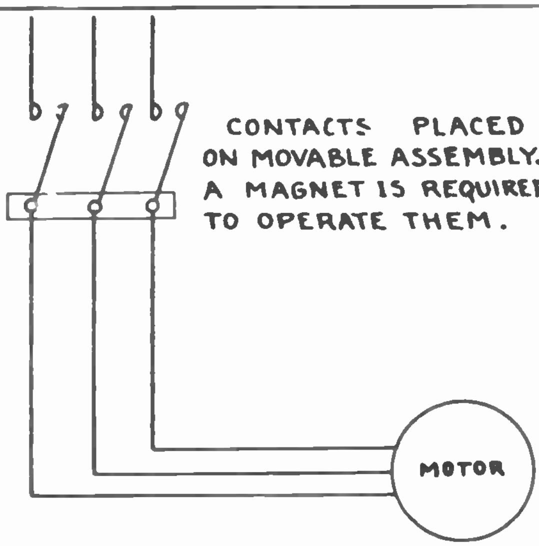
COYNE



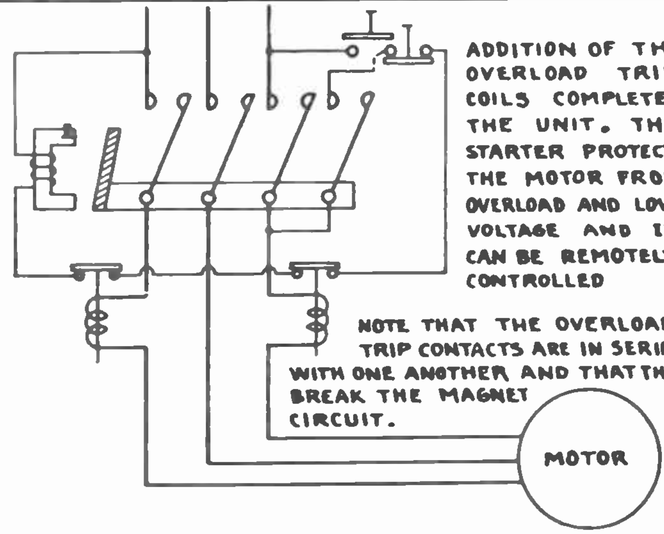
HAND OPERATED ACROSS-THE-LINE SWITCH.



BY ADDITION OF THE STICK CONTACTS AND THE DOTTED CONNECTIONS, THE STICK CIRCUIT IS COMPLETED AND THE MAGNET REMAINS ENERGIZED AFTER THE START BUTTON IS RELEASED.

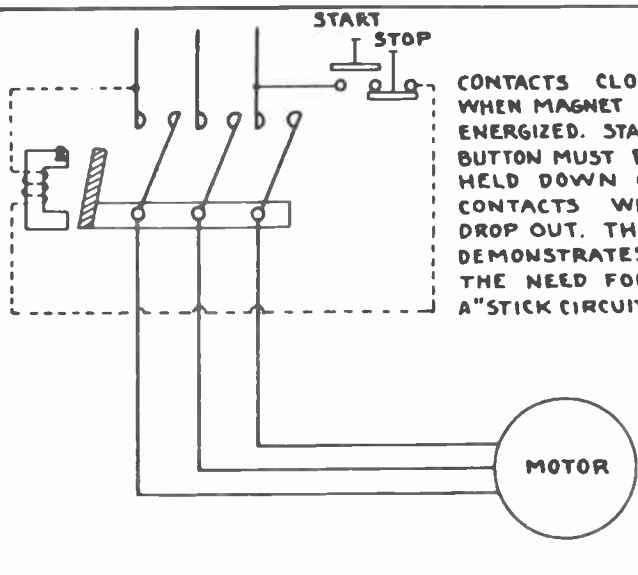


CONTACTS PLACED ON MOVABLE ASSEMBLY. A MAGNET IS REQUIRED TO OPERATE THEM.

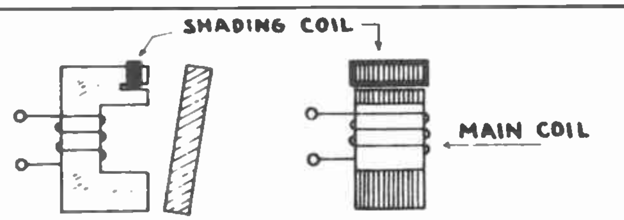


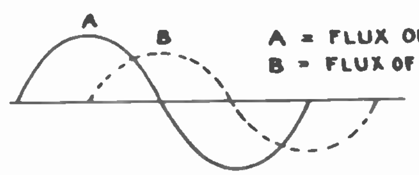
ADDITION OF THE OVERLOAD TRIP COILS COMPLETES THE UNIT. THIS STARTER PROTECTS THE MOTOR FROM OVERLOAD AND LOW VOLTAGE AND IT CAN BE REMOTELY CONTROLLED

NOTE THAT THE OVERLOAD TRIP CONTACTS ARE IN SERIES WITH ONE ANOTHER AND THAT THEY BREAK THE MAGNET CIRCUIT.



CONTACTS CLOSE WHEN MAGNET IS ENERGIZED. START BUTTON MUST BE HELD DOWN OR CONTACTS WILL DROP OUT. THIS DEMONSTRATES THE NEED FOR A "STICK CIRCUIT".





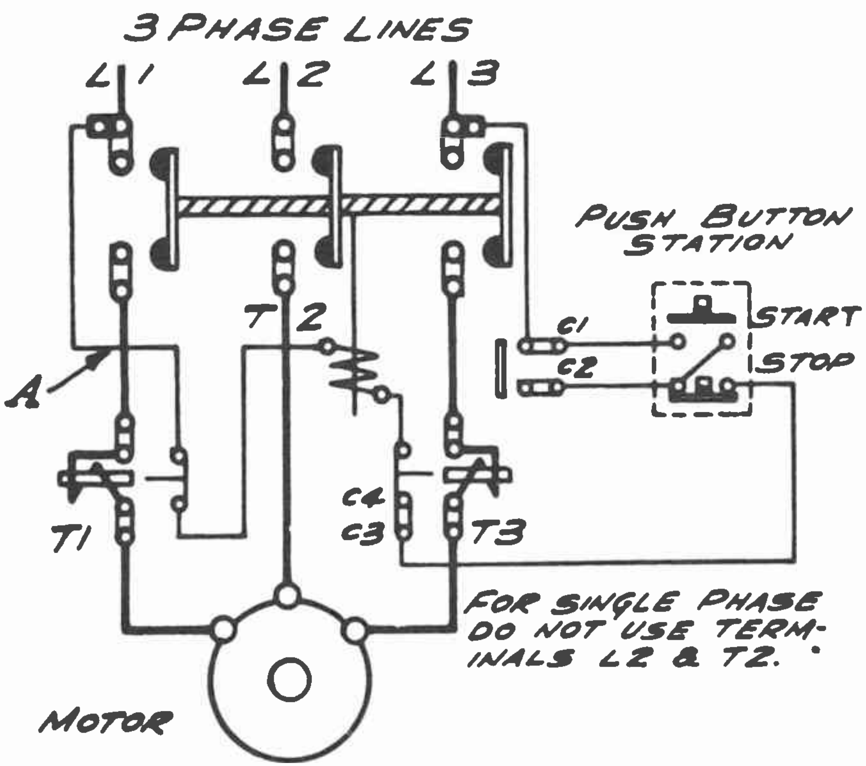
A = FLUX OF MAIN COIL
B = FLUX OF SHADING COIL

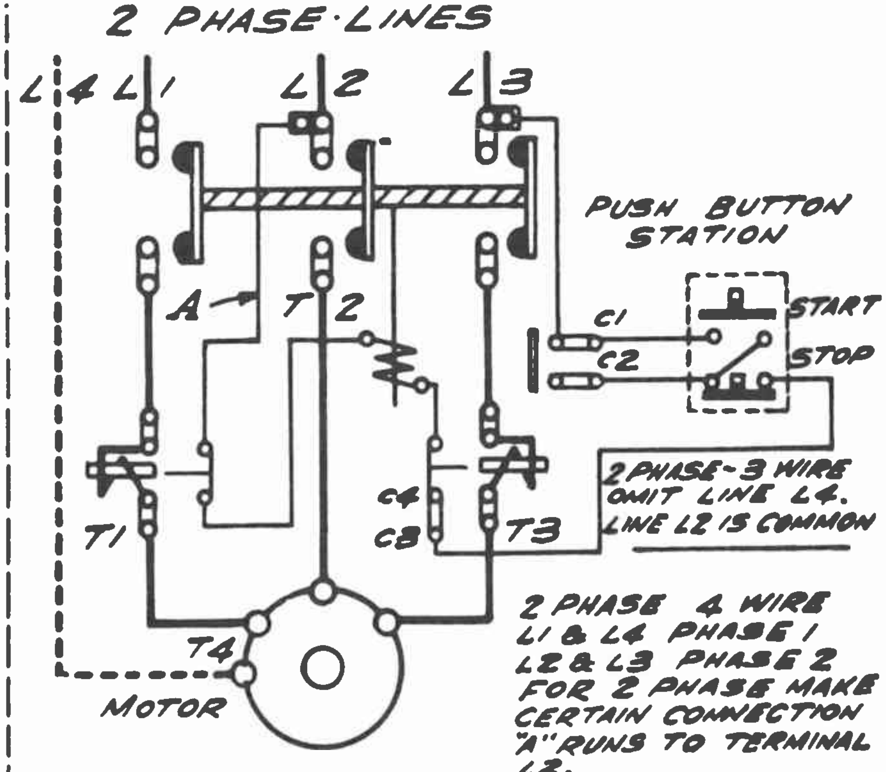
THE SHADING COIL IS USED TO PREVENT VIBRATION OF THE MAGNET ARMATURE, DUE TO PULSATIONS IN THE PULL CAUSED BY THE MAGNETIC FLUX FALLING TO ZERO TWICE PER CYCLE. AS SHOWN BY THE CURVES, THE SHADING COIL SETS UP A FLUX IN THE POLE FACE 90° OUT OF PHASE WITH THE FLUX OF THE MAIN COIL, THEREBY PRODUCING A PULL ON THE ARMATURE AT ALL TIMES.

COYNE.

DEVELOPMENT OF AN

ACROSS-THE-LINE STARTER



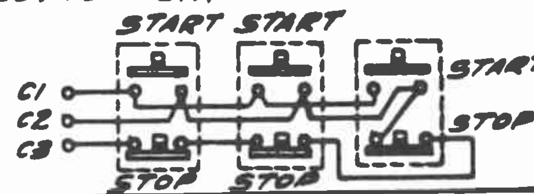


RELAY ELEMENTS

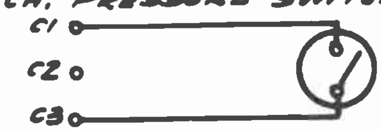
ULTIMATE TRIPPING VALUE

25°C	40°C	25°C	40°C
		35.0	30.0
10.0	8.5	39.0	33.0
11.0	9.5	43.0	37.0
12.0	10.5	47.0	40.0
13.5	11.5	52.0	45.0
15.0	12.5	57.0	49.0
16.5	13.6	63.0	54.0
18.0	14.8	69.0	59.0
20.0	16.5	76.0	65.0
22.0	18.0	84.0	72.0
24.0	20.0	92.0	78.0
26.0	21.5	100.0	85.0
29.0	24.0	110.0	94.0
32.0	26.5	121.0	103.0

CONNECTIONS FOR 2 OR MORE PUSH BUTTON STATIONS



CONNECTIONS FOR 2 WIRE CONTROL DEVICE SUCH AS THERMOSTAT, FLOAT SWITCH, PRESSURE SWITCH, ETC.



SINGLE PHASE CONNECTIONS

Make certain that switch coil and motor connections agree with the voltage supply.

220 VOLTS

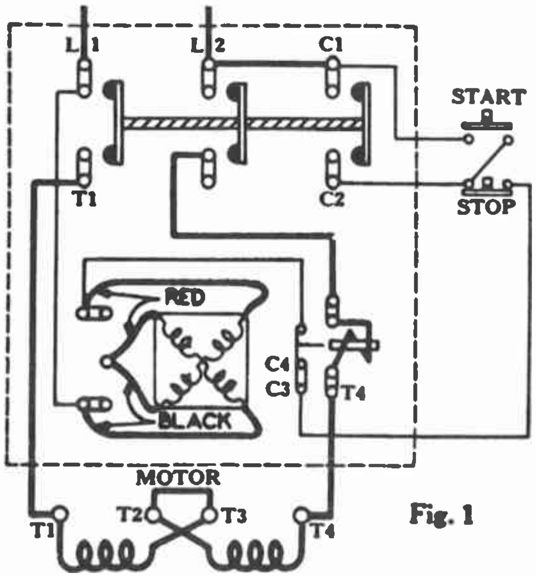


Fig. 1

110 VOLTS

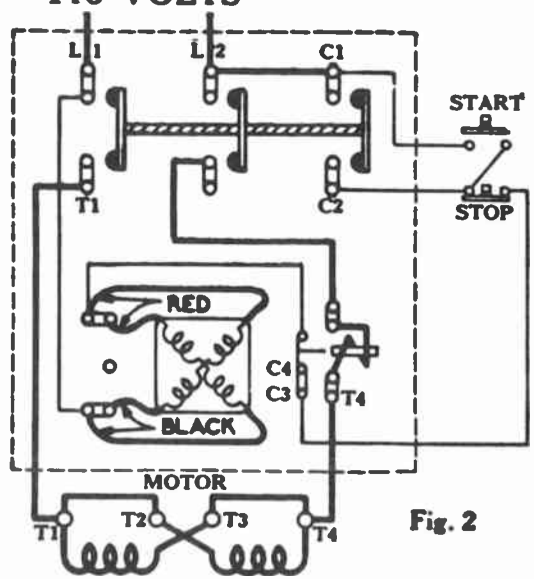


Fig. 2

110 VOLTS

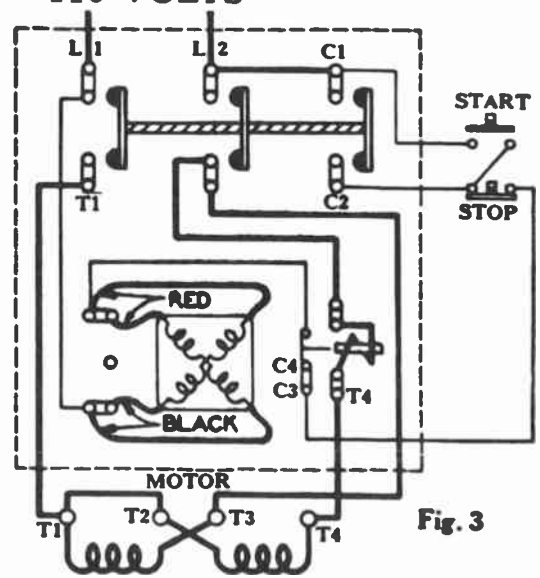
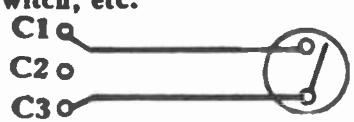


Fig. 3

Single Phase
Max. H. P. Rating

1½ h.p.	110 Volts
3 h.p.	220 Volts

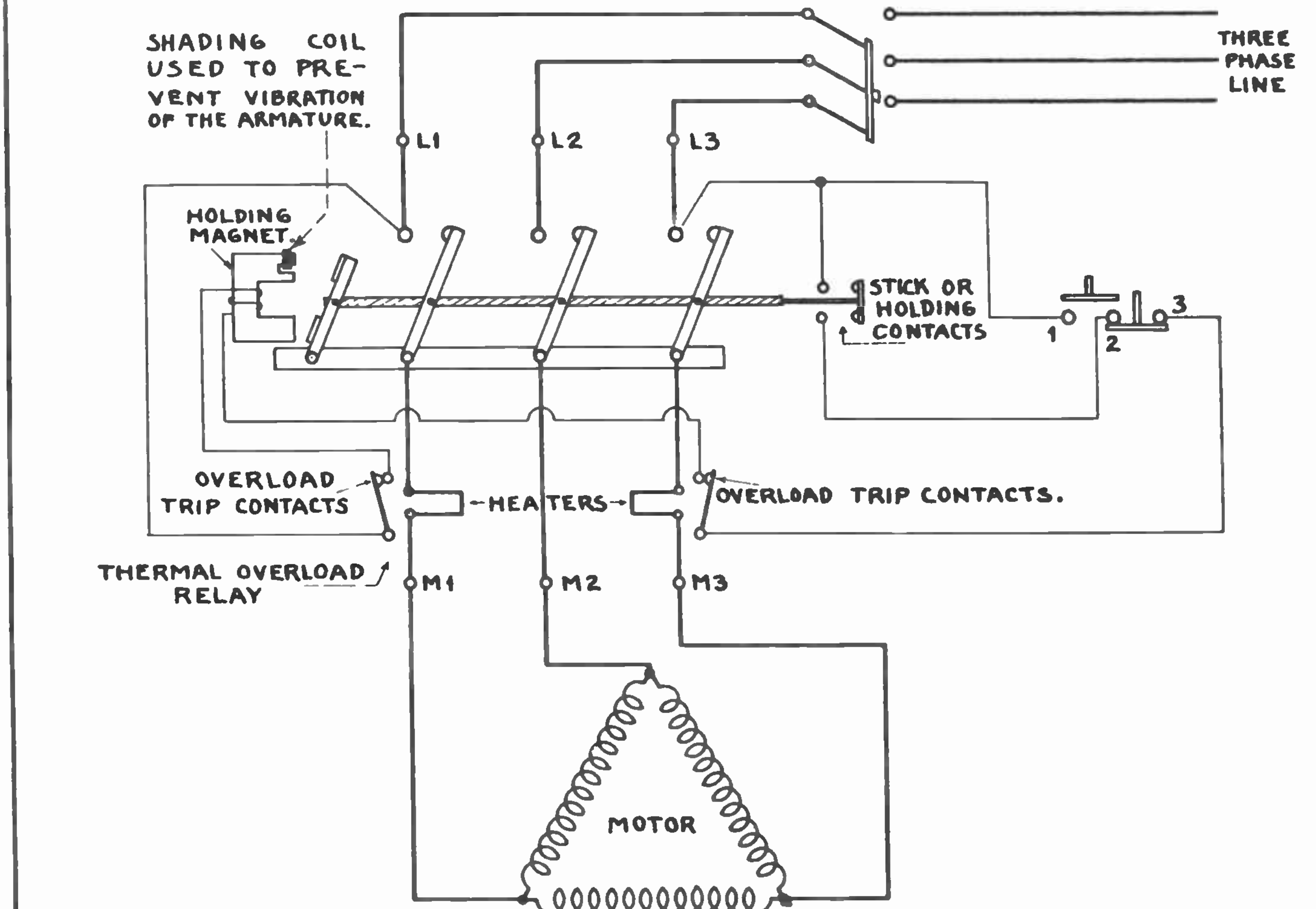
Connections for 2 Wire control device such as Thermostat, Float Switch, Pressure Switch, etc.



NOTE: Fig. 3 illustrates a wiring arrangement which makes possible using the same thermal element for a motor connected to either 110 or 220 volts. It requires an extra line between the motor terminal T 3 and the starter terminal as per diagram, Fig 3. The maximum common rating of a starter wired in this manner is 1½ h.p. for 110 and 220 volts.

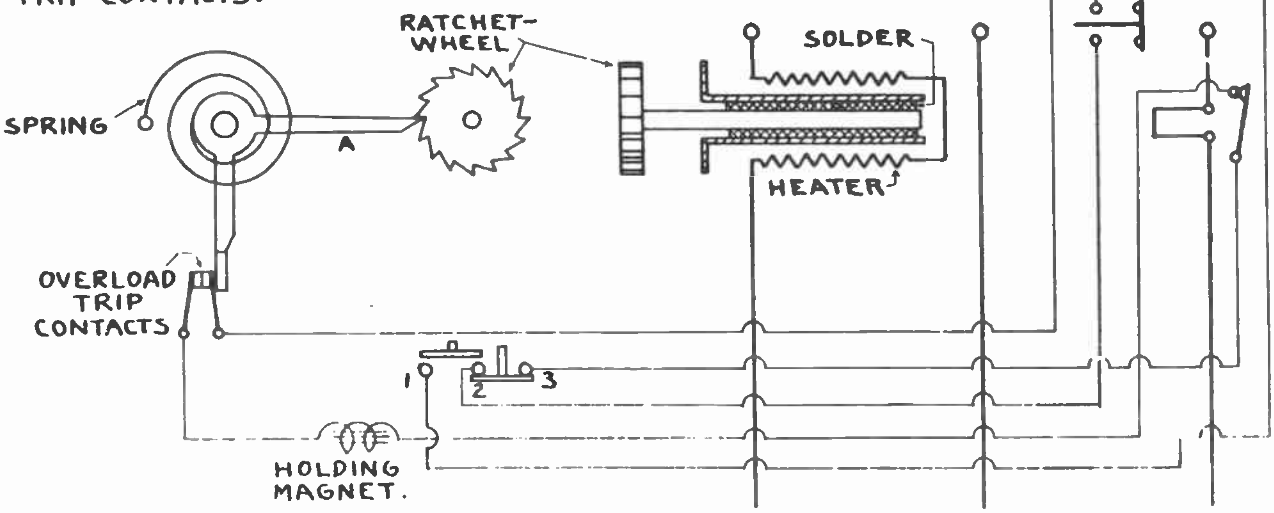
ALLEN BRADLEY

ACROSS THE LINE AUTOMATIC MOTOR STARTING SWITCH. TYPE "A".



COYNE ELECTRICAL SCHOOL.

WHEN AN OVERLOAD OCCURS THE HEATER MELTS THE SOLDER WHICH ALLOWS THE ARM "A" TO MOVE UPWARD OPENING OVERLOAD TRIP CONTACTS.



DETAIL OF THERMAL OVERLOAD RELAY (SOLDER TYPE).

AUTOMATIC A-C LINE STARTERS ALLIS-CHALMERS

Size 2
Type S Lo-Maintenance GENERAL PURPOSE Motor Control

WIRING DIAGRAMS

25-60 Cycle ***3 Pole** **110-600 Volts**

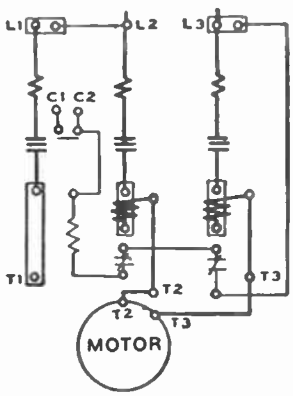


Fig. 1 — Single Phase

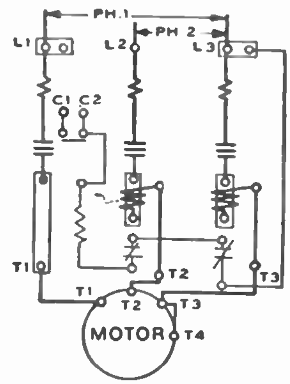
Max. Hp Rating

110 v — 3 hp
220 v — 7½ hp
440/550 v — 10 hp

Fig. 2 — 2 Phase, 3 Wire

Max. Hp Rating

110 v — 7½ hp
220 v — 15 hp
440/550 v — 25 hp



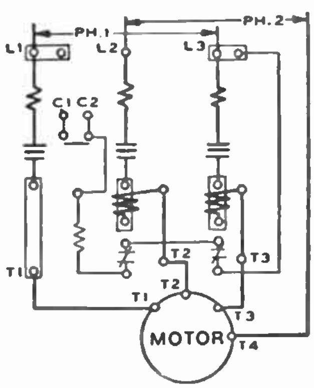


Fig. 3 — 2 Phase, 4 Wire

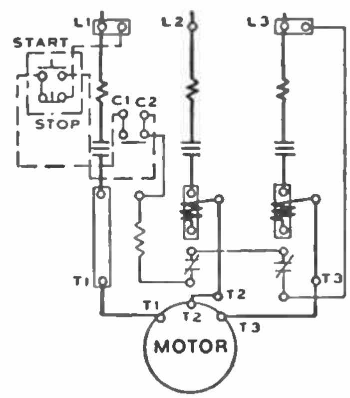
Max. Hp Rating

110 v — 7½ hp
220 v — 15 hp
440/550 v — 25 hp

Fig. 4 — 3 Phase

Max. Hp Rating

110 v — 7½ hp
220 v — 15 hp
440/550 v — 25 hp



WIRING DIAGRAMS FOR PILOT CONTROL

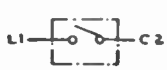


Fig. 5 — 2 Wire Maintained Contact

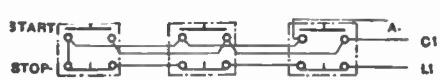


Fig. 6 — Connections for 2 or more P. B. Stations

AUTOMATIC A-C LINE STARTERS ALLIS-CHALMERS

CAGE MOTOR STARTERS

Typical Wiring Diagrams

General Purpose Type S Starters

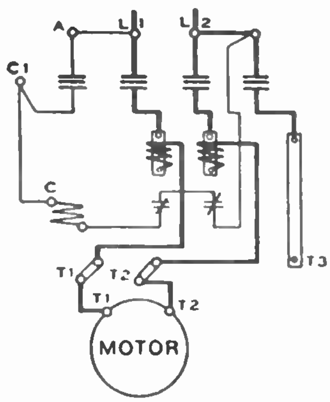


Fig. 1 — Single Phase

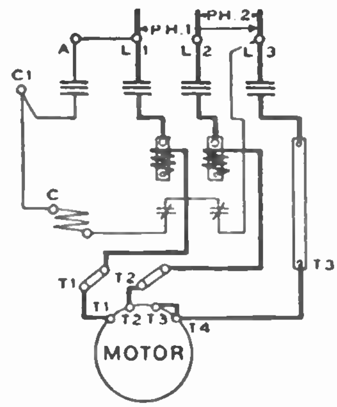


Fig. 2 — 2 Phase, 3 Wire

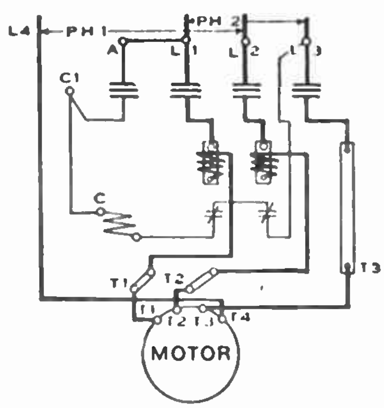


Fig. 3 — 2 Phase, 4 Wire

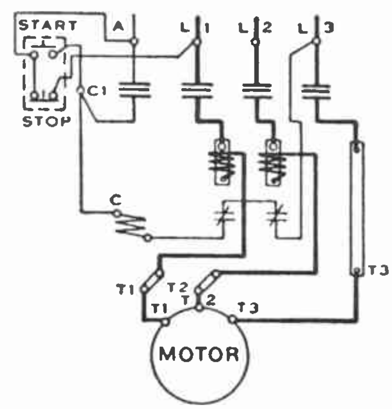


Fig. 4 — 3 Phase

WIRING DIAGRAMS FOR PILOT CONTROL

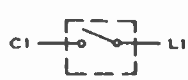


Fig. 5 — 2 Wire Maintained Contact

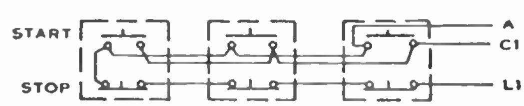
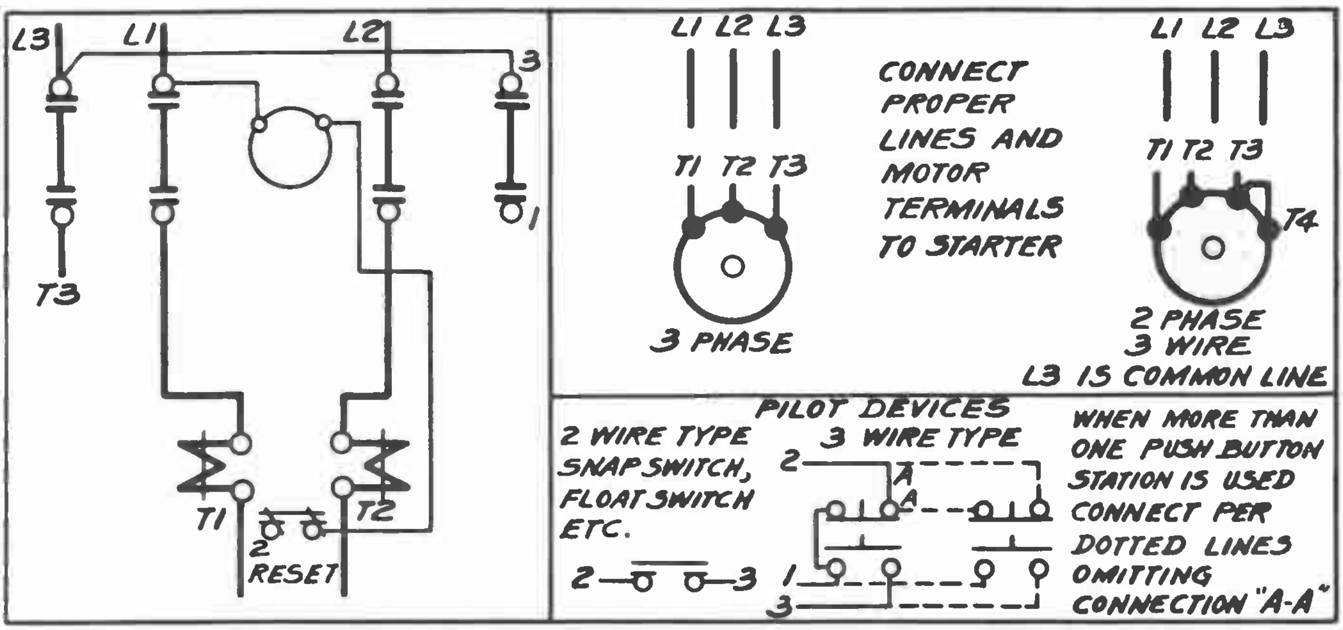


Fig. 6 — Connections for 2 or more P. B. Stations

NOTE: When External "Stop" Button or 2 Wire Maintained Contact is used remove A-L1 Jumper.

FRONT VIEW DIAGRAM



TITLE CONNECTIONS FOR A.C. AUTOMATIC STARTER WITH #489 OVERLOAD WITH RESET

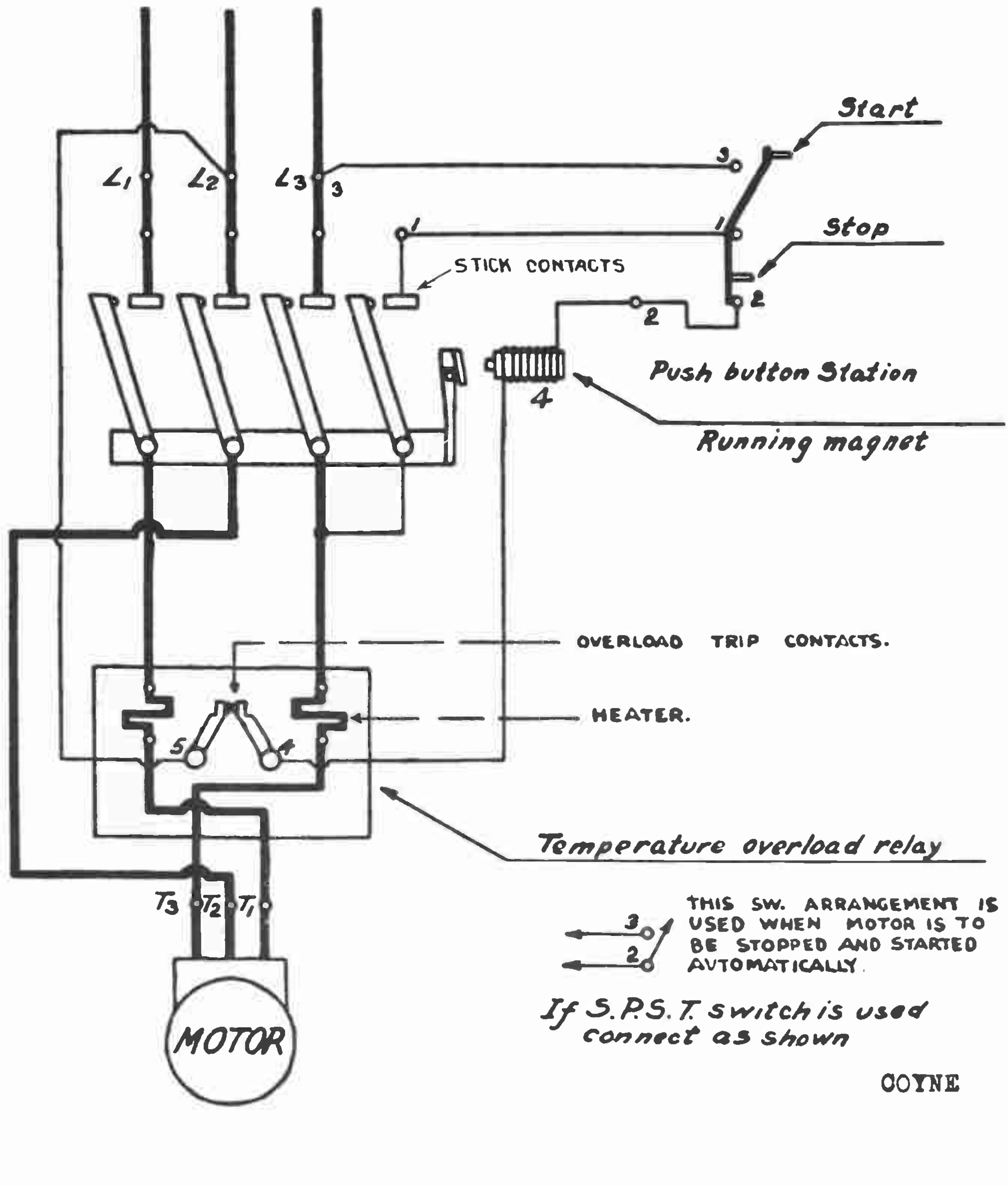
DRAWN BY [signature]	TRACED BY	TYPE AAA3	SUP. NO.
CHECKED BY [signature]	APPROVED BY [signature]	BULL. NO. 9586	SUP. BY NO.
A / B	C / D	ORDER NO. DEV. 4048-10	9004/DI

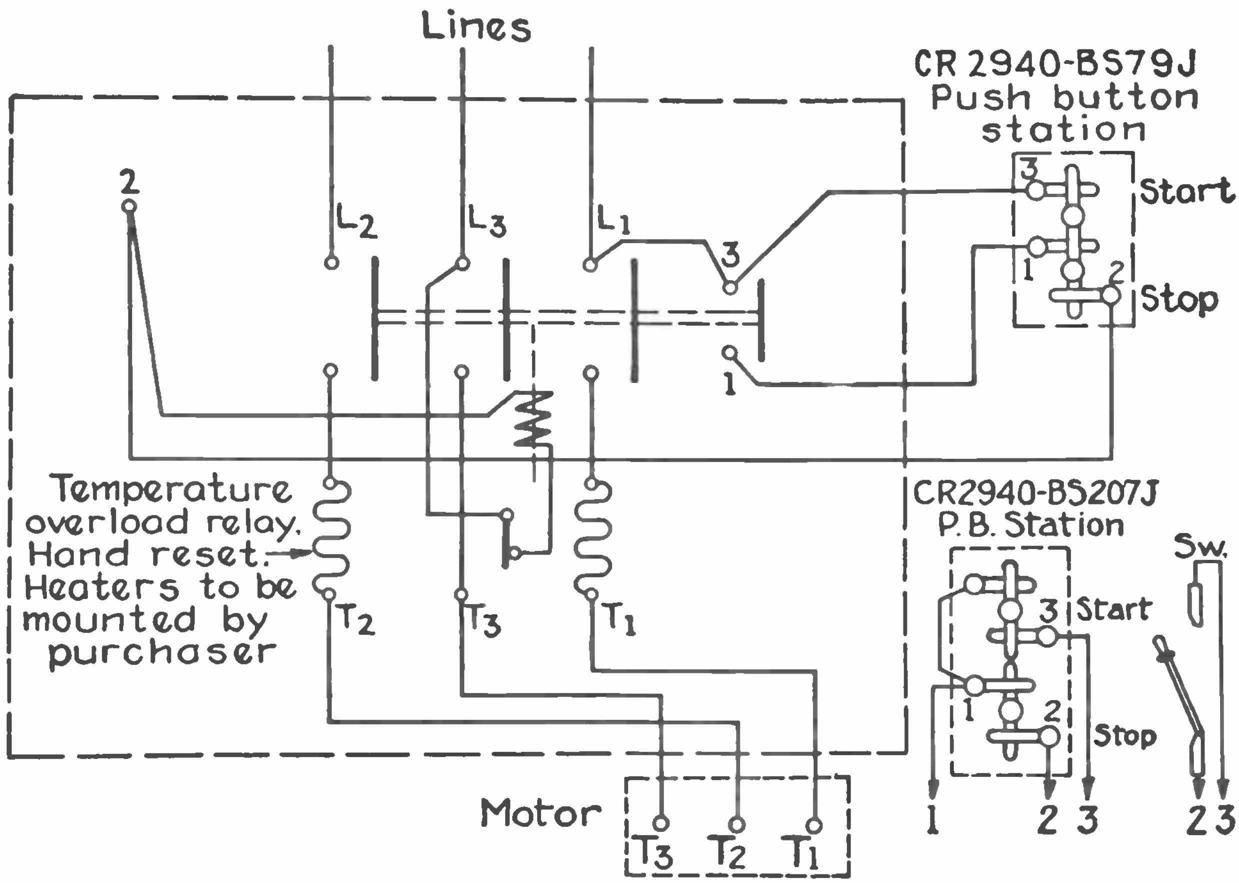
CUTLER-HAMMER, INC. MILWAUKEE NEW YORK

FORM 28 1000 2-38

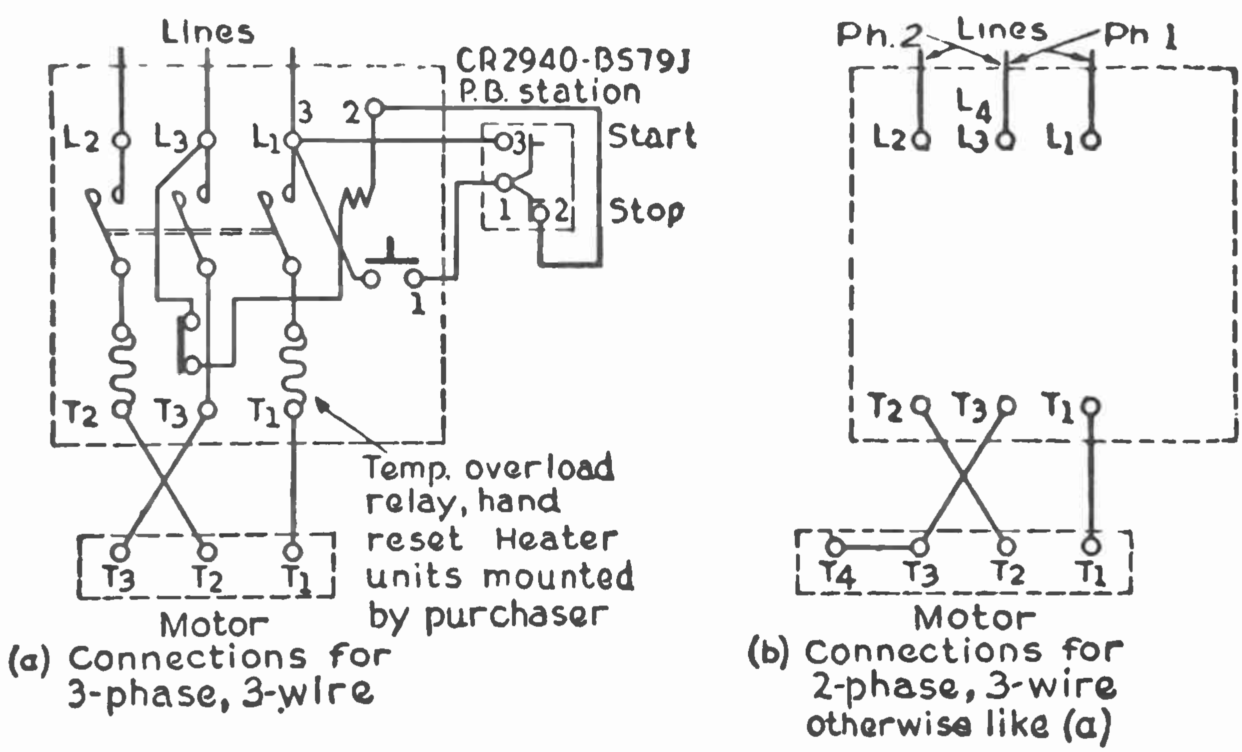
CHARLES BRUNING CO., INC.

GENERAL ELECTRIC MAGNETIC SWITCH

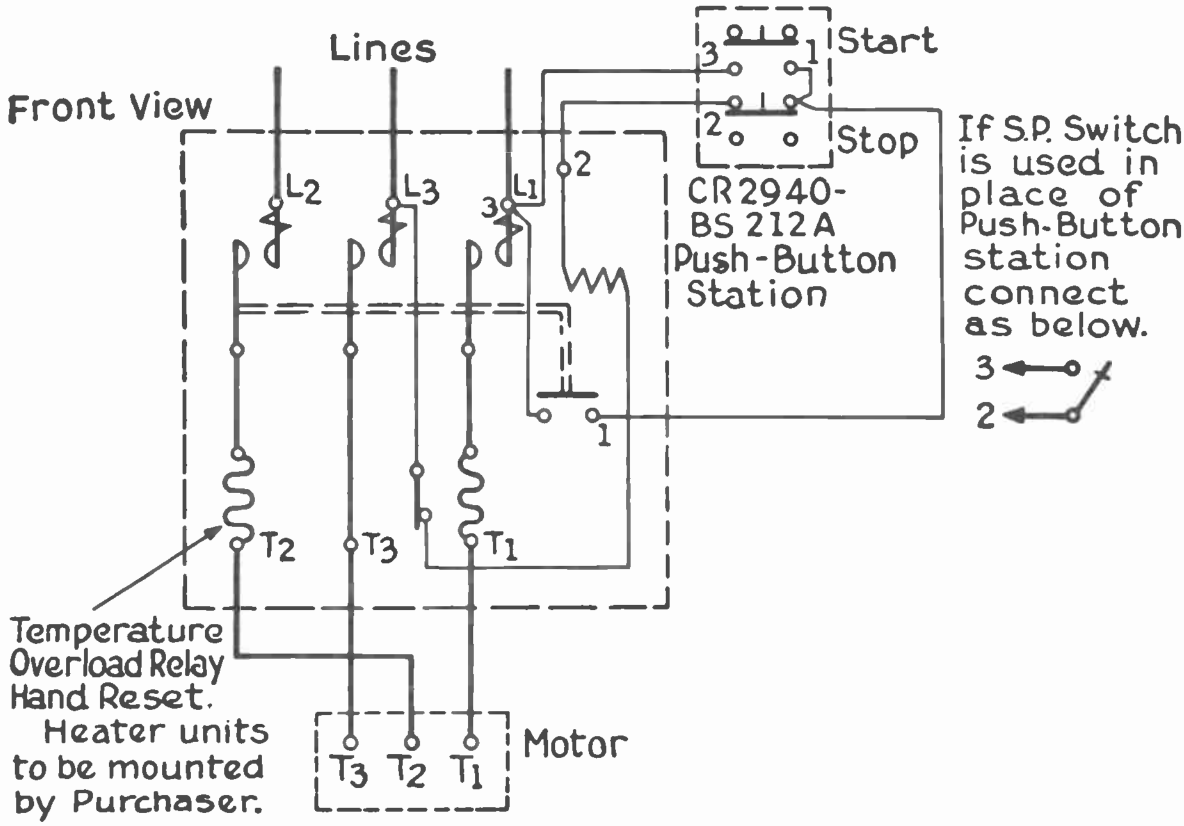




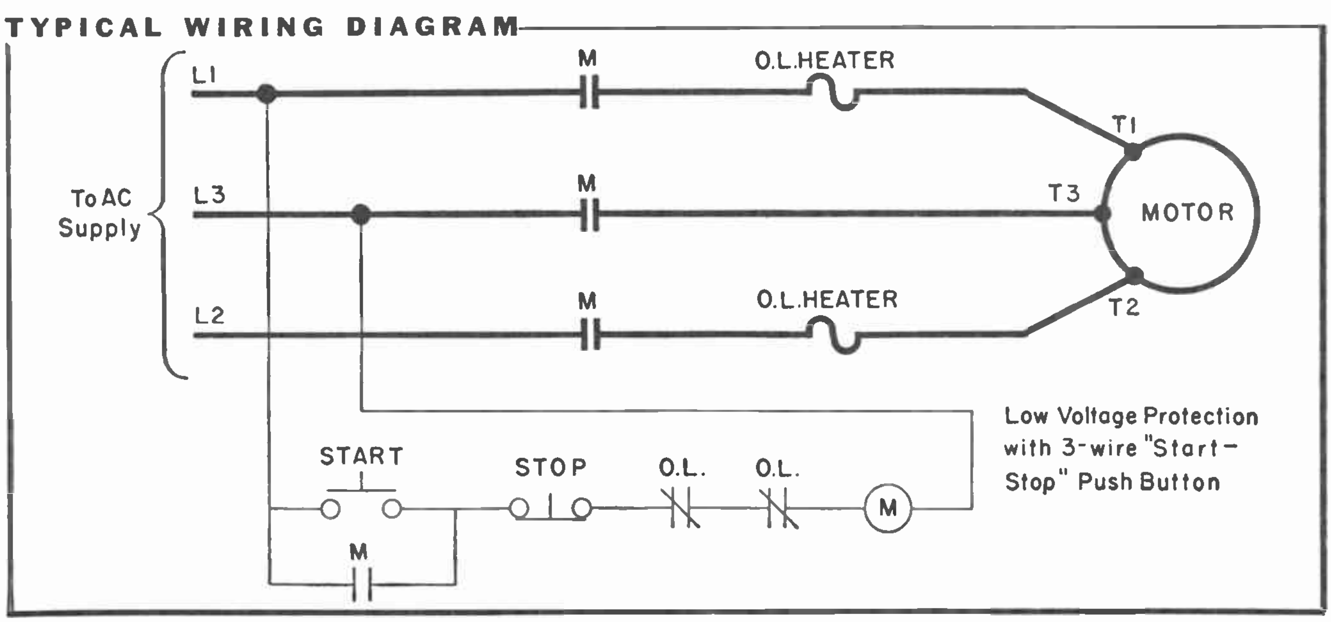
MAGNETIC LINE STARTER, 3-PHASE 3-WIRE MOTORS GENERAL ELECTRIC



MAGNETIC LINE STARTER, 3-PHASE 3-WIRE MOTORS GENERAL ELECTRIC

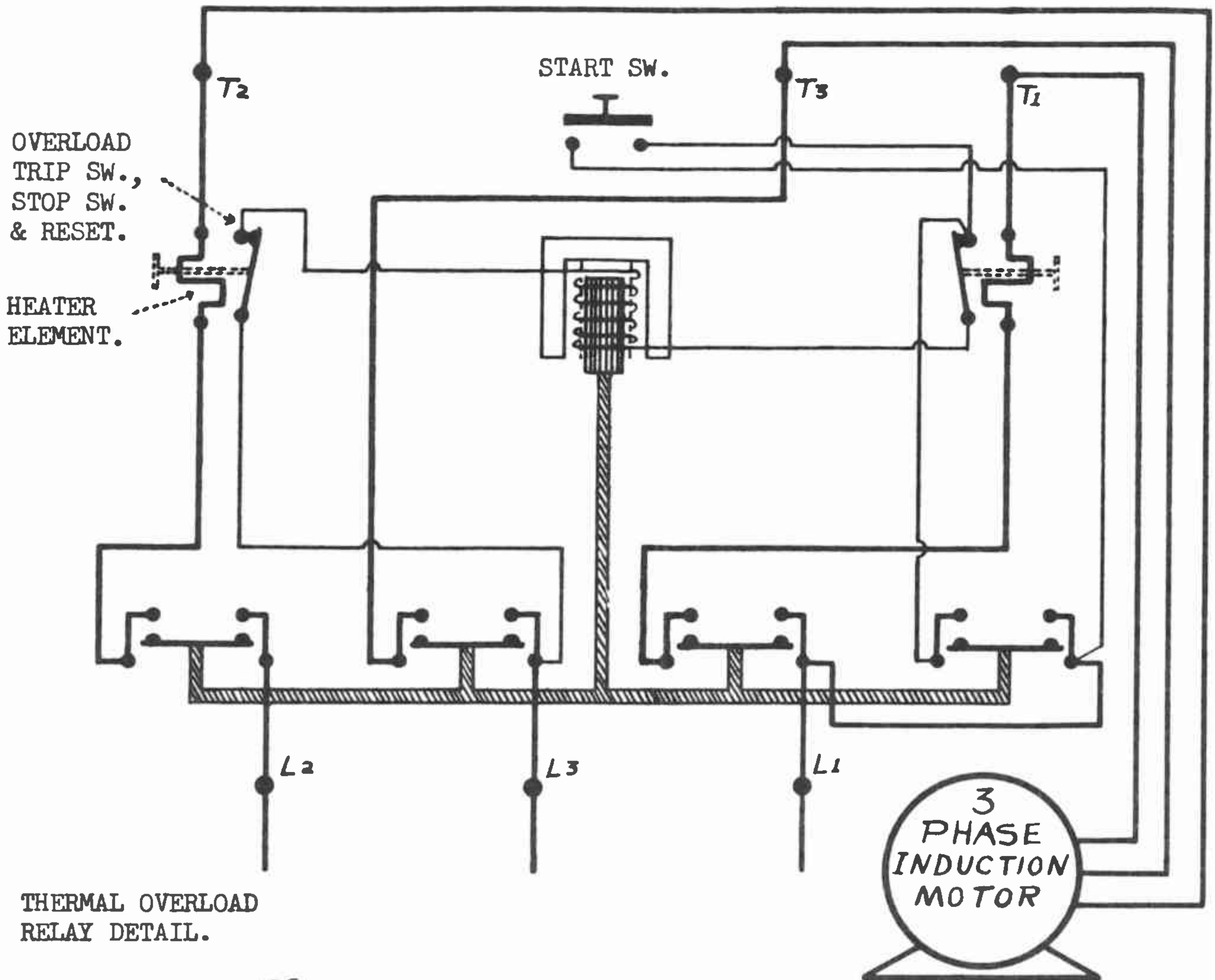


MAGNETIC LINE STARTER, 3-PHASE 3-WIRE MOTORS GENERAL ELECTRIC

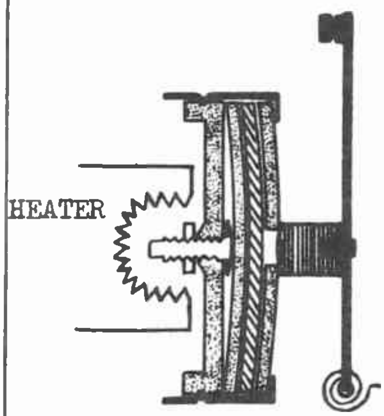


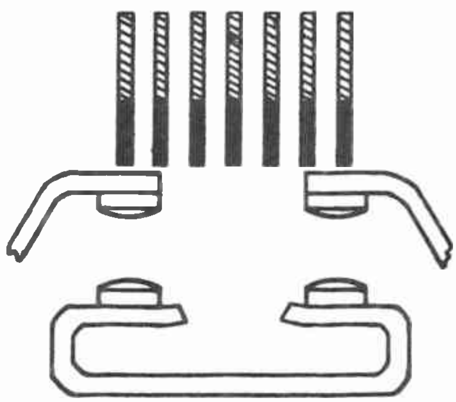
MAGNETIC LINE STARTER, 3-PHASE 3-WIRE MOTORS WESTINGHOUSE

3 PHASE ACROSS THE LINE MOTOR STARTER. (WESTINGHOUSE)



THERMAL OVERLOAD RELAY DETAIL.





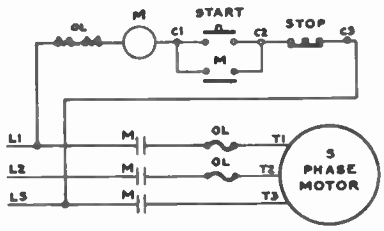
"DE-ION" ARC QUENCHER.

As the contacts separate, the specially shaped moving contact gives a magnetic reaction that forces the arc into the "DE-ION" grids where it is sliced into a series of arcs. At the next zero point on the I cycle, the air adjacent to each grid is deionized, and the arc is put out.

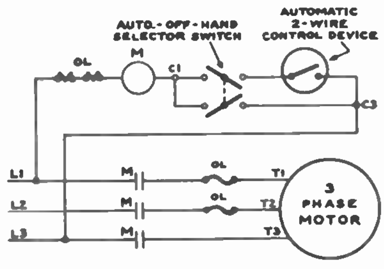
The bi-metal diaphragm consists of a soft metal disc such as brass (shaded with diagonal lines) placed between 2 steel discs of diaphragm steel. The adjusting screw, which is supported by a steel bridge, conducts the heat to the bi-metal diaphragm. The brass expands more rapidly than the steel with a rise in temperature. If the screw is properly adjusted, the diaghragm center will move toward the overload trip switch and open it, interrupting the magnet circuit, thus releasing the motor from the supply when an overload occures. Thermal overload releases usually require resetting by hand.

WIRING DIAGRAMS

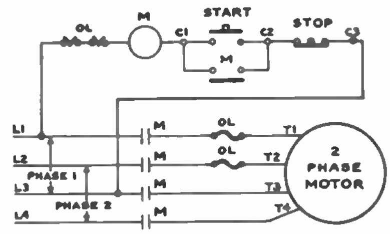
CLASS 8536 A. C. LINE VOLTAGE MAGNETIC STARTERS—TWO AND THREE PHASE



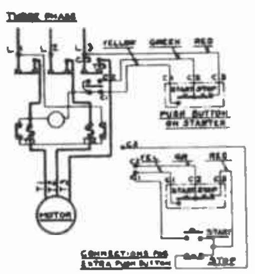
LINE DIAGRAM FOR THREE POLE STARTER USED WITH THREE PHASE MOTOR



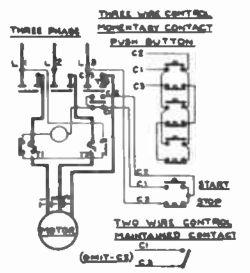
LINE DIAGRAM FOR THREE POLE STARTER WITH SELECTOR SWITCH USED WITH THREE PHASE MOTOR



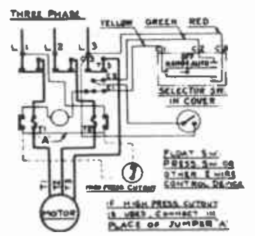
LINE DIAGRAM FOR FOUR POLE STARTER USED WITH TWO PHASE MOTOR ON FOUR WIRE POWER SYSTEM



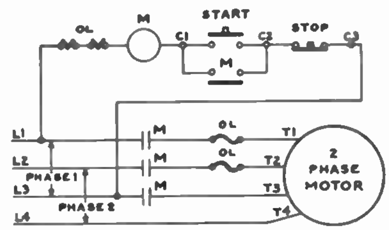
WIRING DIAGRAM FOR TYPE S-18A STARTER USED WITH THREE PHASE MOTOR



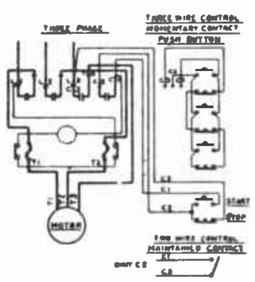
WIRING DIAGRAM FOR TYPE S-18B STARTER USED WITH THREE PHASE MOTOR



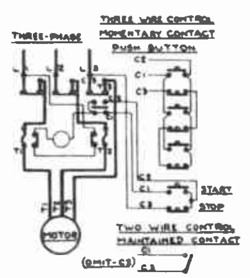
WIRING DIAGRAM FOR TYPE S-18C STARTER USED WITH THREE PHASE MOTOR



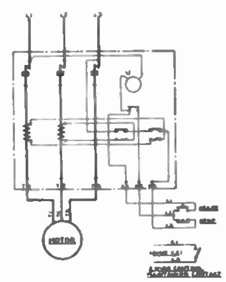
LINE DIAGRAM FOR THREE POLE STARTER USED WITH TWO PHASE MOTOR ON FOUR WIRE POWER SYSTEM



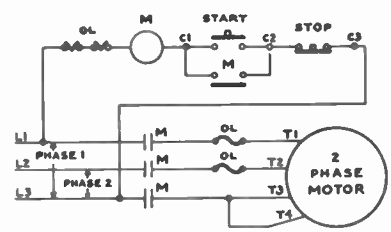
WIRING DIAGRAM FOR TYPE R-10B STARTER USED WITH THREE PHASE MOTOR



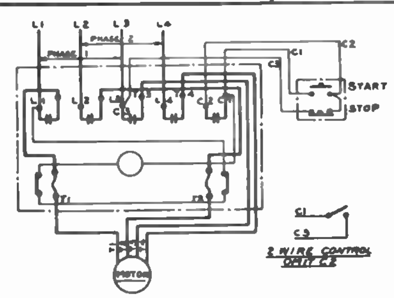
WIRING DIAGRAM FOR TYPE T-2 OR U-2 STARTER USED WITH THREE PHASE MOTOR



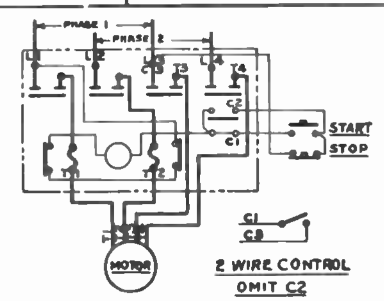
WIRING DIAGRAM FOR TYPE G-1 STARTER USED WITH THREE PHASE MOTOR



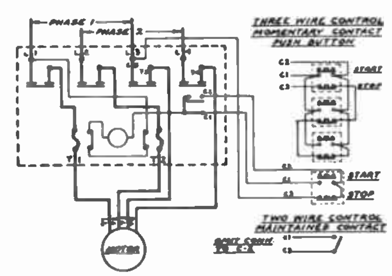
LINE DIAGRAM FOR THREE POLE STARTER USED WITH TWO PHASE MOTOR ON THREE WIRE POWER SYSTEM



WIRING DIAGRAM FOR TYPE R-12B STARTER USED WITH TWO PHASE MOTOR



WIRING DIAGRAM FOR TYPE S-20B STARTER USED WITH TWO PHASE MOTOR

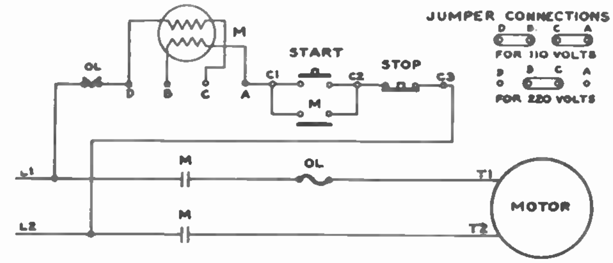


WIRING DIAGRAM FOR TYPE T-4 OR U-4 STARTER USED WITH TWO PHASE MOTOR

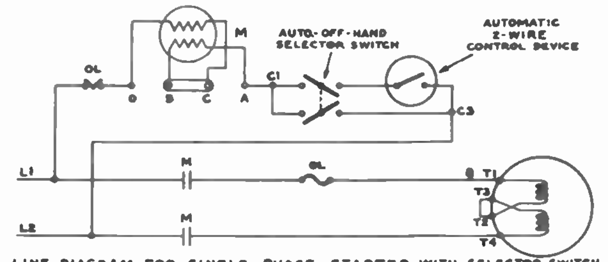
1748-B10

WIRING DIAGRAMS

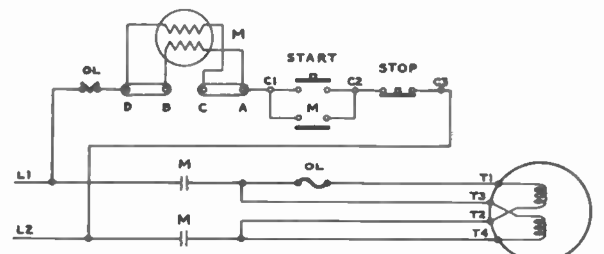
A. C. LINE VOLTAGE MAGNETIC STARTERS—SINGLE PHASE CLASS 8536



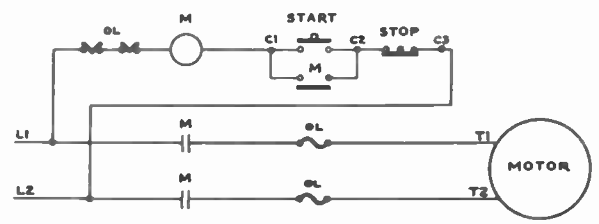
LINE DIAGRAM FOR SINGLE PHASE STARTER USED WITH SINGLE VOLTAGE MOTOR



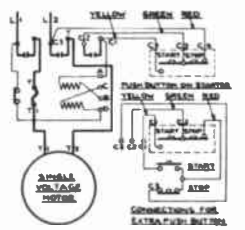
LINE DIAGRAM FOR SINGLE PHASE STARTER WITH SELECTOR SWITCH USED WITH DUAL VOLTAGE MOTOR CONNECTED FOR 220 VOLTS



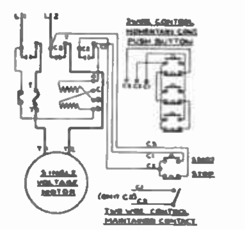
LINE DIAGRAM FOR SINGLE PHASE STARTER USED WITH DUAL VOLTAGE MOTOR CONNECTED FOR 110 VOLTS



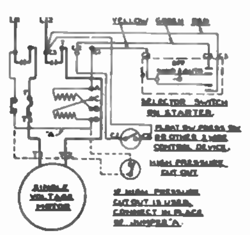
LINE DIAGRAM FOR SIZE II OR III THREE POLE STARTER USED ON SINGLE PHASE



TYPE R-8A

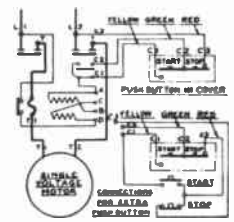


TYPE R-8B

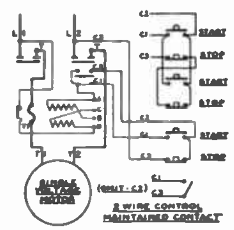


TYPE R-8C

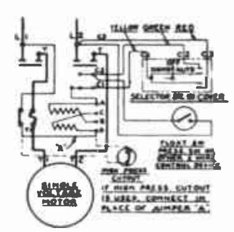
WIRING DIAGRAMS FOR SIZE O, SINGLE PHASE STARTERS USED WITH A SINGLE VOLTAGE MOTOR. SEE RIGHT HAND COLUMN FOR COIL JUMPER POSITIONS AND CONNECTIONS FOR DUAL VOLTAGE MOTORS.



TYPE S-14A

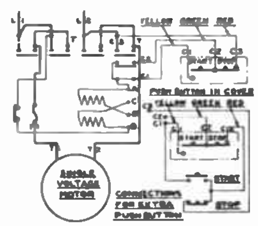


TYPE S-14B

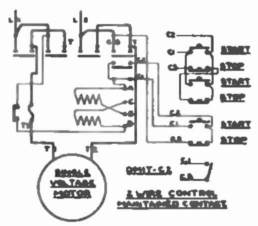


TYPE S-14C

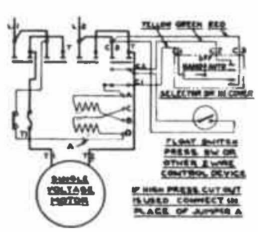
WIRING DIAGRAMS FOR SIZE I, SINGLE PHASE STARTERS USED WITH A SINGLE VOLTAGE MOTOR. SEE RIGHT HAND COLUMN FOR COIL JUMPER POSITIONS AND CONNECTIONS FOR DUAL VOLTAGE MOTORS.



TYPE S-16A



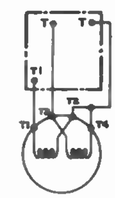
TYPE S-16B



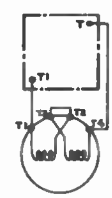
TYPE S-16C

WIRING DIAGRAMS FOR SIZE 1½, SINGLE PHASE STARTERS USED WITH A SINGLE VOLTAGE MOTOR. SEE RIGHT HAND COLUMN FOR COIL JUMPER POSITIONS AND CONNECTIONS FOR DUAL VOLTAGE MOTORS.

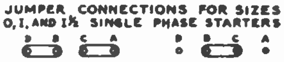
WIRING DIAGRAM FOR SINGLE PHASE STARTER USED WITH DUAL VOLTAGE MOTOR CONNECTED FOR 110 VOLTS.

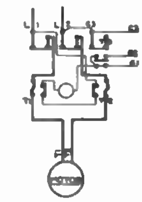


WIRING DIAGRAM FOR SINGLE PHASE STARTER USED WITH DUAL VOLTAGE MOTOR CONNECTED FOR 220 VOLTS.



JUMPER CONNECTIONS FOR SIZES O, I, AND 1½ SINGLE PHASE STARTERS





WIRING DIAGRAM FOR SIZE II OR III THREE POLE STARTER USED ON SINGLE PHASE

1748-89

AC Magnetic — Full Voltage — Type S

COMBINATION STARTERS WITH DISCONNECTING SWITCHES

Typical Wiring Diagrams

25-60 Cycle **3 Pole** **110-600 Volts**

ALLIS-CHALMERS

(WIRING DIAGRAMS FOR UNFUSED COMBINATION)

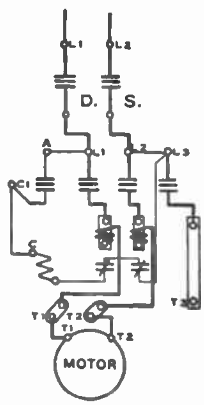


Fig. 1 — Single Phase

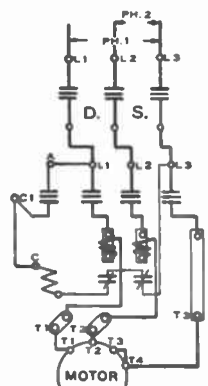


Fig. 2 — 2 Phase, 3 Wire

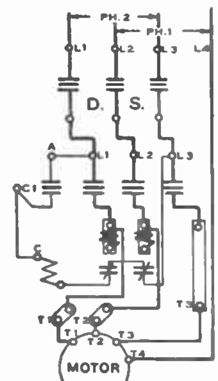


Fig. 3 — 2 Phase, 4 Wire

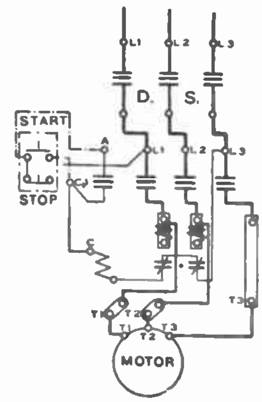


Fig. 4 — 3 Phase

(WIRING DIAGRAMS FOR FUSED COMBINATION)

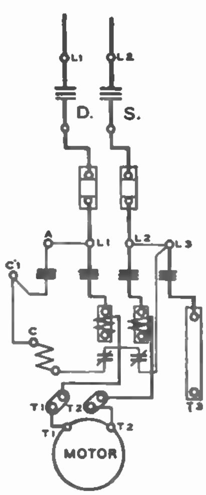


Fig. 5—Single Phase

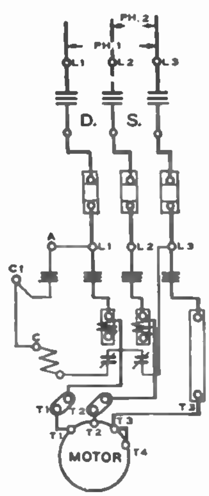


Fig. 6 — 2 Phase, 3 Wire

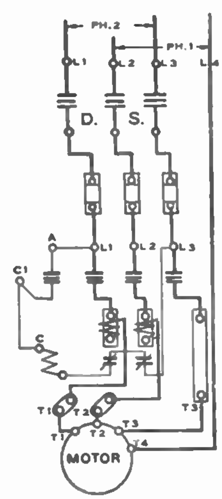


Fig. 7 — 2 Phase, 4 Wire

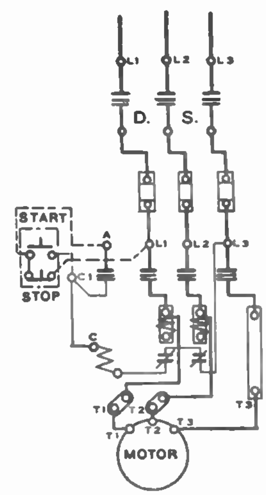


Fig. 8 — 3 Phase

WIRING DIAGRAMS FOR PILOT CONTROL

Fig. 9 — 2 Wire Maintained Contact

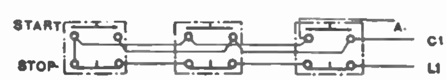
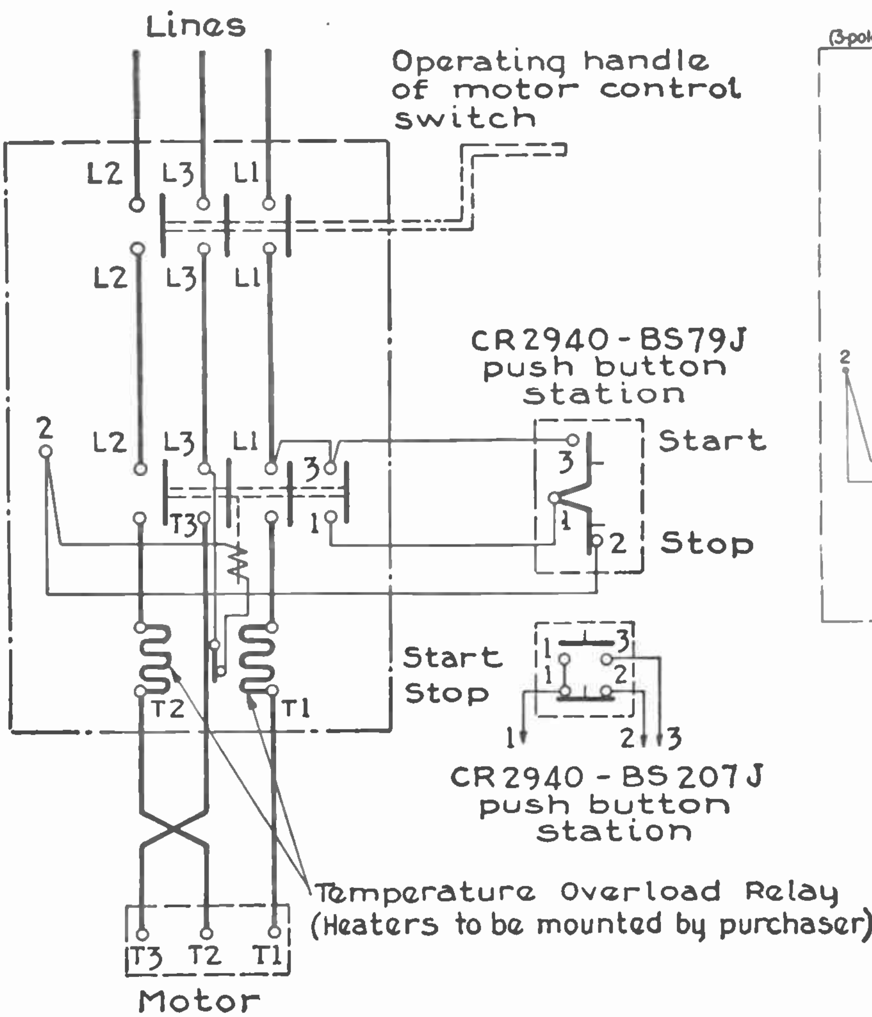
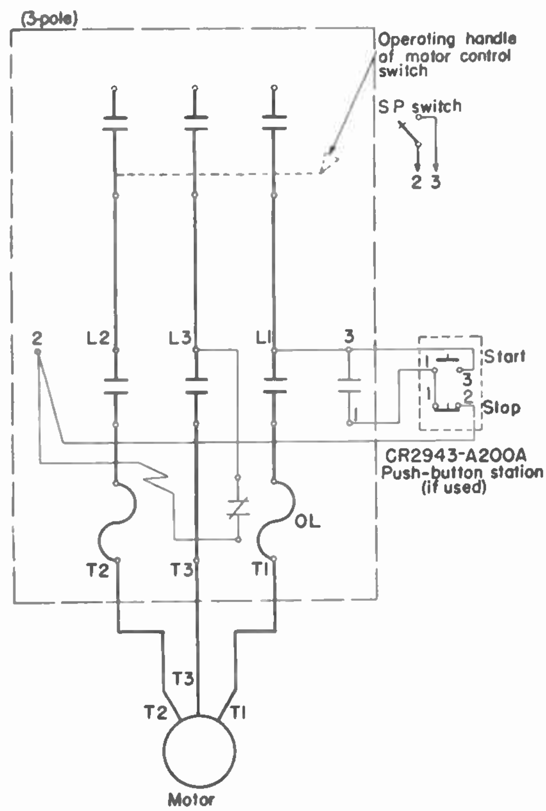


Fig. 10 — Connections for 2 or more P. B. Stations

NOTE: When External "Stop" Button or 2 Wire Maintained Contact is used remove A-L1 Jumper.

MAGNETIC COMBINATION STARTERS WITH SWITCHES
GENERAL ELECTRIC CR 7008

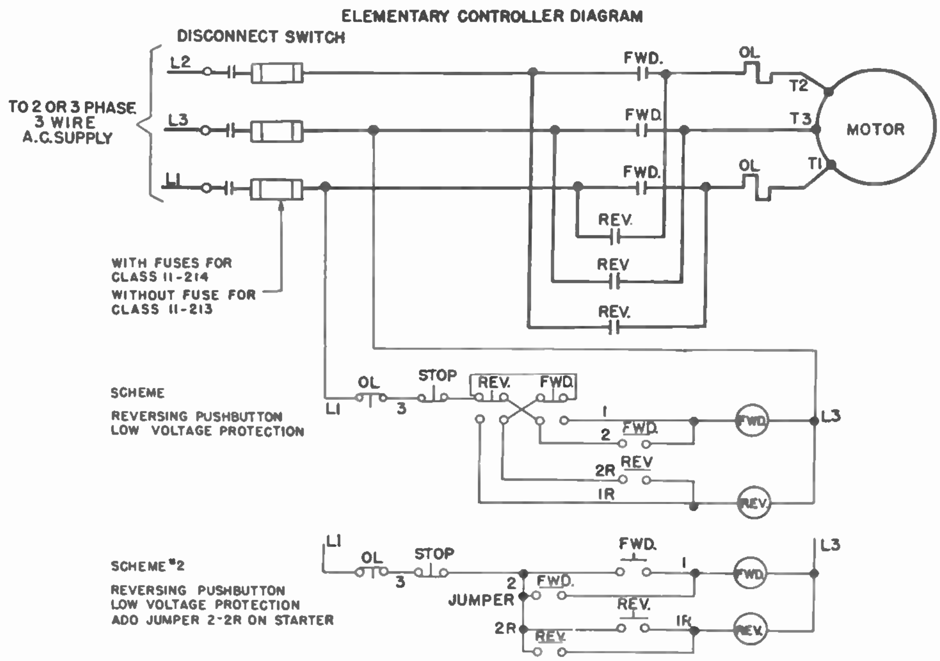




A-C. MAGNETIC "DE-ION" COMBINATION LINESTARTERS WITH MOTOR CIRCUIT SWITCH

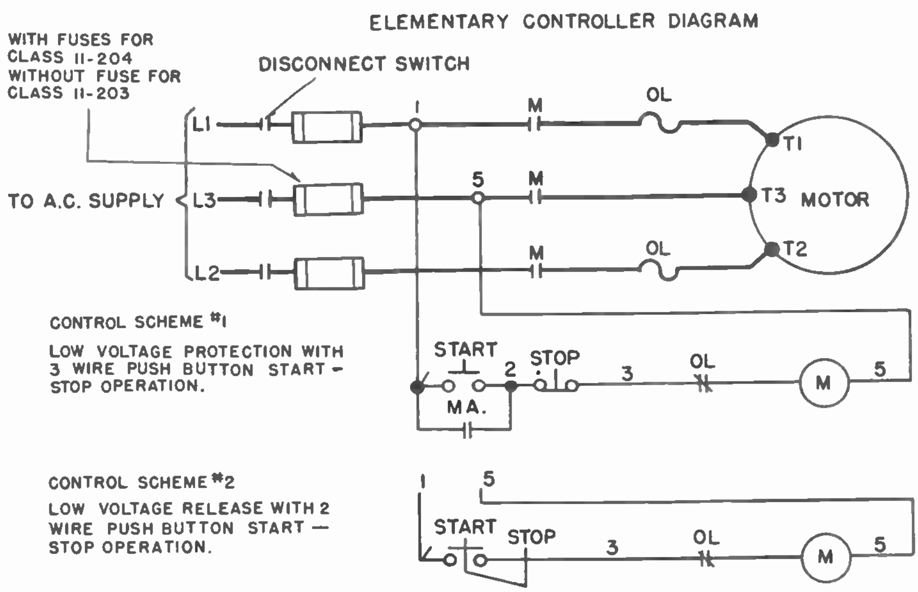
SCHEMATIC WIRING DIAGRAM

CLASSES 11-213 AND 11-214—REVERSING



SCHEMATIC WIRING DIAGRAM

CLASSES 11-203 AND 11-204—NON-REVERSING



COMBINATION STARTERS WITH CIRCUIT BREAKERS, A-C MAGNETIC FULL-VOLTAGE
ALLIS-CHALMERS TYPE S

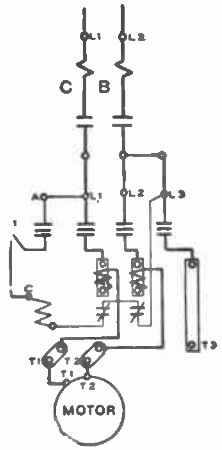


Fig. 1 — Single Phase

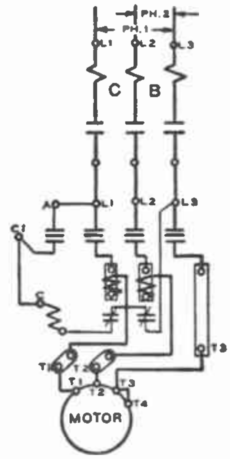


Fig 2 — 2 Phase, 3 Wire

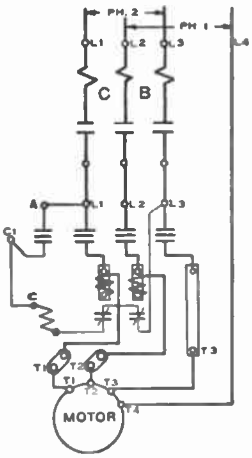


Fig. 3 — 2 Phase, 4 Wire

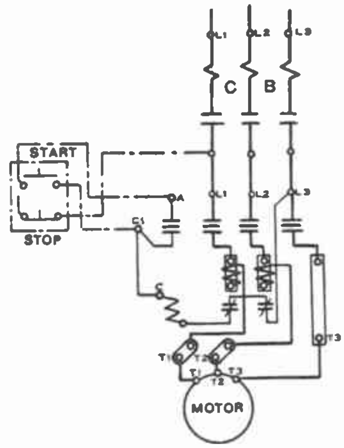


Fig. 4 — 3 Phase

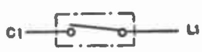


Fig. 5 — 2 Wire Maintained Contact

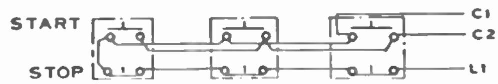
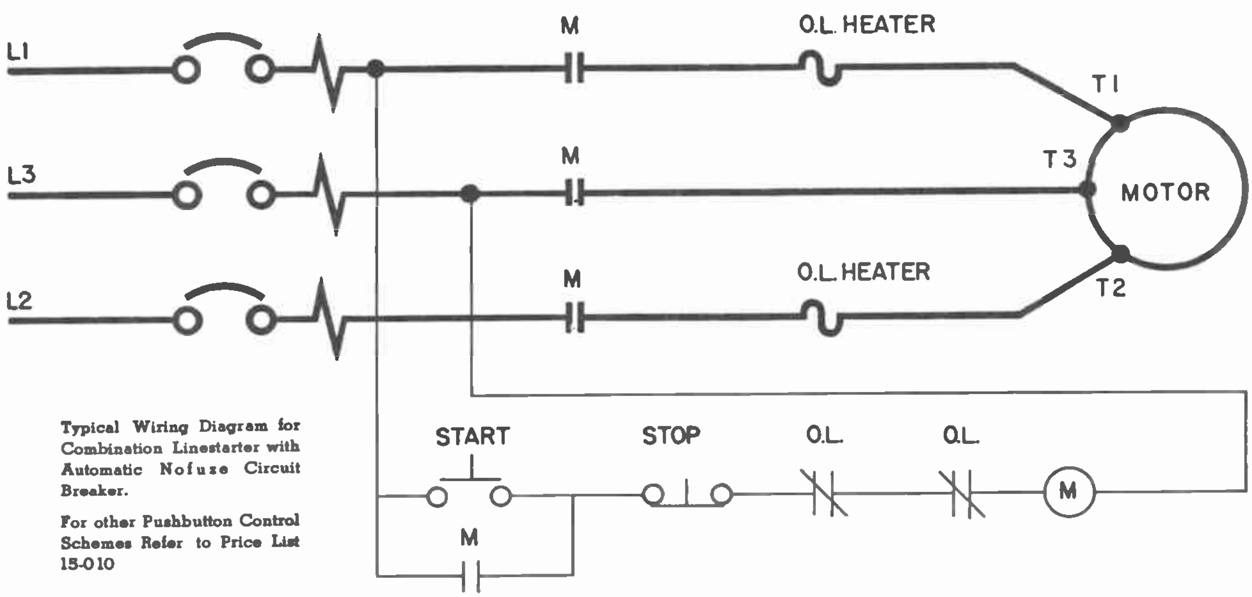


Fig. 6 — Connections for 2 or more P. B. Stations

NOTE: When External "Stop" Button or 2 Wire Maintained Contact is used remove A-L1 Jumper.

COMBINATION STARTER WITH CIRCUIT BREAKER WESTINGHOUSE



Typical Wiring Diagram for Combination Linestarter with Automatic Nofuze Circuit Breaker.

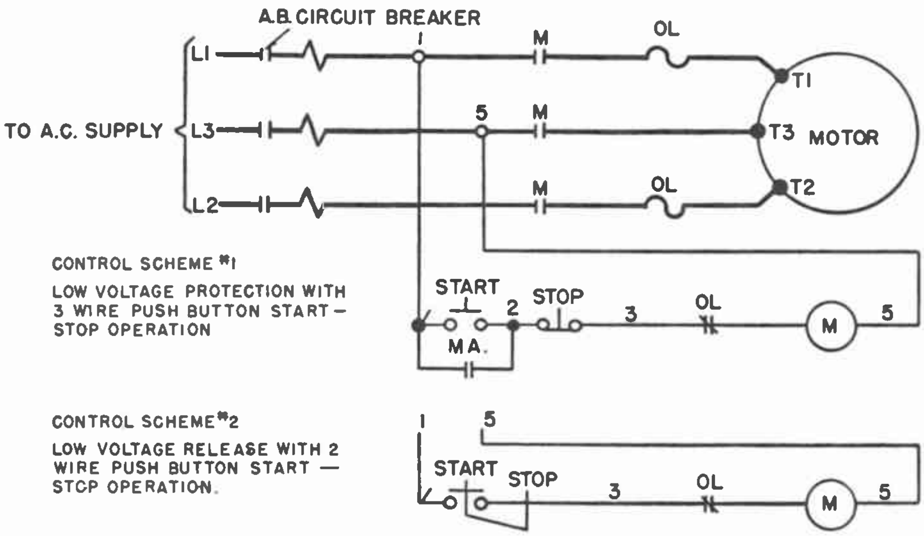
For other Pushbutton Control Schemes Refer to Price List 15-010

COMBINATION MAGNETIC STARTERS WITH CIRCUIT BREAKERS FOR SQUIRREL-CAGE AND WOUND-ROTOR MOTORS WESTINGHOUSE

SCHEMATIC WIRING DIAGRAMS

CLASS 11-206—NON-REVERSING

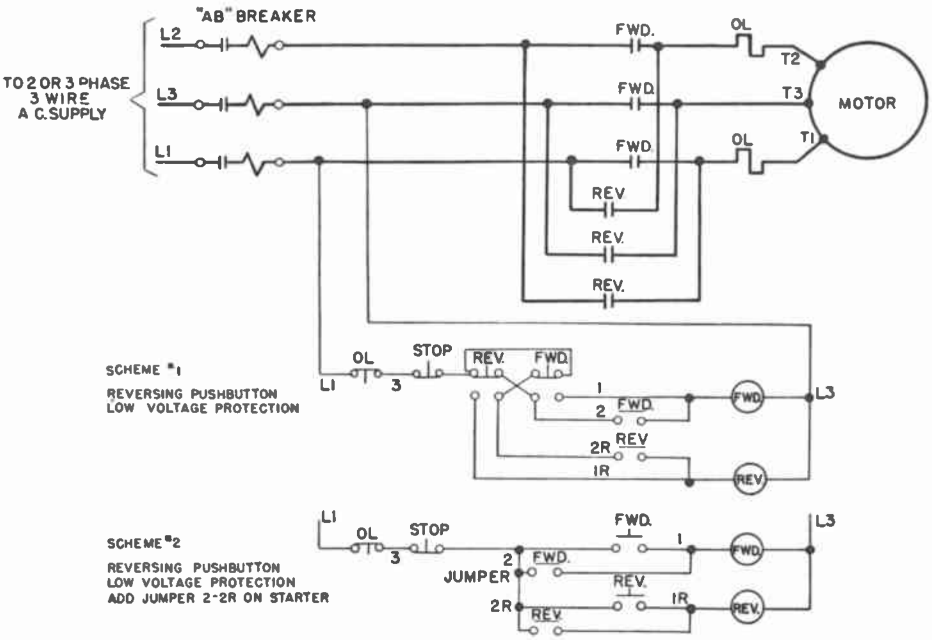
ELEMENTARY CONTROLLER DIAGRAM

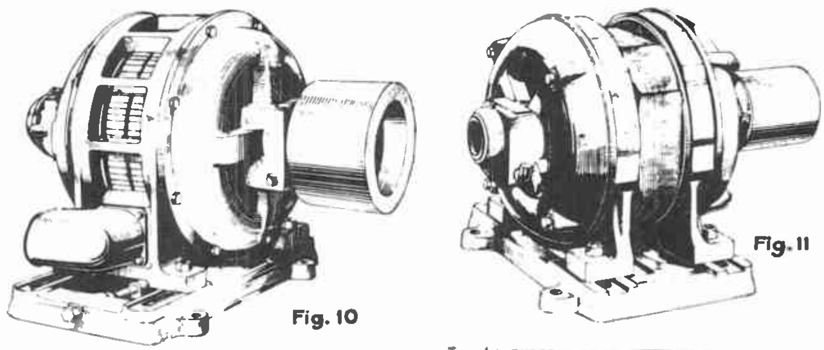


SCHEMATIC WIRING DIAGRAMS

CLASS 11-216—REVERSING

ELEMENTARY CONTROLLER DIAGRAM





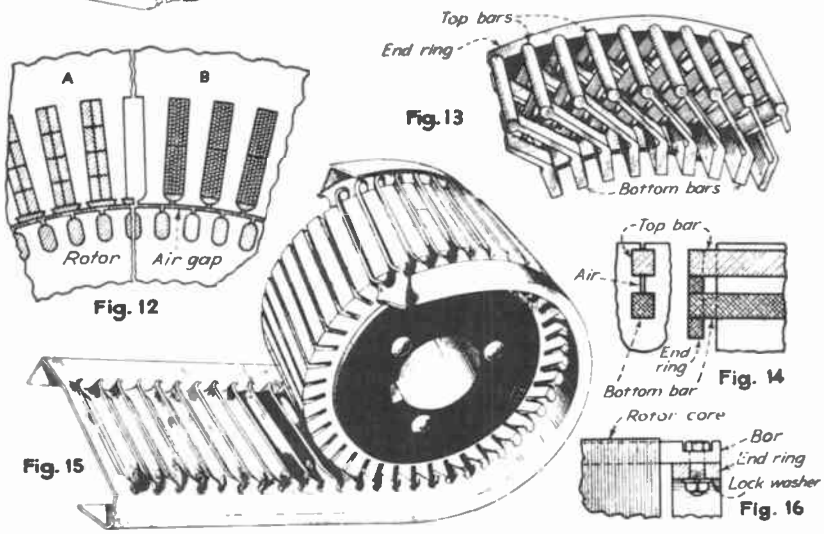
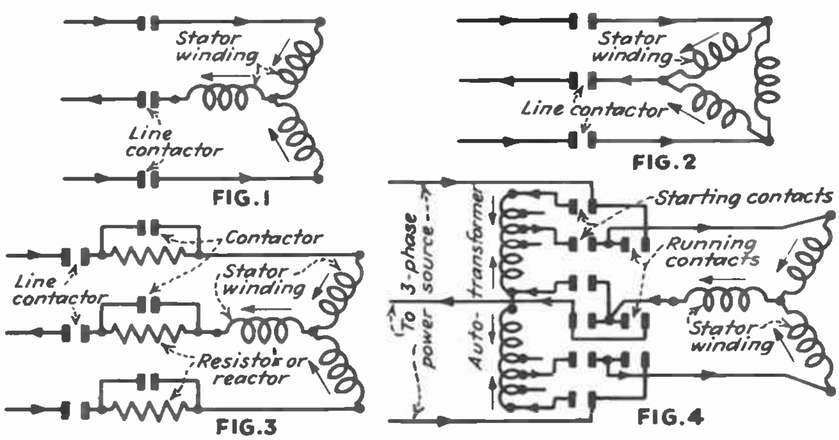


Fig. 10—Skeleton stator frame. Fig. 11—Riveted stator frame. Fig. 12—*A*, stator open slots; *B*, semiclosed slots. Fig. 13—Section of cast, interconnected double-squirrel-cage winding. Fig. 14—Section of simple double-squirrel-cage winding. Fig. 15—Squirrel-cage winding formed from a copper plate. Fig. 16—Joint between rotor bar and end ring



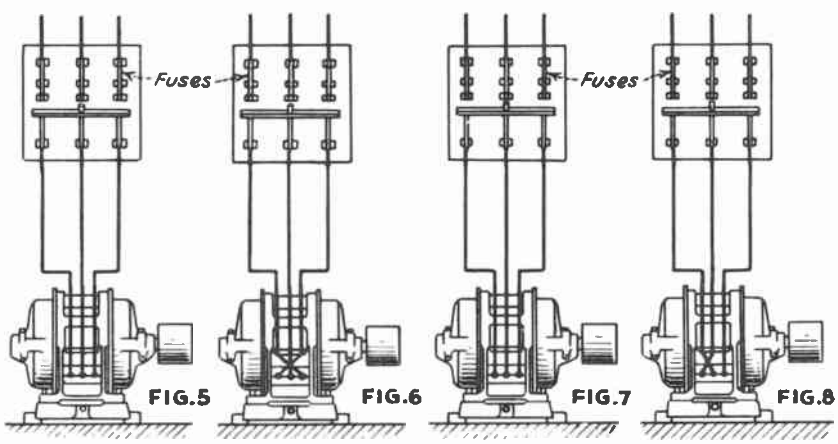
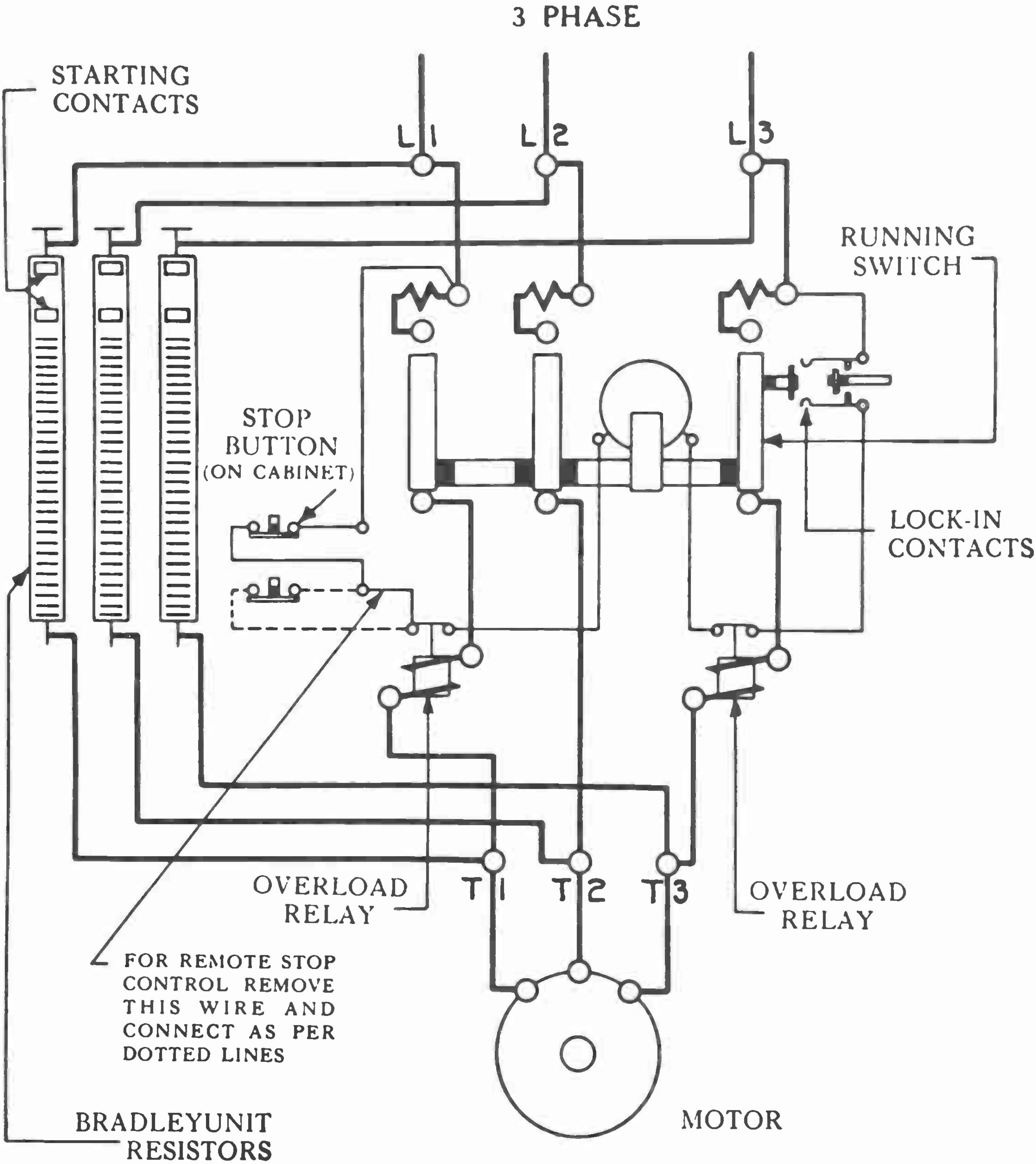
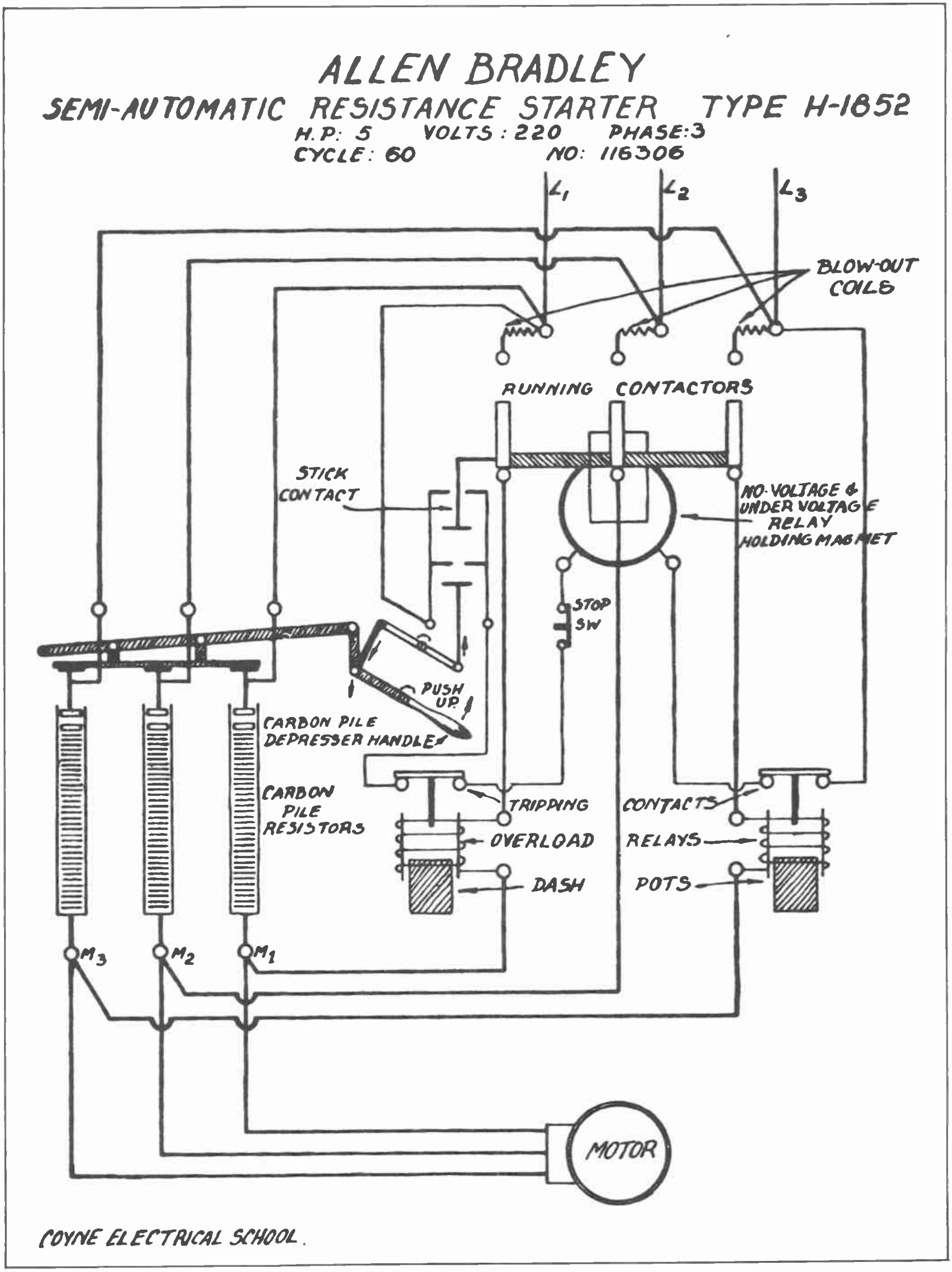


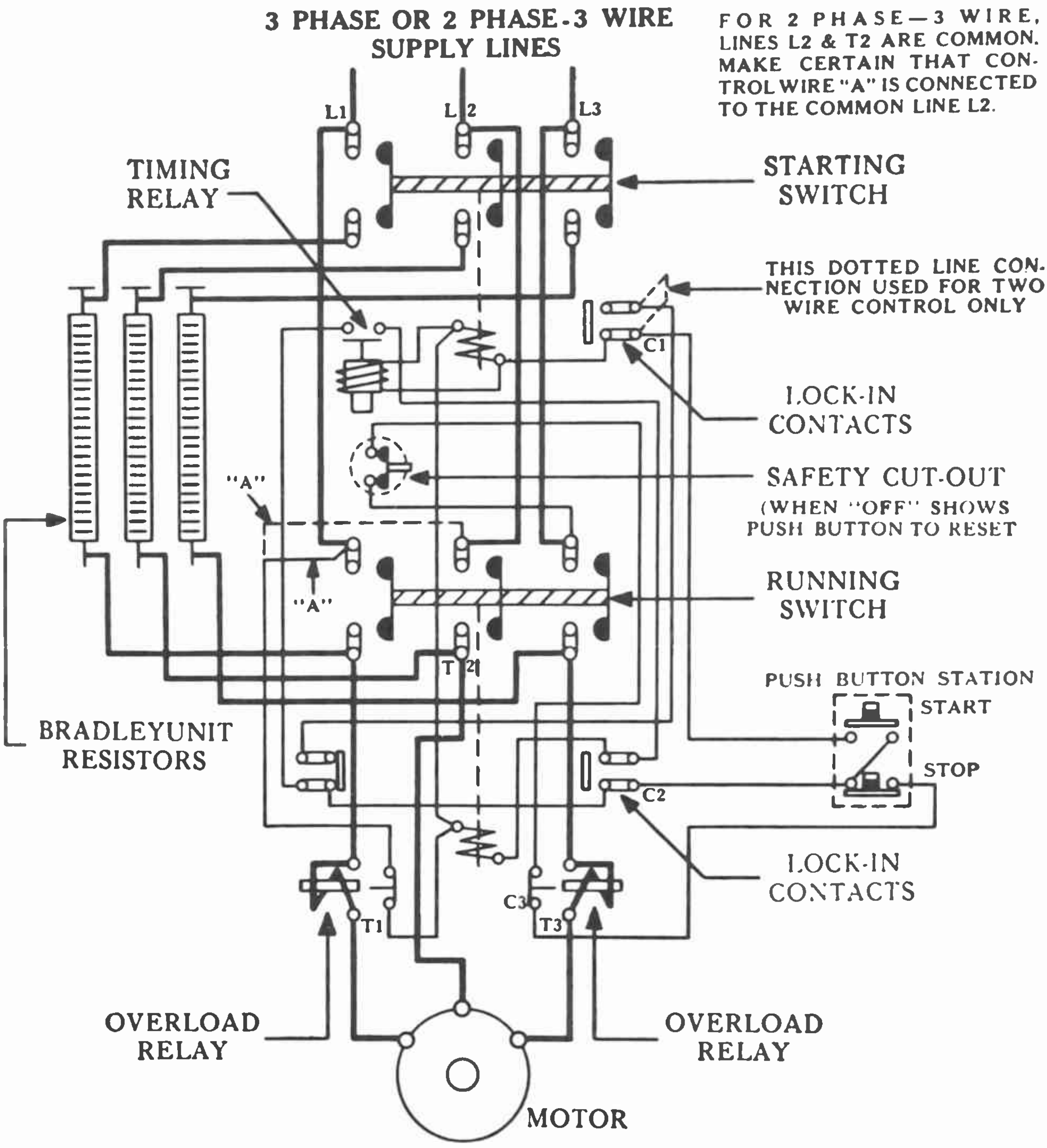
Fig. 1—Diagram of star-connected stator windings. Fig. 2—Stator windings connected delta. Fig. 3—Connections for starting with resistors or reactors in series with stator windings of a 3-phase motor. Fig. 4—Two auto-transformers connected to start a 3-phase motor. Fig. 5—Connections for one direction of rotation and Fig. ⁵, opposite direction of rotation of a 3-wire, 2-phase motor. Figs. 7 and 8—Connections for opposite directions of rotation of a 3-phase motor

SEMI-AUTOMATIC RESISTANCE STARTER ALLEN-BRADLEY

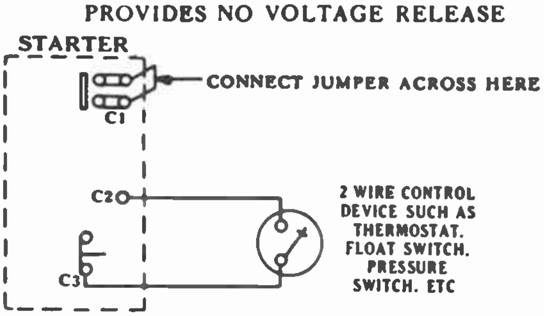



ALLEN BRADLEY
SEMI-AUTOMATIC RESISTANCE STARTER TYPE H-1852
H.P: 5 VOLTS: 220 PHASE:3
CYCLE: 60 NO: 116306
L1
L2
L3
BLOW-OUT COILS
RUNNING CONTACTORS
STICK CONTACT
NO-VOLTAGE & UNDER VOLTAGE RELAY HOLDING MAGNET
STOP SW
PUSH UP
CARBON PILE DEPRESSER HANDLE
CARBON PILE RESISTORS
TRIPPING
CONTACTS
OVERLOAD
RELAYS
DASH
POTS
M3
M2
M1
MOTOR
COYNE ELECTRICAL SCHOOL.

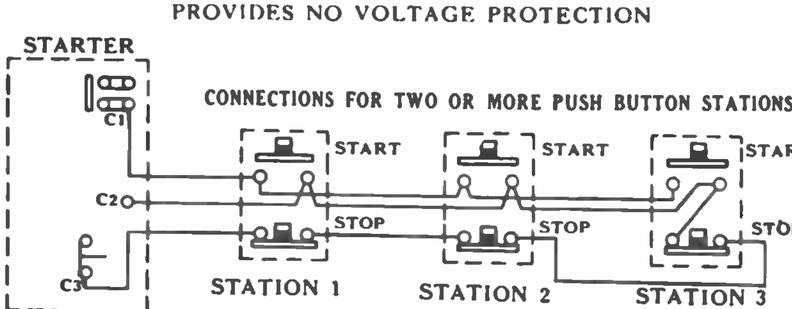
AUTOMATIC RESISTANCE STARTER **ALLEN-BRADLEY**



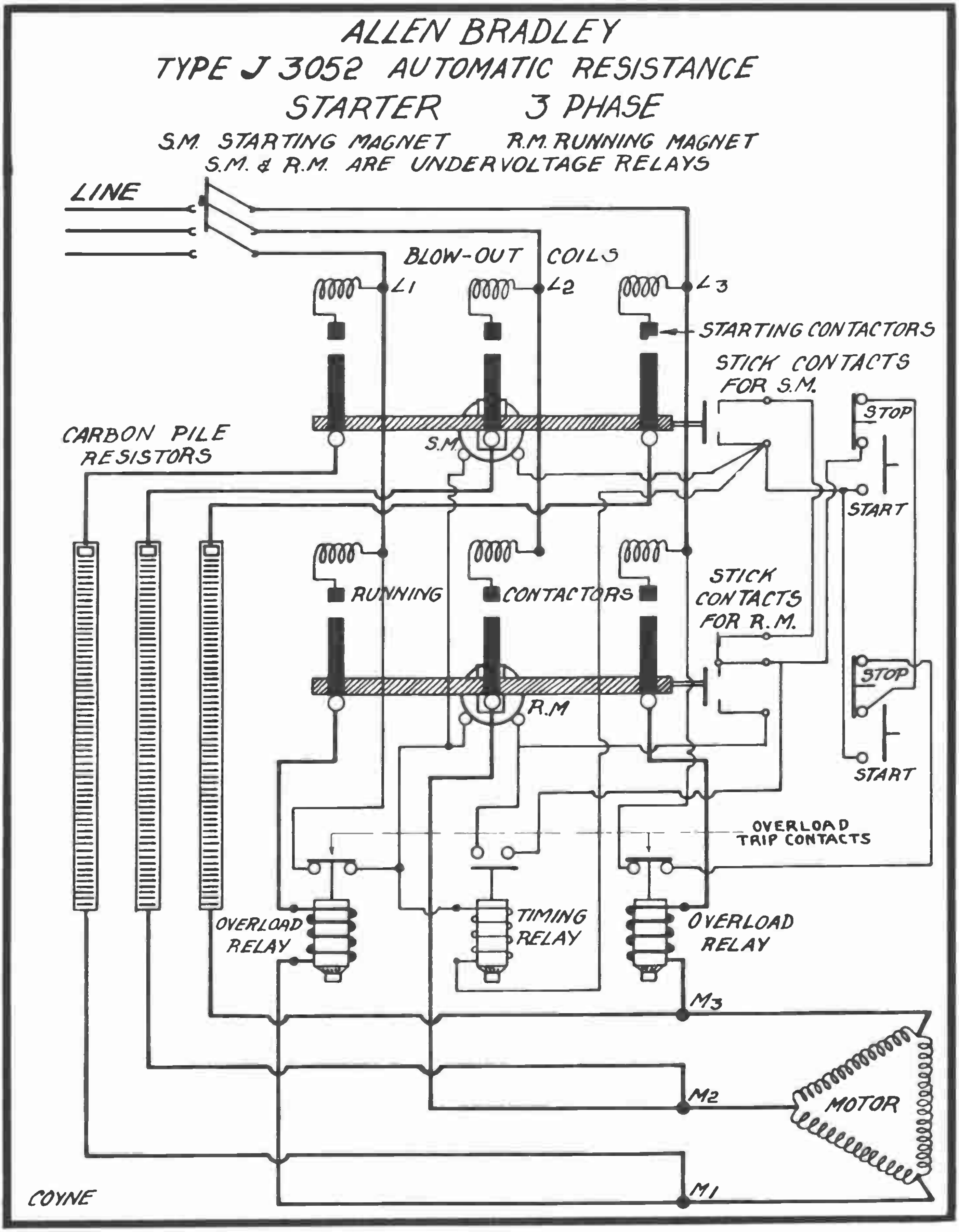
2 WIRE CONTROL CONNECTION
PROVIDES NO VOLTAGE RELEASE

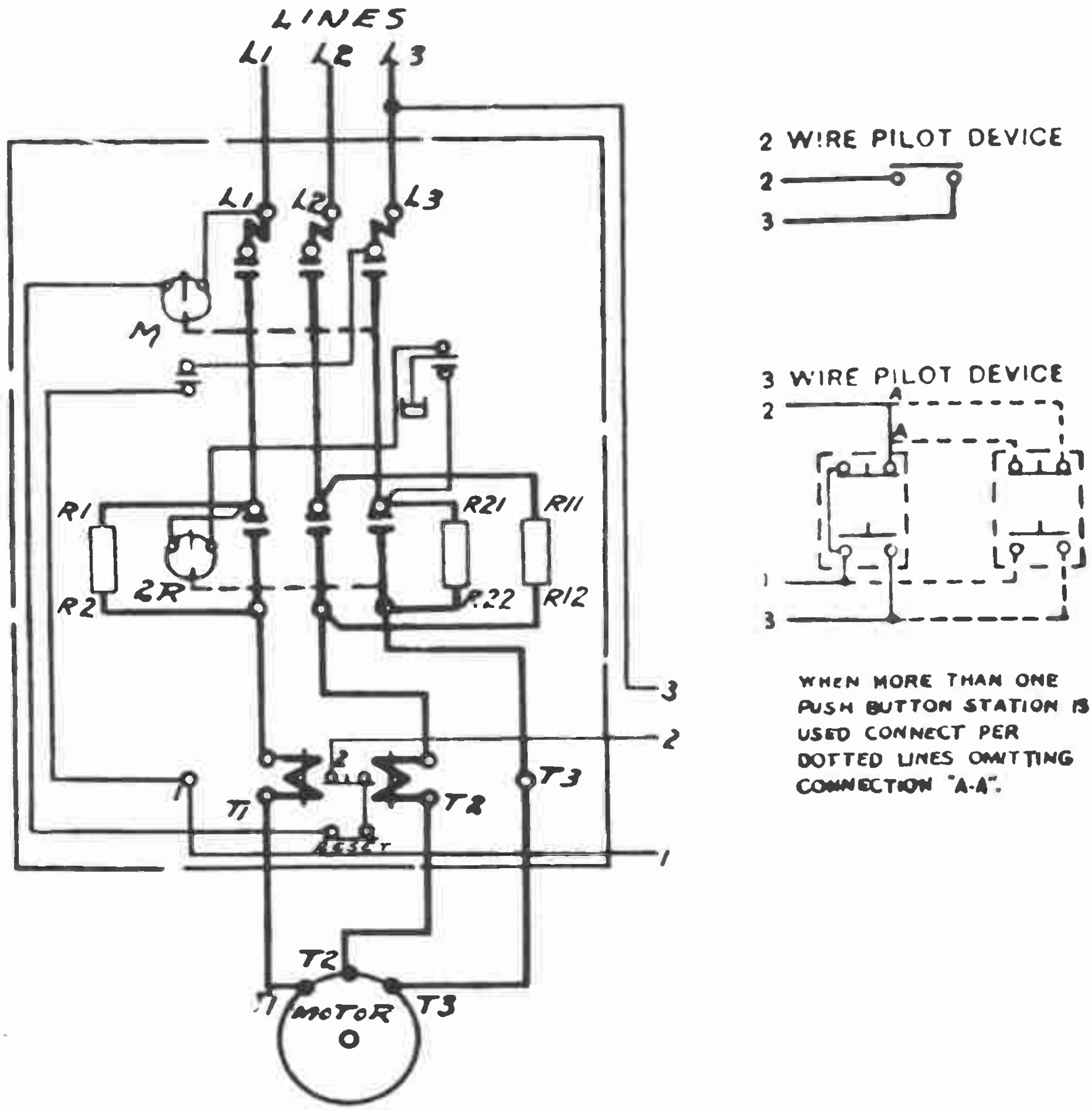


3 WIRE PUSH BUTTON CONNECTIONS
PROVIDES NO VOLTAGE PROTECTION



LAST PUSH BUTTON TO BE CONNECTED LIKE STATION 3


ALLEN BRADLEY
TYPE J 3052 AUTOMATIC RESISTANCE
STARTER 3 PHASE
S.M. STARTING MAGNET R.M. RUNNING MAGNET
S.M. & R.M. ARE UNDERVOLTAGE RELAYS
LINE
BLOW-OUT COILS
L1
L2
L3
STARTING CONTACTORS
STICK CONTACTS FOR S.M.
STOP
START
CARBON PILE RESISTORS
S.M.
RUNNING CONTACTORS
STICK CONTACTS FOR R.M.
R.M.
STOP
START
OVERLOAD TRIP CONTACTS
OVERLOAD RELAY
TIMING RELAY
OVERLOAD RELAY
M3
M2
MOTOR
M1
COYNE



CONNECTIONS FOR PRIMARY RESISTOR AUTOMATIC STARTER

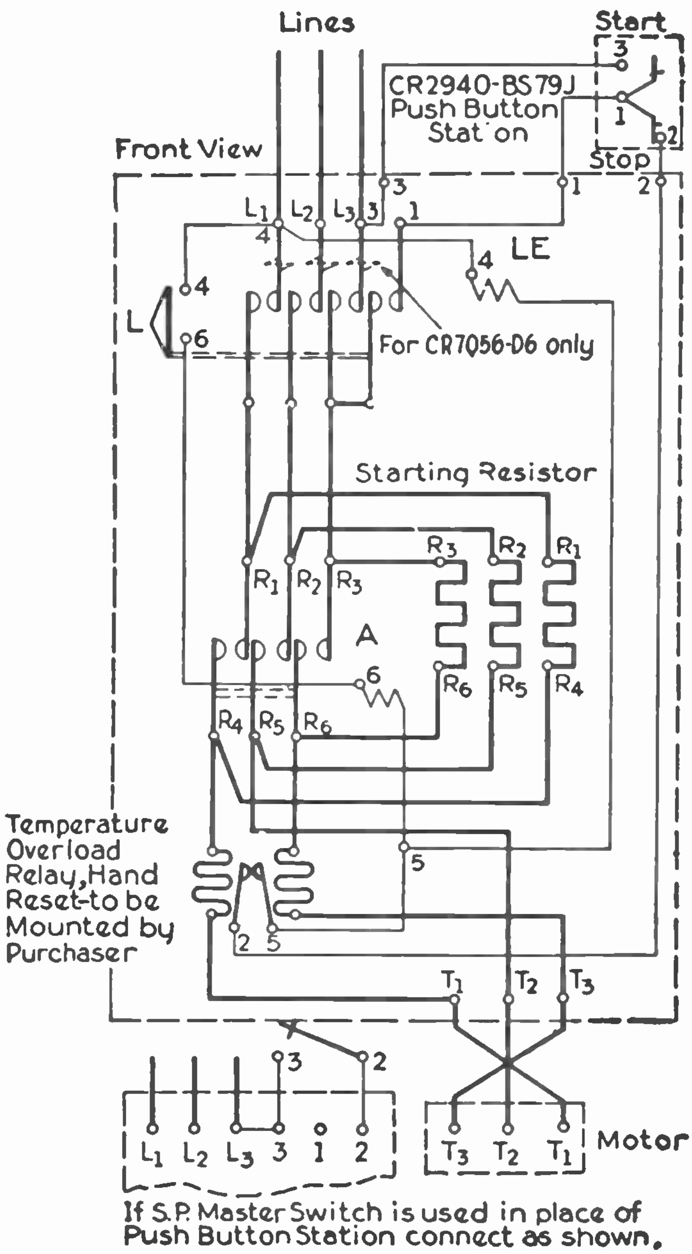
DRAWN BY		TYPE	SUR NO E5727D1
CHECKED BY	APPROVED BY	BULL. NO.	SUP. NO. BY
A	B	ORDER NO. DEV.3701-10	8009I DI

CUTLER-HAMMER INC MILWAUKEE NEW YORK

SINGLE-STEP PRIMARY RESISTOR-TYPE AUTOMATIC STARTER

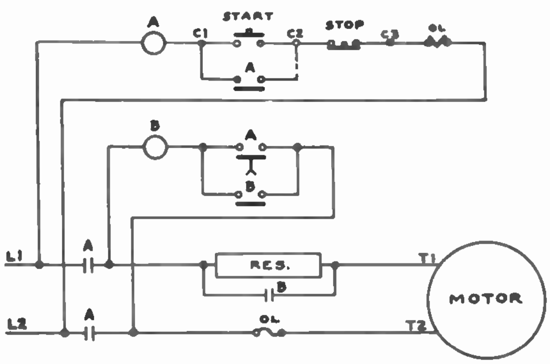
FOR SQUIRREL CAGE INDUCTION MOTORS

GENERAL ELECTRIC CR 7056

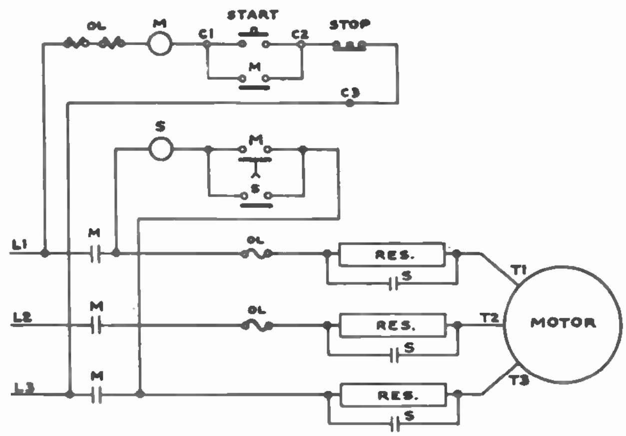


WIRING DIAGRAMS

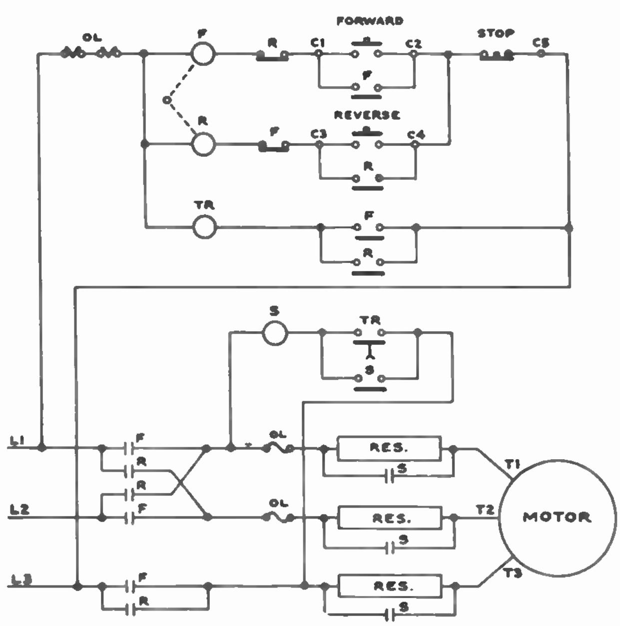
A. C. REDUCED VOLTAGE STARTERS—PRIMARY RESISTOR TYPE CLASSES 8547, 8747



TYPICAL LINE DIAGRAM FOR CLASS 8547 SINGLE PHASE, NON-REVERSING PRIMARY RESISTOR TYPE STARTER



TYPICAL LINE DIAGRAM FOR CLASS 8547 THREE PHASE, NON-REVERSING PRIMARY RESISTOR TYPE STARTER



TYPICAL LINE DIAGRAM FOR CLASS 8747 THREE PHASE, REVERSING PRIMARY RESISTOR TYPE STARTER

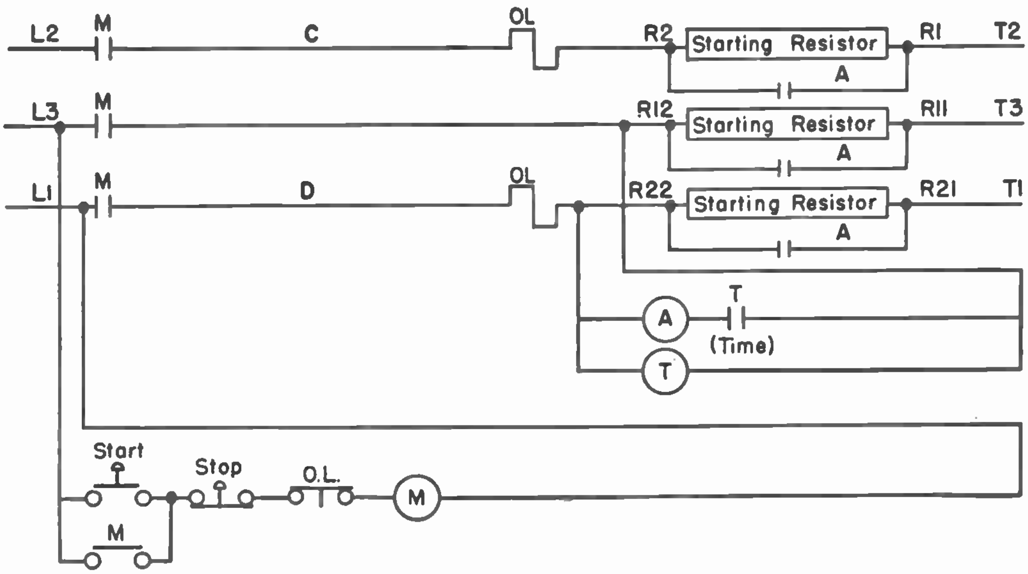
Wiring diagrams changed since previous issue.

MAGNETIC TIME-LIMIT RESISTANCE STARTERS FOR SQUIRREL-CAGE INDUCTION MOTORS

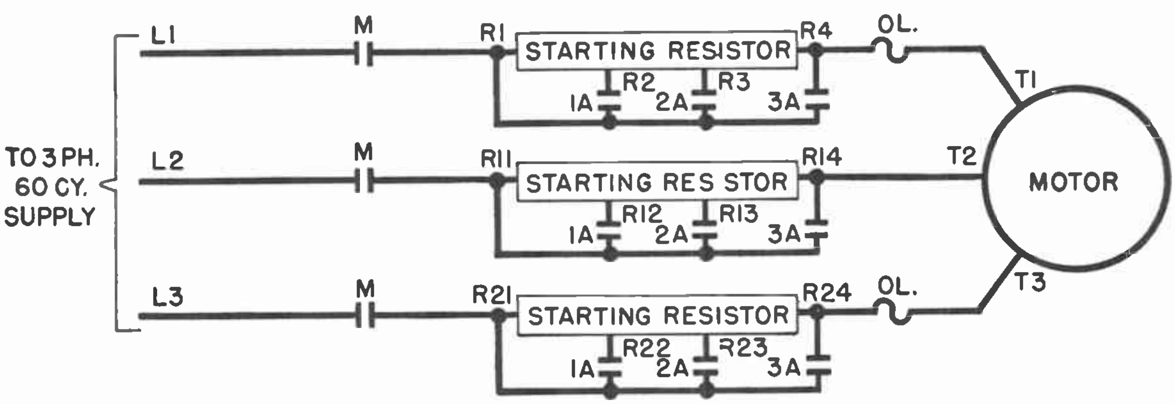
WESTINGHOUSE

SCHEMATIC WIRING DIAGRAMS

TWO-POINT ACCELERATION



THREE-STEPS—FOUR-POINT ACCELERATION



AC Magnetic — Full Voltage — Type S

REVERSING STARTERS

Typical Wiring Diagrams

25-60 Cycle **3 Pole** **110-600 Volts**

ALLIS-CHALMERS

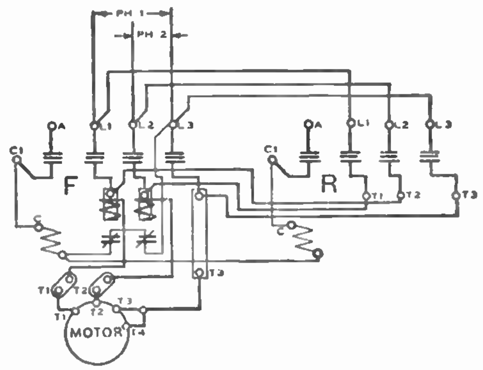


Fig. 1 — 2 Phase, 3 Wire

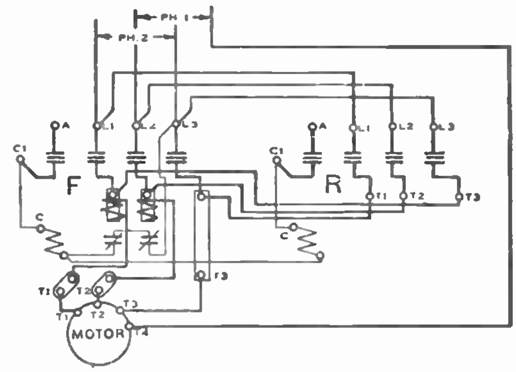


Fig. 2 — 2 Phase, 4 Wire

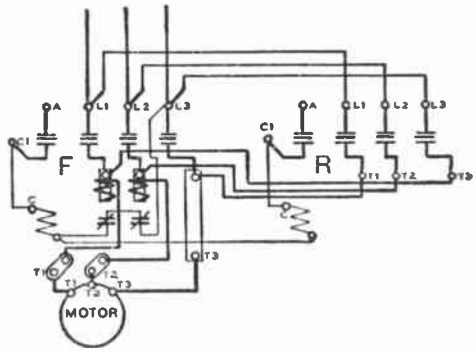


Fig. 3 — 3 Phase

WIRING DIAGRAMS FOR PILOT CONTROLS

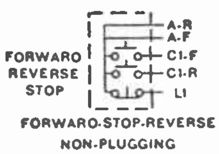


Fig. 4

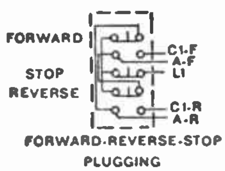


Fig. 5

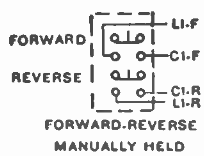
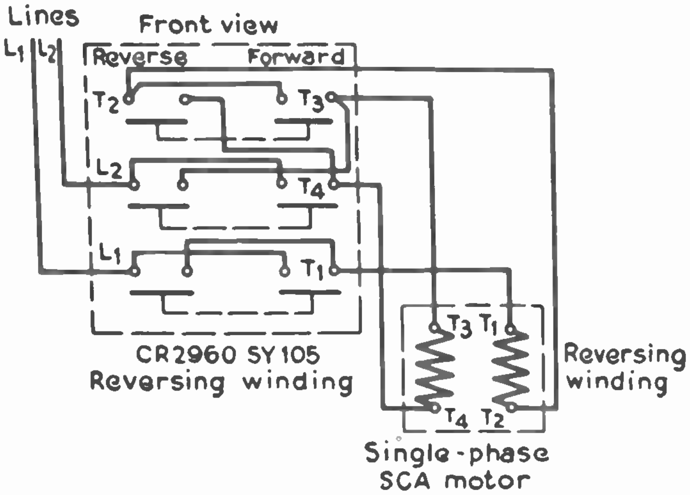
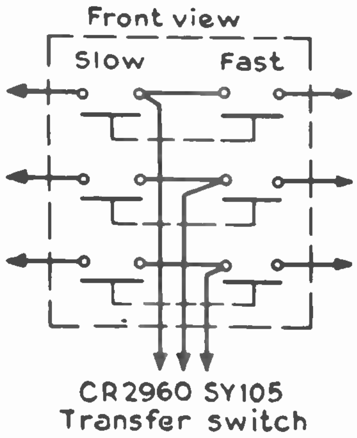


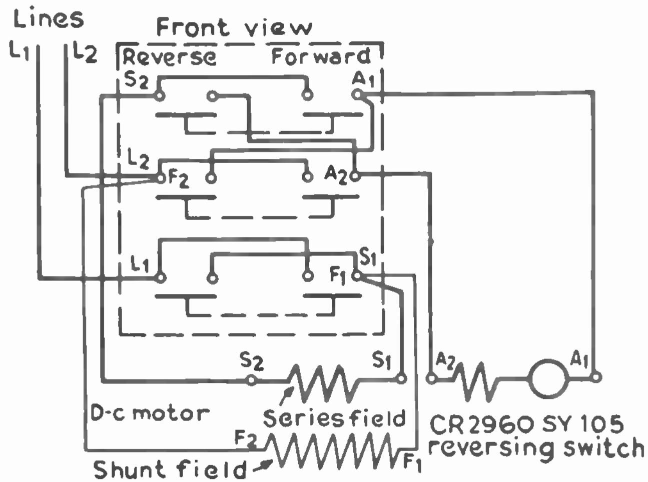
Fig. 6



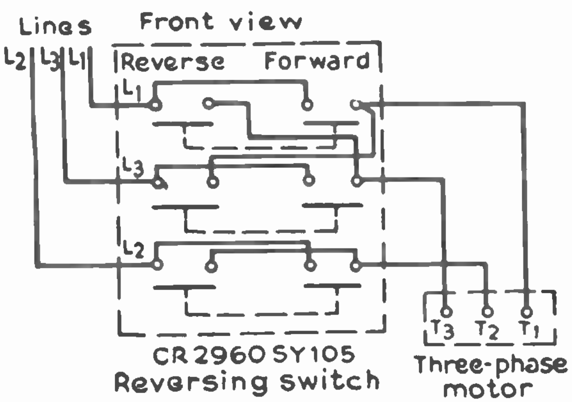
Single-phase motors



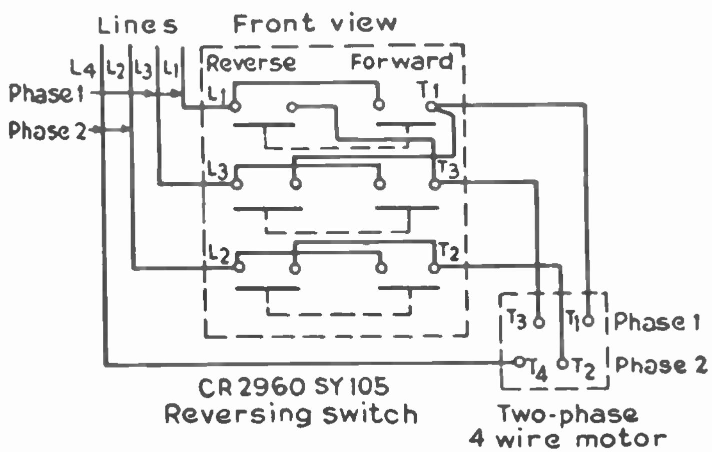
Transfer switch



Direct-current motors

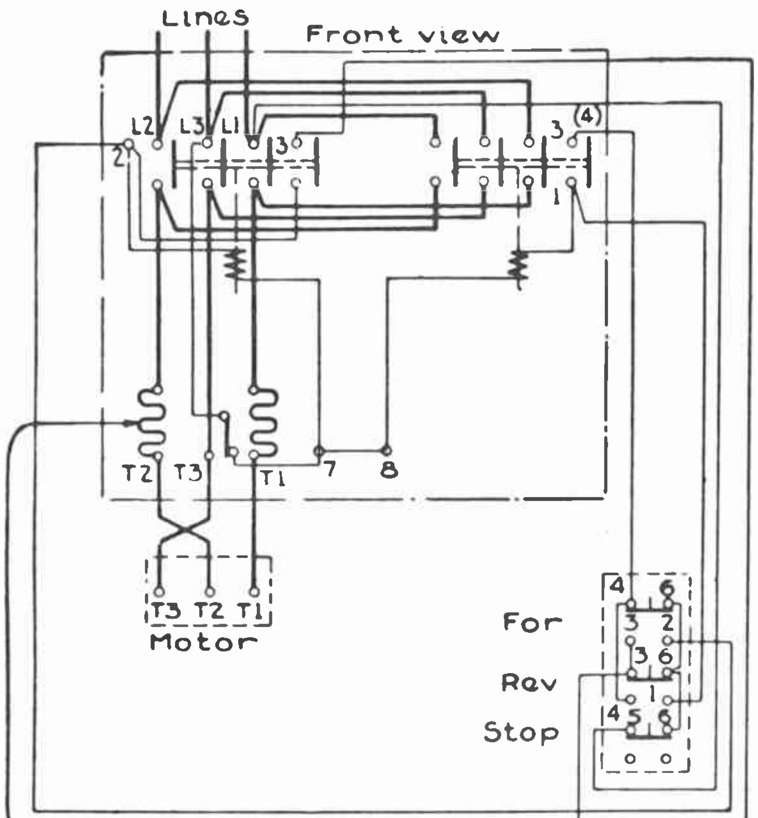


Three-phase motors

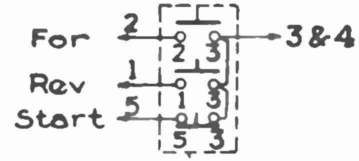


Two-phase motors

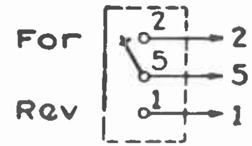
REVERSING MAGNETIC SWITCH, 3-PHASE MOTOR — GENERAL ELECTRIC CR 7009



Temperature overload relay hand reset Heaters to be mounted by Purchaser

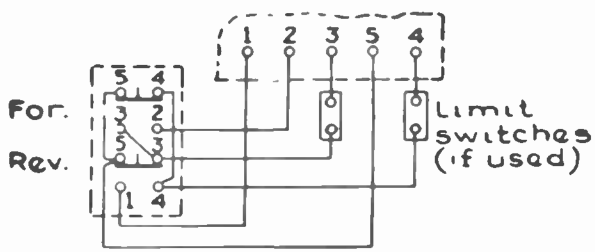


Connections for CR 2940-BS73



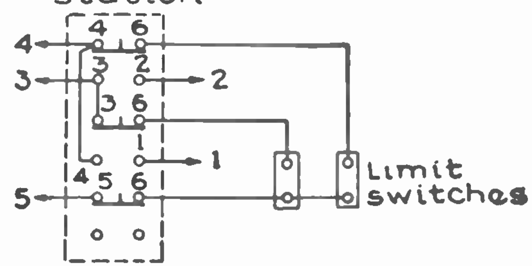
Connections for S.P.D.T. master switch

CR 2940-BS13 push button station



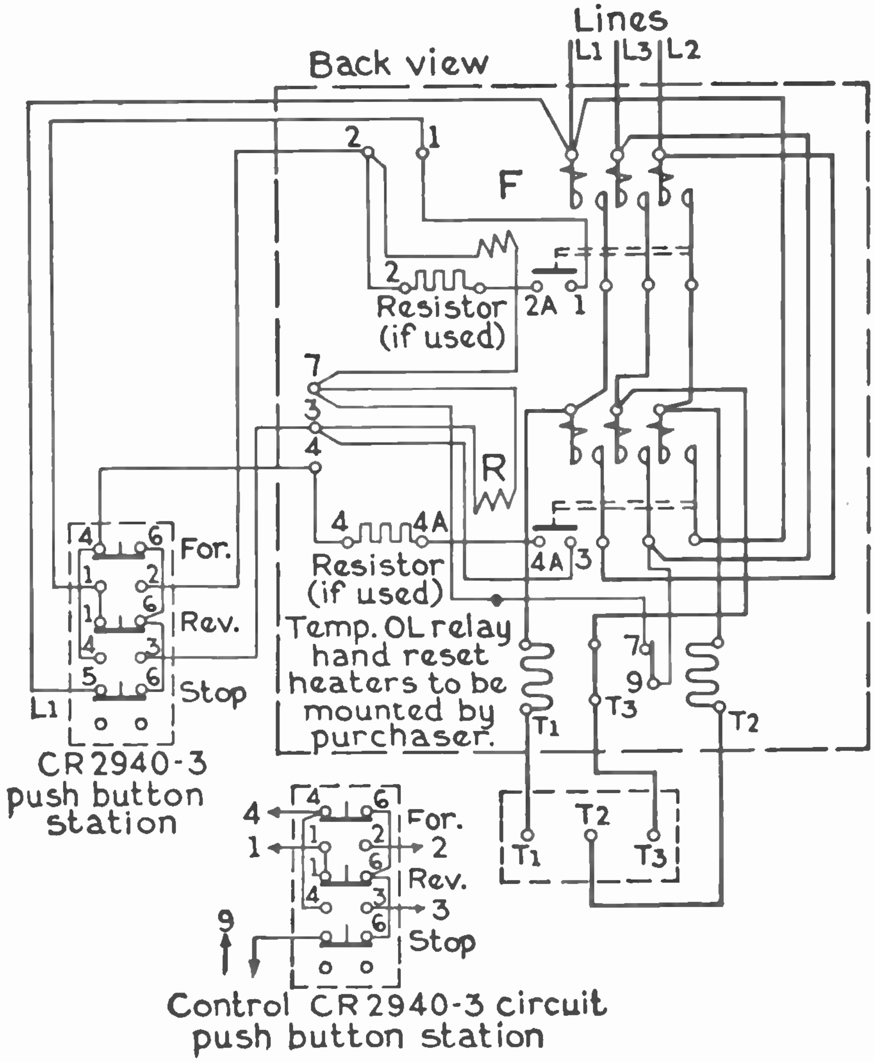
CR2940-BS212 push button if used instead of BS13

CR 2940-BS13 push button station

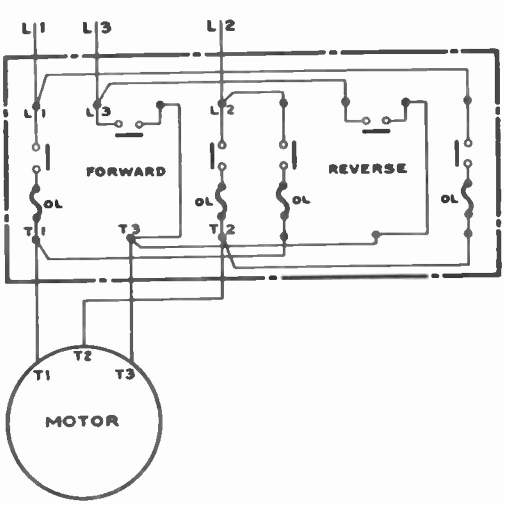


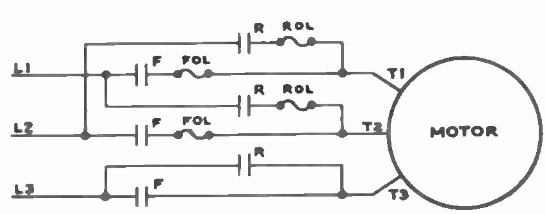
Connect as above if limit switches are used

REVERSING MAGNETIC SWITCH, 3-PHASE MOTORS GENERAL ELECTRIC CR 7009



REVERSING STARTER, 3-PHASE MOTORS SQUARE D CLASS 2510 TYPE W21





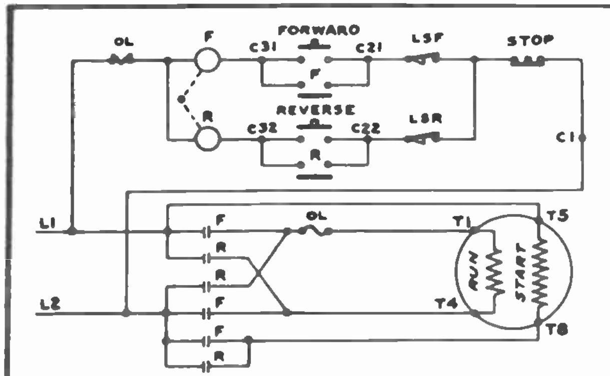
CLASS 2510, TYPE W21
REVERSING STARTER

1748-B4

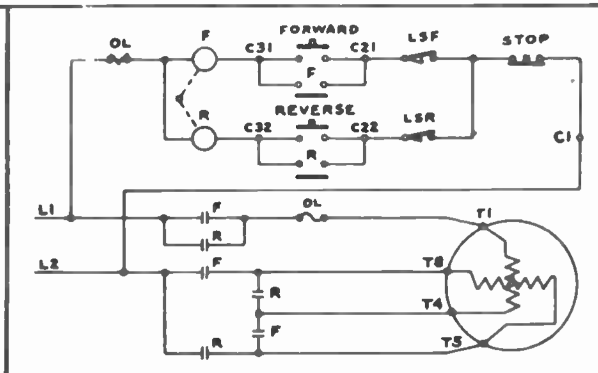
WIRING DIAGRAMS

A. C. REVERSING MAGNETIC STARTERS

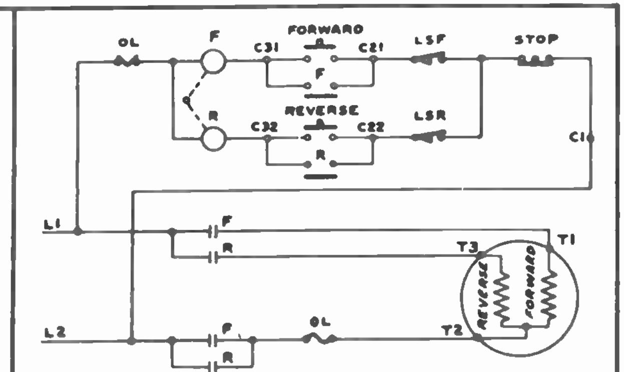
CLASS 8736



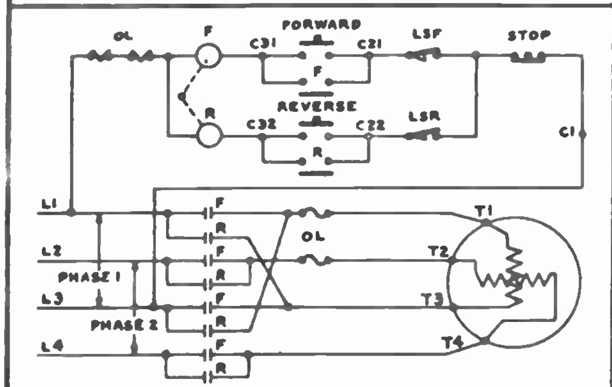
LINE DIAGRAM FOR REVERSING STARTER USED WITH SINGLE PHASE 4-WIRE SPLIT PHASE MOTOR.



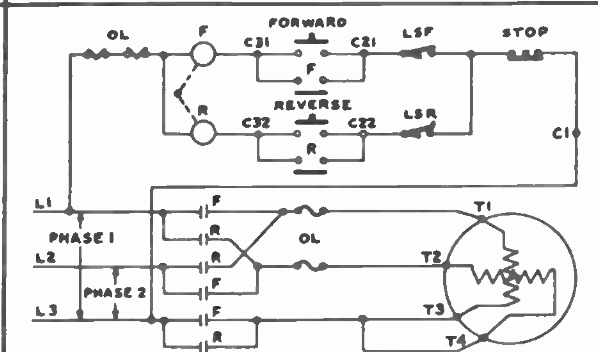
LINE DIAGRAM FOR REVERSING STARTER USED WITH SINGLE PHASE 4 WIRE REPULSION-INDUCTION MOTOR



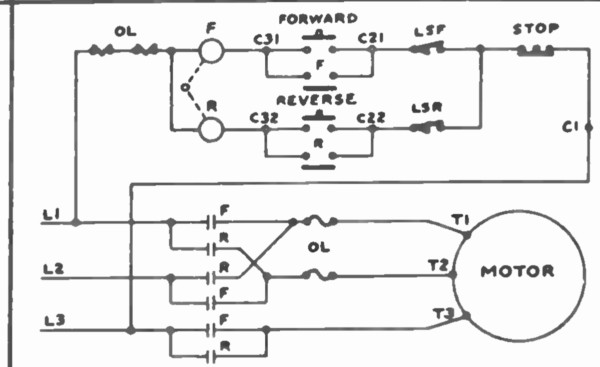
LINE DIAGRAM FOR REVERSING STARTER USED WITH SINGLE PHASE 3 WIRE MOTOR.



LINE DIAGRAM FOR REVERSING STARTER USED WITH TWO PHASE 4-WIRE MOTOR.



LINE DIAGRAM FOR THREE PHASE REVERSING STARTER USED WITH TWO PHASE MOTOR ON 3-WIRE POWER SYSTEM.

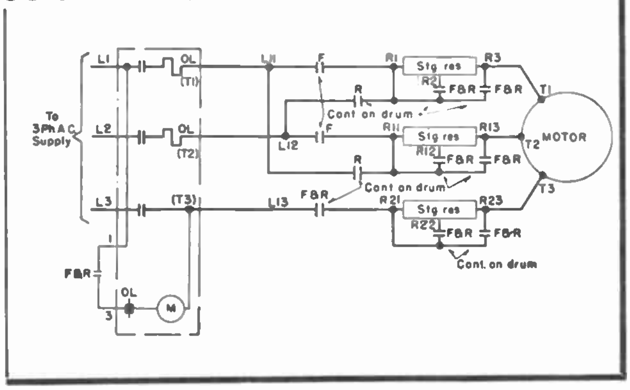


LINE DIAGRAM FOR REVERSING STARTER USED WITH THREE PHASE 3-WIRE MOTOR.

REVERSING A-C MOTOR CONTROLS

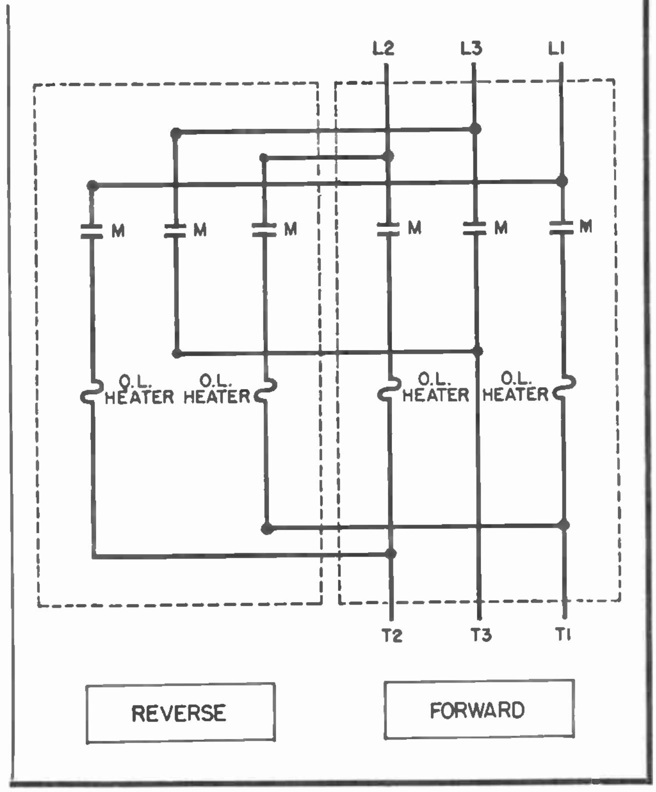
WESTINGHOUSE

SCHEMATIC WIRING DIAGRAM

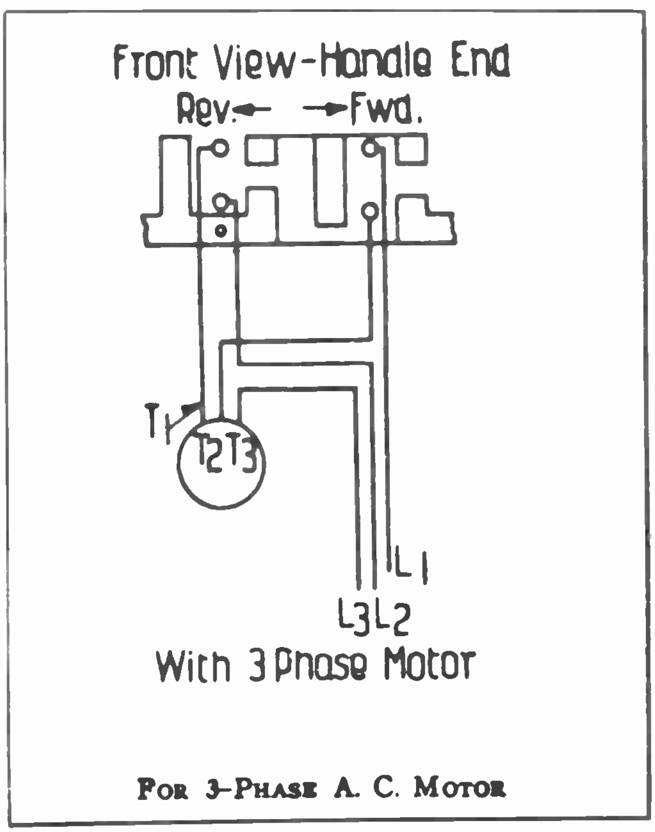


DRUM CONTROLLER

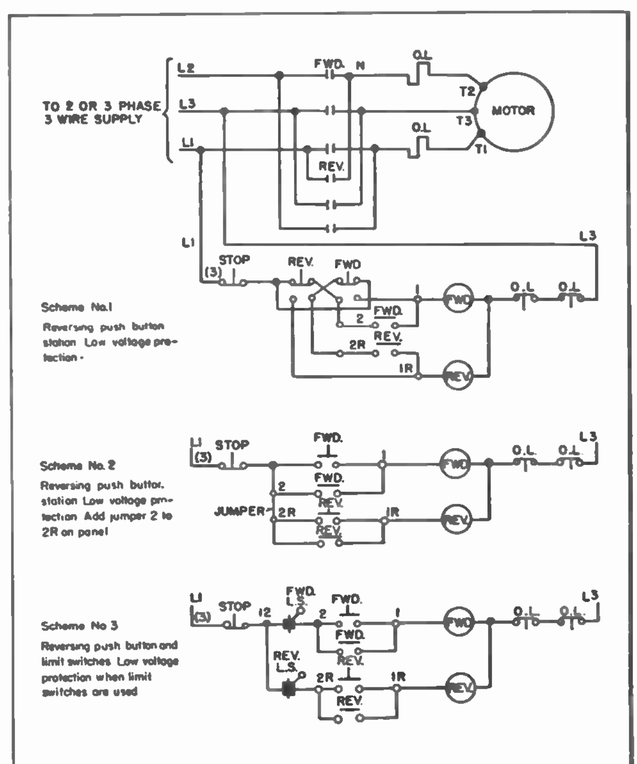
TYPICAL SCHEMATIC DIAGRAM



REVERSING LINE STARTER

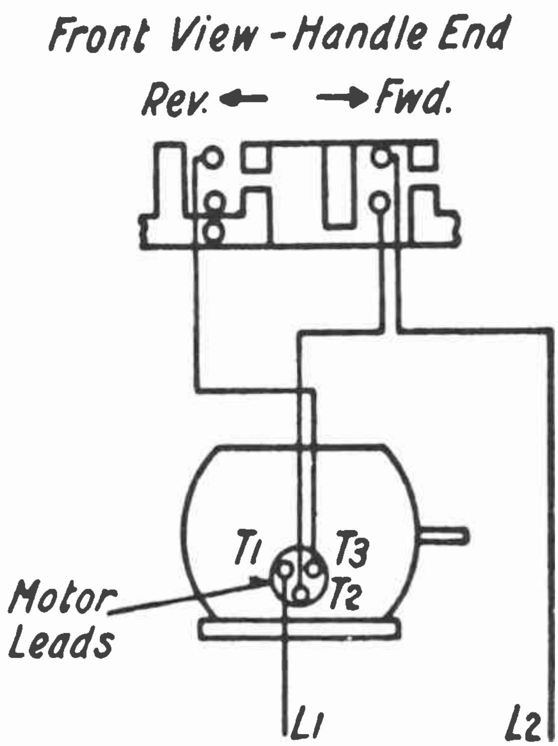


DRUM SWITCH

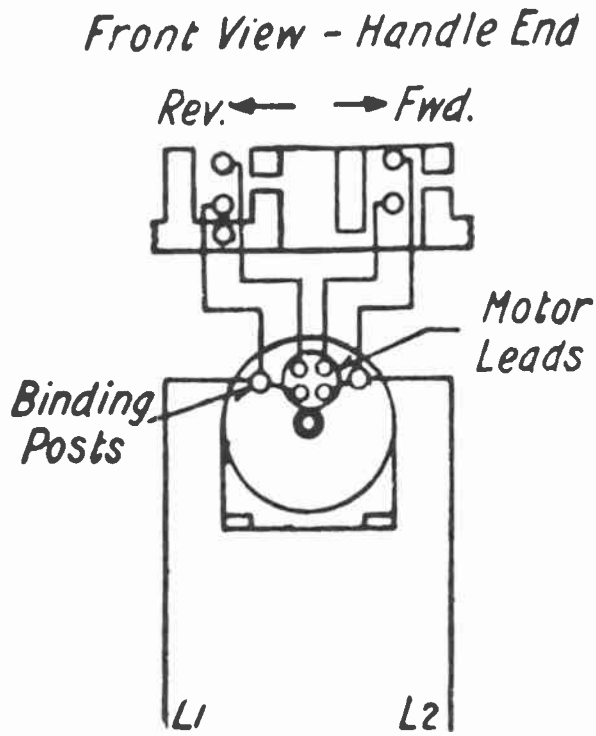


REVERSING LINE STARTER

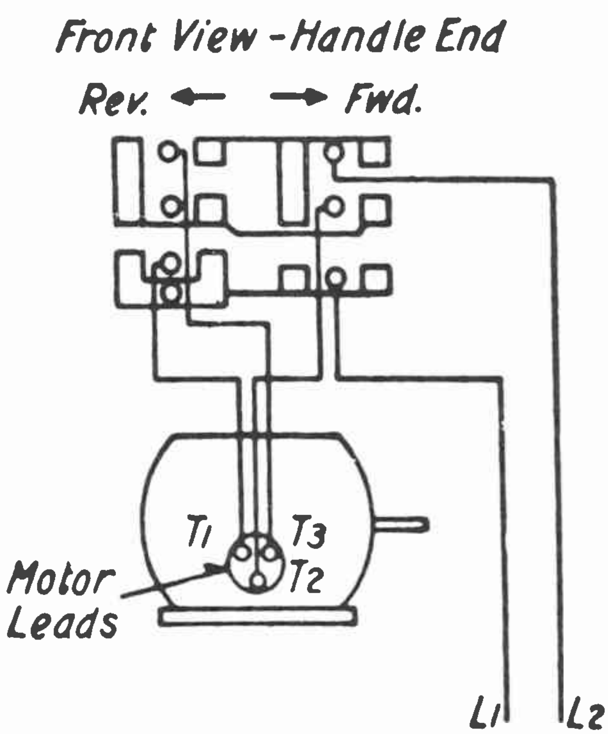
REVERSING DRUM SWITCHES WESTINGHOUSE



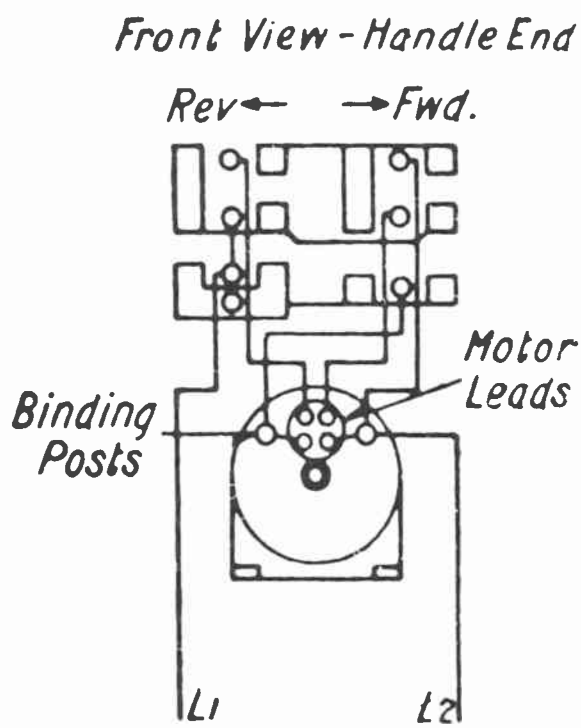
For Type RV or
ARS 1-Phase A.C. Motor



For Type CAH 1-Phase Motor

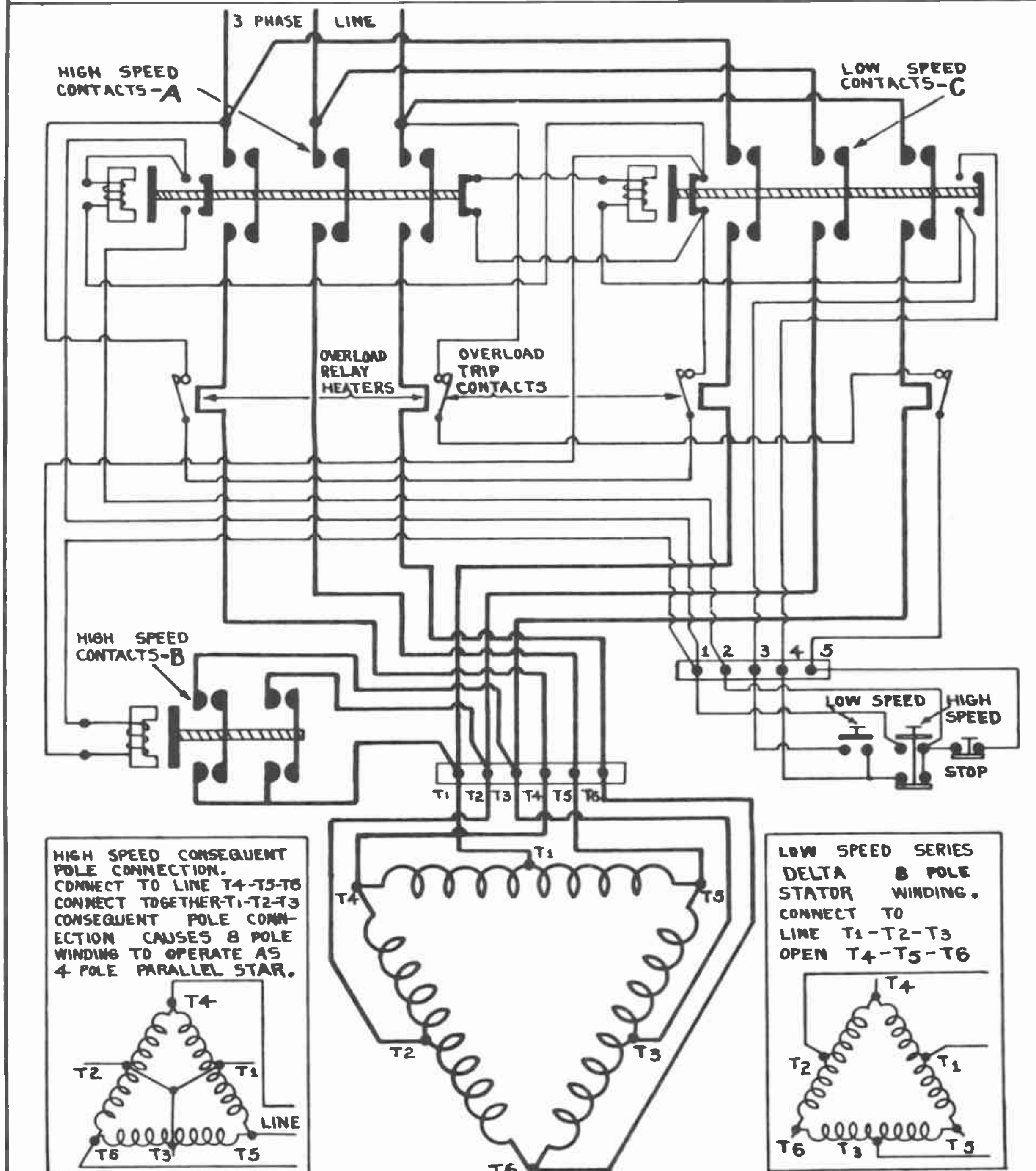


For Type RV or
ARS 1-Phase A.C. Motor



For Type CAH 1-Phase A.C. Motor

2—SPEED CONSEQUENT POLE SQUIRREL CAGE MOTOR AND STARTER



With a given frequency, the speed of an induction motor can be changed only by altering the number of poles. This may be accomplished by: (a) using two distinct windings in the stator; (b) employing a special winding in which the number of poles can be varied by reconnecting the winding external to the motor. The winding in the motor shown above uses the latter method, one connection producing four poles and the other eight and giving speeds of about 1800 and 900 R.P.M. respectively. The required change in connections is easily and quickly made by the special type controller shown above. This starter has three sets of contactors that are so mechanically and electrically interlocked that pressing of the low speed button will close contactor C only, whereas pushing the high speed button will result in A and B being pulled in, and this action will cause C to drop out. A check on the wiring will show that it is impossible for both the high speed and the low speed contactors to be in at the same time. Inspect this equipment, note the action of the relays, and trace the circuits.

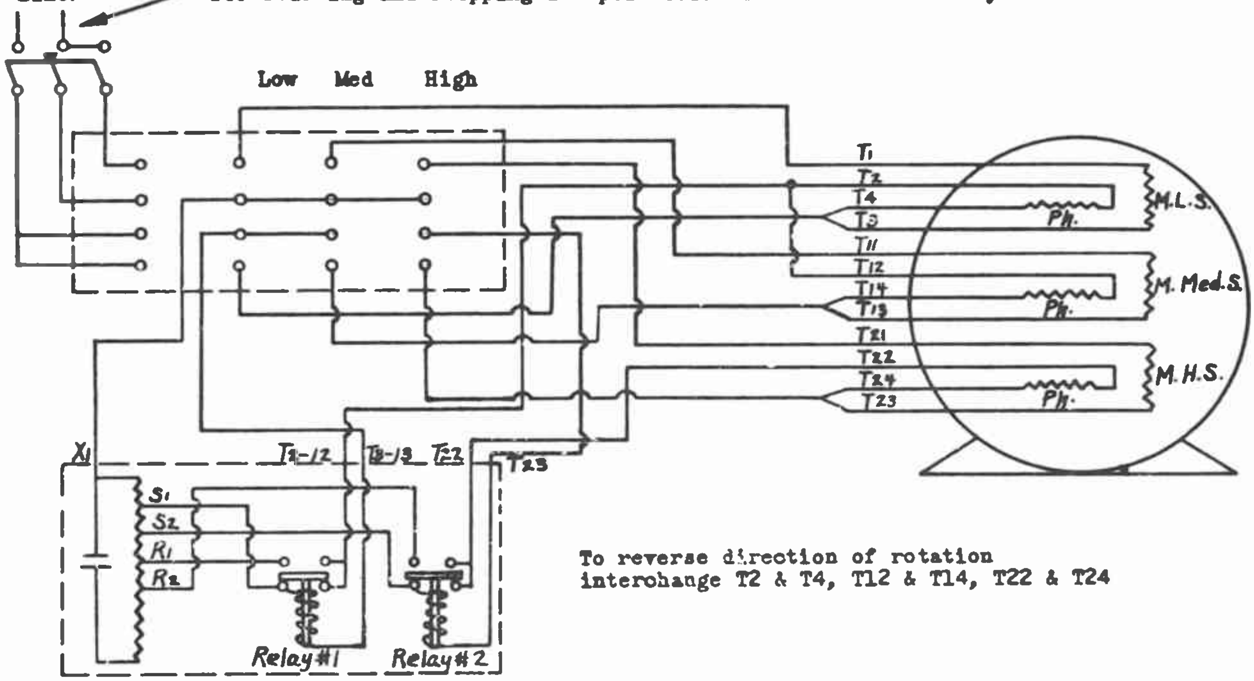
Century

ENGINEERING INFORMATION
CONNECTION DIAGRAMS MULTI-SPEED CAPACITOR MOTORS
TYPE CPXM 3 SPEED 3 WINDING

1 PHASE

TWO RELAY CONTROL SHOWING LOW SPEED & MEDIUM SPEED ON RELAY #1; HIGH SPEED ON RELAY #2

NOTE: Three pole switch must be used for satisfactory operation of relay if used for starting and stopping the motor. If speed changing switch is used for starting and stopping a 2 pole S.T. disconnect switch may be used.

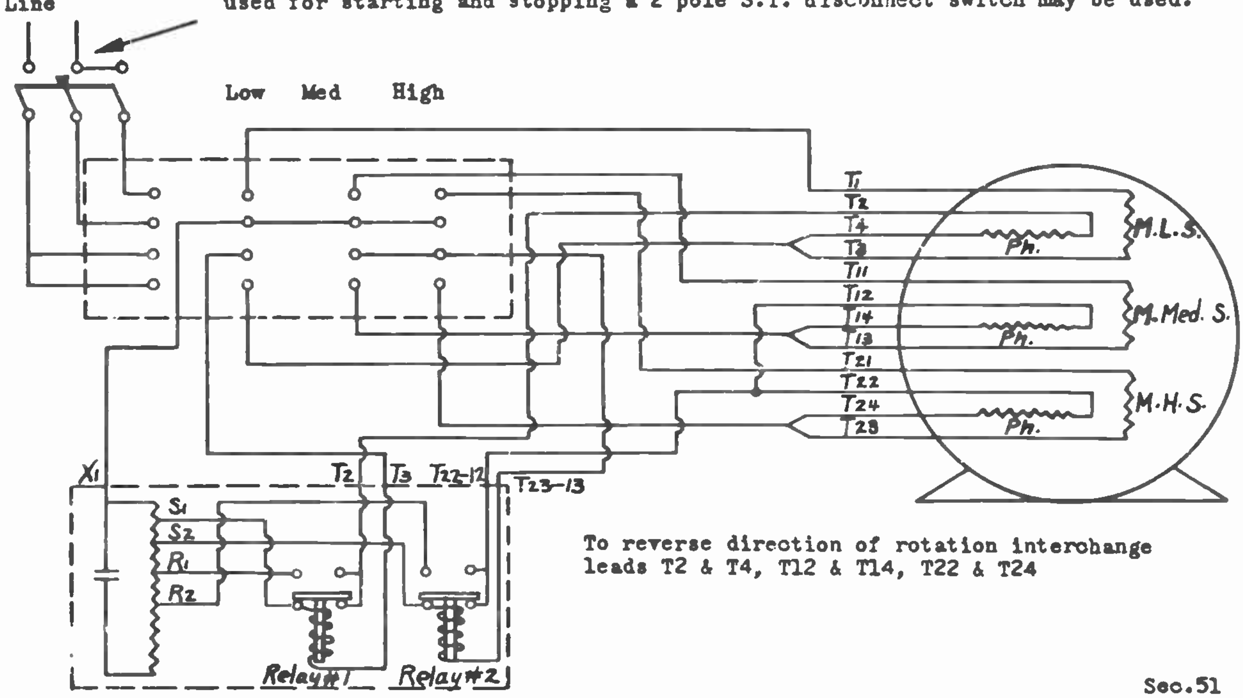


To reverse direction of rotation interchange T2 & T4, T12 & T14, T22 & T24

Capacitor Unit 2 Potential Relays

TWO RELAY CONTROL SHOWING LOW SPEED ON RELAY #1; MEDIUM SPEED & HIGH SPEED ON RELAY #2

NOTE: Three pole switch must be used for satisfactory operation of relay if used for starting and stopping the motor. If speed changing switch is used for starting and stopping a 2 pole S.T. disconnect switch may be used.



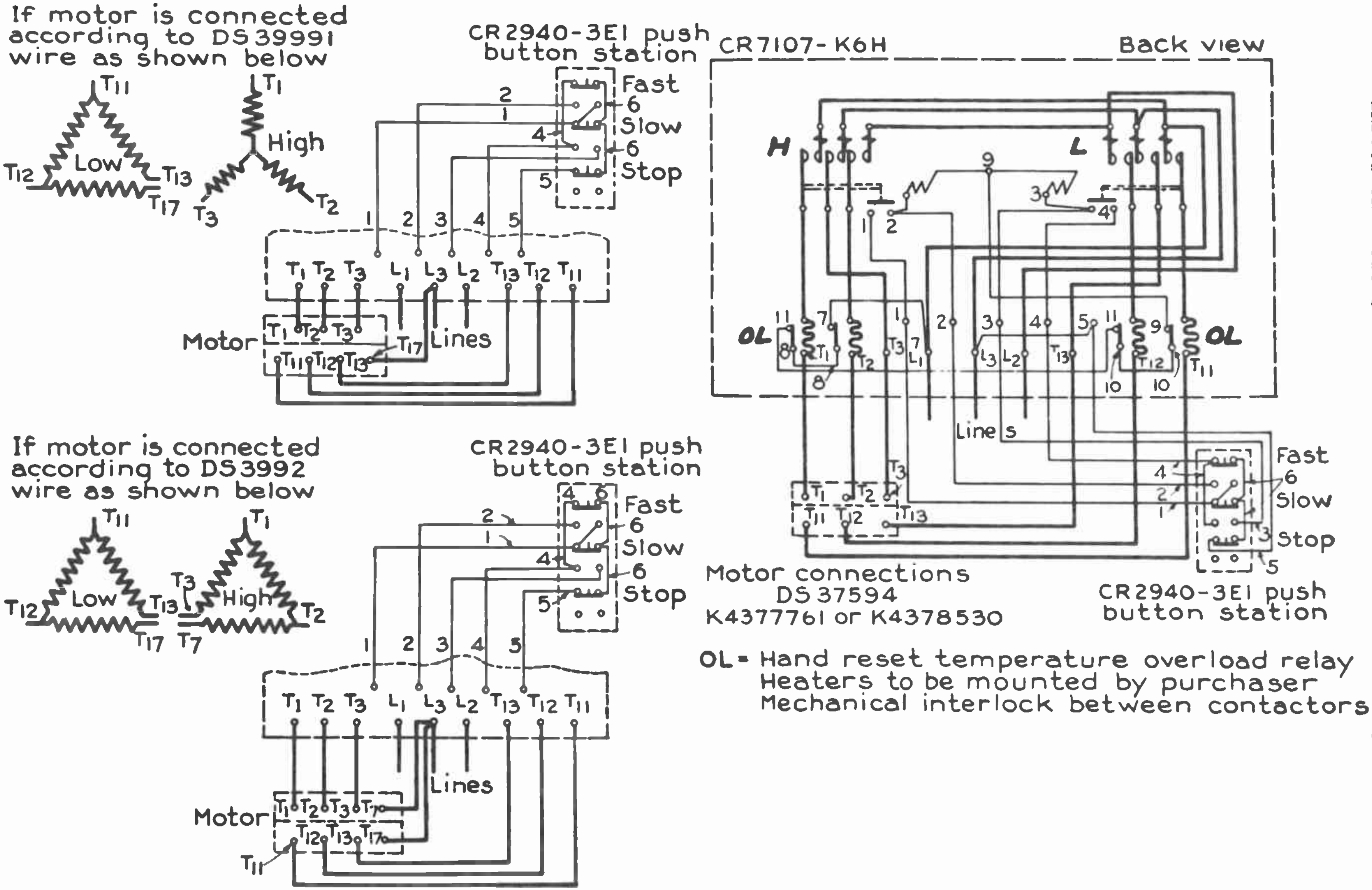
To reverse direction of rotation interchange leads T2 & T4, T12 & T14, T22 & T24

Capacitor Unit - 2 Potential Relays

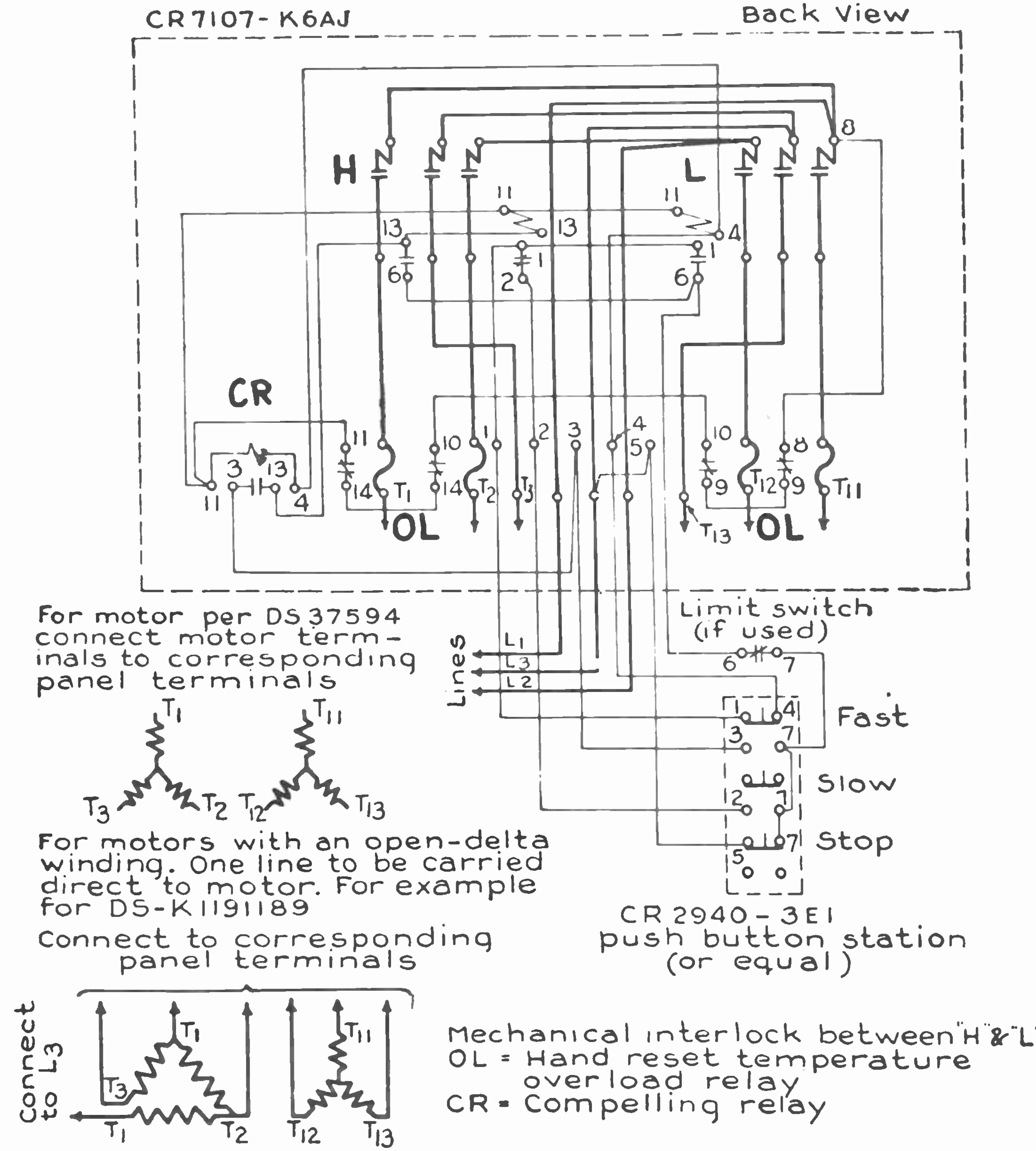
Sec.51

MAGNETIC SWITCH. FOR LOW-VOLTAGE TWO-SPEED SEPARATE WINDING SQUIRREL-CAGE INDUCTION MOTORS

GENERAL ELECTRIC CR 7107

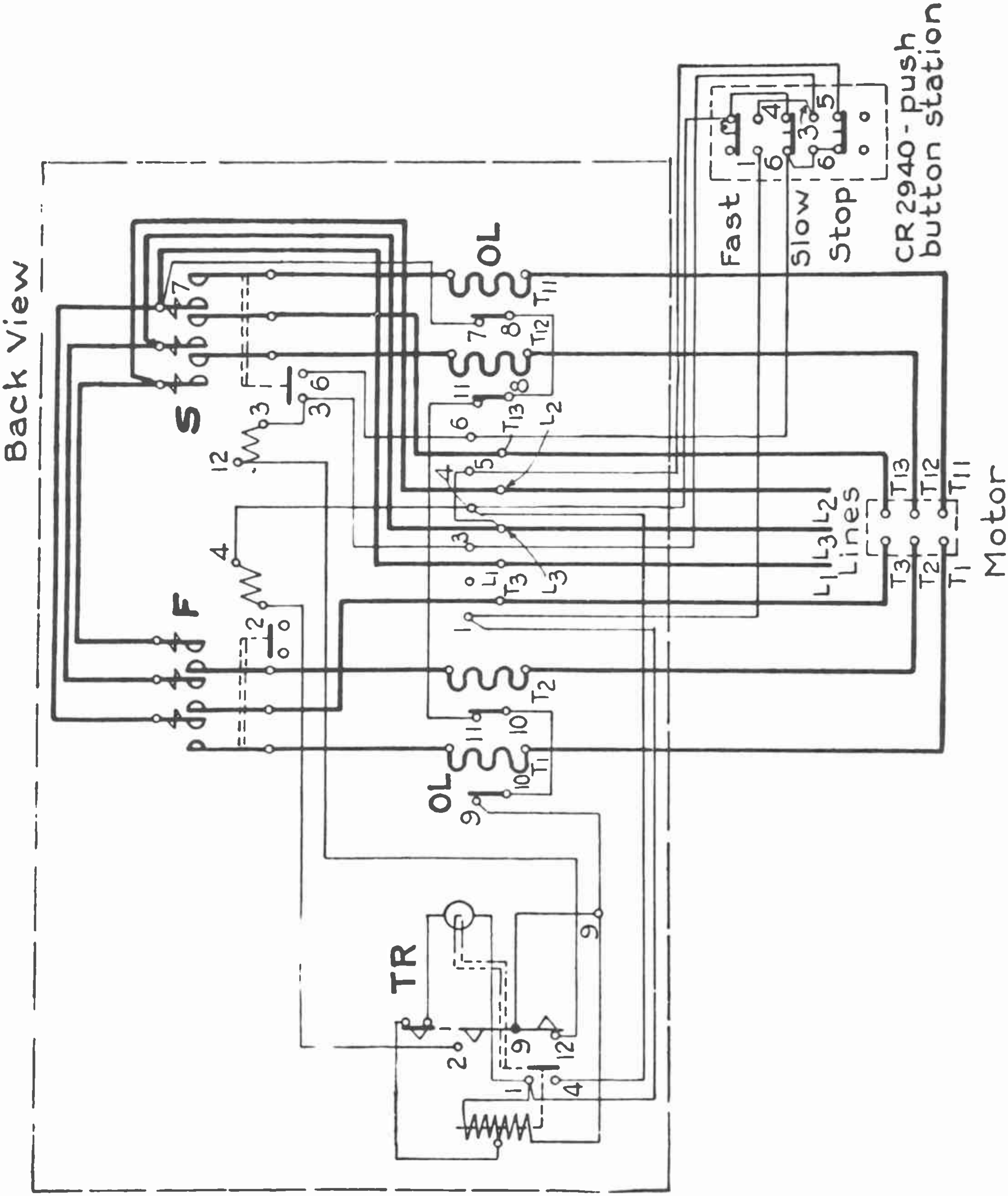


MAGNETIC SWITCH WITH COMPELLING RELAY. FOR LOW-VOLTAGE 2-SPEED SEPARATE WINDING SQUIRREL-CAGE INDUCTION MOTORS GENERAL ELECTRIC CR 7107



MAGNETIC SWITCH WITH SEQUENCE RELAY. FOR LOW-VOLTAGE 2-SPEED SEPARATE WINDING SQUIRREL-CAGE INDUCTION MOTORS

GENERAL ELECTRIC CR 7107



REVERSING AND NON-REVERSING

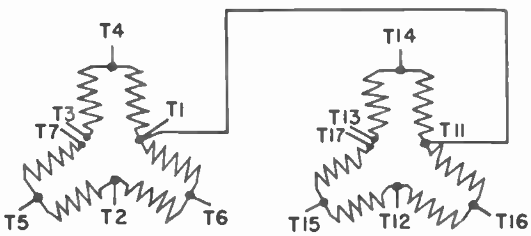
MANUAL MULTI-SPEED DRUM CONTROLLERS

FOR MULTI-SPEED SQUIRREL CAGE MOTORS

SCHEMATIC WIRING DIAGRAMS

FOUR-SPEED DRUMS

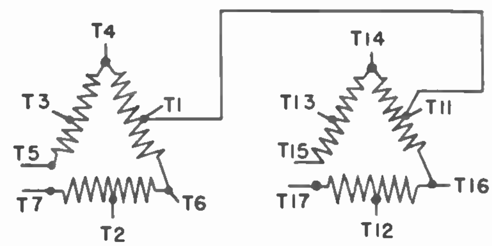
CONSTANT TORQUE



POINT	L1	L2	L3	OPEN	TOGETHER
REVERSE	T2	T1,T11	T3,T7	T4,T5,T6	
OFF	C				
1ST FORWARD	T1,T11	T2	T3,T7	T4,T5,T6	
2ND FORWARD	T1,T11	T12	T13,T17	T14,T15,T16	
3RD FORWARD	T6	T4	T5		T1,T2,T3,T7
4TH FORWARD	T16	T14	T15		T11,T12,T13,T17

MOTORS WITHOUT T7 OR T17 LEADS, LEAVE THESE LEADS DISCONNECTED AT THE CONTROLLER

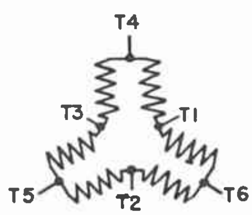
CONSTANT HORSEPOWER



POINT	L1	L2	L3	OPEN	TOGETHER
REVERSE	T2	T1	T3		T4,T5,T6,T7
OFF		C			
1ST FORWARD	T1	T2	T3		T4,T5,T6,T7
2ND FORWARD	T11	T12	T13		T14,T15,T16,T17
3RD FORWARD	T6	T4	T5,T7	T1,T2,T3	
4TH FORWARD	T16	T14	T15,T17	T11,T12,T13	

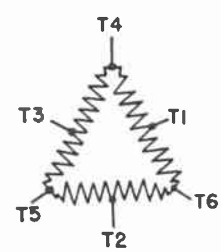
TWO-SPEED DRUMS—SINGLE WINDING MOTORS

CONSTANT TORQUE



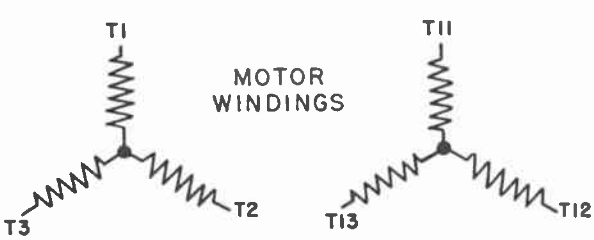
SPEED	L1	L2	L3	TOGETHER
LOW	T1	T2	T3	
HIGH	T6	T4	T5	T1,T2,T3

CONSTANT HORSEPOWER



SPEED	L1	L2	L3	TOGETHER
LOW	T1	T2	T3	T4,T5,T6
HIGH	T6	T4	T5	

TWO-SPEED DRUMS—TWO WINDING MOTORS

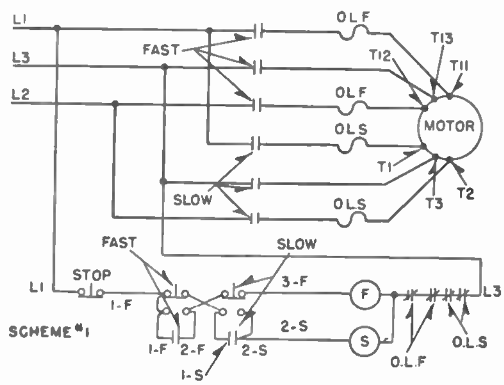


ON THE VARIOUS POINTS OF THE SWITCH, CONNECTIONS ARE MADE FROM THE LINE TO MOTOR TERMINALS AS INDICATED BELOW

SPEED	L1	L2	L3	CONNECT TOGETHER
LOW	T1	T2	T3	NONE
HIGH	T11	T12	T13	NONE

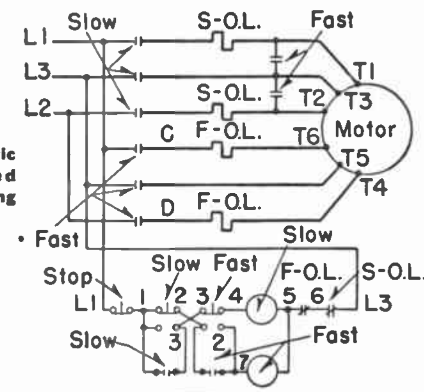
TWO-SPEED MAGNETIC CONTROLLER, NON-REVERSING, FOR SQUIRREL-CAGE INDUCTION MOTORS
WESTINGHOUSE

SCHEMATIC WIRING DIAGRAMS—CLASS 11-950



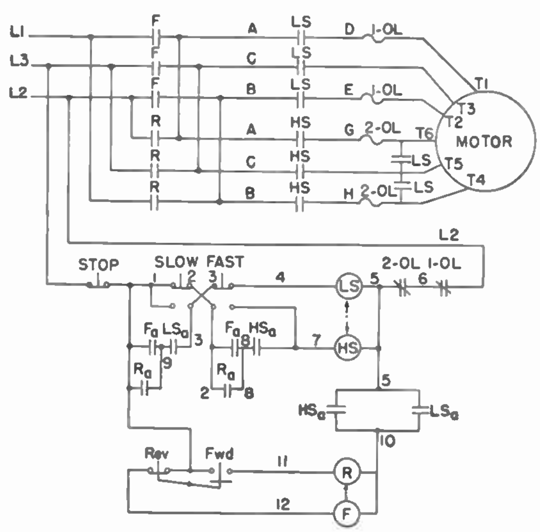
Left: Schematic for Two-Speed 2-Winding Motor

Right: Schematic for Two-Speed Single Winding Motor



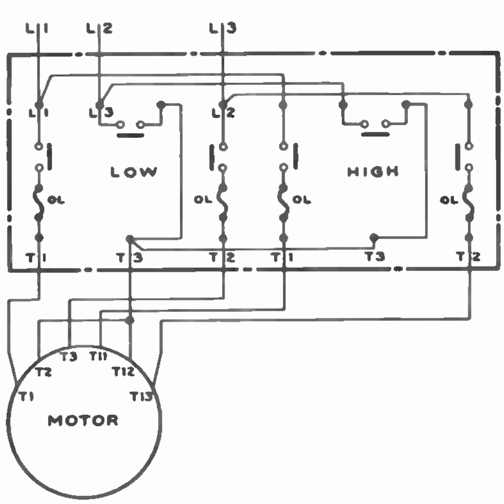
SCHEMATIC WIRING DIAGRAM

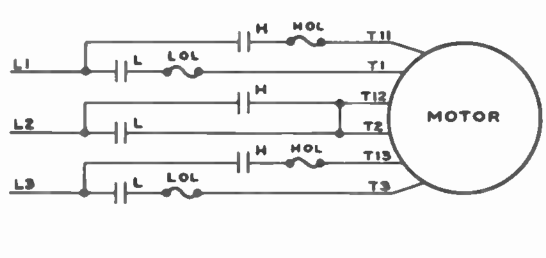
For Class 11-951



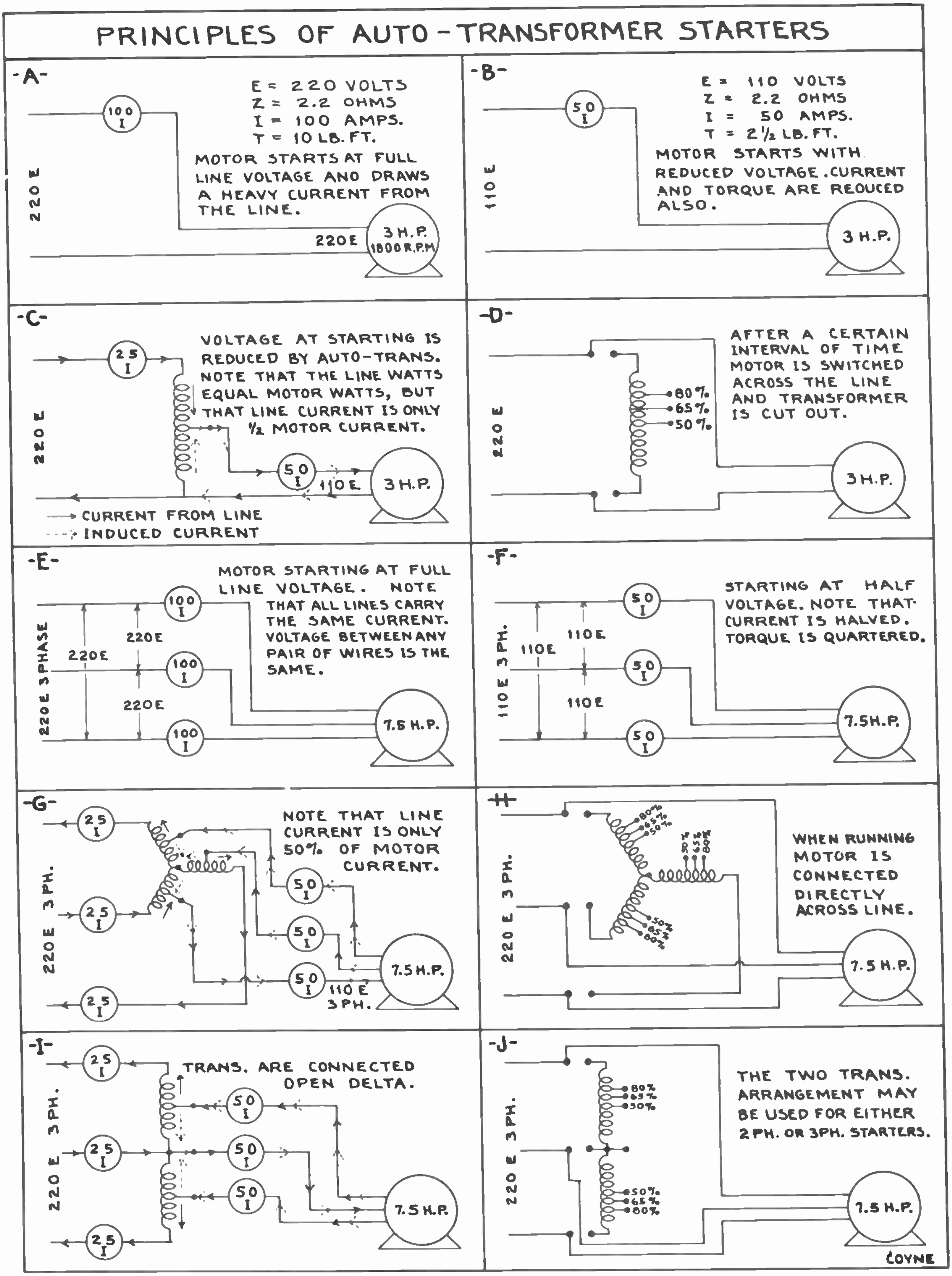
TWO-SPEED MAGNETIC CONTROLLER
REVERSING
FOR SQUIRREL-CAGE INDUCTION MOTORS
WESTINGHOUSE

SQUARE D COMPANY

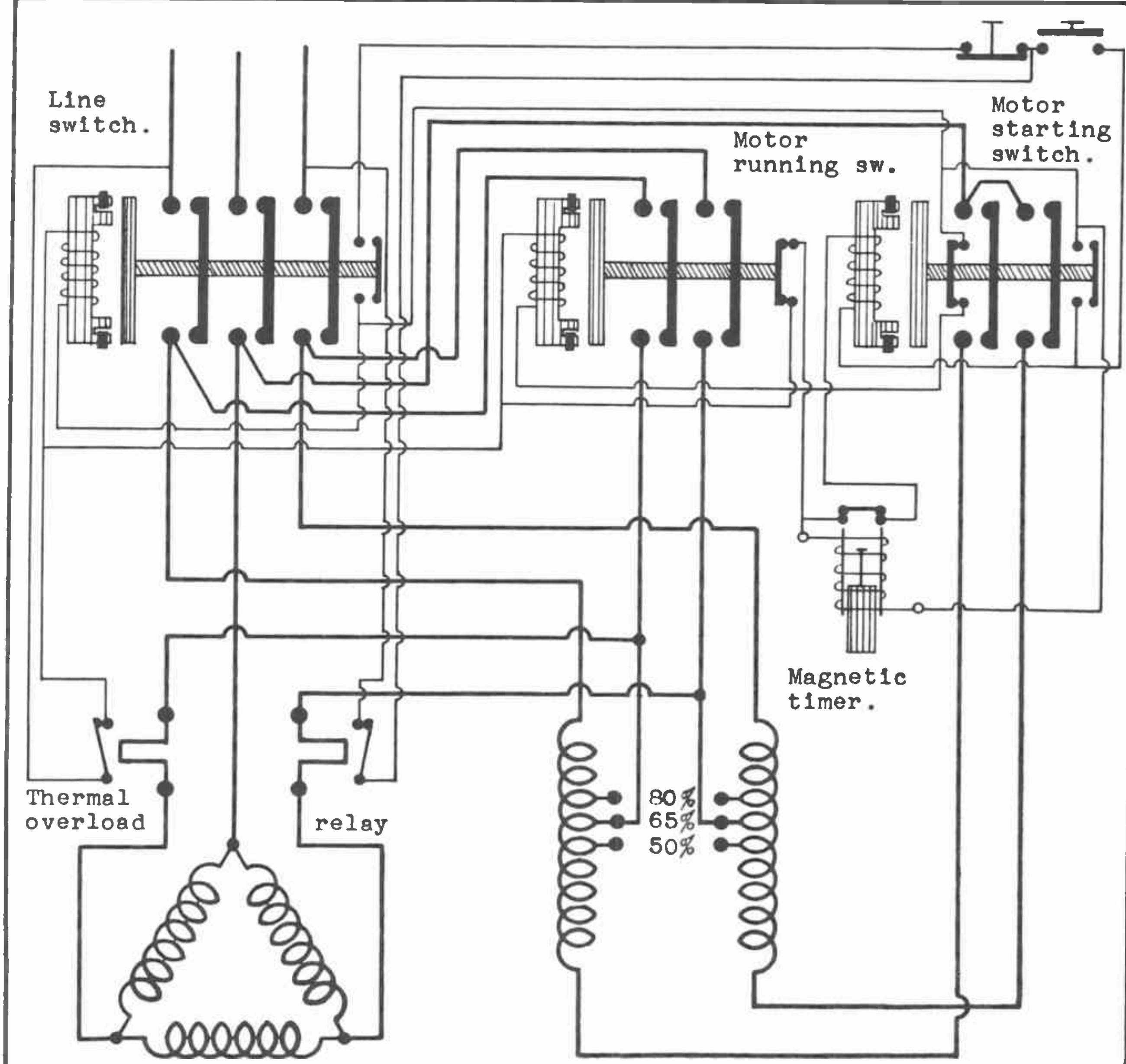




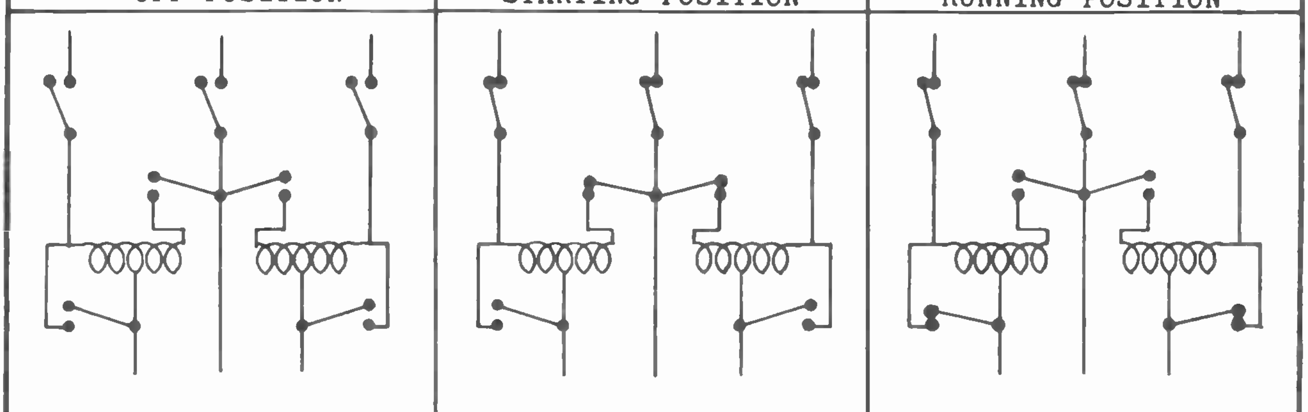
CLASS 2510, TYPE W20
FOR TWO-SPEED SEPARATE WINDING "Y" CONNECTED MOTORS.

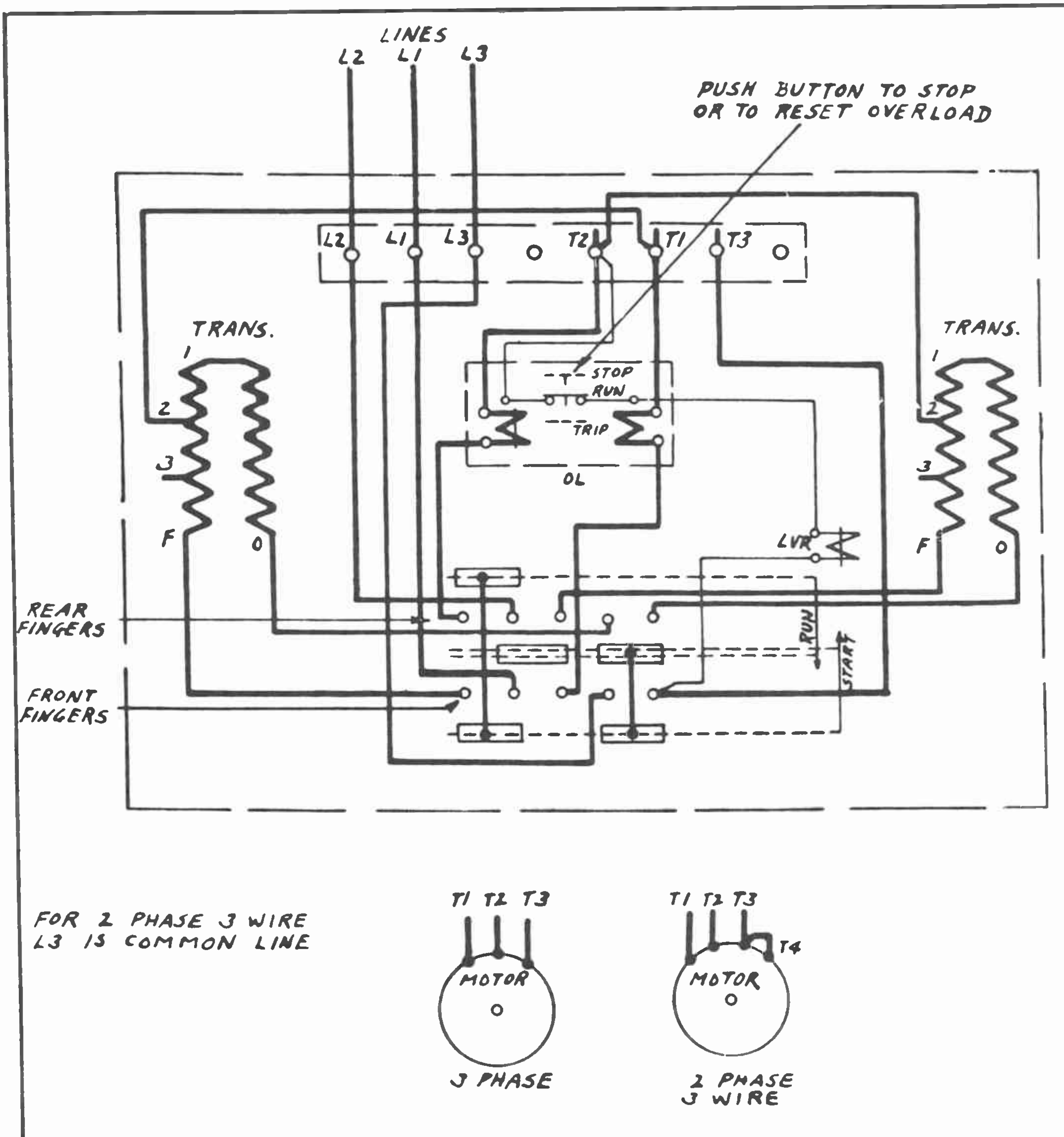

PRINCIPLES OF AUTO-TRANSFORMER STARTERS
-A-
E = 220 VOLTS
Z = 2.2 OHMS
I = 100 AMPS.
T = 10 LB. FT.
MOTOR STARTS AT FULL LINE VOLTAGE AND DRAWS A HEAVY CURRENT FROM THE LINE.
100 I
220 E
220E
3 H.P. 1800 R.P.M.
-B-
E = 110 VOLTS
Z = 2.2 OHMS
I = 50 AMPS.
T = 2 1/2 LB. FT.
MOTOR STARTS WITH REDUCED VOLTAGE. CURRENT AND TORQUE ARE REDUCED ALSO.
50 I
110 E
3 H.P.
-C-
VOLTAGE AT STARTING IS REDUCED BY AUTO-TRANS. NOTE THAT THE LINE WATTS EQUAL MOTOR WATTS, BUT THAT LINE CURRENT IS ONLY 1/2 MOTOR CURRENT.
25 I
50 I
220 E
110 E
3 H.P.
CURRENT FROM LINE
INDUCED CURRENT
-D-
AFTER A CERTAIN INTERVAL OF TIME MOTOR IS SWITCHED ACROSS THE LINE AND TRANSFORMER IS CUT OUT.
80 %
65 %
50 %
220 E
3 H.P.
-E-
MOTOR STARTING AT FULL LINE VOLTAGE. NOTE THAT ALL LINES CARRY THE SAME CURRENT. VOLTAGE BETWEEN ANY PAIR OF WIRES IS THE SAME.
100 I
220E
220 E 3PHASE
7.5 H.P.
-F-
STARTING AT HALF VOLTAGE. NOTE THAT CURRENT IS HALVED. TORQUE IS QUARTERED.
50 I
110E
110 E 3PH.
7.5H.P.
-G-
NOTE THAT LINE CURRENT IS ONLY 50% OF MOTOR CURRENT.
25 I
50 I
220 E 3 PH.
110 E 3 PH.
7.5 H.P.
-H-
WHEN RUNNING MOTOR IS CONNECTED DIRECTLY ACROSS LINE.
80%
65%
50%
220 E 3 PH.
7.5 H.P.
-I-
TRANS. ARE CONNECTED OPEN DELTA.
25 I
50 I
220 E 3 PH.
7.5 H.P.
-J-
THE TWO TRANS. ARRANGEMENT MAY BE USED FOR EITHER 2 PH. OR 3 PH. STARTERS.
80%
65%
50%
220 E 3 PH.
7.5 H.P.
COYNE

ALLEN BRADLEY AUTO TRANSFORMER STARTER -



OFF POSITION	STARTING POSITION	RUNNING POSITION

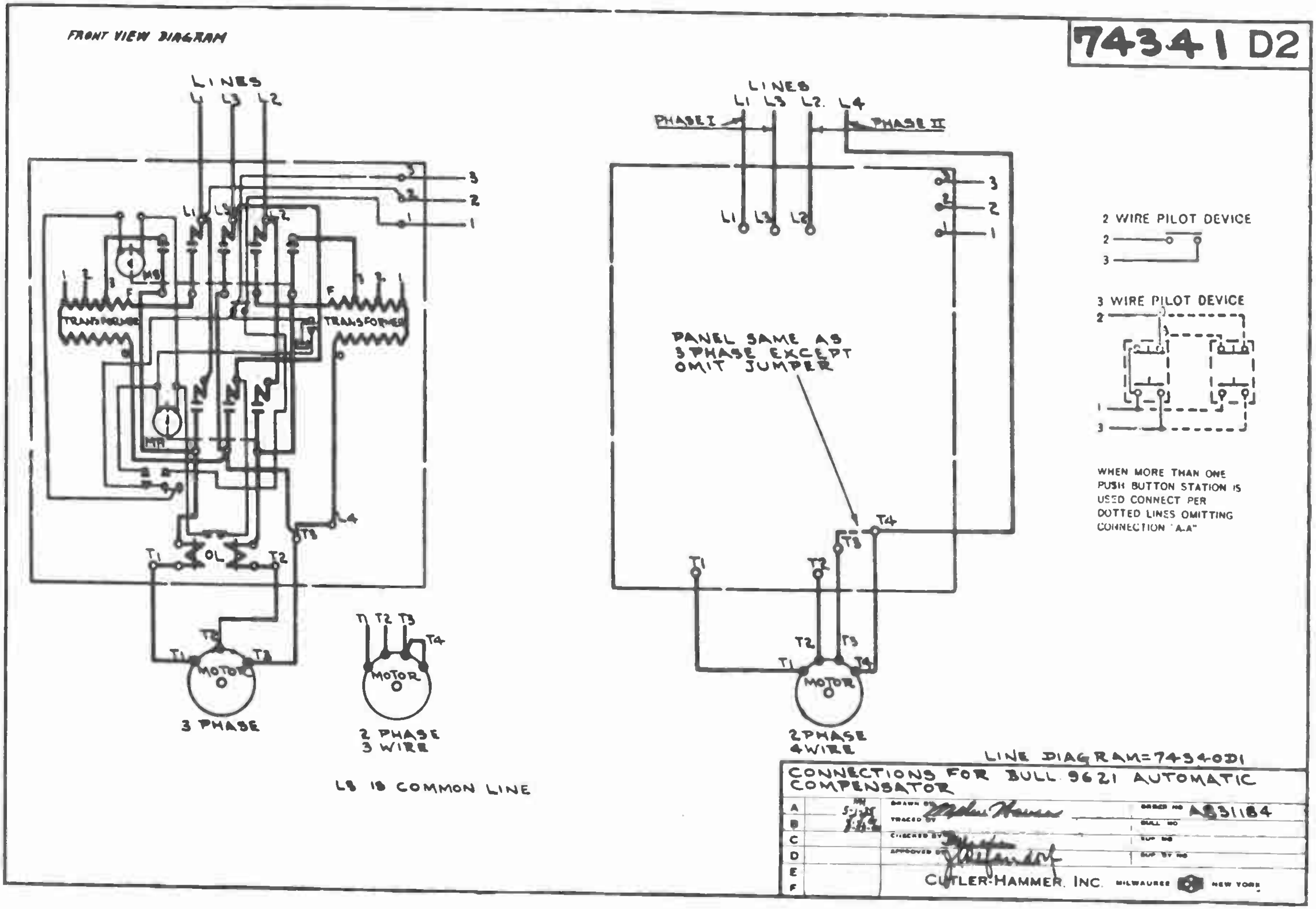




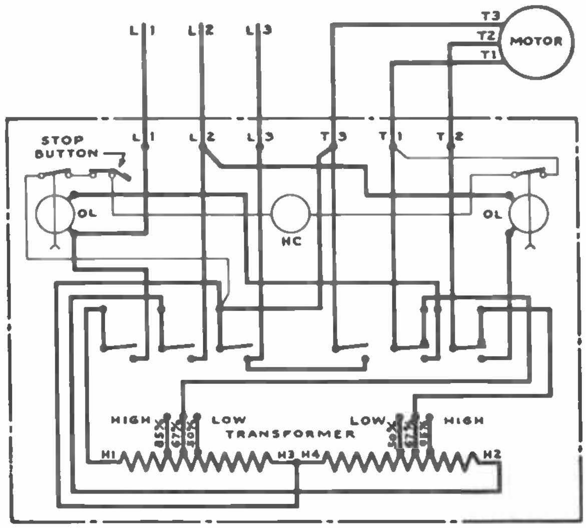
TITLE CONNECTIONS FOR AUTO-TRANSFORMER STARTER WITH OVERLOAD AND LOW VOLTAGE PROTECTION – 2 PHASE 3 WIRE OR 3 PHASE.

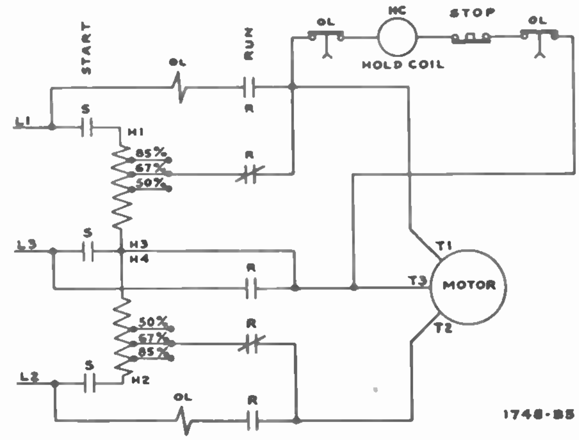
DRAWN BY	REDRAWN BY	TYPE	SUP. NO
CHECKED BY	APPROVED BY	BULL. NO	SUP. BY NO
A B C D		ORDER NO DEV. 1408-10	39945 DI

CUTLER-HAMMER INC. MILWAUKEE NEW YORK


FRONT VIEW DIAGRAM
74341 D2
LINES
L1 L3 L2
3
2
1
TRANSFORMER
TRANSFORMER
MS
MR
OL
T1
T2
T3
L4
MOTOR
3 PHASE
T1 T2 T3 T4
MOTOR
2 PHASE
3 WIRE
L3 IS COMMON LINE
LINES
L1 L3 L2 L4
PHASE I
PHASE II
PANEL SAME AS
3 PHASE EXCEPT
OMIT JUMPER
T4
T3
T2
T1
MOTOR
2 PHASE
4 WIRE
2 WIRE PILOT DEVICE
3 WIRE PILOT DEVICE
WHEN MORE THAN ONE
PUSH BUTTON STATION IS
USED CONNECT PER
DOTTED LINES OMITTING
CONNECTION "A-A"
LINE DIAGRAM=74340D1
CONNECTIONS FOR BULL 9621 AUTOMATIC
COMPENSATOR
A
B
C
D
E
F
A831184
CUTLER-HAMMER, INC.
MILWAUKEE
NEW YORK

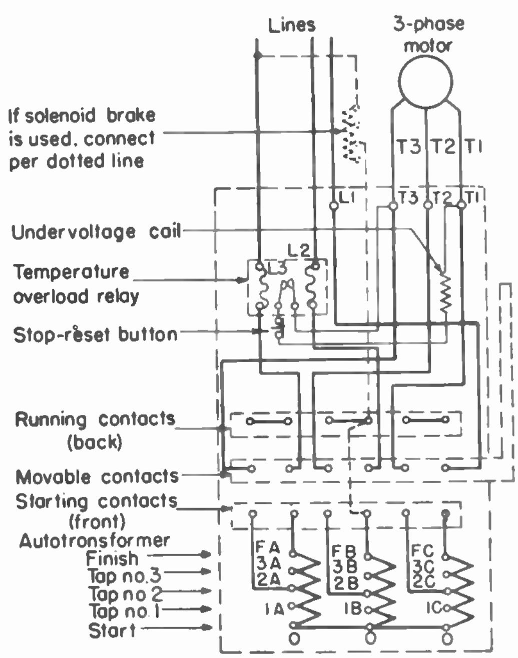
A. C. MANUAL COMPENSATORS SQUARE D CLASS 2205



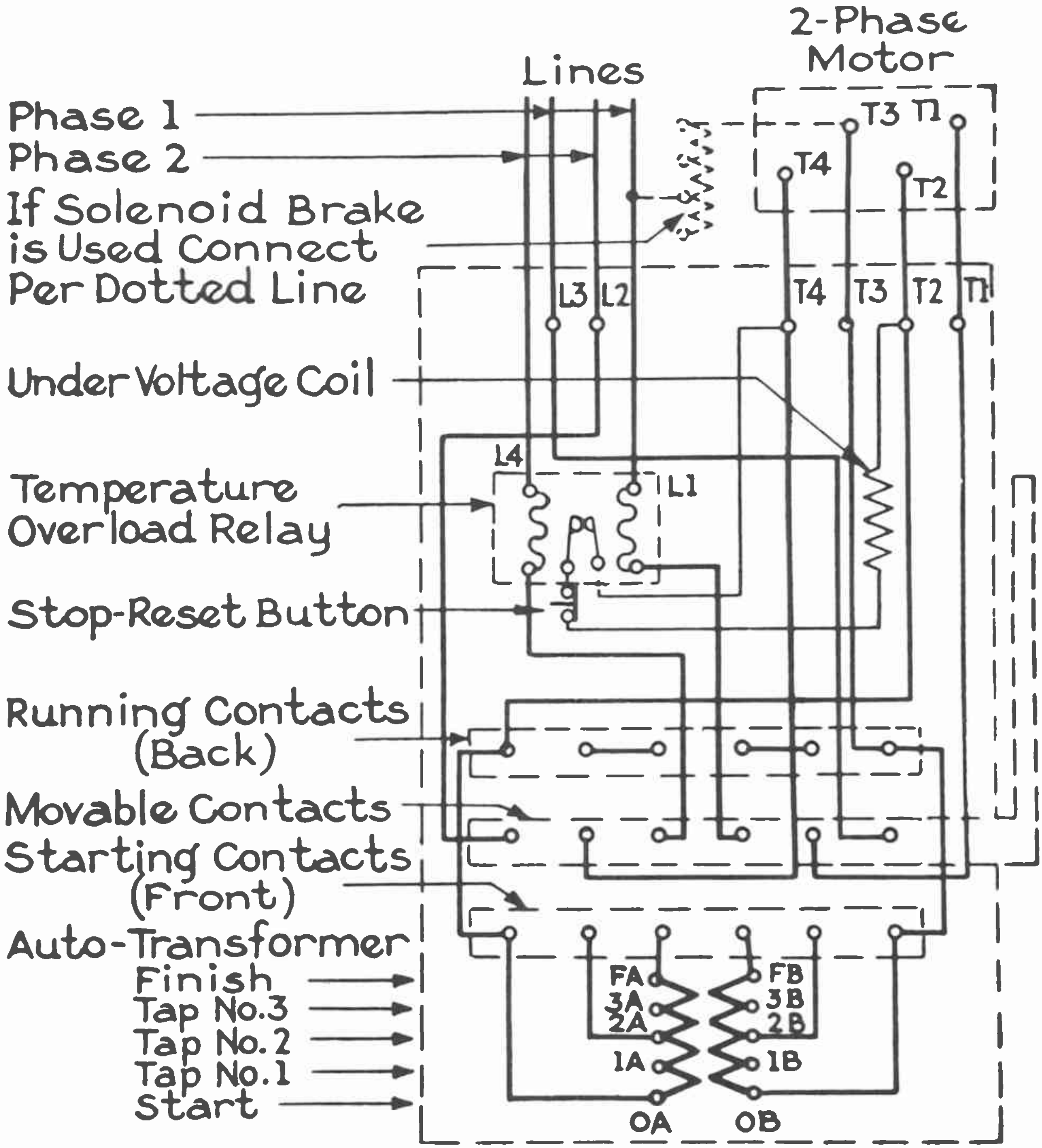


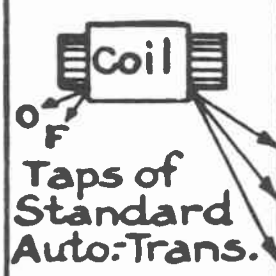
CLASS 2205 THREE PHASE A.C. MANUAL COMPENSATOR WITH OIL DASHPOT TYPE MAGNETIC OVERLOAD RELAYS

LOW-VOLTAGE THREE-PHASE HAND COMPENSATOR
GENERAL ELECTRIC CR 1034



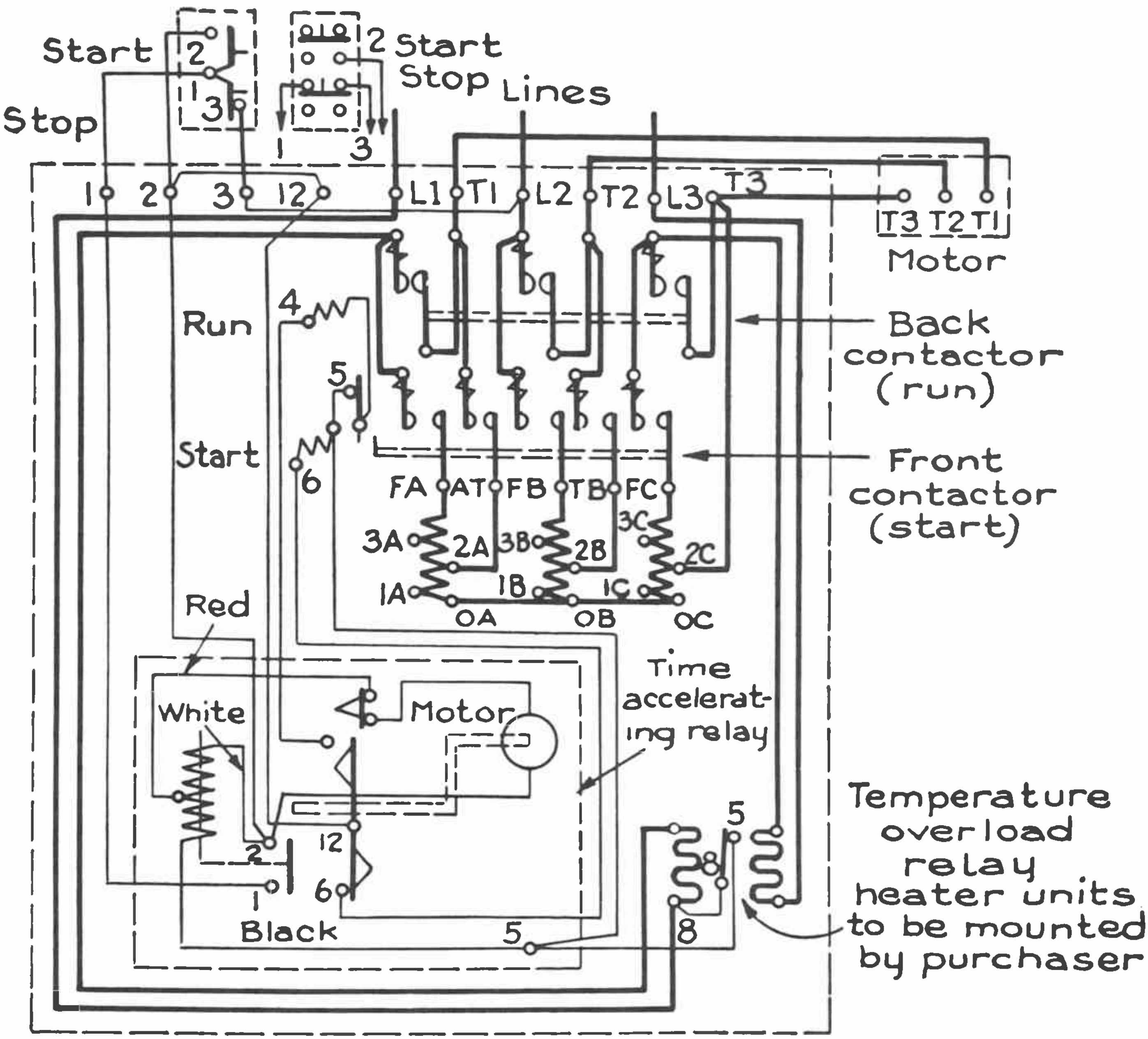
LOW-VOLTAGE TWO-PHASE HAND COMPENSATOR - GENERAL ELECTRIC CR 1034



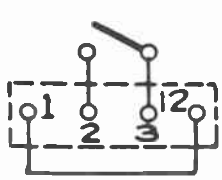


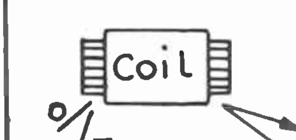
Tap No.	Percent Line Volts Obtained	
	2 Taps	3 Taps
1	65	50
2	80	65
3	—	80

AUTOMATIC COMPENSATOR WITH THREE-PHASE SQUIRREL CAGE INDUCTION MOTOR
GENERAL ELECTRIC CR 7051

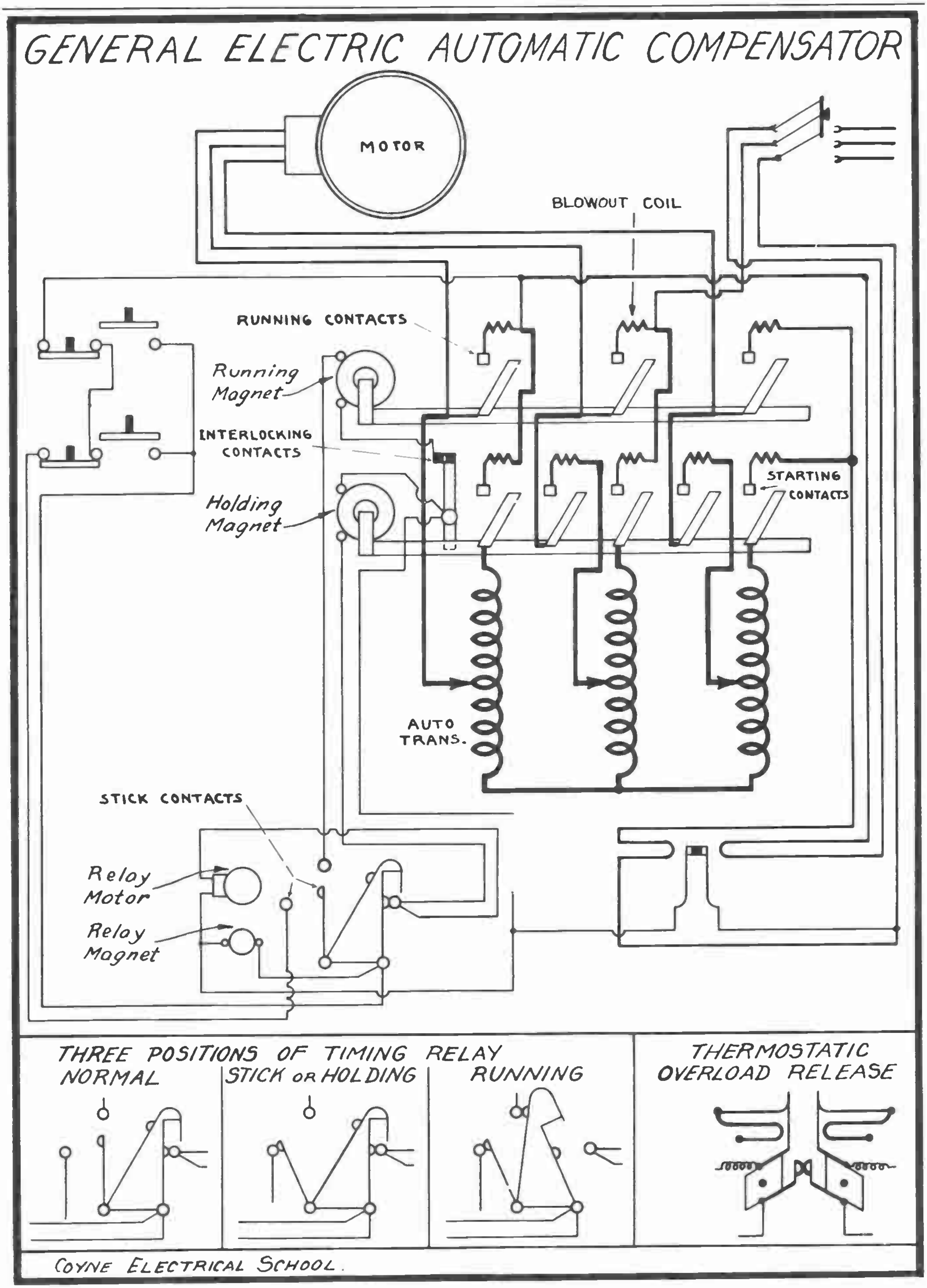


If S.P. master switch is used connect as shown

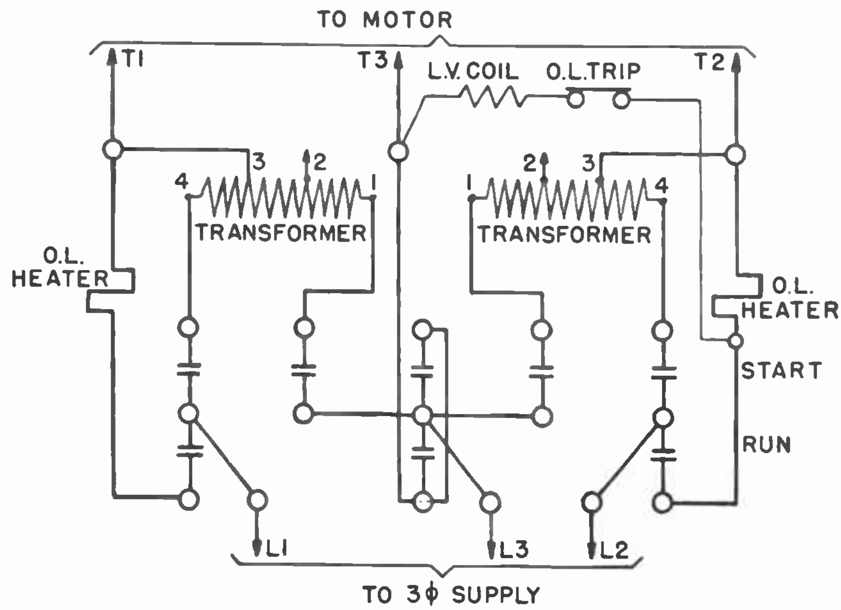




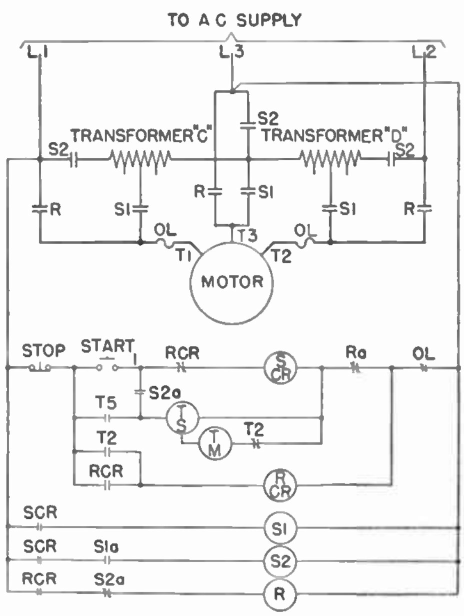
Tap No.	Per cent line volts obtained
	2 Taps
1	65
2	80

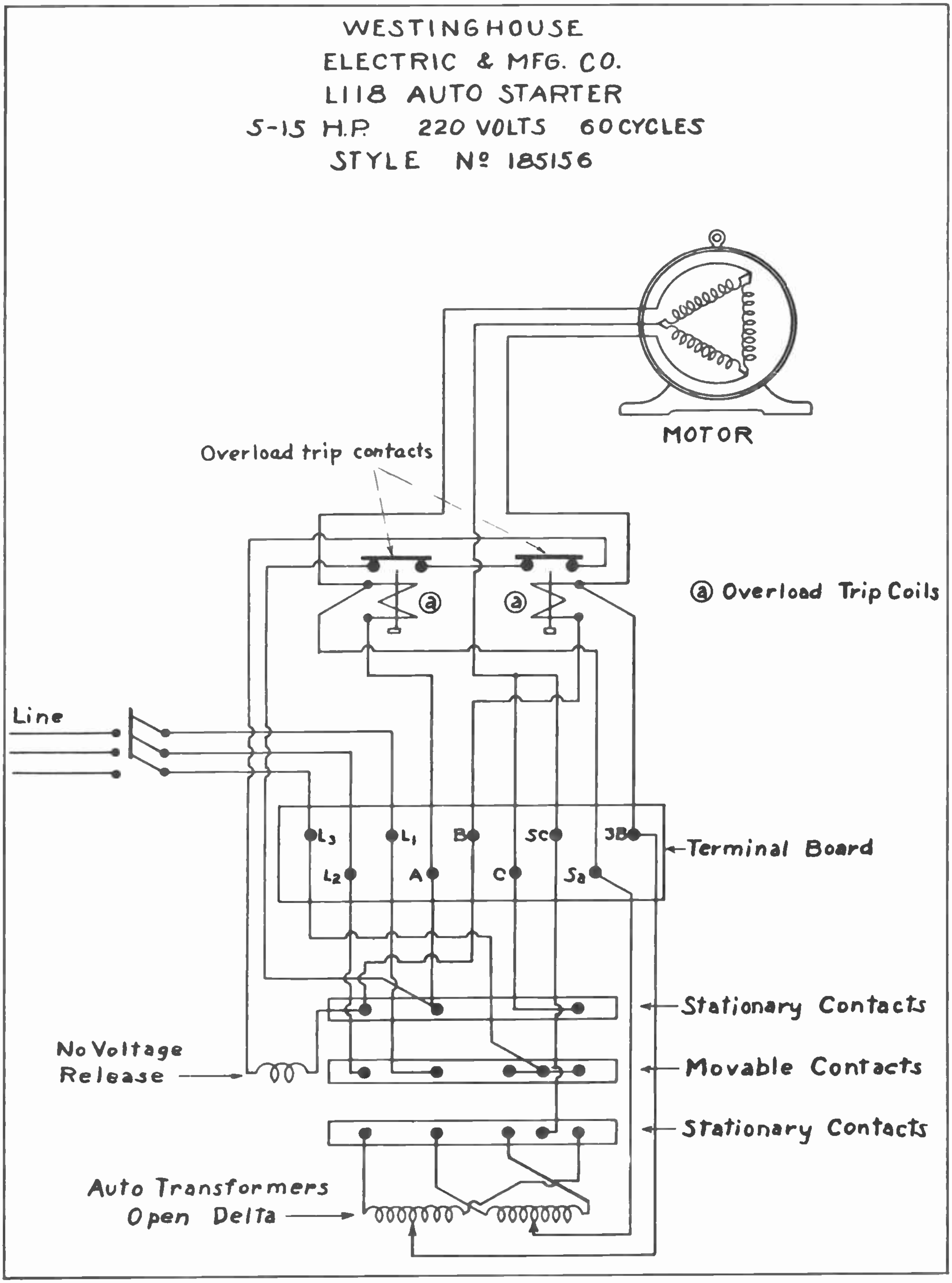

GENERAL ELECTRIC AUTOMATIC COMPENSATOR
MOTOR
BLOWOUT COIL
RUNNING CONTACTS
Running Magnet
INTERLOCKING CONTACTS
Holding Magnet
STARTING CONTACTS
AUTO TRANS.
STICK CONTACTS
Relay Motor
Relay Magnet
THREE POSITIONS OF TIMING RELAY
NORMAL
STICK OR HOLDING
RUNNING
THERMOSTATIC OVERLOAD RELEASE
COYNE ELECTRICAL SCHOOL.

MANUAL COMPENSATOR NON-REVERSING - WESTINGHOUSE SCHEMATIC DIAGRAM

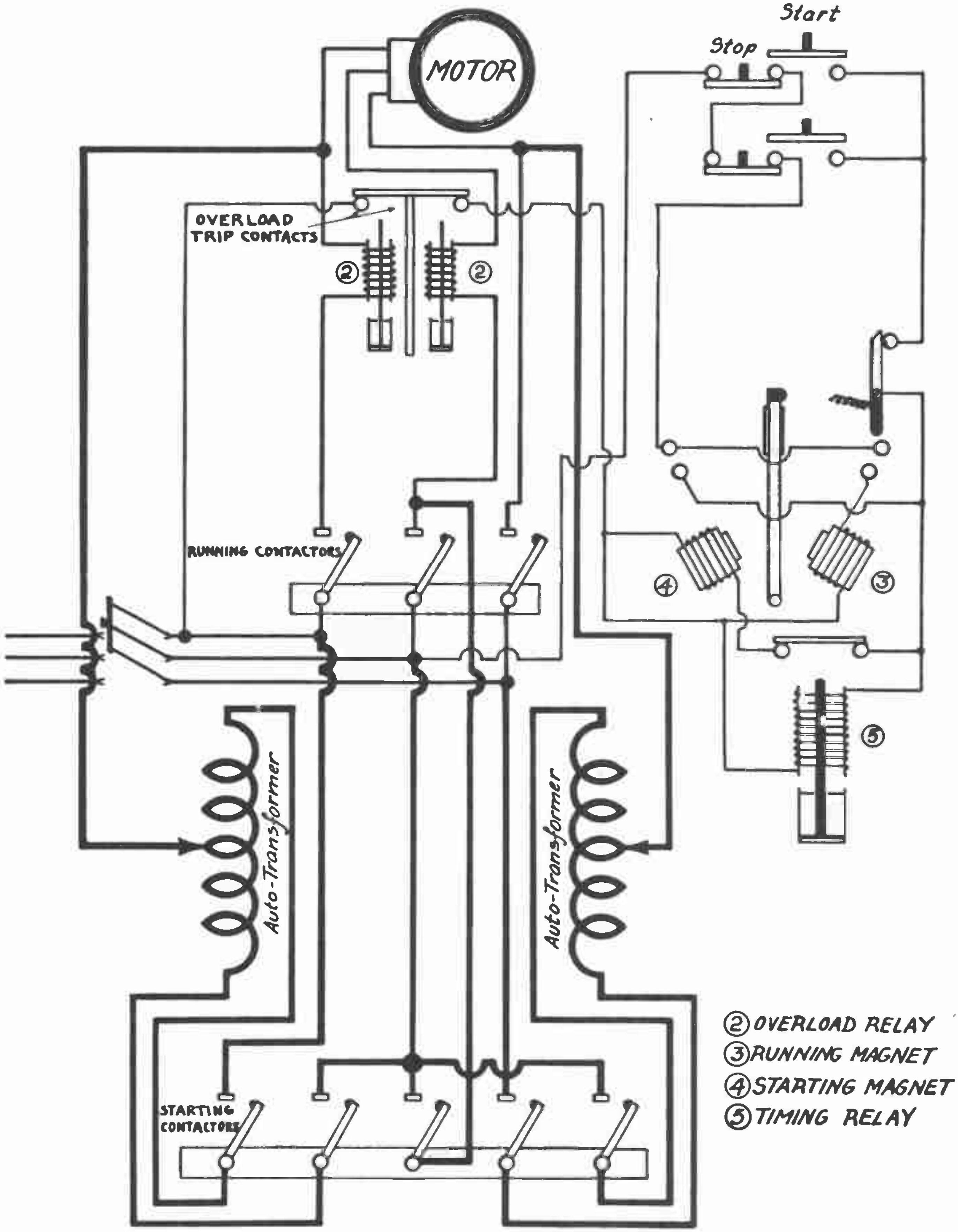


MAGNETIC COMPENSATOR NON-REVERSING - WESTINGHOUSE SCHEMATIC DIAGRAM




WESTINGHOUSE
ELECTRIC & MFG. CO.
L118 AUTO STARTER
5-15 H.P. 220 VOLTS 60 CYCLES
STYLE Nº 185156
MOTOR
Overload trip contacts
ⓐ Overload Trip Coils
Line
L3
L1
B
SC
3B
L2
A
C
Sa
Terminal Board
Stationary Contacts
Movable Contacts
Stationary Contacts
No Voltage Release
Auto Transformers Open Delta

WESTINGHOUSE AUTOMATIC COMPENSATOR



Speed Adjustment

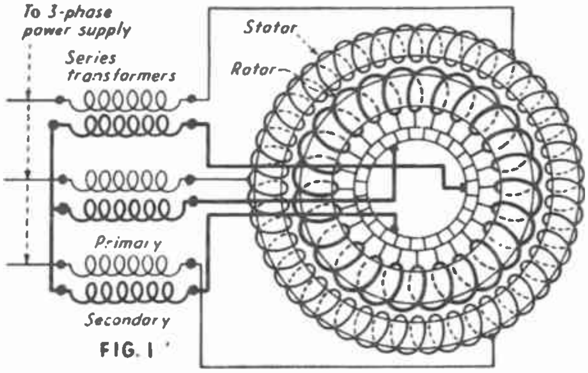


FIG. 1

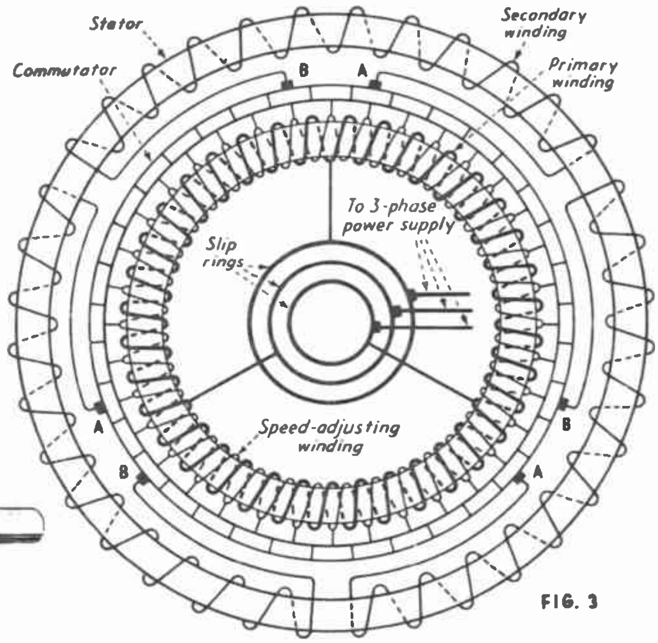


FIG. 3

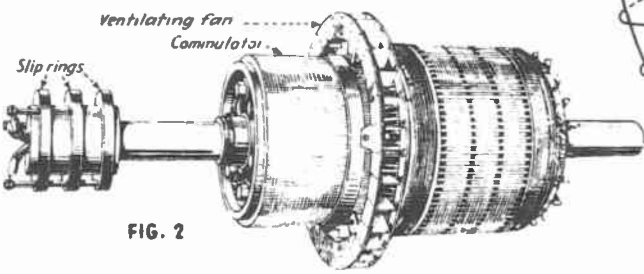


FIG. 2

Fig. 1—Diagram of polyphase commutator motor, speed of which is varied by changing position of brushes. Fig. 2—Rotor for adjustable-speed polyphase motor. Fig. 3—Diagram of rotor and stator circuits for a polyphase adjustable-speed motor

Wound-Rotor Motors

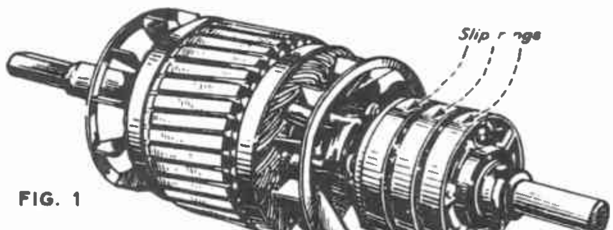
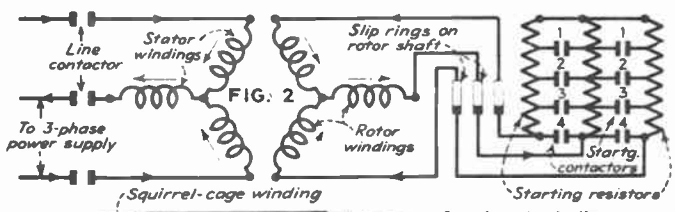


FIG. 1



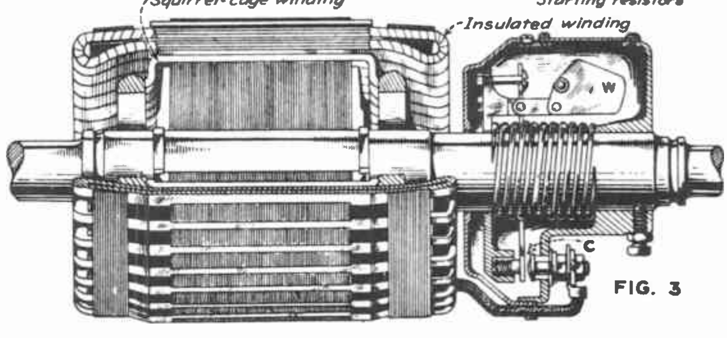
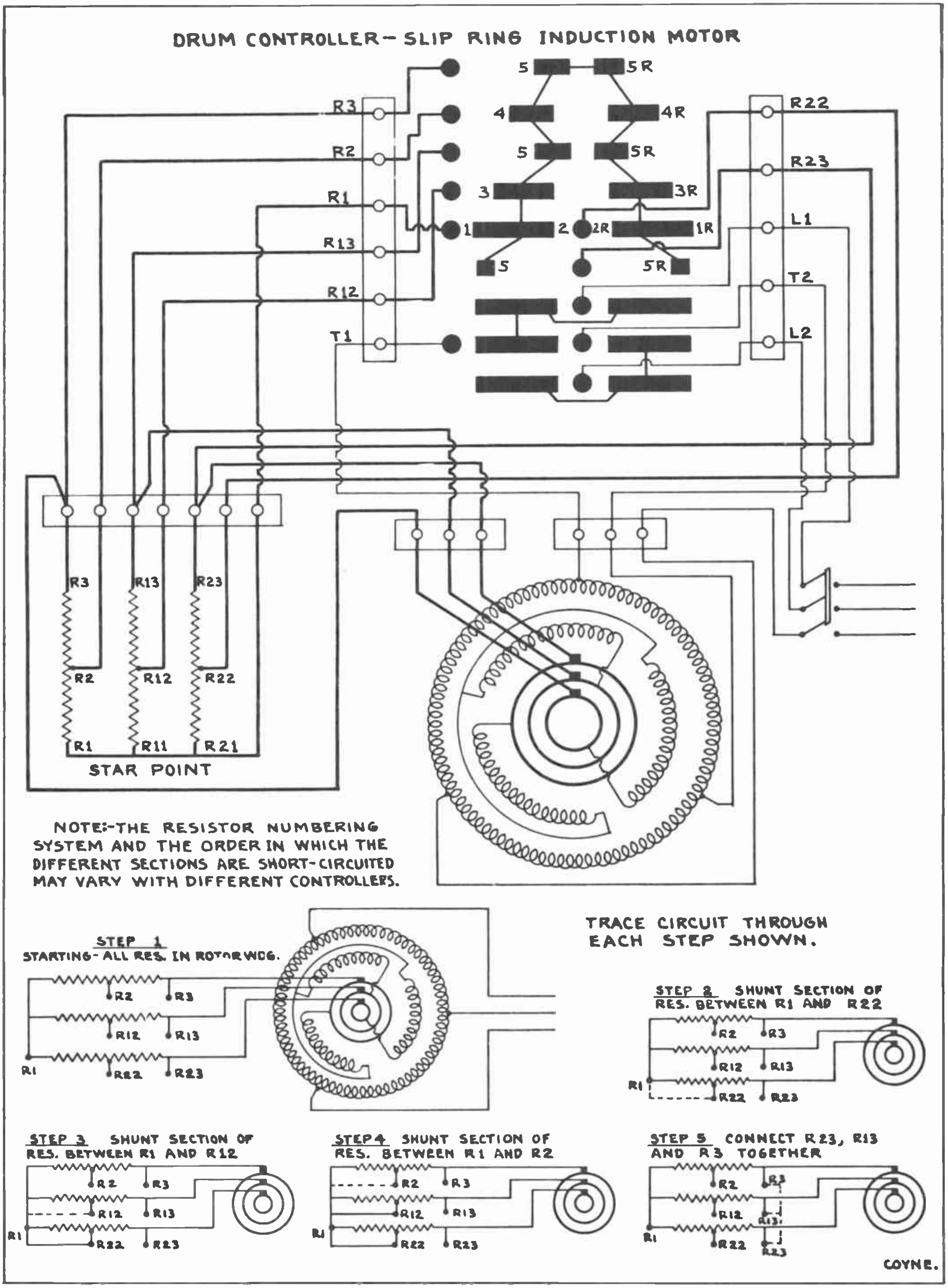
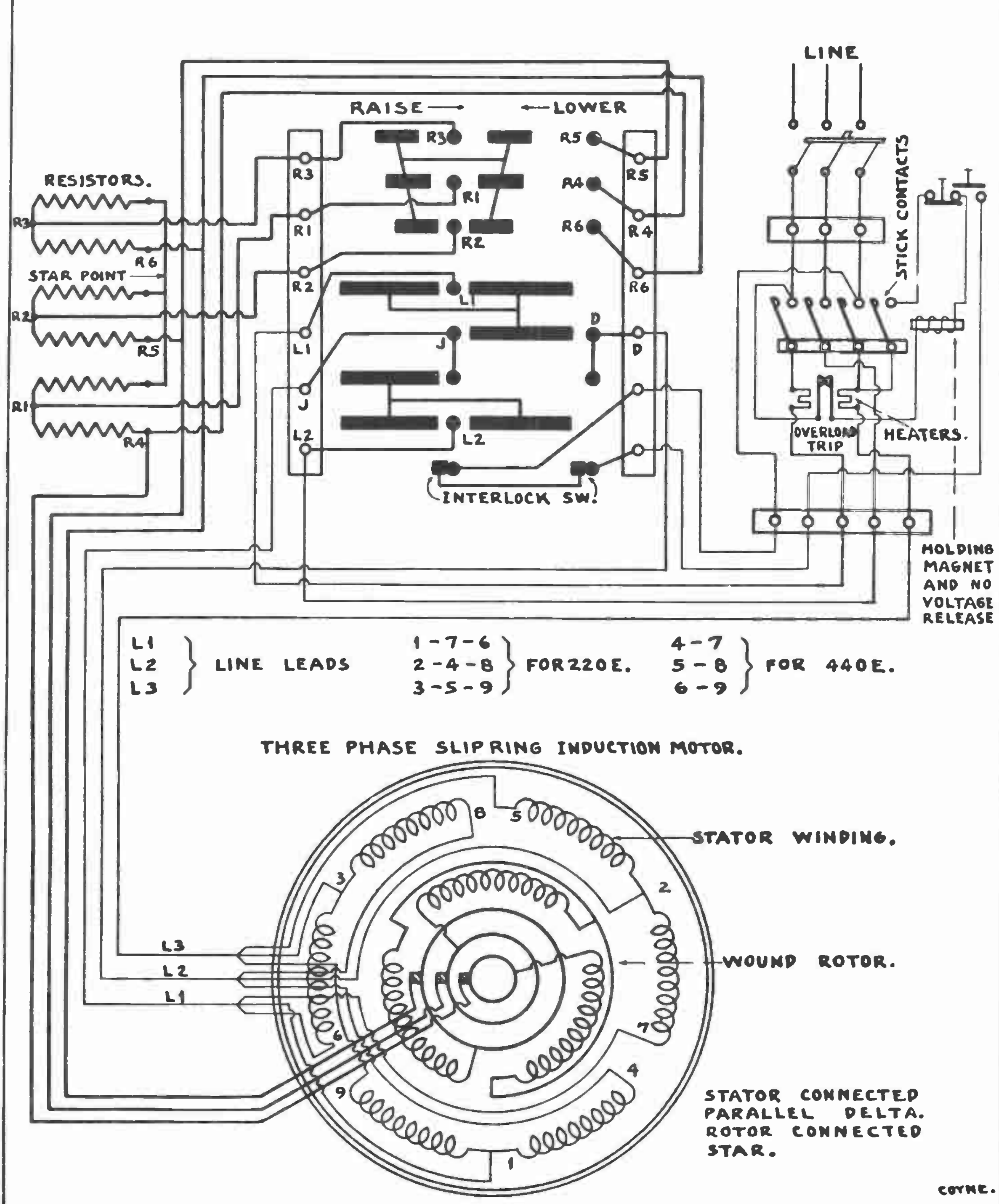


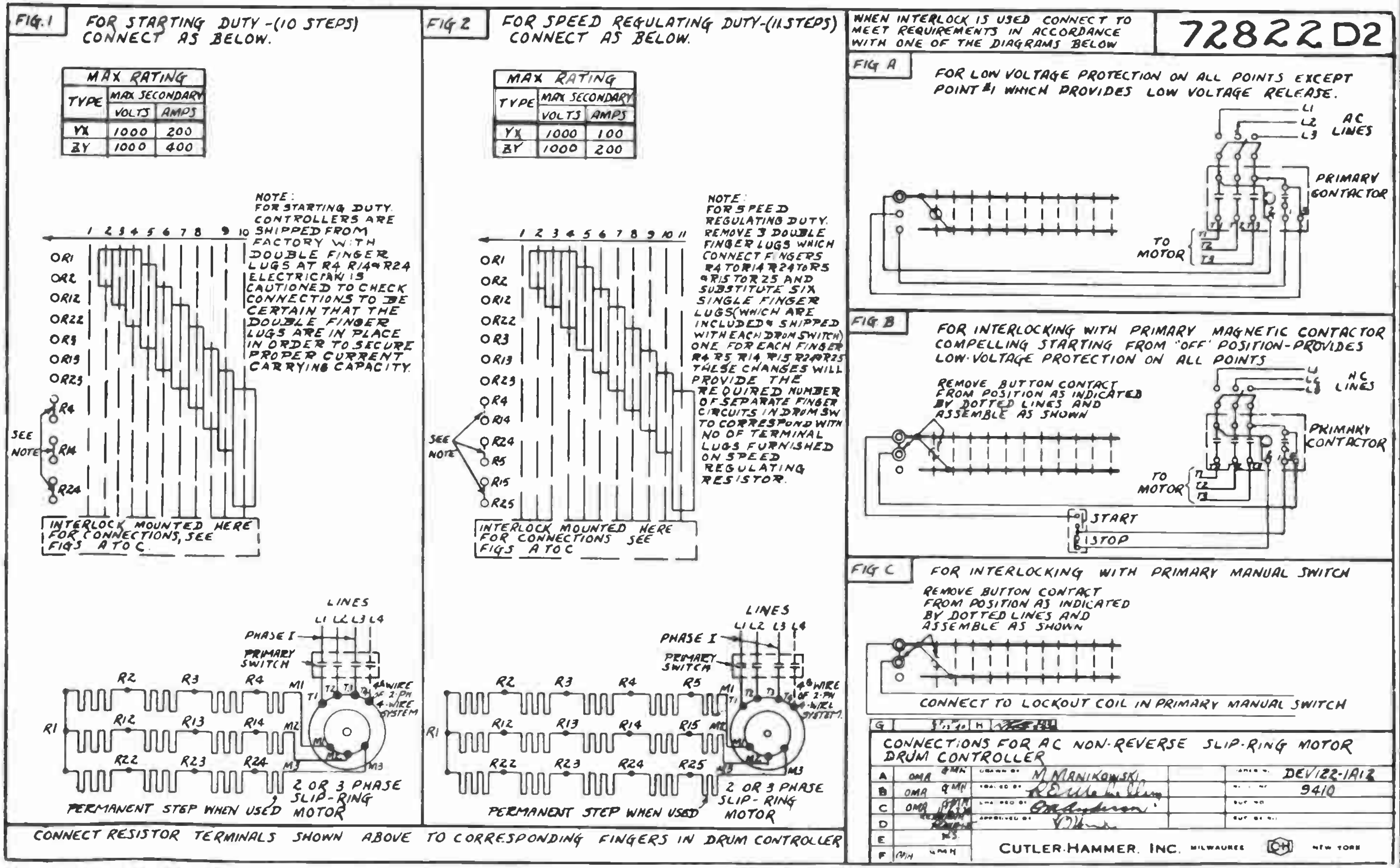
FIG. 3

Fig. 1—Rotor for a wound-rotor or slip-ring motor. Fig. 2—Diagram of wound-rotor motor and its starting resistance. Fig. 3—Combination of a squirrel-cage and a coil winding on rotor, for automatic starting.


DRUM CONTROLLER— SLIP RING INDUCTION MOTOR
5
5R
4
4R
5
5R
3
3R
1
2
2R
1R
5
5R
R3
R2
R1
R13
R12
T1
R22
R23
L1
T2
L2
R3
R13
R23
R2
R12
R22
R1
R11
R21
STAR POINT
NOTE:-THE RESISTOR NUMBERING SYSTEM AND THE ORDER IN WHICH THE DIFFERENT SECTIONS ARE SHORT-CIRCUITED MAY VARY WITH DIFFERENT CONTROLLERS.
TRACE CIRCUIT THROUGH EACH STEP SHOWN.
STEP 1
STARTING- ALL RES. IN ROTOR WDG.
R2
R3
R12
R13
R1
R22
R23
STEP 2 SHUNT SECTION OF RES. BETWEEN R1 AND R22
R2
R3
R12
R13
R1
R22
R23
STEP 3 SHUNT SECTION OF RES. BETWEEN R1 AND R12
R2
R3
R12
R13
R1
R22
R23
STEP 4 SHUNT SECTION OF RES. BETWEEN R1 AND R2
R2
R3
R12
R13
R1
R22
R23
STEP 5 CONNECT R23, R13 AND R3 TOGETHER
R2
R3
R12
R13
R1
R22
R23
COYNE.

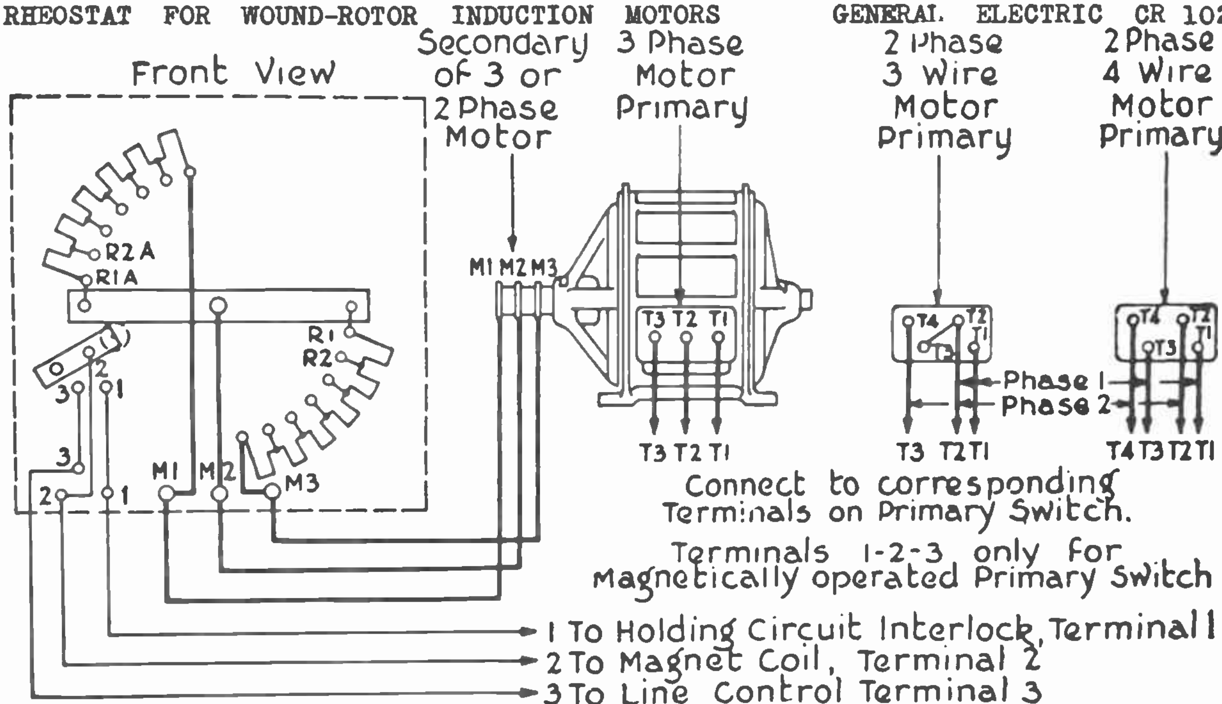
DRUM CONTROLLER (5 SPEED).




72822 D2
FIG. 1 FOR STARTING DUTY - (10 STEPS) CONNECT AS BELOW.
MAX RATING
TYPE | MAX SECONDARY VOLTS | AMPS
YX | 1000 | 200
ZY | 1000 | 400
NOTE: FOR STARTING DUTY CONTROLLERS ARE SHIPPED FROM FACTORY WITH DOUBLE FINGER LUGS AT R4 R14 & R24 ELECTRICIAN IS CAUTIONED TO CHECK CONNECTIONS TO BE CERTAIN THAT THE DOUBLE FINGER LUGS ARE IN PLACE IN ORDER TO SECURE PROPER CURRENT CARRYING CAPACITY.
INTERLOCK MOUNTED HERE FOR CONNECTIONS, SEE FIGS A TO C.
SEE NOTE
PERMANENT STEP WHEN USED
2 OR 3 PHASE SLIP-RING MOTOR
FIG 2 FOR SPEED REGULATING DUTY - (11 STEPS) CONNECT AS BELOW.
MAX RATING
TYPE | MAX SECONDARY VOLTS | AMPS
YX | 1000 | 100
ZY | 1000 | 200
NOTE: FOR SPEED REGULATING DUTY. REMOVE 3 DOUBLE FINGER LUGS WHICH CONNECT FINGERS R4 TO R14 R24 TO R5 & R15 TO R25 AND SUBSTITUTE SIX SINGLE FINGER LUGS (WHICH ARE INCLUDED & SHIPPED WITH EACH DRUM SWITCH) ONE FOR EACH FINGER R4 R5 R14 R15 R24 R25 THESE CHANGES WILL PROVIDE THE REQUIRED NUMBER OF SEPARATE FINGER CIRCUITS IN DRUM SW TO CORRESPOND WITH NO OF TERMINAL LUGS FURNISHED ON SPEED REGULATING RESISTOR.
INTERLOCK MOUNTED HERE FOR CONNECTIONS SEE FIGS A TO C
LINES
PHASE I
PRIMARY SWITCH
4 WIRE OF 2-PH 4-WIRE SYSTEM
CONNECT RESISTOR TERMINALS SHOWN ABOVE TO CORRESPONDING FINGERS IN DRUM CONTROLLER
WHEN INTERLOCK IS USED CONNECT TO MEET REQUIREMENTS IN ACCORDANCE WITH ONE OF THE DIAGRAMS BELOW
FIG A FOR LOW VOLTAGE PROTECTION ON ALL POINTS EXCEPT POINT #1 WHICH PROVIDES LOW VOLTAGE RELEASE.
AC LINES
PRIMARY CONTACTOR
TO MOTOR
FIG B FOR INTERLOCKING WITH PRIMARY MAGNETIC CONTACTOR COMPELLING STARTING FROM "OFF" POSITION - PROVIDES LOW-VOLTAGE PROTECTION ON ALL POINTS
REMOVE BUTTON CONTACT FROM POSITION AS INDICATED BY DOTTED LINES AND ASSEMBLE AS SHOWN
START
STOP
FIG C FOR INTERLOCKING WITH PRIMARY MANUAL SWITCH
REMOVE BUTTON CONTACT FROM POSITION AS INDICATED BY DOTTED LINES AND ASSEMBLE AS SHOWN
CONNECT TO LOCKOUT COIL IN PRIMARY MANUAL SWITCH
CONNECTIONS FOR AC NON-REVERSE SLIP-RING MOTOR DRUM CONTROLLER
M. MANIKOWSKI
DEV122-1A12
9410
CUTLER-HAMMER, INC. MILWAUKEE NEW YORK

RHEOSTAT FOR WOUND-ROTOR INDUCTION MOTORS

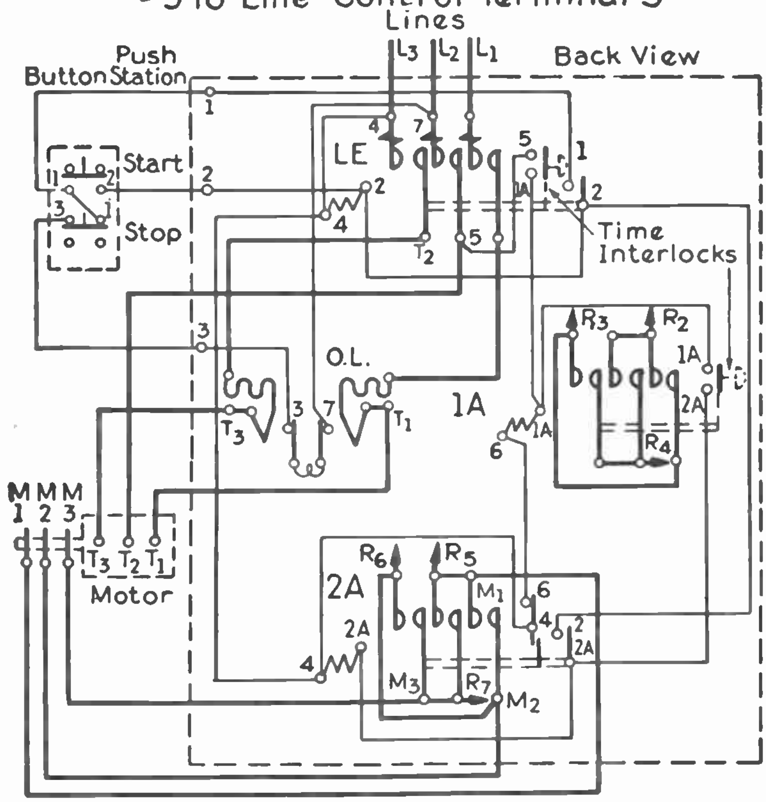
GENERAL ELECTRIC CR 1028

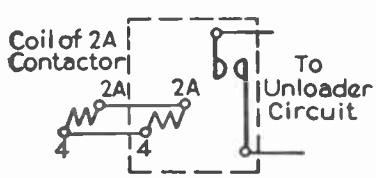


AUTOMATIC STARTER

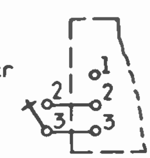
GENERAL ELECTRIC

CR 7022

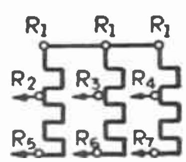




Connection of CR2811 Switch to Operate Unloader



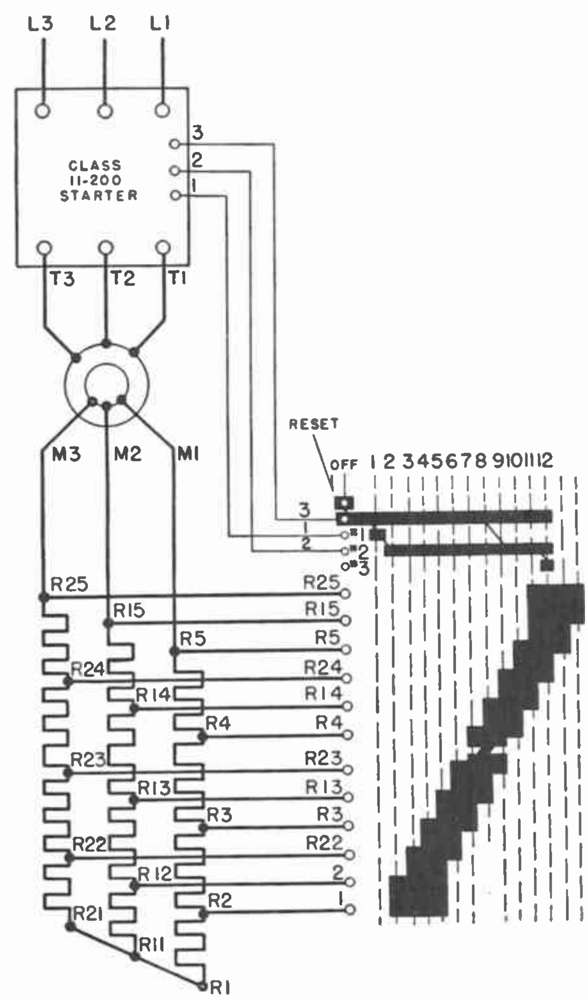
If S.P. Master Switch is used instead of Push Button Station Connect as above



Connect "R" Terminals on Resistor to Corresponding "R" Terminals on Panel

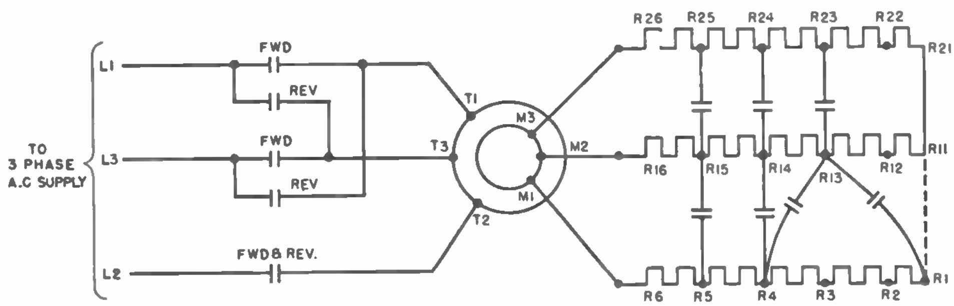
DRUM CONTROLLER, NON-REVERSING, SECONDARY CONTROL WESTINGHOUSE

SCHEMATIC DIAGRAM OF TYPICAL WIRING CONNECTION



DRUM CONTROLLER, REVERSING, PRIMARY AND SECONDARY CONTROL WESTINGHOUSE

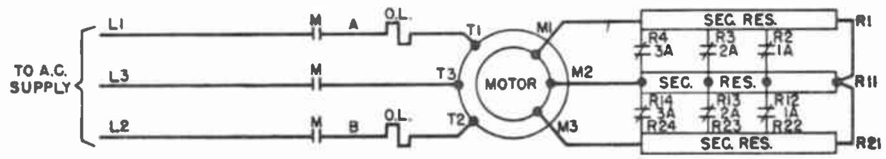
SCHEMATIC WIRING DIAGRAM



R5 TO R6
R15 TO R16
R25 TO R26
PERMANENT SLIP RESISTORS WHEN USED.
WHEN NOT USED CONNECT M1 — M2 — M3
TO R5 — R15 & R25 RESPECTIVELY.

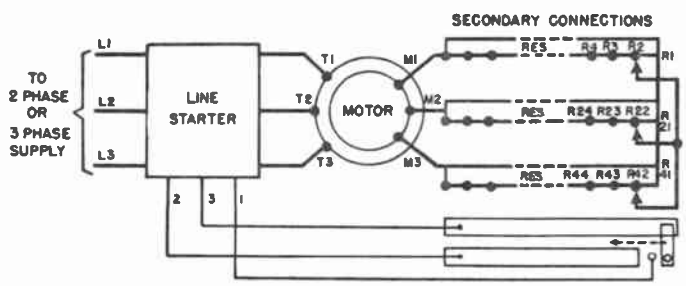
MAGNETIC, NON REVERSING AND REVERSING — WESTINGHOUSE

SCHEMATIC WIRING DIAGRAM

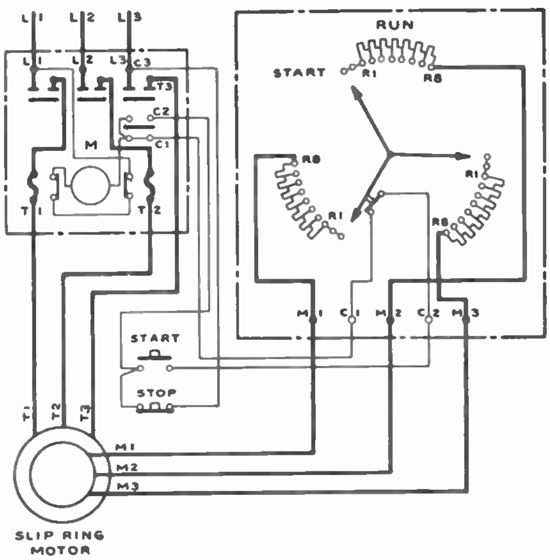


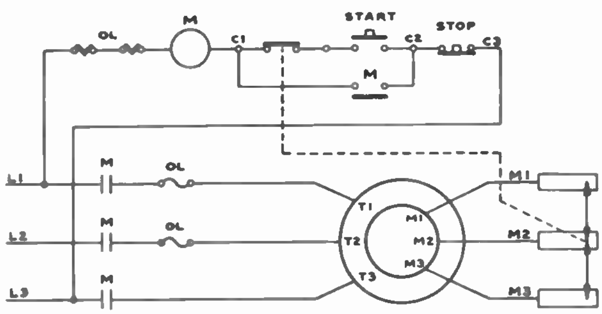
STARTING AND SPEED REGULATING RHEOSTAT — WESTINGHOUSE

SCHEMATIC WIRING DIAGRAM



A. C. MANUAL SPEED REGULATORS — CLASS 2310



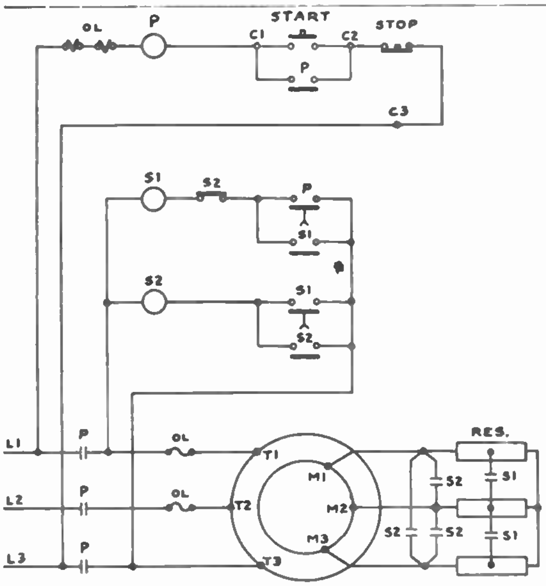


CLASS 2310 MANUAL SPEED REGULATOR INTERLOCKED WITH CLASS 8536 MAGNETIC STARTER FOR CONTROL OF SLIP RING MOTOR

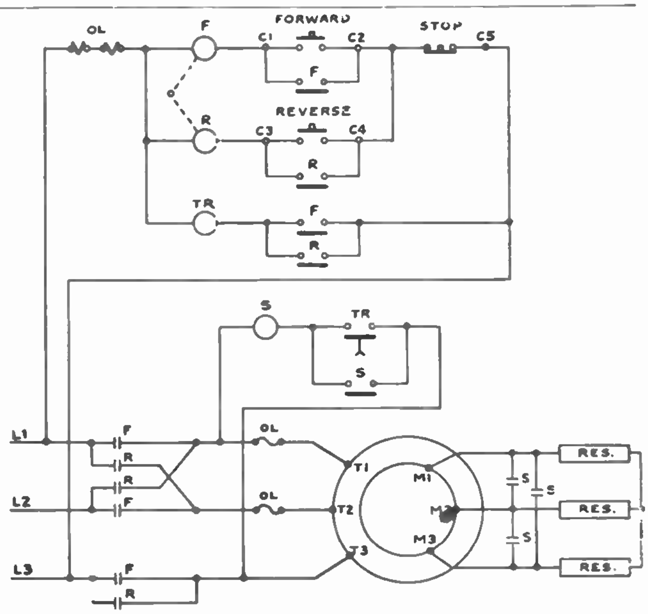
1748-88

WIRING DIAGRAMS

CLASS 8550, 8750 — SECONDARY RESISTOR TYPE REDUCED VOLTAGE STARTERS



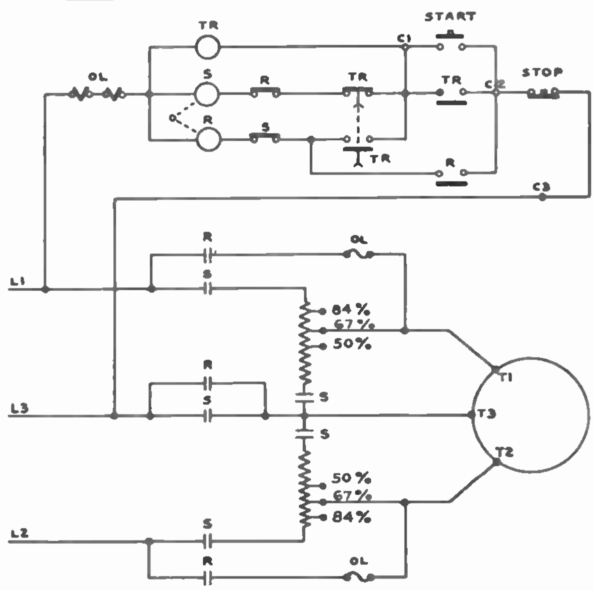
TYPICAL LINE DIAGRAM FOR CLASS 8550 NON-REVERSING WOUND ROTOR MOTOR STARTER WITH THREE POINTS OF ACCELERATION.



TYPICAL LINE DIAGRAM FOR CLASS 8750 REVERSING WOUND ROTOR MOTOR STARTER WITH TWO POINTS OF ACCELERATION.

1748-B8

CLASS 8606 — A. C. AUTOMATIC COMPENSATORS



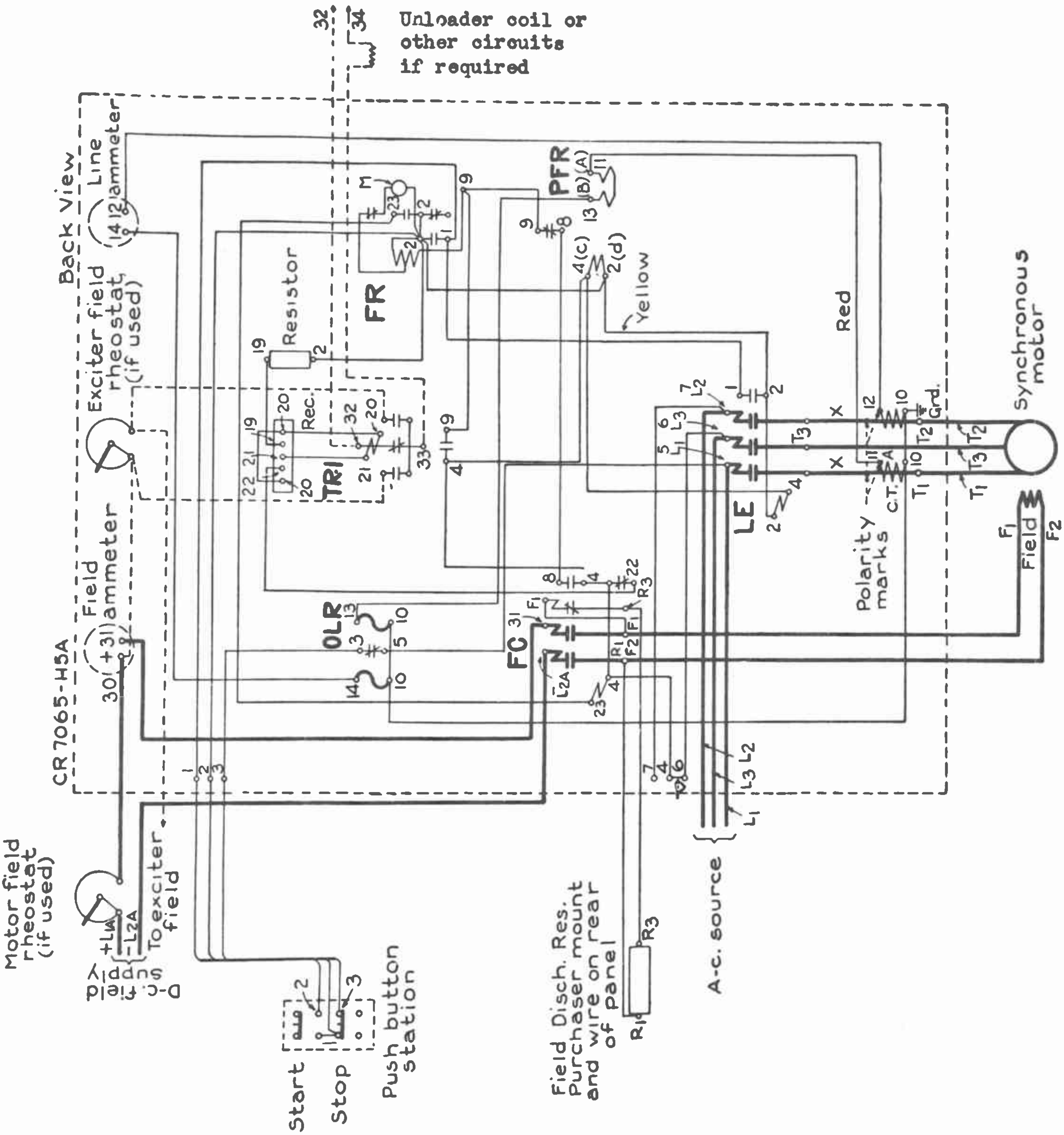
TYPICAL LINE DIAGRAM FOR CLASS 8606 AIR BREAK TYPE A.C. MAGNETIC COMPENSATOR

1748-B8

No changes since previous issue.

FULL-VOLTAGE STARTER FOR LOW-VOLTAGE SYNCHRONOUS MOTORS

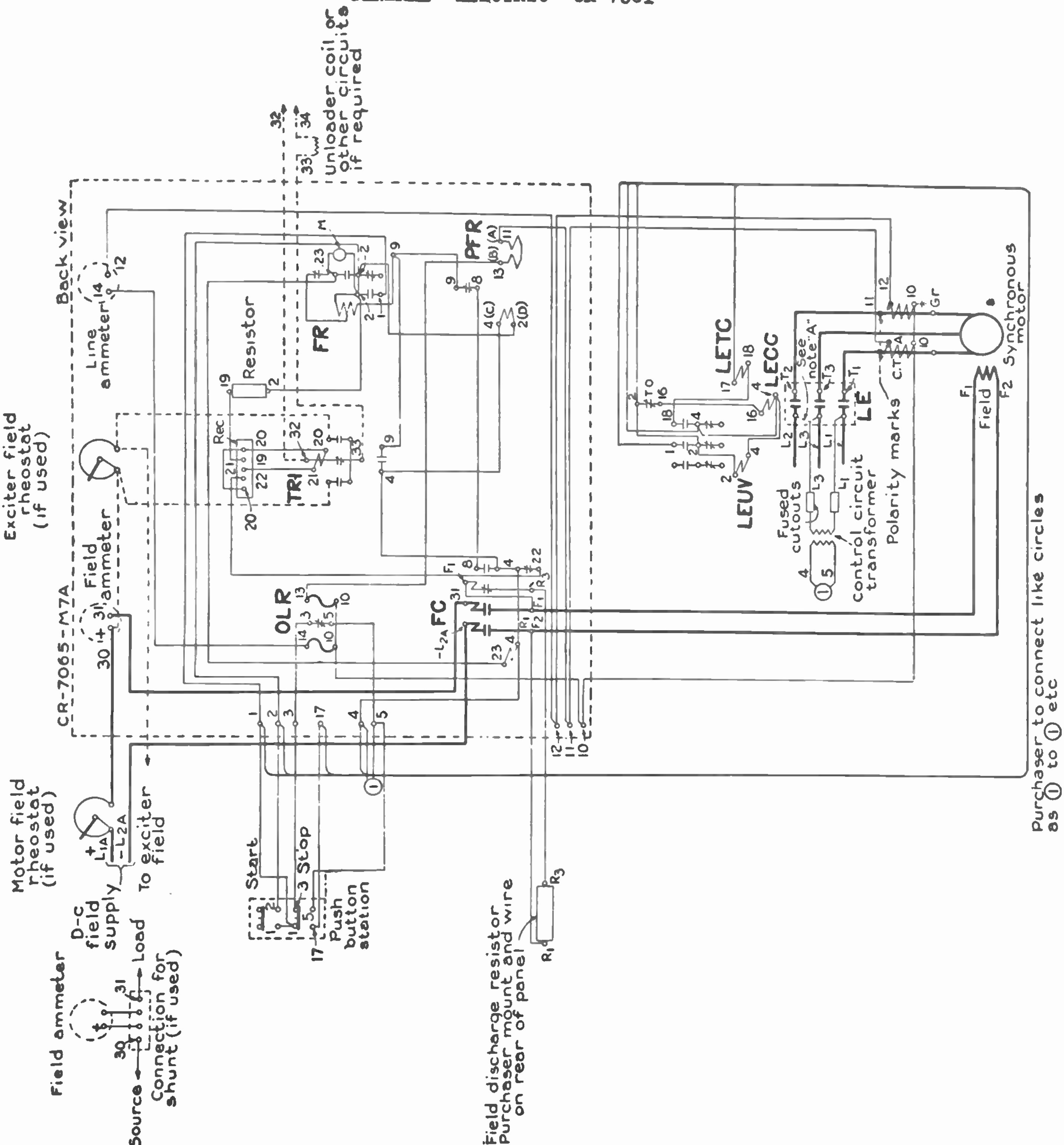
GENERAL ELECTRIC CR 7061



OLR = Temperature stator overload relay (hard reset). TRI = Time-delay relay set for approximately 2 seconds. FR = Definite-time field-application relay adjustable for approx 2 to 40 seconds. FC = Field-application and discharge contactor. PFR = Power-factor field-removal relay. LE = Line contactor. REC = Copper-oxide rectifier for TRI. C.T. = Current transformers.

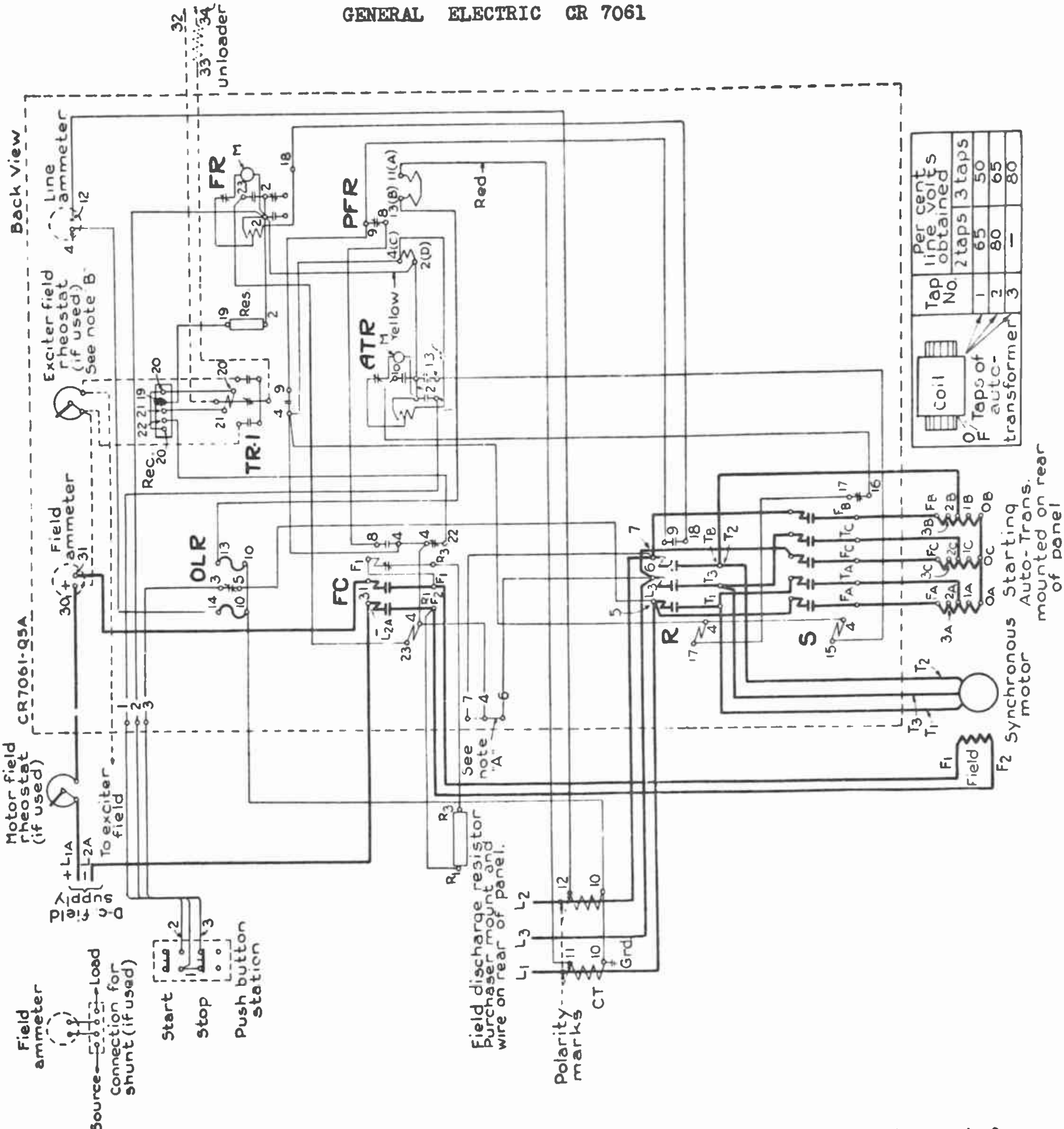
FULL VOLTAGE STARTER FOR HIGH VOLTAGE SYNCHRONOUS MOTORS

GENERAL ELECTRIC CR 7061



LE = Line contactor. C.T. = Current transformers. OLR = Temperature stator overload relay (hand reset). TRI = Time-delay relay for approximately 2 seconds. FR = Definite time field application relay adjustable for approximately 2 to 40 seconds. FC = Field-application and discharge contactor. PFR = Power-factor field-removal relay. LECC = Line contactor closing coil. LEUV = Line contactor undervoltage release coil. LETC = Line contactor tripping coil. REC = Copper-oxide rectifier for TRI.

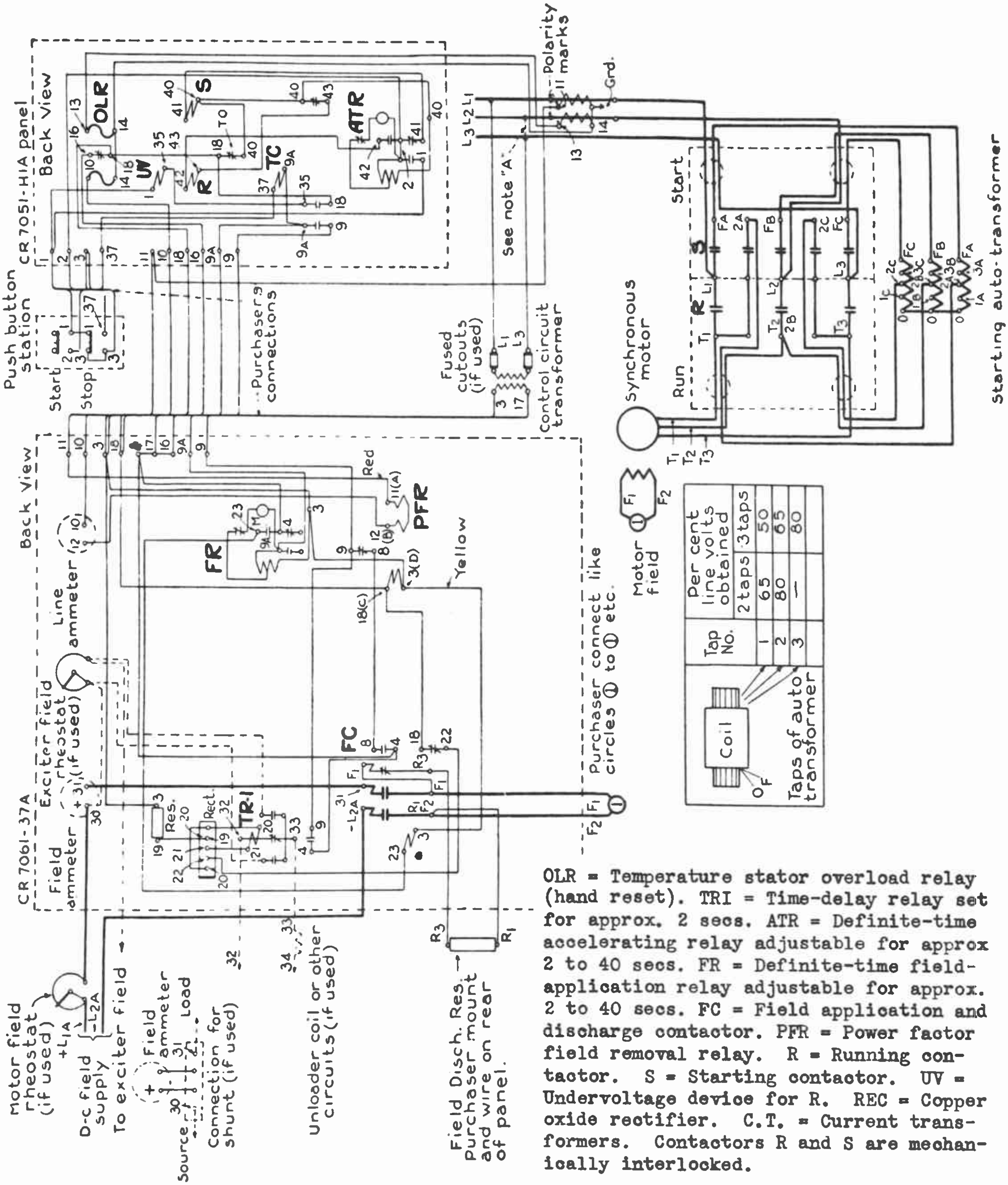
REDUCED-VOLTAGE STARTER FOR LOW-VOLTAGE SYNCHRONOUS MOTORS
GENERAL ELECTRIC CR 7061



OLR = Temperature stator overload relay (hand reset). TRI = Time delay relay set for approximately 2 seconds. ATR = Definite-time accelerating relay adjustable for approx. 2 to 40 seconds. FR = Definite-time field application relay, adjustable for approx. 2 to 40 seconds. FC = Field-application and discharge contactor. PFR = Power-factor field removal relay. R = Running contactor. S = Starting contactor. REC = Copper-oxide rectifier. C.T. = Current transformers. Contactors R and S are mechanically interlocked.

REDUCED-VOLTAGE STARTER FOR HIGH-VOLTAGE SYNCHRONOUS MOTORS

GENERAL ELECTRIC CR 7061

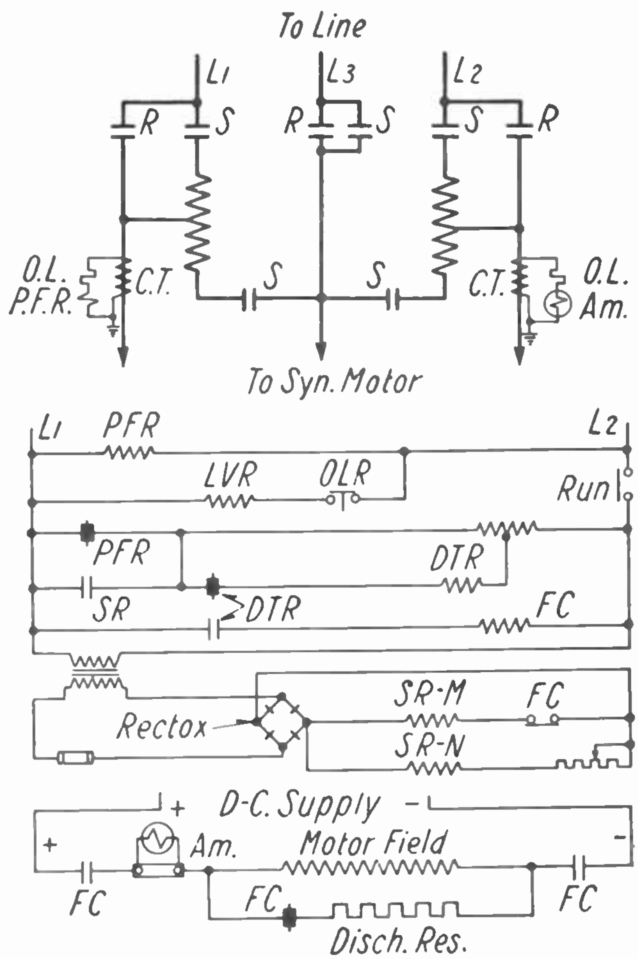


Tap No.	Per cent line volts obtained: 2 taps	Per cent line volts obtained: 3 taps
1	65	50
2	80	65
3	—	80

OLR = Temperature stator overload relay (hand reset). TRI = Time-delay relay set for approx. 2 secs. ATR = Definite-time accelerating relay adjustable for approx 2 to 40 secs. FR = Definite-time field-application relay adjustable for approx. 2 to 40 secs. FC = Field application and discharge contactor. PFR = Power factor field removal relay. R = Running contactor. S = Starting contactor. UV = Undervoltage device for R. REC = Copper oxide rectifier. C.T. = Current transformers. Contactors R and S are mechanically interlocked.

SEMI-MAGNETIC REDUCED VOLTAGE STARTER FOR SYNCHRONOUS MOTORS

AUTO-TRANSFORMER TYPE WESTINGHOUSE



Typical Schematic Diagram Showing the Wiring of a Class 14-040 Starter

Symbols

PFR —Power Factor Relay
LVR—Low Voltage Relay
OLR —Overload Relay
DTR—Definite Time Re'ay
FC—Field Contactor
SR—Sequence Relay

STARTING AND CONTROLLING THE SPEED OF D. C. MOTORS

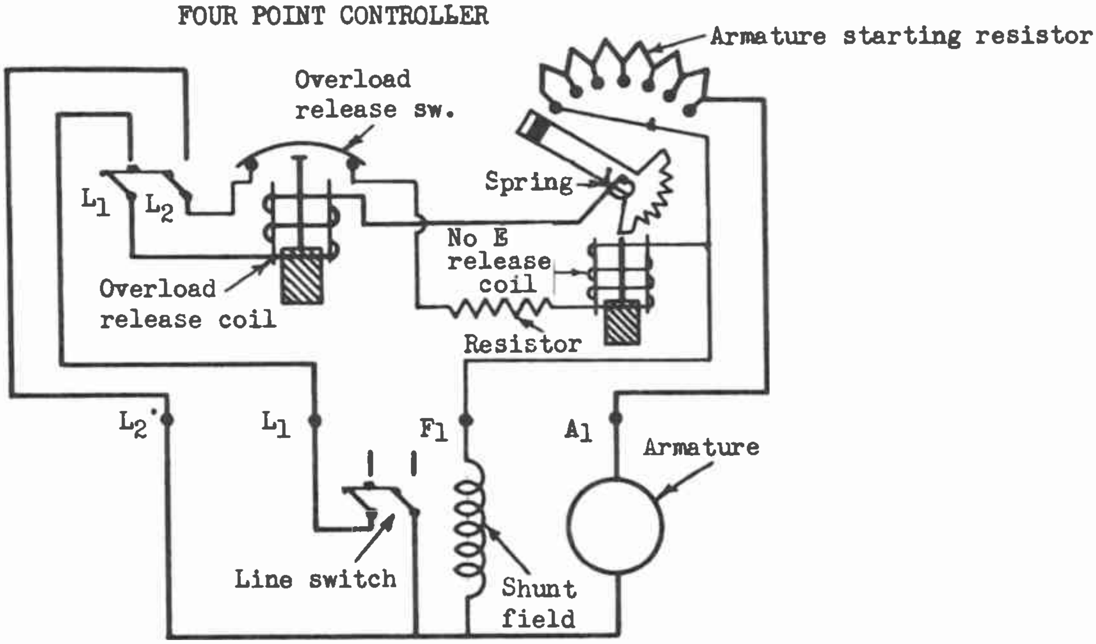
Small D.C. motors (fractional H.P.) may be started across the line. The resistance of the armature winding is high in comparison to the resistance of larger armatures. Large armatures have low resistance because heavy wire is used to wind them.

When starting a D.C. motor larger than fractional H.P. in size full line voltage should not be applied to the armature. A resistor should be connected in series with the armature to produce a voltage drop and apply a low voltage to the armature during the starting period. The starting period is from 10 to 45 seconds.

The starting current should be limited to 1½ or 2 times full load current except when starting heavy torque loads which will require as much as 3 times full load current. After the motor attains normal speed the current through the armature can be determined by the formula; effective voltage divided by armature resistance. This value will be proportional to the mechanical load on the motor.

The shunt field must be connected so it will receive full line voltage when starting. The field must be maximum strength to produce good starting torque and for the armature to quickly generate CEMF.

FOUR POINT CONTROLLER



The NO VOLTAGE RELEASE COIL allows the spring on the power arm to return the power arm to the "off" position if the voltage on the line drops to a low or zero value.

OVERLOAD PROTECTION is provided by connecting an overload release coil in series with the load circuit. When the current reaches overload value the plunger will be drawn up and break the holding coil circuit. The spring on the power arm will return it to the off position.

COYNE

STARTING AND CONTROLLING THE SPEED OF D.C. MOTORS (continued)

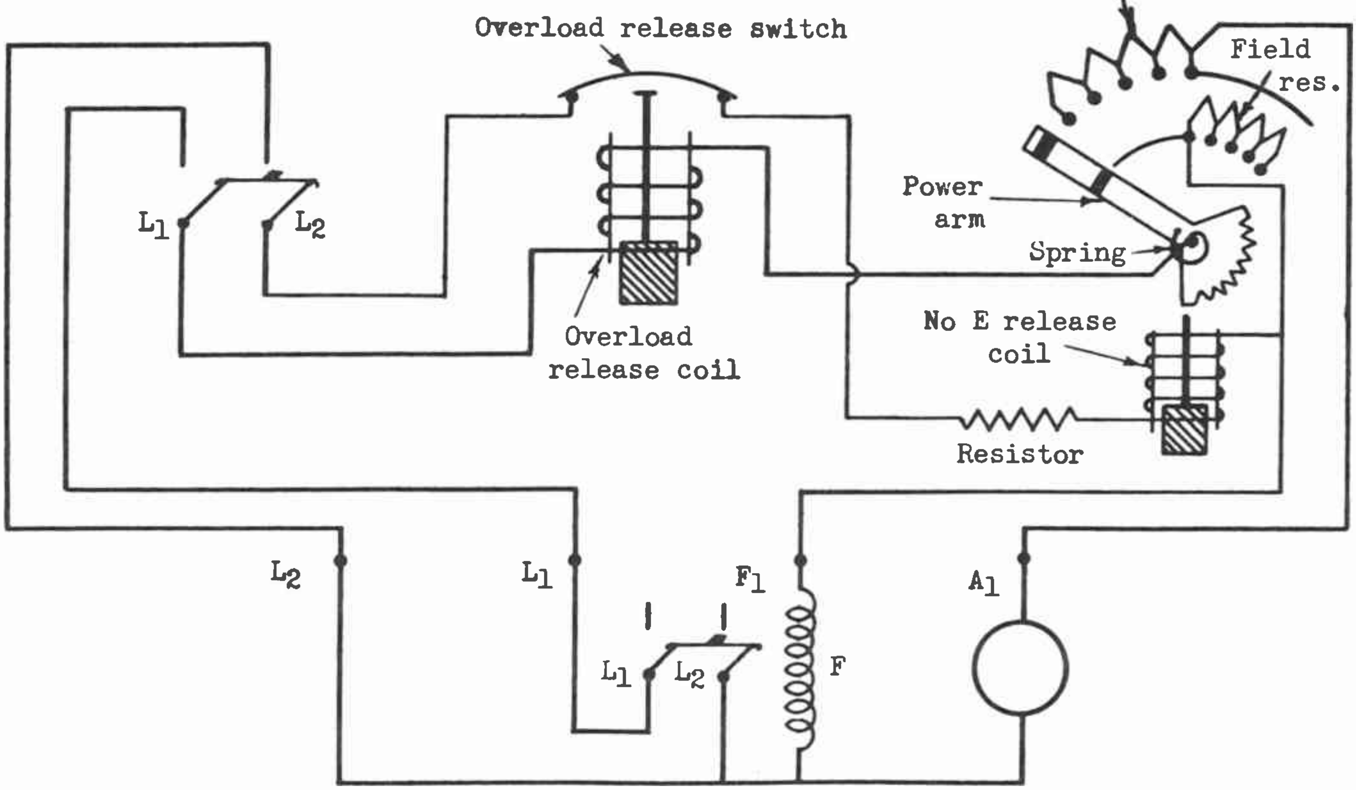
The speed of a D.C. motor varies in direct proportion to the voltage applied to the armature and in inverse proportion to the strength of the field flux.

When a motor is operating with the rated voltage applied to the armature and field (with or without load) it is operating normally and the speed obtained is called NORMAL SPEED.

SPEED CONTROL BELOW NORMAL SPEED (armature control)

The speed can be controlled below normal by connecting a regulating resistor in series with the armature. The speed will vary with the voltage applied to the armature. The torque will not be affected because connecting a resistor in series with the armature does not change the amount of current through the armature. This value will be constant if the mechanical load is constant. The H.P. output will vary with the speed because the H.P. output is proportional to the speed and torque.

FOUR POINT CONTROLLER



SPEED CONTROL ABOVE NORMAL SPEED (field control)

The speed can be controlled above normal on shunt and compound motors by connecting a shunt field rheostat in series with the shunt field. The speed will vary inversely with the field strength. Weakening the field will increase the speed because the armature must rotate faster to generate a sufficient amount of CEMF to limit the current through the armature in proportion to the mechanical load on the motor. Decreasing the field strength will decrease the torque. The H.P. output will not be affected because the H.P. output is always proportional to the speed and torque. When the speed increases and the torque decreases the product of the two will not change. COYNE

FAIRBANKS-MORSE ELECTRIC MACHINERY CATECHISM

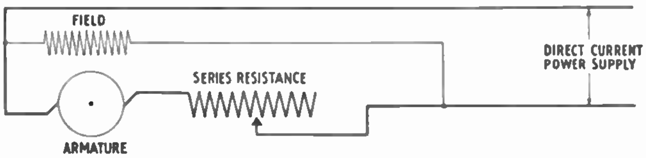


Diagram showing speed control of a direct-current motor by means of a resistance in series with the armature. More resistance gives lower speed.

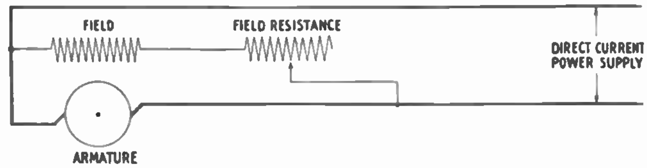
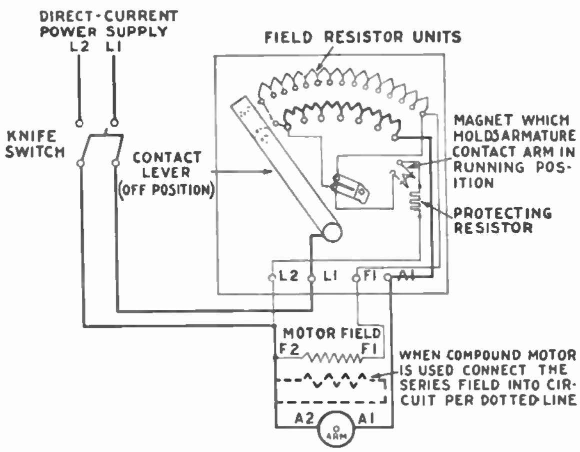
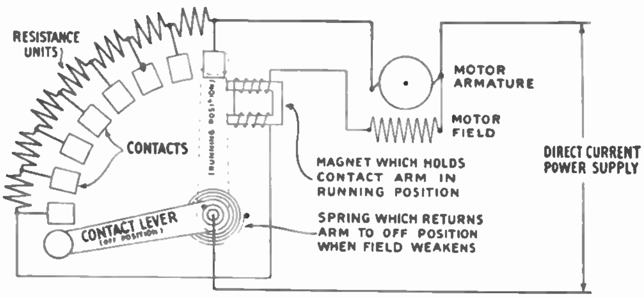


Diagram showing speed control of a direct-current motor by means of a resistance in series with the field. More resistances gives higher speed



Schematic diagram of the starter and speed regulator



Schematic diagram of a direct-current motor starter showing how the resistance units in series with the armature are cut out in starting and how the low-voltage magnet is connected to the field circuit of the machine

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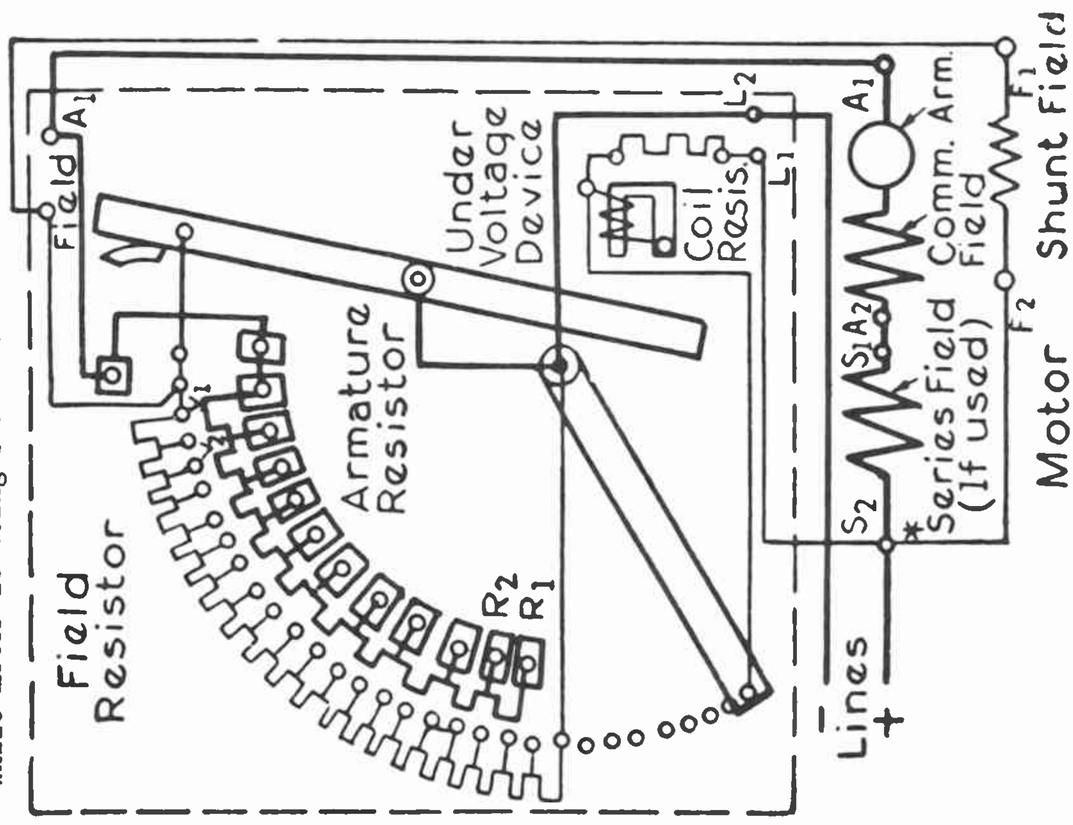
SPEED REGULATING RHEOSTAT FOR SHUNT-WOUND MOTORS - GENERAL ELECTRIC CR 1203

Speed control by varying a resistance in the shunt field circuit. One set of segments controls the field resistor, the other set of segments controls the starting resistor. The field resistor is shorted by the auxiliary arm while motor is being started.



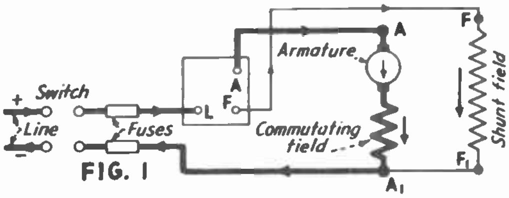


FIG. 1

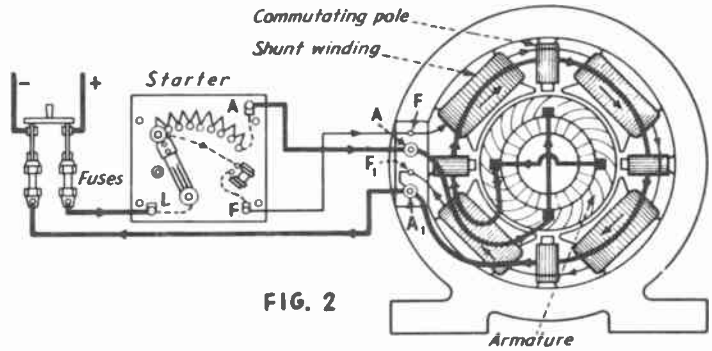


FIG. 2


FIG. 3


FIG. 4


FIG. 5

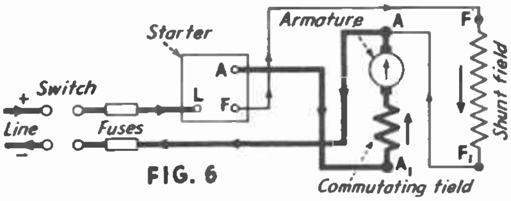


FIG. 6

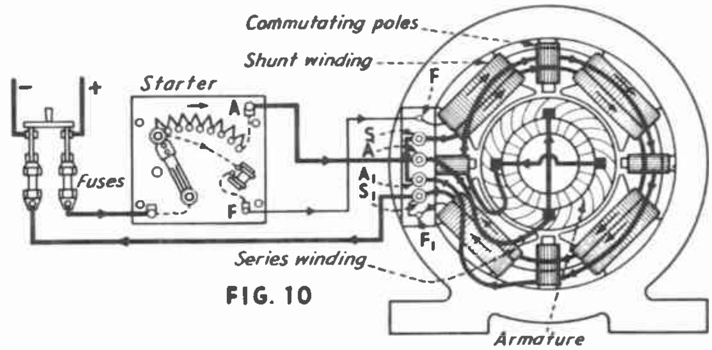


FIG. 10

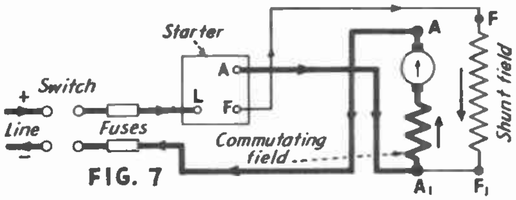


FIG. 7

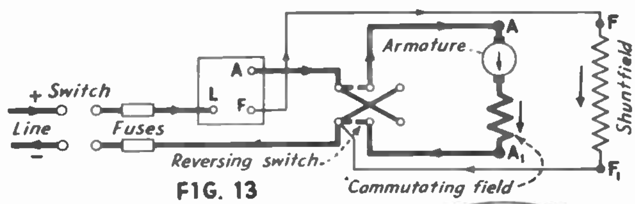


FIG. 13

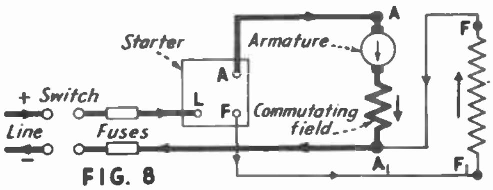


FIG. 8

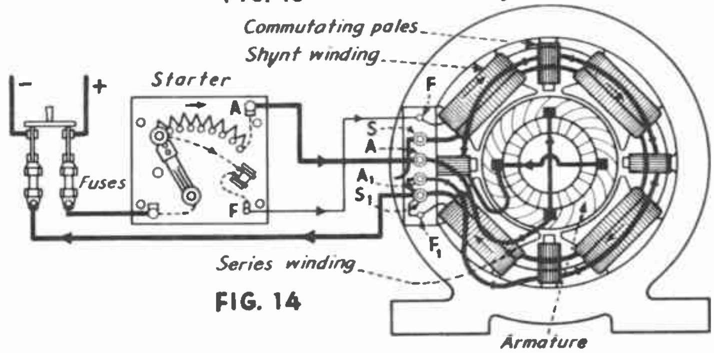


FIG. 14

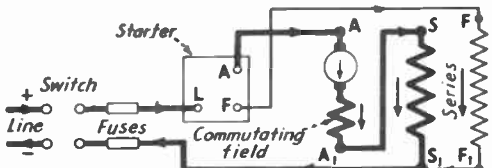


FIG. 9

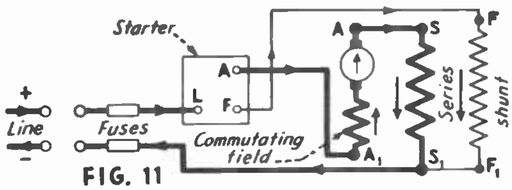


FIG. 11

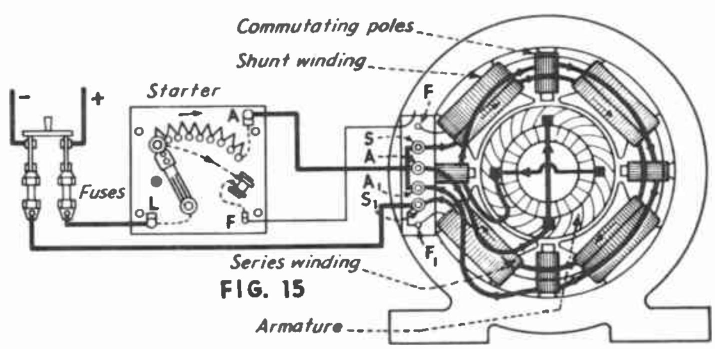


FIG. 15

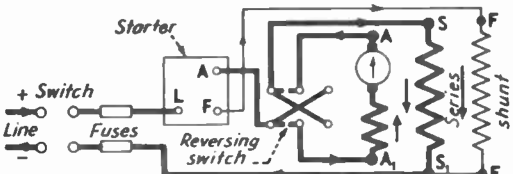
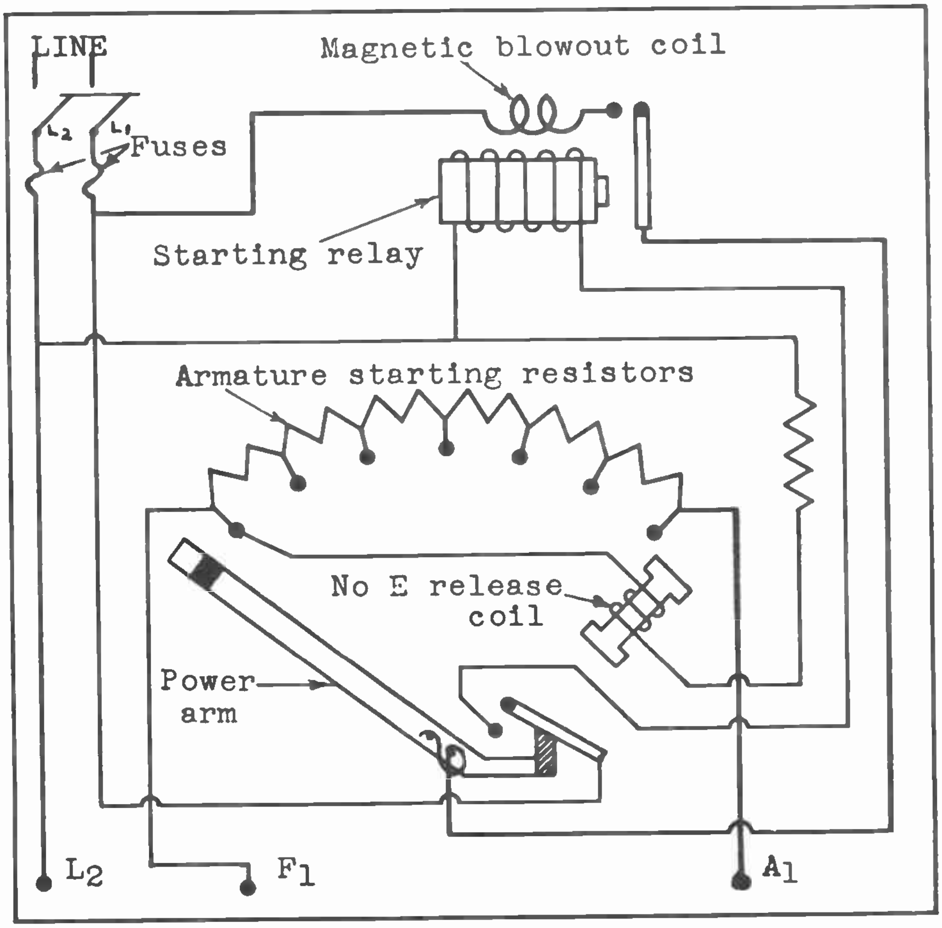


FIG. 12

Fig. 1—Diagram of shunt motor and starter, Fig. 2. Figs. 3 and 4—Symbols for coils. Figs. 4 and 5—Symbols for resistance. Fig. 6—Same as Fig. 1, but current reversed in armature circuits. Fig. 7—Wrong connection for reversing shunt motor. Fig. 8—Same as Fig. 1, except current is reversed in shunt field coils. Fig. 9—Diagram of compound motor and starter, Fig. 10. Fig. 12—Reversing switch connected in armature circuit of compound motor. Fig. 13—Reversing switch connected in armature circuit of shunt motor. Fig. 14—Series winding cut out of compound motor to test polarity of shunt-field coils. Fig. 15—Shunt winding cut out of compound motor to test polarity of series coils.

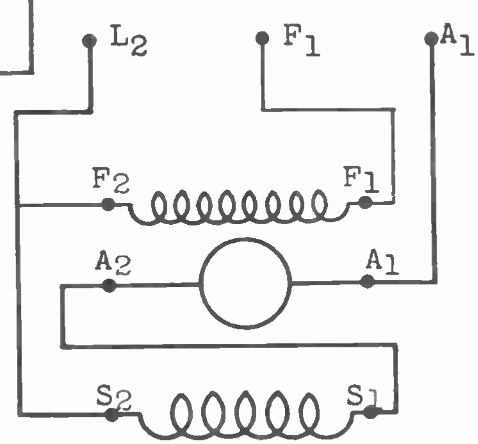
INDUSTRIAL CONTROLLER
Starting duty only



Draw a detailed diagram of the motor. Show all parts such as field poles, brushes, armature, terminals and the position of the terminal board. Test the motor terminals with test lamp to identify them.

Connect the motor to the controller as shown by the connection diagram. Trace the starting relay, field, armature and no E release coil circuits and have the diagram OKed by the instructor before wiring the job.

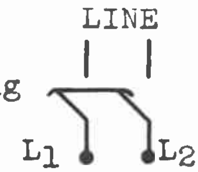
Connection Diagram



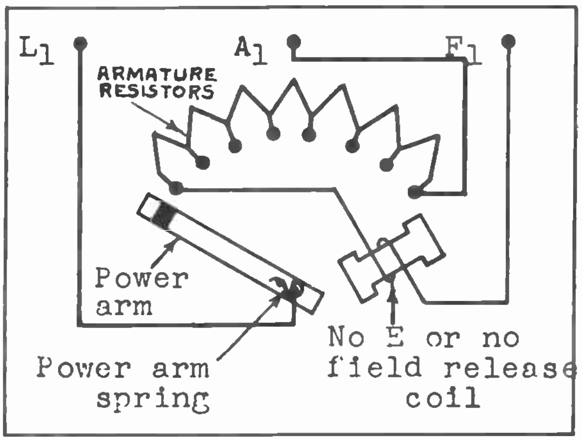
Connect as shown for compound motor.
For shunt motor connect A_2 to L_2

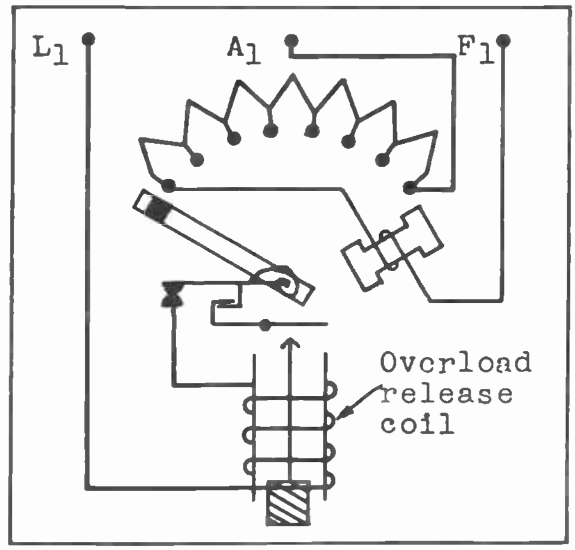
3 POINT STARTER DIAGRAMS

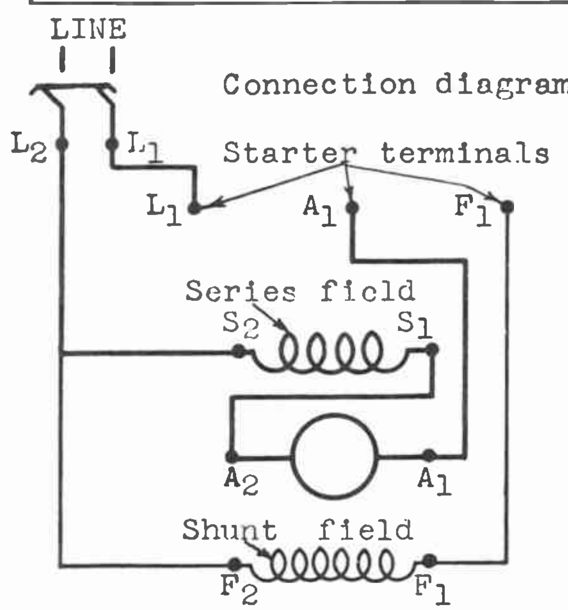
3 point starter for starting duty only.



3 point starter for starting duty only. The overload release coil protects the motor against overloads.





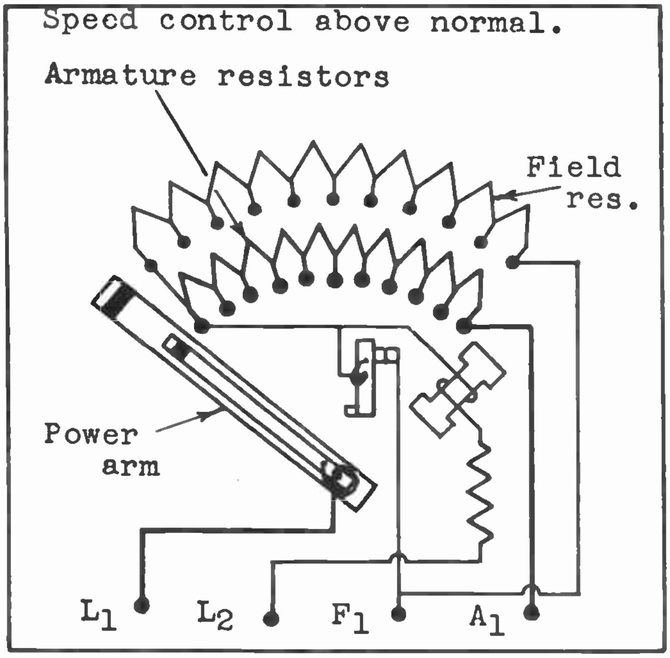


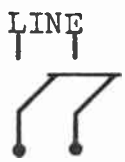
Connect as shown for compound motor.
For shunt motor connect A_2 to L_2.

Draw a detailed diagram of the motor. Show all parts such as field poles, brushes, armature, terminals and the position of the terminal board. Test the motor terminals with test lamp to identify them. Connect the motor to the starter as shown by the connection diagram.

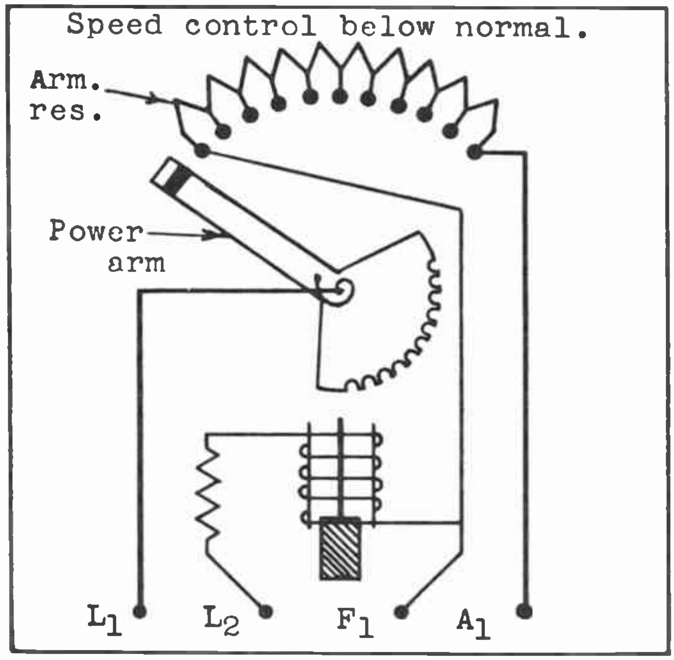
4 POINT CONTROLLERS

4 Point controller for starting & regulating duties.

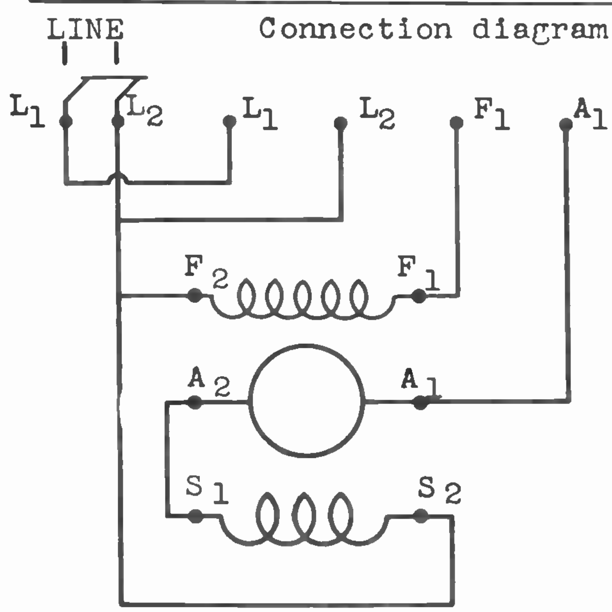




4 Point controller for starting & regulating duties.



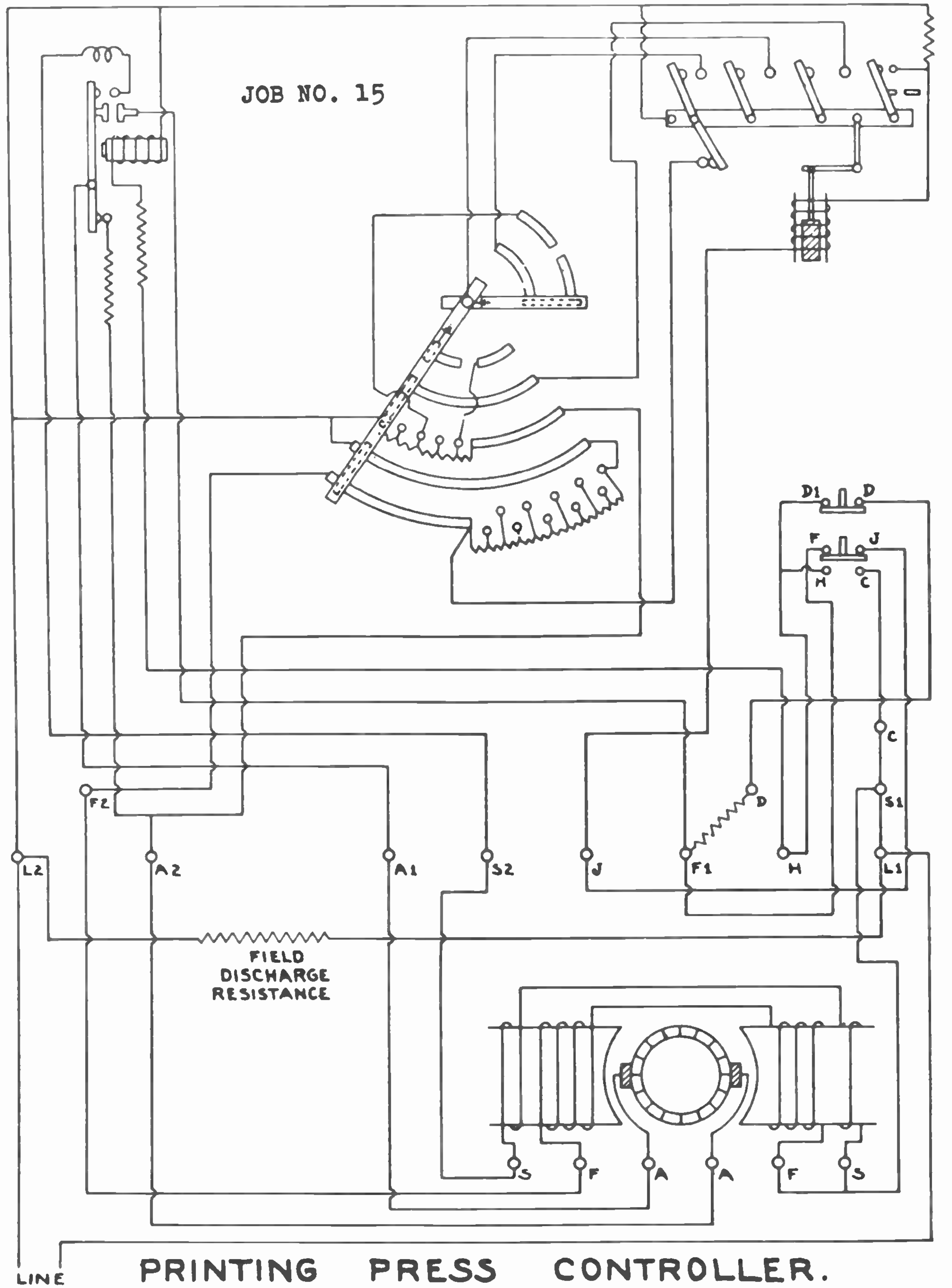
Connection diagram



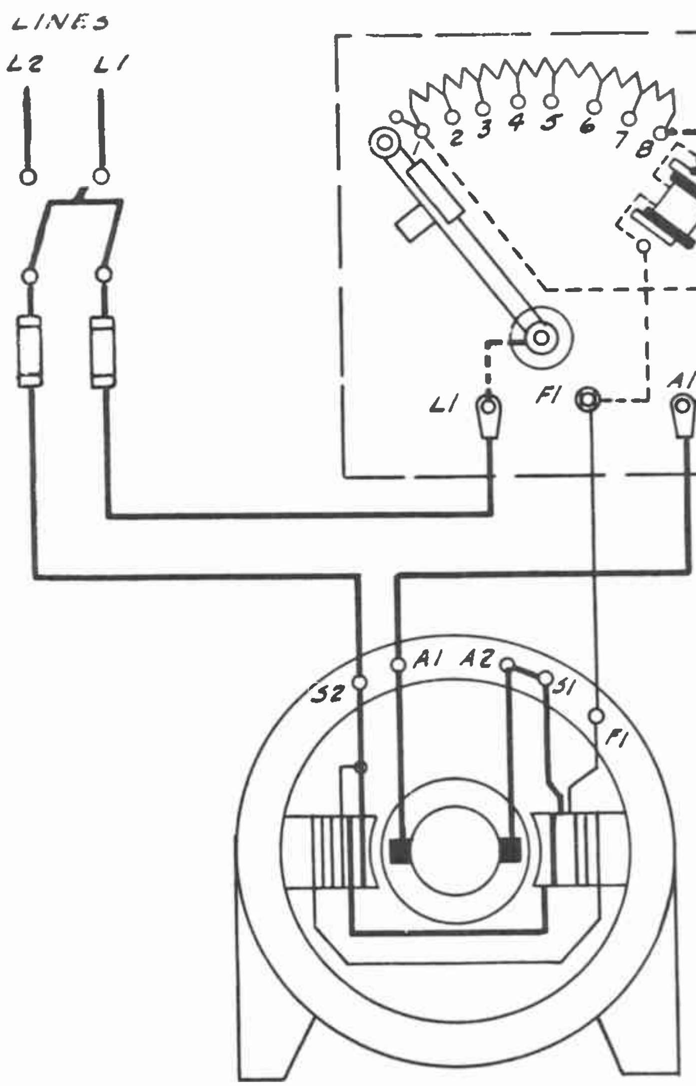
Connect as shown for compound motor. For shunt motor connect A_2 to L_2.

Draw diagram of motor in detail. Show all parts, such as, field poles, armature, brushes, terminal board and terminals. Test motor terminals to identify them. Trace armature, field and holding coil circuits. Have the diagram checked and OKed before wiring the job.

Coyne



PRINTING PRESS CONTROLLER.



IF MOTOR IS SHUNT WOUND
TERMINALS "S1" AND "S2"
WILL BECOME COMMON

TITLE CONNECTIONS FOR DIRECT CURRENT MOTOR STARTING RHEOSTAT WITH LOW VOLTAGE PROTECTION.

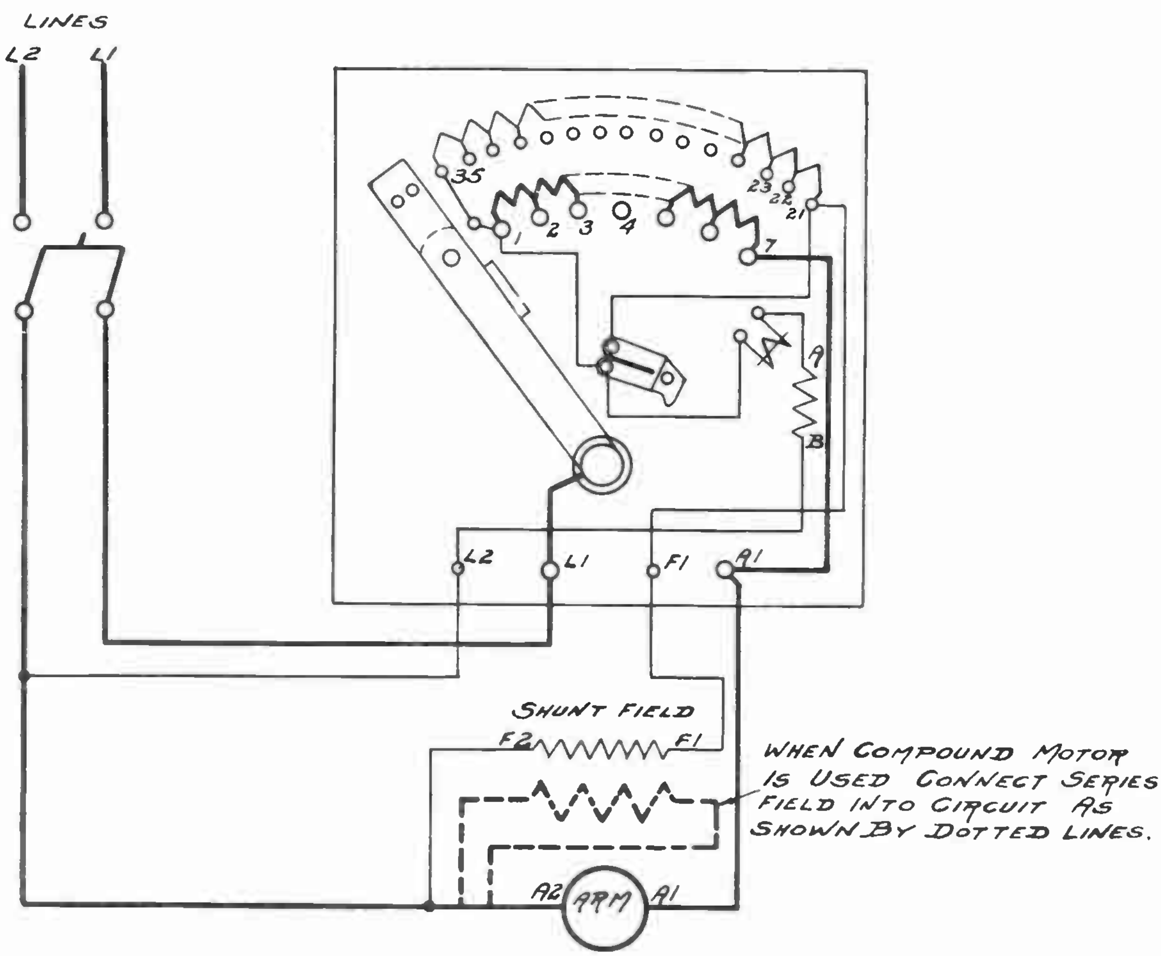
RETRACED BY	TRACED BY LEO. M. ZEMAN	TYPE "A"	SUP. NO
CHECKED BY	APPROVED BY	BULL NO 2110 & 2111	SUP BY NO.
A	B	C	D	ORDER NO STANDARD	19273D

CUTLER-HAMMER, INC. MILWAUKEE NEW YORK

ORIGINAL TRACING FILED WITH PATENT DRAWINGS

20311D

ORDER NO	NO. REQ'D	DEPARTMENT	RAW MAT. SPEC. WITH PART NO. & AMOUNT REQ'D



BULL. NO. 2230
CLASS NO. 74446
TYPE A

STANDARD ORDER NO.

CONNECTIONS FOR COMPOUND MOTOR STARTER WITH NO VOLTAGE

NAME: RELEASE FOR SHUNT OR COMPOUND MOTOR

FINISHED PART NO. | FINISH

SUPERSEDES NO: T14163-D

SUPERSEDED BY NO.

FIRST ASSEMBLY WHERE USED

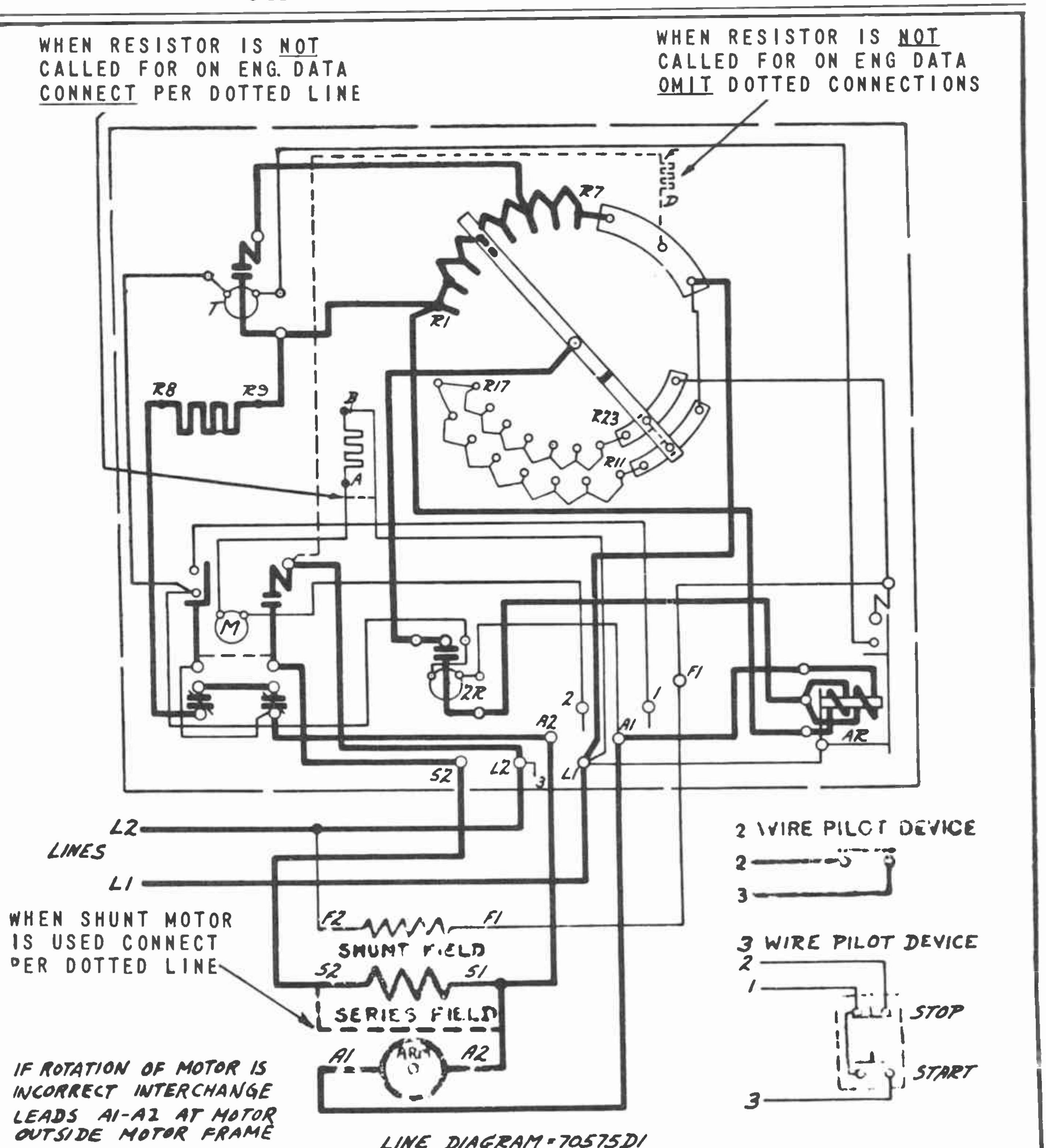
A			D			
B			E			
C			F			

SCALE | DRAWN BY | CHECKED BY: H.R. HUTH | APPROVED BY: H.R. HUTH

TOLERANCES ON ALL FRACTIONAL MACHINED DIMENSIONS TO BE ± .015
TOLERANCES ON ALL DECIMAL DIMENSIONS TO BE ± .005" UNLESS OTHERWISE SPECIFIED.

C-H THE CUTLER-HAMMER MFG. CO., MILWAUKEE, WIS.

20311D

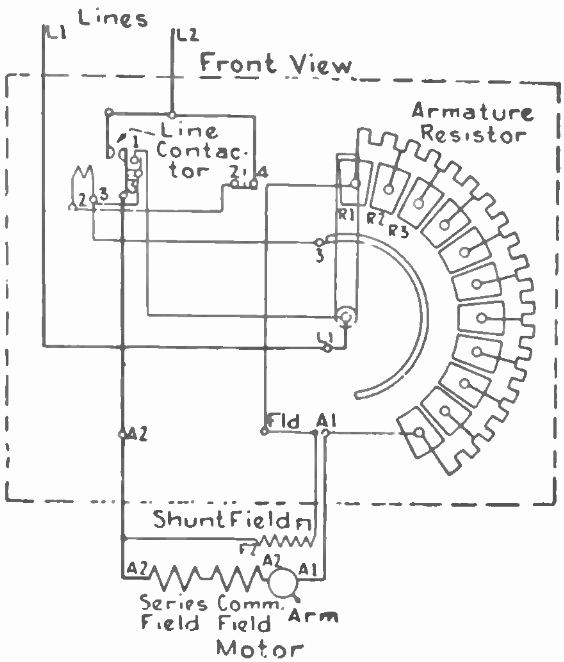


TITLE CONNECTIONS FOR D.C. SPEED REGULATOR.

DRAWN BY McMueller	TRACED BY McMueller	TYPE	SUP NO
CHECKED BY Feldhausen	APPROVED BY W. H. Roberts	BULL. NO	S.P. BY NO
A	B	C	D	ORDER NO A696719	70577D1

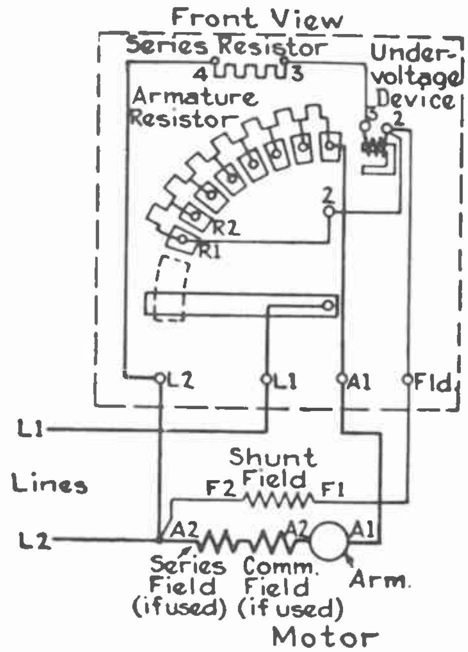
CUTLER-HAMMER, INC. MILWAUKEE NEW YORK

SPEED REGULATING RHEOSTATS



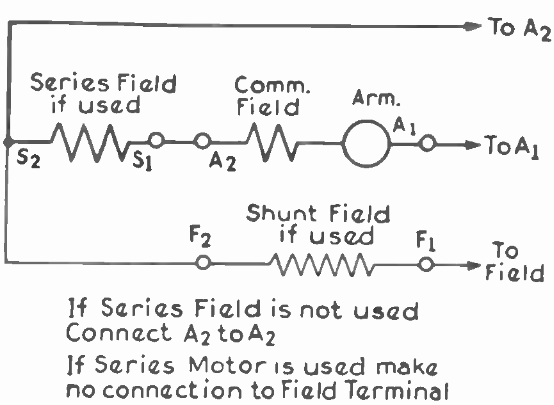
CR1220-B1 for shunt- or compound-wound motors (with contactor)

GENERAL ELECTRIC



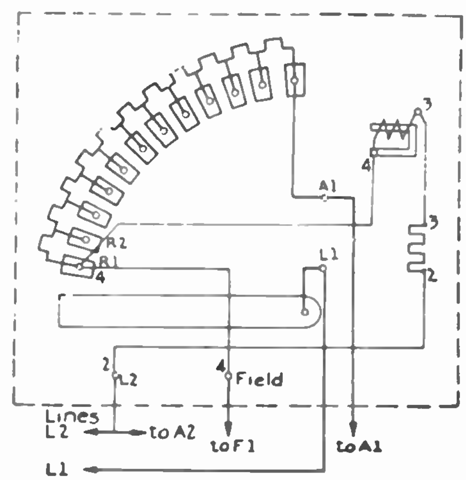
CR1224-B1 for shunt- or compound-wound motors (without contactor)

STARTING RHEOSTAT



Motor connections

GENERAL ELECTRIC CR 1003

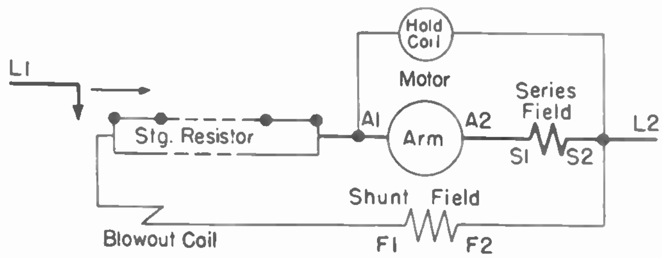


For small d-c motors
115 and 230 volts

RHEOSTAT CONTROLS FOR D-C MOTORS WESTINGHOUSE

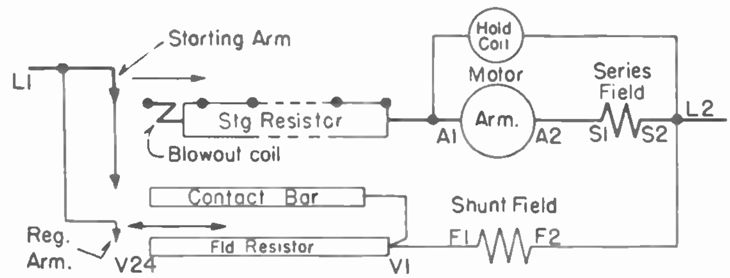
7010 Starting only. For series, shunt, or compound wound motors.
7210 Starting and regulating. Increase only. Shunt wound motors only.
7310 Starting and regulating. Reduction only. Series, shunt, or compound.
7350 Starting and regulating. Increase or reduction. Shunt wound only.

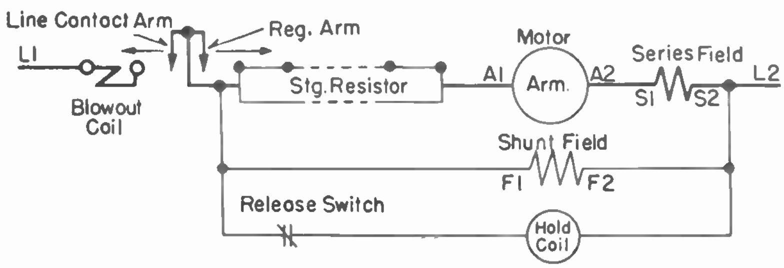
WIRING DIAGRAMS



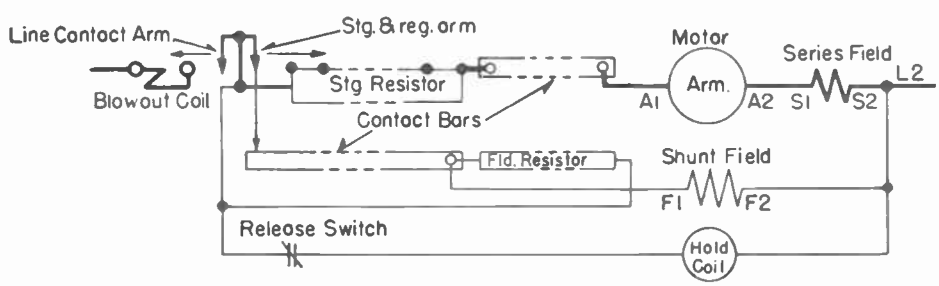
Class 7010 Rheostat

Class 7210 Rheostat





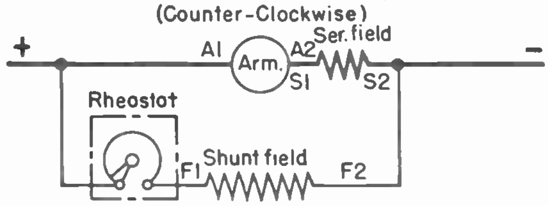
Class 7310 Rheostat



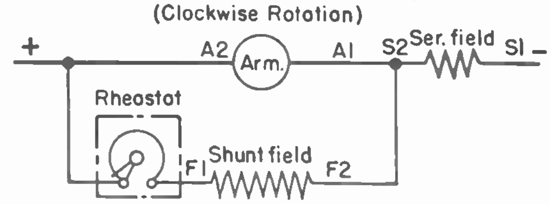
Class 7350 Rheostat

D-C FIELD RHEOSTAT CONNECTIONS

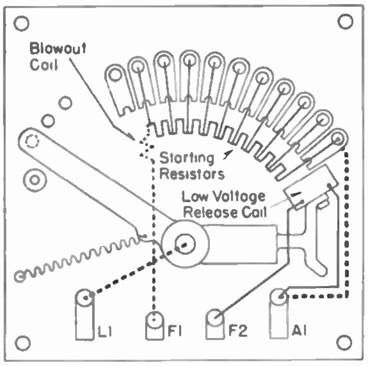
MOTOR CONNECTIONS
(Counter-Clockwise)



GENERATOR CONNECTIONS
(Clockwise Rotation)



CLASS 7010 RHEOSTATS—Starting Duty Only



OPERATION

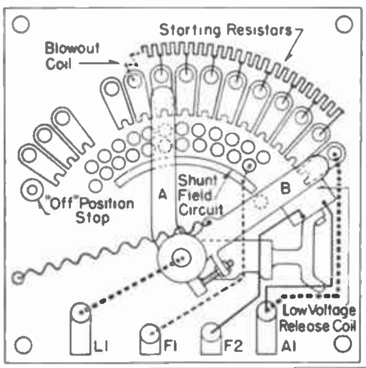
Start by slowly moving handle to right to run position—resistors progressively cut-out until motor is at full speed. Arm is held by magnet. To stop—return handle to "off".

RATINGS AND DIMENSIONS—CLASS 7010

MAXIMUM HORSEPOWER				FRAME SIZE	OVERALL DIMENSIONS, INCHES†		
32 VOLTS	115 VOLTS	230 VOLTS	440-550 VOLTS		WIDTH	HEIGHT	DEPTH
..	½	½	...	0	4 3/4	4 3/4	3 3/4
..	2	3	...	1	7 7/16	8 7/8	8
1	3	7½	7½	2	12	14¼	11 5/16
2	10	25	20	3A	16½	19 7/8	14 3/16
5	25	50	...	4A	20½	23 7/8	14 1/[illegible]
..	..	...	50	4B	20½	23 7/8	17 11/16
..	75	150	150	5	27½	34 7/8	21½

†If Heavy Duty NEMA Class 135 Resistors are supplied for Ratings 1-50 Hp., 230 Volts these dimensions may be exceeded.

CLASS 7210 RHEOSTATS—Starting and Regulating Duty • Field Control



OPERATION

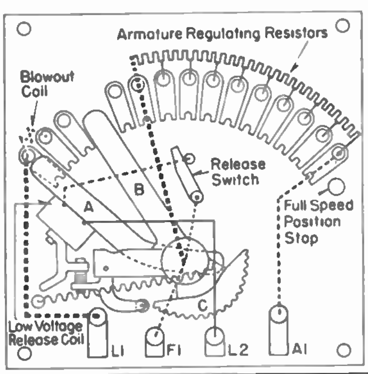
Started and brought to base speed same as 7010. To increase speed, move handle to left which moves arm A and cuts in field resistors—connected to round buttons. Maximum speed. controlled by adjustment C. To stop return handle to "off".

RATINGS AND DIMENSIONS—CLASS 7210

MAXIMUM HORSEPOWER		FRAME SIZE	OVERALL DIMENSIONS, INCHES		
115 VOLTS	230 VOLTS		WIDTH	HEIGHT	DEPTH
10	25	3B	16½	19 7/8	16 9/16
25	50	4B	20½	23 7/8	17 11/32
75	150	5A	27½	42 7/8*	21½

*Includes externally mounted Type WL Rheostat.

CLASS 7310 RHEOSTATS—Regulating Duty • Armature Control



OPERATION

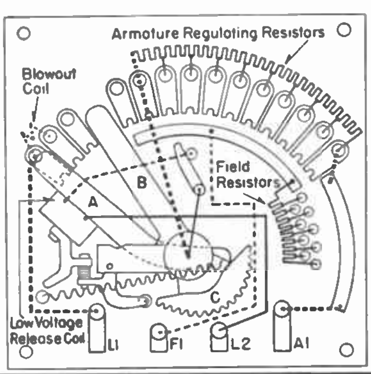
Start by moving handle to left, which pushes arm A to left-hand contact where it is held by magnet. To increase speed—move handle to right to cut out armature resistors. Arm held by pawl and rachet C. To stop—return handle to "off".

RATINGS AND DIMENSIONS—CLASS 7310

MAXIMUM HORSEPOWER			FRAME SIZE	OVERALL DIMENSIONS, INCHES		
115 VOLT	230 VOLT	440-550 VOLT		WIDTH	HEIGHT	DEPTH
2	2	2	3A	16½	19 7/8	14 3/16
10	10	5	3C†	16½	17 3/8	17 5/8
..	20	...	3E	18 5/8	23½	20¼
25	40	...	4D	18 5/8	23½	28 7/8
40	75	...	5	27½	34 7/8	21½

* Slightly larger for constant torque.

CLASS 7350 RHEOSTATS—Regulating Duty • Armature and Field Control



OPERATION

Same as above, except after maximum base speed is reached, further movement of handle to right will move arm B to cut in field resistors for greater speed increase. Arm held by pawl and rachet C. To stop, return handle to "off".

RATINGS AND DIMENSIONS—CLASS 7350

MAXIMUM HORSEPOWER			FRAME SIZE	OVERALL DIMENSIONS, INCHES		
115 VOLTS	230 VOLTS	440-550 VOLTS		WIDTH	HEIGHT	DEPTH
2	2	2	3B	16½	19 7/8	16 9/16
10	10	5	3D*	16½	17 3/8	20 3/16
..	20	...	3E	18 5/8	23½	20¼

* Slightly larger for Constant torque.

Direct-Current Control Circuits

Ease in shooting trouble on d.c. controls depends largely on a clear understanding of the basic principles and circuits used. It is the purpose of these data sheets to give that information.

In general, d.c. motors of less than 2-hp. rating can be started across the line, but with larger motors it is usually necessary to put resistance in series with the armature when it is connected to the line. This resistance, which reduces the initial starting current to a point where the motor can commutate successfully, is shorted out in steps as the motor comes up to speed and the countervoltage generated is sufficient to limit the current peaks to a suitable value. Accelerating contactors that short out successive steps of starting resistance may be controlled by countervoltage or by definite-time relays.

For small motors used on auxiliary devices the counter-c.m.f. starter is satisfactory. The definite time starter is more widely used, however, and has the advantage of being independent of load conditions.

The following diagrams illustrate some of the circuits commonly used for d.c. motor control.

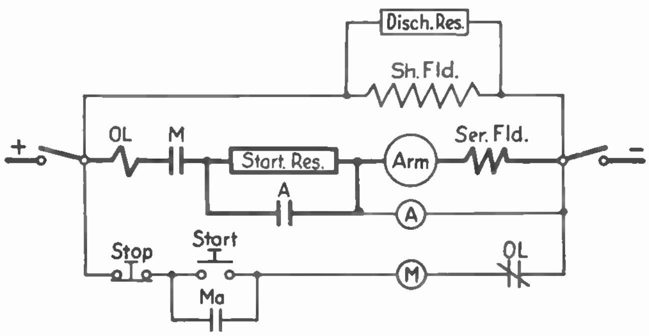


Figure 1. Basic requirements of a non-reversing d.c. starter in its simplest form.

When the start pushbutton is depressed line contactor *M* closes, energizing the motor armature through the starting resistance. As the motor comes up to speed the countervoltage, and the voltage across motor armature and series field, increases. At a predetermined value the accelerating contactor A closes, shorting out the starting resistance.

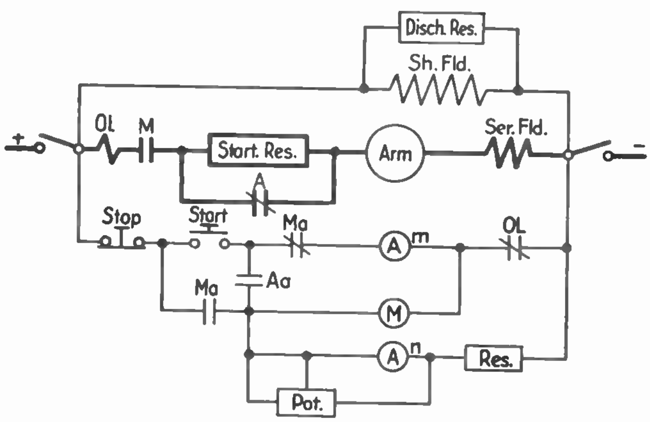


Figure 2. Typical, non-reversing constant-speed, definite-time starter. The accelerating contactor is equipped with a time-delay mechanism. This contactor, A, is of the magnetic-flux-decay type. It is spring-closed, equipped with two coils, and has a magnetic circuit that retains enough magnetism to hold the contactor armature closed and the contact open indefinitely. Main coil *Am* has sufficient pull to pick up the armature and produce permanent magnetization. Neutralizing coil *An* is connected for polarity opposite to the main coil. It is not strong enough to affect the pick-up or holding ability of the main coil but, when the latter is deenergized, the neutralizing coil will buck the residual magnetism so that the contactor armature is released by the spring and the contacts close. By adjusting the potentiometer the voltage impressed on this coil and hence the time required for the contactor to drop out can be varied. When the start button is depressed accelerating contactor coil *Am* is energized, causing contact *A* to open and auxiliary contact *Aa* to close. Contact *Aa* energizes line contactor *M*, and normally open auxiliary contacts *Ma* establish a holding circuit. Neutralizing coil *An* is also energized. Opening of contact *Ma* deenergizes coil *Am* and contactor *A* starts timing. At the set time the main normally closed contacts on *A* close, shorting out the starting resistance and putting the motor across the line.

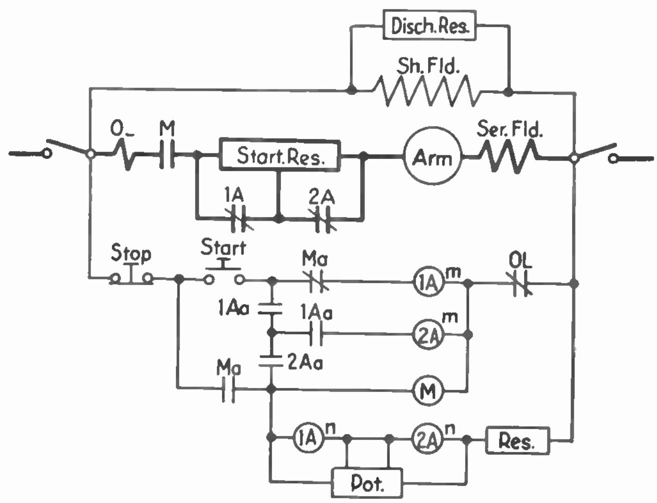


Figure 3. The same kind of a starter as in Figure 2 but designed for use with a motor of larger horsepower.

This starter provides two steps of definite-time starting. The operation is essentially the same as in Figure 2 but the first accelerating contactor, *1A*, does not short out all the starting resistance. It also starts *2A* timing, which finally shorts out the remaining resistance. The normally open auxiliary contacts on the accelerating contactors in Figures 2 and 3 are arranged so that it is necessary for the accelerators to pick up before the line contactor can be energized. This is a safety interlocking scheme that prevents starting the motor across the line, if the accelerating contactors are not functioning properly.

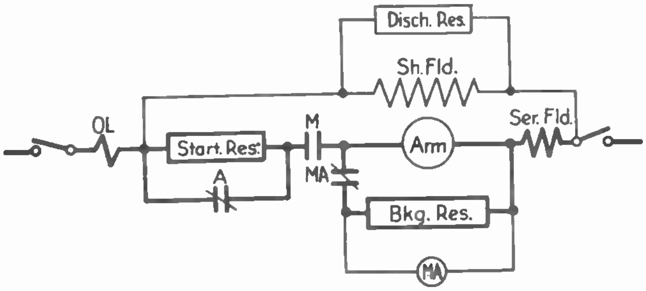


Figure 4. One way of producing dynamic braking.

Control circuits have been omitted, since they are a duplicate of those shown in Figures 2 and 3. Line contactor *M* has two poles, one normally open and the other normally closed. Both poles are equipped with an operating coil and are on the same armature, which is hinged between the contacts. In starting, when line contactor *M* closes normally closed contact *MA* opens. When the stop button is depressed the line contactor drops out and contact *MA* closes. The motor, now acting as a generator, is connected to the braking resistor and coil *MA* is energized by the resultant voltage. It causes *M* to seal in tightly, establishing good contact pressure and preventing this contact from bouncing open.

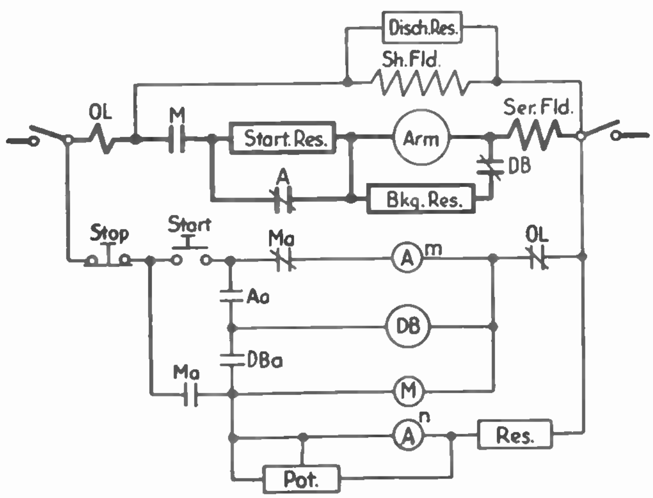


Figure 5. In the more modern types of controllers a separate spring-closed contactor is used for dynamic braking.

Operation is similar to that described for Figure 2, except that the energizing of coil *Am* and the picking up of accelerating contactor *A*, closing contact *Aa*, energizes dynamic braking contactor *DB*, which in turn energizes line contactor *M* through its auxiliary contact, *DBa*. This arrangement not only insures that the dynamic braking contactor is open, but also that it is open before the line contactor can close. In order to obtain accurate inching, such as is required for most machine tool drives, the motor must respond instantly to the operation of the pushbutton. In the scheme shown in Figure 5 the closing of the line contactor is delayed until the accelerating contactor and the dynamic braking contactor pick up.

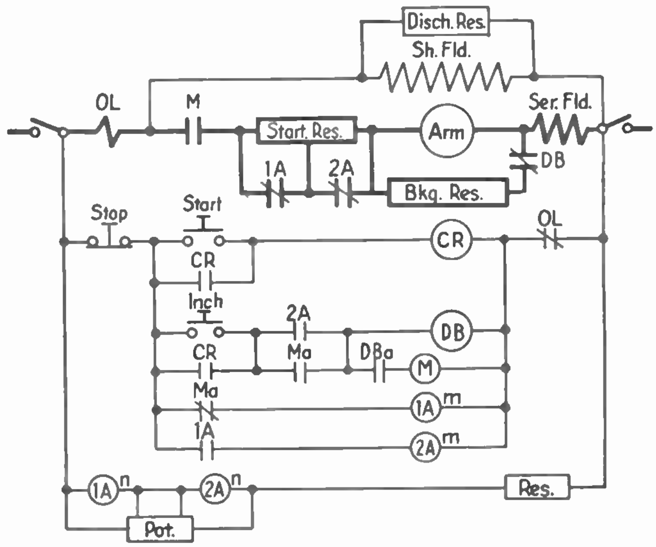


Figure 6. Arrangement to secure quicker response of motor, for more accurate inching.

Accelerating contactors *1A* and *2A* are energized in the off position. Hence, when the start button is depressed, the dynamic braking contactor picks up immediately and its auxiliary contact *DBa* picks up *M* line contactor.

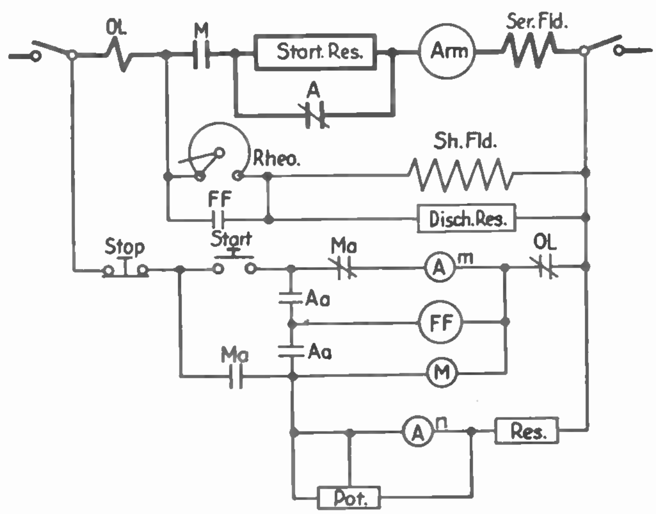


Figure 7. One method of connecting full field relay, used with adjustable-speed motors having a speed range in excess of 2 to 1. Coil *FF* is energized by the closing of the normally open auxiliary contact Aa and remains closed until the last accelerating contactor drops out. Contacts of the full field relay, *FF*, are connected to short out the field rheostat thereby applying maximum field strength to the motor during the starting period.

Direct-Current Control Circuits

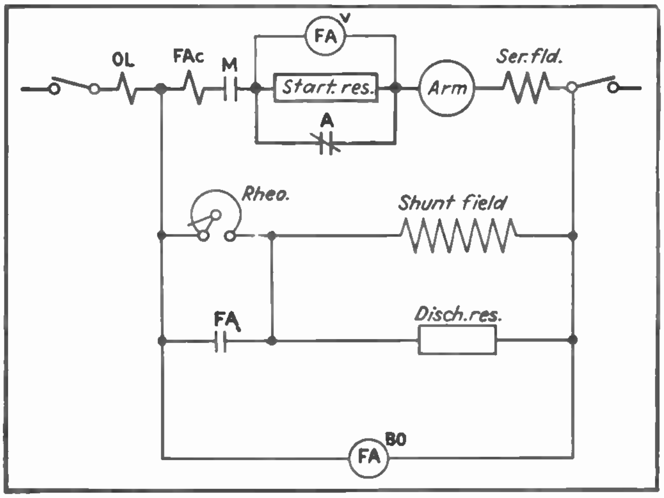
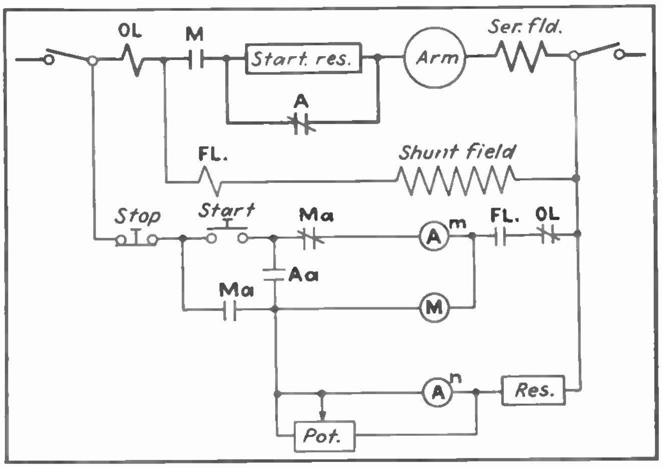


Figure 8. Another method of applying the full-field relay.

This arrangement insures full field on starting, and provides for limiting the armature current when the motor is accelerating from the full-field speed to the speed set by the rheostat. Field accelerating relay *FA* is equipped with two coils, one a voltage coil connected across the starting resistance, the other a current coil connected in series with the motor armature. See Figure 2 for the remainder of the circuit. When line contactor *M* closes the voltage drop across the starting resistor is practically line voltage, and relay *FA* is picked up quickly. When accelerating contactor *A* closes, voltage coil *FAv* is shorted, but closing of *A* produces a second current peak, and current coil *FAc* holds relay *FA* closed. As motor approaches full-field speed this current decays and allows the *FA* contacts to open, weakening the motor field. When the motor attempts to accelerate the line current again increases. If it exceeds the pick-up value of coil *FAc* the relay will close its contacts, arresting acceleration and causing a decay of line current, which again causes *FA* to drop out. High inductance of the motor field, plus inertia of the motor and drive prevent rapid changes in speed. Hence the motor will not reduce its speed, but the increased field current will reduce the armature current and cause *FA* to drop out. The fluttering action will continue until the motor reaches the speed set by the rheostat. Setting of the *FA* relay current coil determines the maximum current draw during this part of the acceleration period. Since relay *FA* must handle the highly inductive field circuit, a good blowout arrangement is necessary. Hence the relay is usually equipped with a shunt blowout coil, *FAbo*.

Figure 9. Connections of field loss relay, to prevent excessive speed if the shunt field is deenergized while voltage remains on the armature.

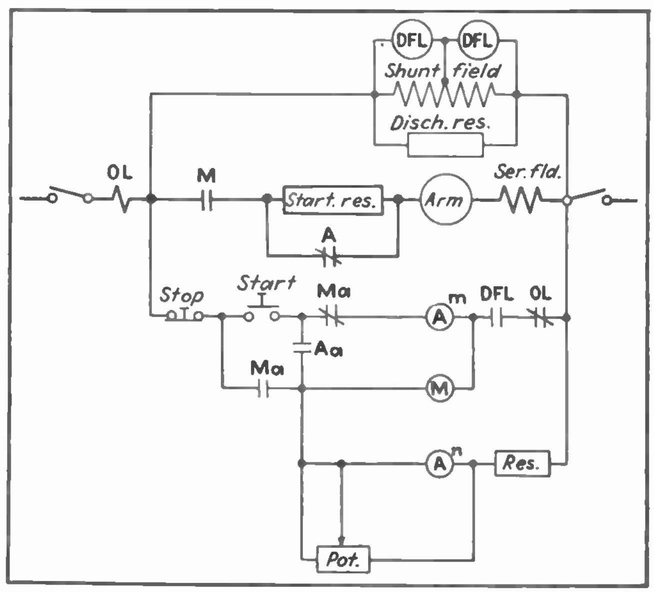
It usually consists of a current relay in series with the motor shunt field and is adjusted to pick up on full-field current and remain closed at any current within the operating range of the motor field current. Contacts of relay *FL* are connected in series with the overload relay contacts so that the opening of its contacts will deenergize the control by opening the line contactor. This type of field loss protection does not protect against the possibility of a short



circuit across a part of the field, say across the one field coil. This would cause the motor speed to rise considerably but the current in the field circuit would also rise. Consequently, the series current relay would not respond.

Figure 10. Application of differential field loss protection.

The differential field loss relay *DFL* is equipped with two voltage coils connected to buck each other. Each is connected across one-half of the field winding. Normally the voltage across each coil is the same, hence the relay stays in the out position with its normally closed contacts closed. Shorting out of one field coil or other failure causing an un-



Direct-Current Control Circuits

balance of these voltages causes the relay to pick up, opening its contacts and dropping out the line contactor, deenergizing the motor.

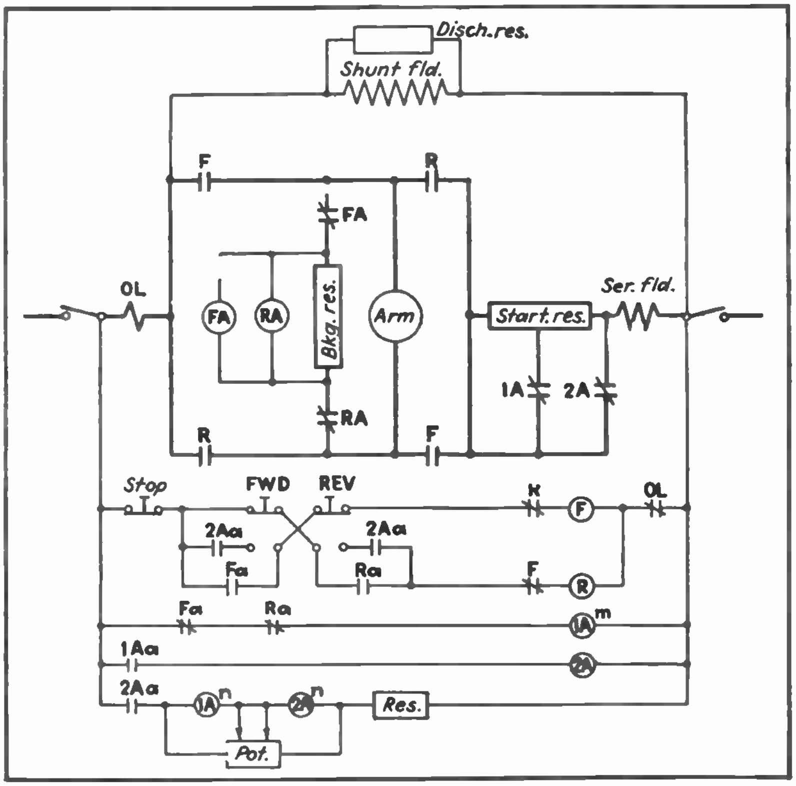


Figure 11. One form of reversing dynamic braking control, consisting of multi-pole contactors having two poles normally open and one pole normally closed. Accelerating contactors 1A and 2A are energized in the off position, as in Figure 6. Depressing the forward button energizes forward contactor F, closing the two normally open contacts F and opening the normally closed contact FA. Opening of normally closed auxiliary contact Fa starts the timing cycle of the accelerating contactors. Closing of the normally open auxiliary contact Fa establishes a holding circuit. When the stop or reverse button is depressed contactor F drops out, closing normally closed contact FA and setting up a dynamic braking circuit through the braking resistors, which energizes coils FA and RA. These coils hold the normally closed contact closed, and the normally open contacts open until the braking current drops to a low value. This action prevents bouncing of the back contacts and plugging the motor, because if the reverse button were depressed during the braking period contactor coil R would not have sufficient strength to overcome the pull of the RA coil until the motor had almost stopped.

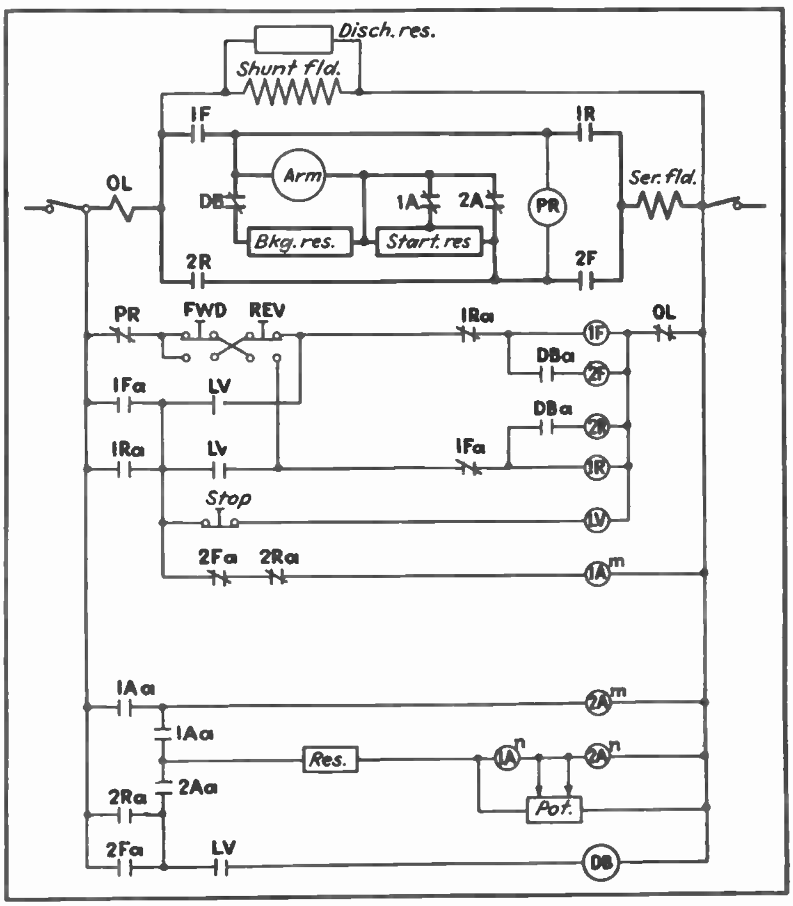


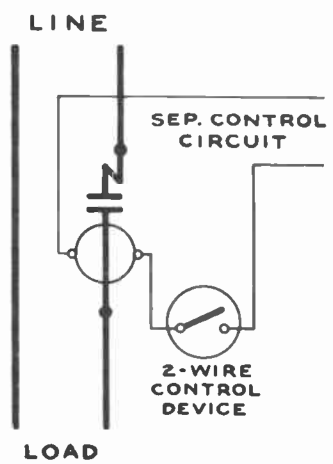
Figure 12. Another form of reversing dynamic braking starter using a spring-closed dynamic braking contactor and single-pole normally open directional contactors. When start button is depressed contactor *IF* is energized. Closing the normally open auxiliary contact *IFa* energizes relay *LV* to establish a holding circuit and also energizes accelerating contact *1A*; *1A* contactor energizes *2A*, and *2A* energizes *DB*. In turn, *DBa* energizes *2F* and normally closed contact *2Fa* starts the accelerating timing.

Depressing the stop button drops out *LV*, closing *DB* immediately. Plugging is prevented by relay *PR*, a voltage relay connected across the motor armature. Its normally closed contacts remain open, preventing the pick up of the reverse directional contacts until the armature speed drops down to a safe value for plugging.

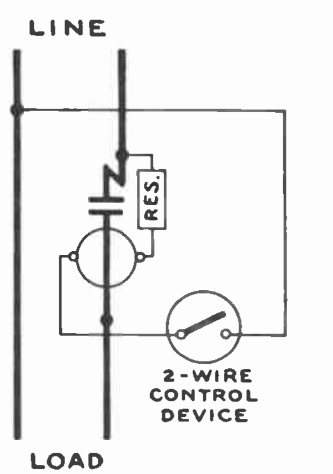
WIRING DIAGRAMS

D. C. MAGNETIC RELAYS AND LINE VOLTAGE STARTERS — CLASSES 7001, 7032

Class 7001



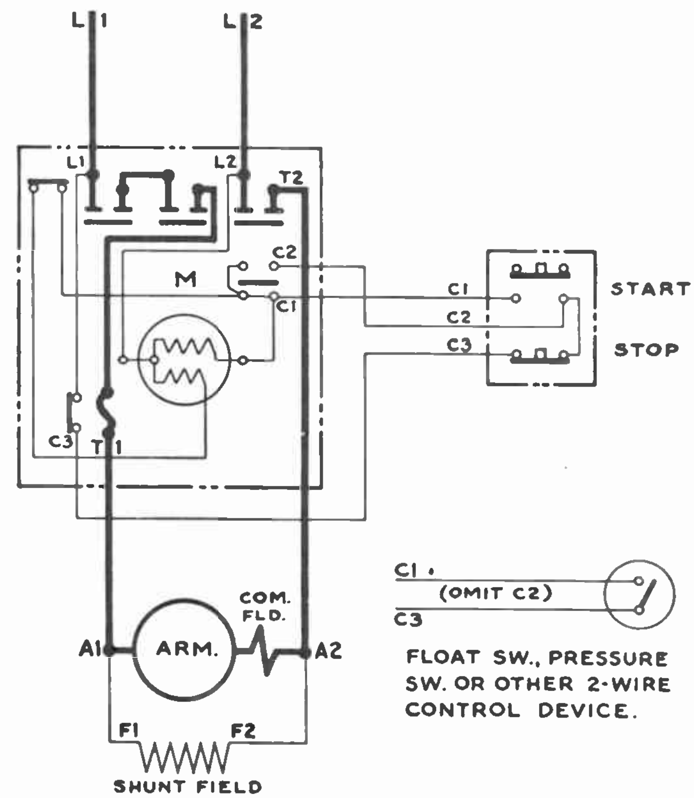
TYPE J-30



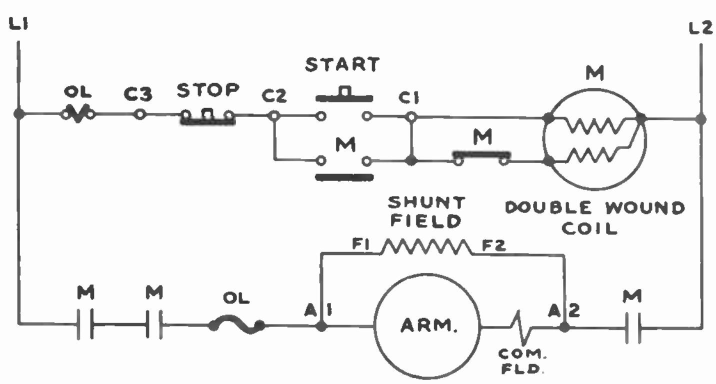
TYPE J-31

NOTE: CLASS 7001 - TYPE K RELAYS ARE WIRED THE SAME AS CLASS 8501 TYPE K. SEE CLASS 8501 WIRING DIAGRAMS.

Class 7032

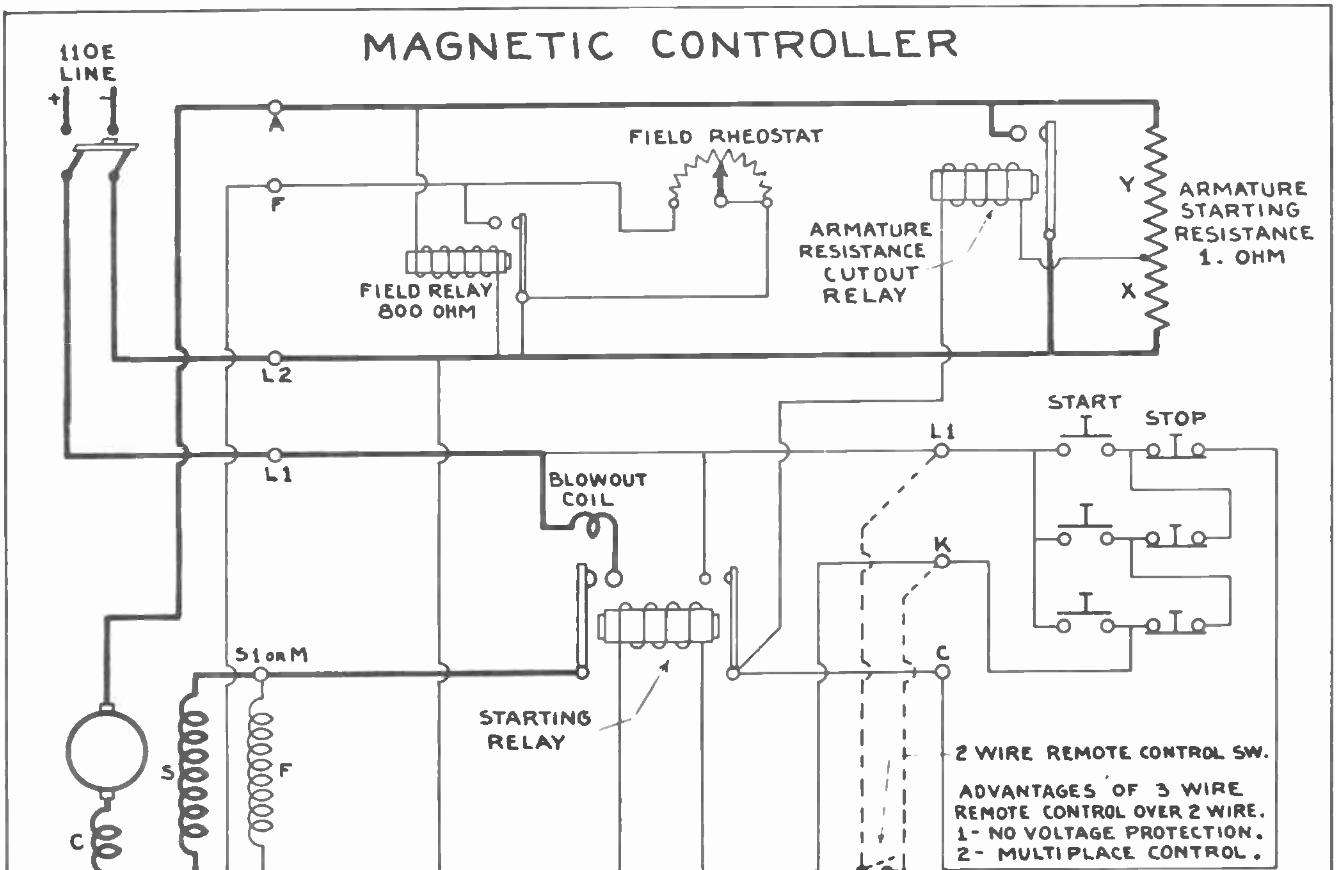


CLASS 7032 TYPE S-2
D.C. LINE VOLTAGE STARTER



ON GROUNDED SYSTEMS, L2 IS GROUNDED LINE.

1748-C12



The term "magnetic controller" is commonly used to apply to controllers on which the operation depends almost entirely on relays. Controllers of this type have a number of separate circuits, each operated by a relay switch.

These controllers are used extensively on large industrial motors, steel mill motors, and elevator motors. They can be designed to give any desired operation.

Example: Let us assume we start a 110E, 40I, 5 h.p. motor without a load.

Starting current equals $1\frac{1}{2}$ x 40I or 60I.

Armature starting resistance equals 1 ohm.

Voltage drop across arm. starting res. equals 60I x 1R=60Ed.

Voltage drop across section of res. marked "X" equals 1/3 of Ed across entire res. or 20Ed.

Therefore, the voltage applied to the armature resistance cut-out relay when starting, equals 110E — 20Ed or 90 volts. This relay is adjusted so that it will not close its switch until it receives approximately full line voltage. The voltage across the relay increases as the current through "Y" + "X" decreases. Current flow will decrease to approximately 6I, because of C.E.M.F. built up in the motor as it increases in speed. This may be proven by the following figures:

Total voltage drop across "Y" + "X" after motor attains normal speed equals 6I x 1R=6Ed.

Now the voltage drop across "X" will be 1/3 of 6 or 2Ed, leaving 110 minus 2 or 108E to operate the armature res. cut-out relay. This voltage is high enough to operate the relay and close its switch, which cuts out or shunts the armature starting resistance.

The field relay closes when starting to give full strength field. When the armature res. cut-out relay closes, the field relay is shorted out of the circuit. This allows the speed to be controlled above normal by adjusting the shunt field rheostat.

MAGNETIC REDUCED VOLTAGE STARTER ALLIS CHALMERS TYPE 5926

Application

The type 5926 starters are used for starting constant or adjustable speed d-c motors in machine tool or general purpose applications where occasional inching or jogging may be required. They are also applicable to other heavy duty and special service drives such as fans, blowers, pumps, compressors, etc. They are of the magnetic reduced voltage type—the motor is accelerated up to normal speed by cutting successive steps of resistor out of the armature circuit by magnetic contactors.

Jogging is accomplished in the standard starter by the use of a push button station with pigtail and jogging attachment. The NEMA definition of jogging is: "Jogging or inching is the quickly repeated closure of the circuit to start a motor from rest for the purpose of accomplishing small movements of the driven machine."

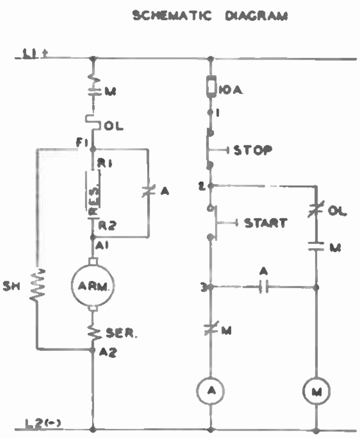
Class 135 resistors are used and the operator may jog the equipment for a total of ten seconds out of each 80 seconds. This may consist of a number of short jogging periods or a smaller number of longer jogging periods, providing the total does not exceed 10 seconds out of each 80 seconds.

These starters cannot be held closed against an overload since the reset mechanism opens the main contactor coil circuit and protects the motor from injury.

Construction

The type 5926 starters are furnished for either 115, 230 or 550 volts d-c operation and consist of standard contactors and relays mounted on compound bases, all enclosed in NEMA Type I general purpose cases. Heavy duty Allis-Chalmers type D and E magnetic contactors are used.

Each starter contains a line contactor, magnetic time delay accelerating contactors, a thermal overload relay, and a set of class 135 resistors in an enclosure.

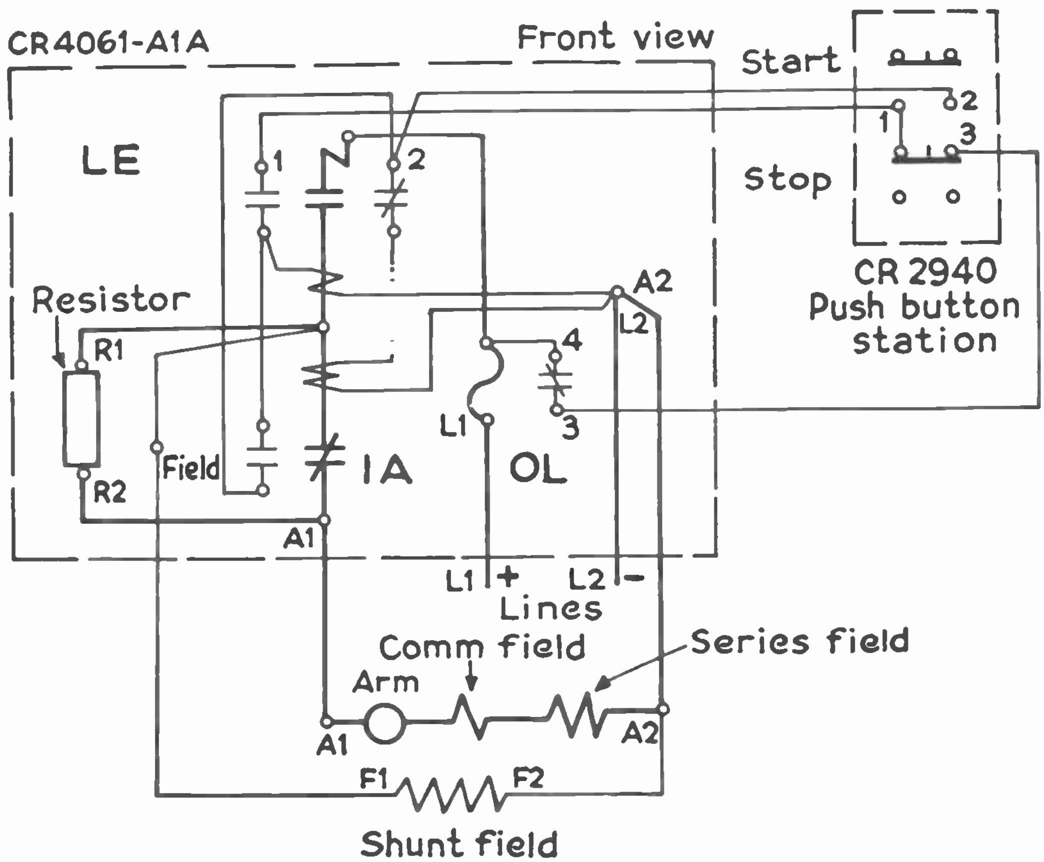


Schematic diagram of typical Type 5926 starter

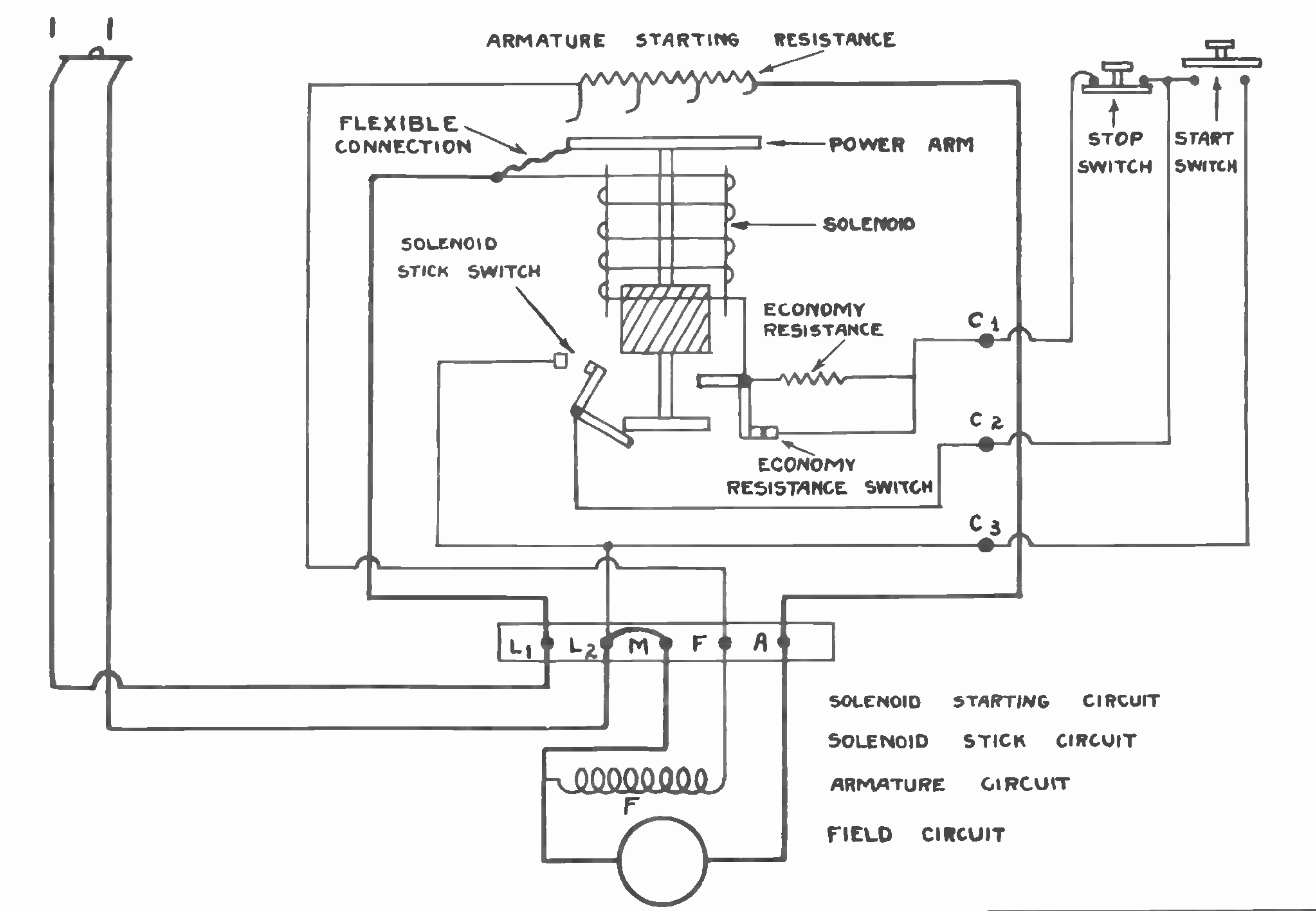
MAGNETIC CONTROLLER

Reduced voltage starting.

GENERAL ELECTRIC CR 4061



SOLENOID STARTER

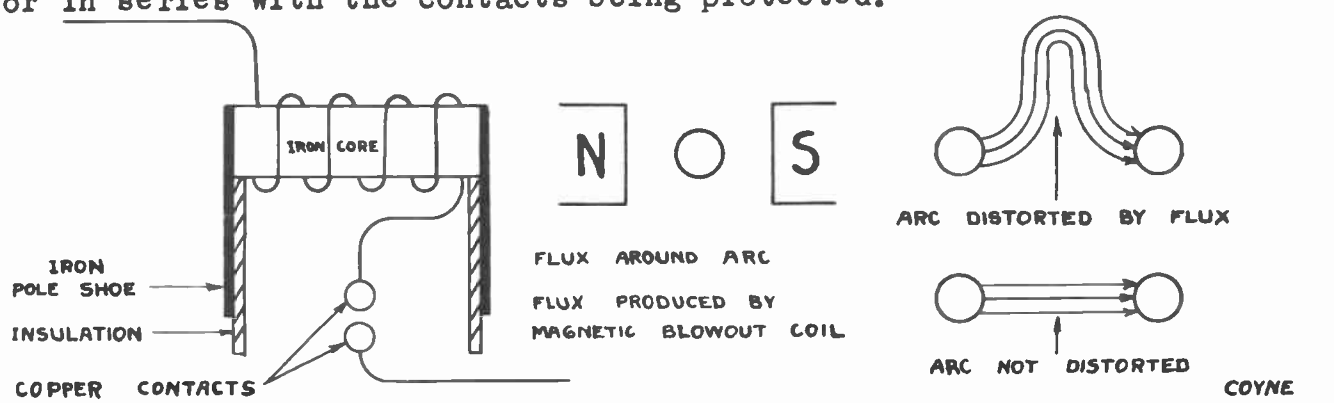


MAGNETIC BLOWOUT COIL

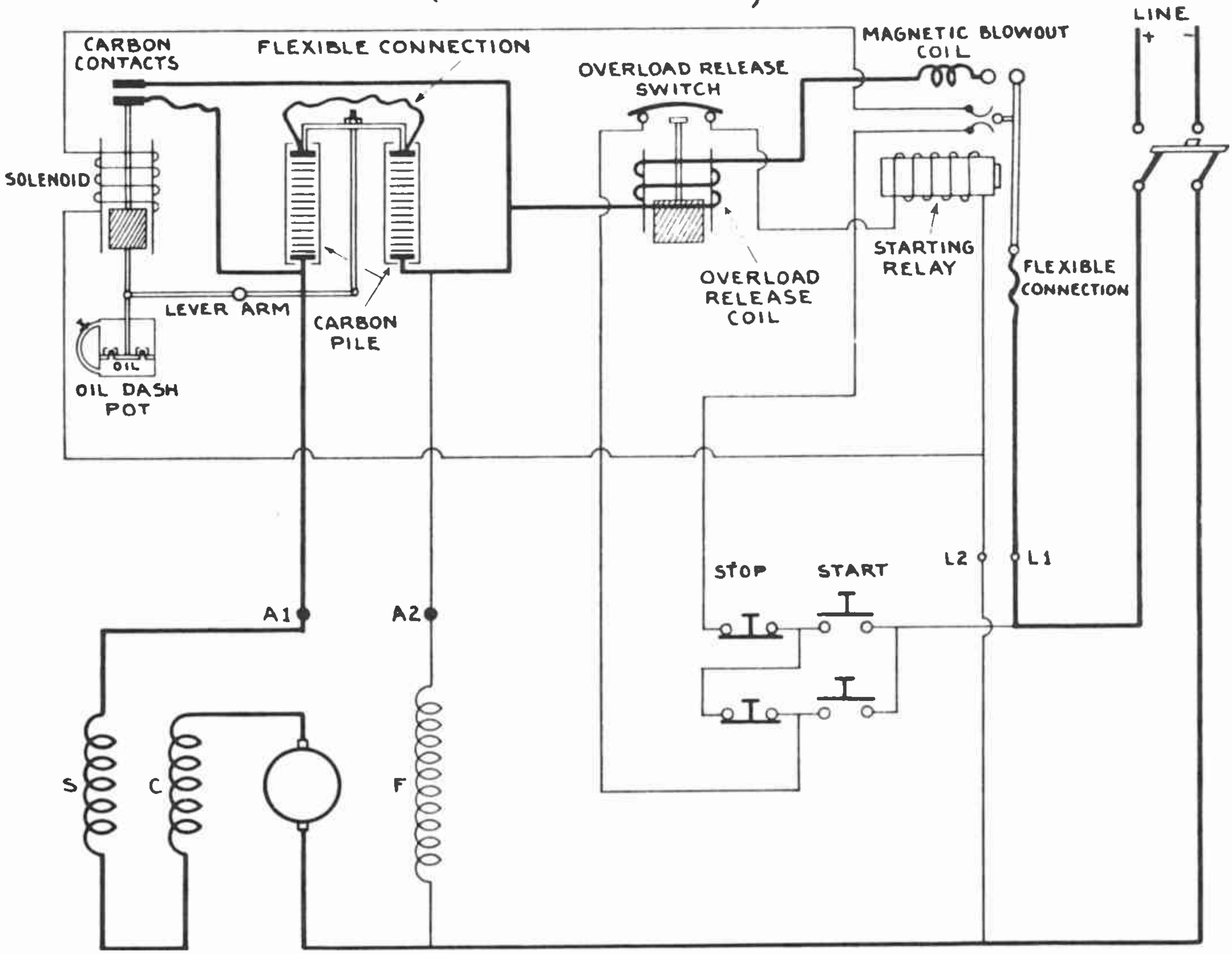
A magnetic blowout coil is for the purpose of providing a strong magnetic field to extinguish the arc drawn when the circuit is broken. It consists of a few turns of heavy wire wound on an iron core which has its poles placed on either side of the contacts where the circuit is broken. This arrangement provides a powerful magnetic field where the circuit is broken.

The arc is a conductor and has a magnetic field set up around it. This field will be reacted upon by the flux of the blowout coil distorting the arc so that it is quickly broken or extinguished. This prevents the arc from burning the contacts.

Magnetic blowout coils are connected in series with the line or in series with the contacts being protected.



CARBON PILE STARTER
(ALLEN - BRADLEY)

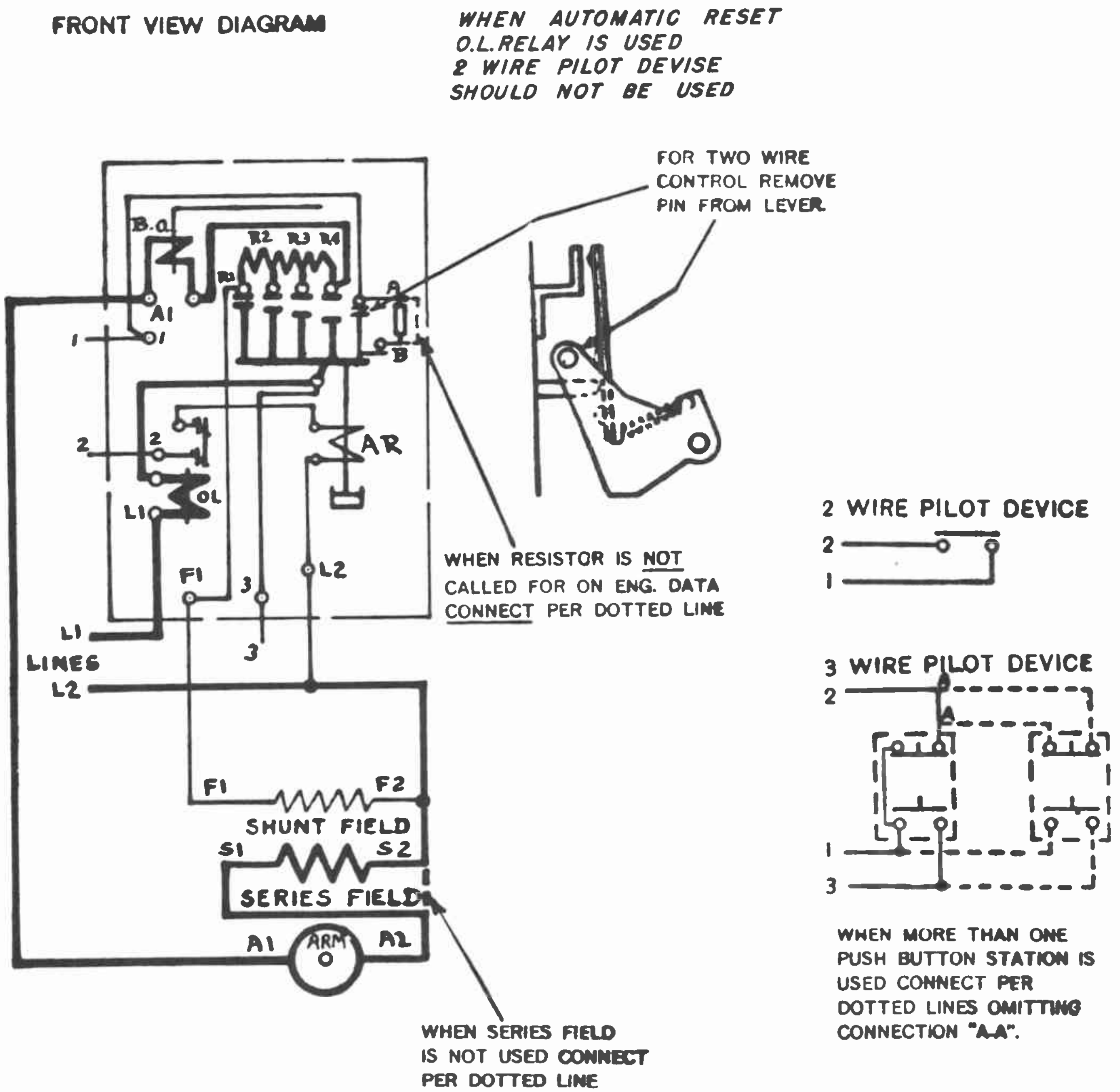


In certain classes of work it is desirable to have very gradual application of the starting torque of the motor when the machine is first put in operation. To accomplish this, it is necessary to start the motor with extremely high resistance in the armature circuit, and limit the starting current to a very low value.

For this purpose, carbon pile starters are made with resistance elements consisting of small carbon disks stacked in tubes of non-combustible material with an insulating lining.

As long as these disks are left loose in the tube, the resistance through them is very high. If pressure is applied to these carbon disks, their combined resistance will be lowered because the greatest resistance is at the contacts between disks. As pressure increases, resistance decreases allowing more current to flow.

This allows the motor to start very slowly, and its speed will gradually increase until normal speed is attained.



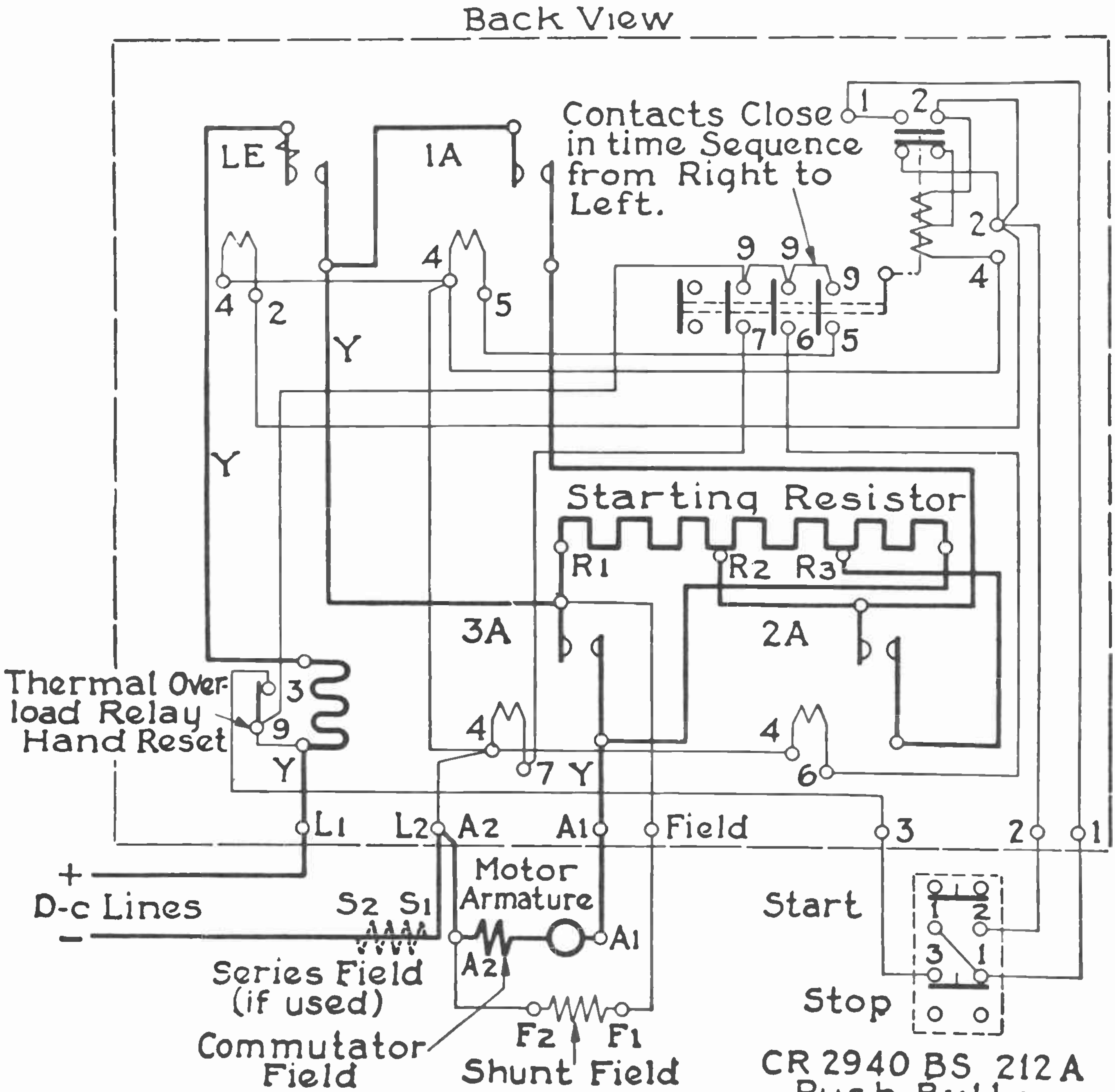
LINE DIAGRAM = 87026DI

TITLE: CONNECTIONS FOR D. C. TIME LIMIT AUTOMATIC STARTER.

DRAWN BY C. MINOR	TRACED BY H.W. LENTEN	TYPE A	SUP. NO. 50439DI
CHECKED BY A.F. WEISS	APPROVED BY C. STANSBURY	BULL. NO. 6106	SUP. BY NO.
A G.M.H. R.E.M. · B G.M.H. L.R.B.	C R.N.C. R.S. · D L.R.S. W.C.F.	ORDER NO. DEV. 1378-11	39915DI

CUTLER-HAMMER INC. MILWAUKEE NEW YORK

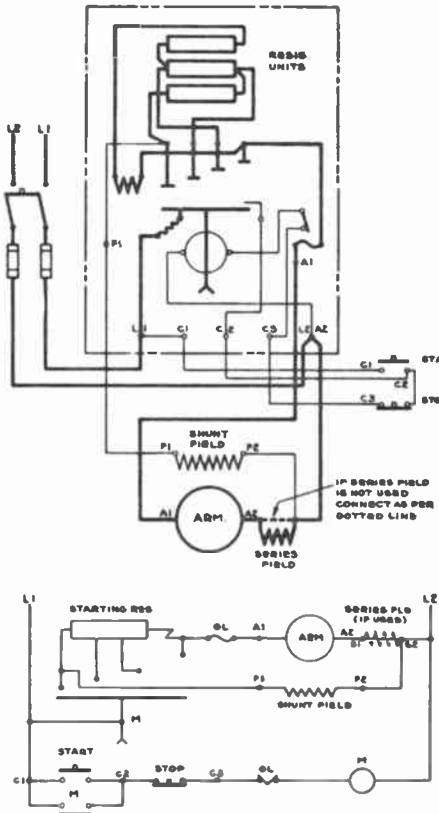
MAGNETIC ACCELERATING CONTROLLER GENERAL ELECTRIC CR 4065



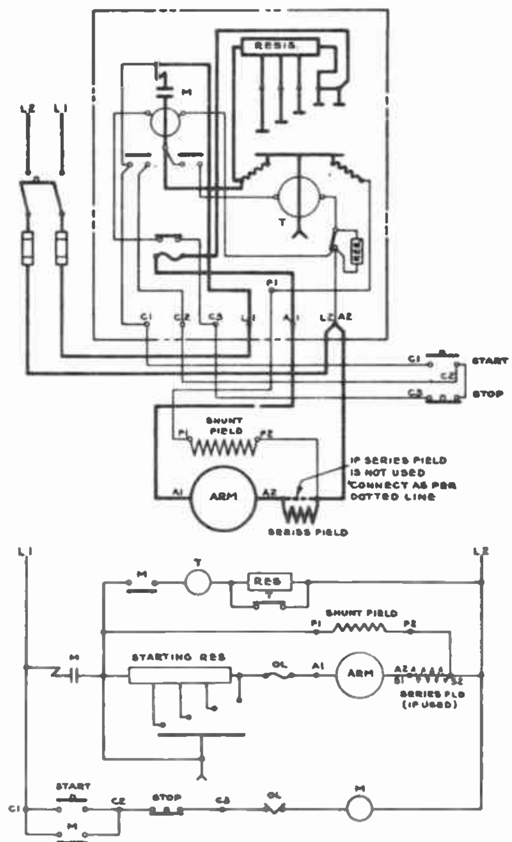
If Series Field is Used, Connect F2 to S2 Instead of to A2 as Shown.

Wiring Diagrams

Classes 7107, 7120 — D. C. Time Limit Acceleration Starters

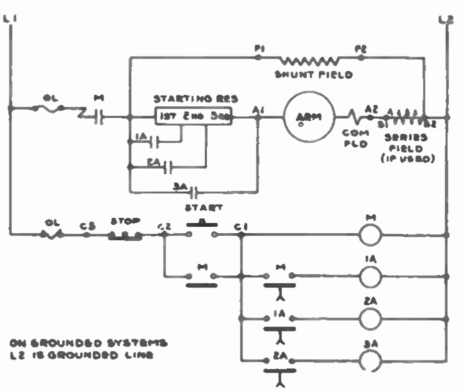


CLASS 7107 DC STANDARD DUTY TIME LIMIT ACCELERATION STARTER.

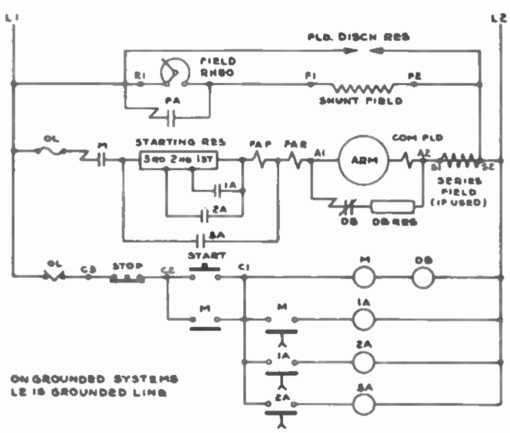


CLASS 7120, TYPE EM-2 D.C. STANDARD DUTY TIME LIMIT ACCELERATION STARTER.

Classes 7135, 7136 — D. C. Time Acceleration Starters



LINE DIAGRAM FOR DC CLASS 7135 HEAVY DUTY TIME LIMIT ACCELERATION STARTER WITH FOUR POINTS OF ACCELERATION.

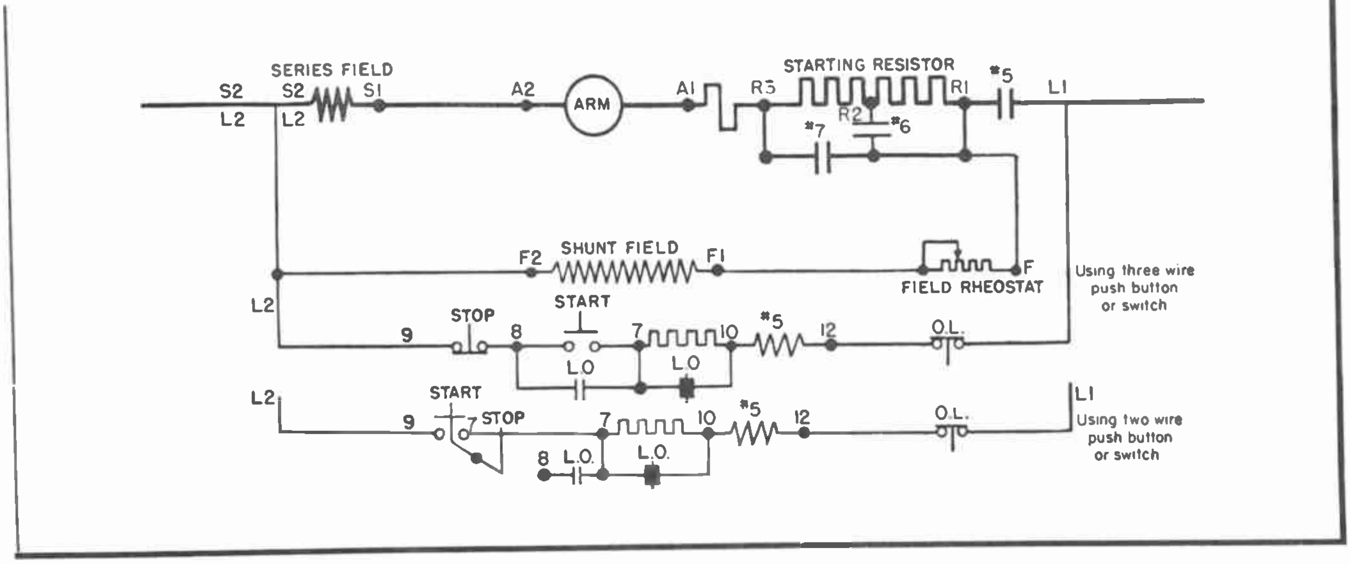


LINE DIAGRAM FOR DC CLASS 7136 HEAVY DUTY TIME LIMIT ACCELERATION STARTER WITH DYNAMIC BRAKING.

1748-B14

MAGNETIC NON-REVERSING TIMESTARTER FOR CONSTANT SPEED D-C MOTORS
WESTINGHOUSE 8512

TYPICAL SCHEMATIC DIAGRAM



PILOT CONTROL DEVICES FOR USE WITH CLASS 8512 TIMESTARTERS

STANDARD DUTY PUSHBUTTONS—Surface, Flush-Mounted, Dust and Water-tight, are compact, safe and easy to install. Type SD-2. See P.L. 15-020.

HEAVY DUTY PUSHBUTTONS—Standard steel surface mounted, flush plate mounted pushbuttons, Dust and Water-tight, or for Hazardous Locations are available. Oil immersed or air break Pushbuttons can also be supplied. See P.L. 15-010.

FLOAT SWITCHES—For controlling motor-driven pumps. May be supplied for chain or rod operation. Weather-proof —all parts treated to resist corrosion. See P.L. 15-040.

PRESSURE AND VACUUM SWITCHES—For automatic control of motor-driven pumps, air compressors, etc. See P.L. 15-061.

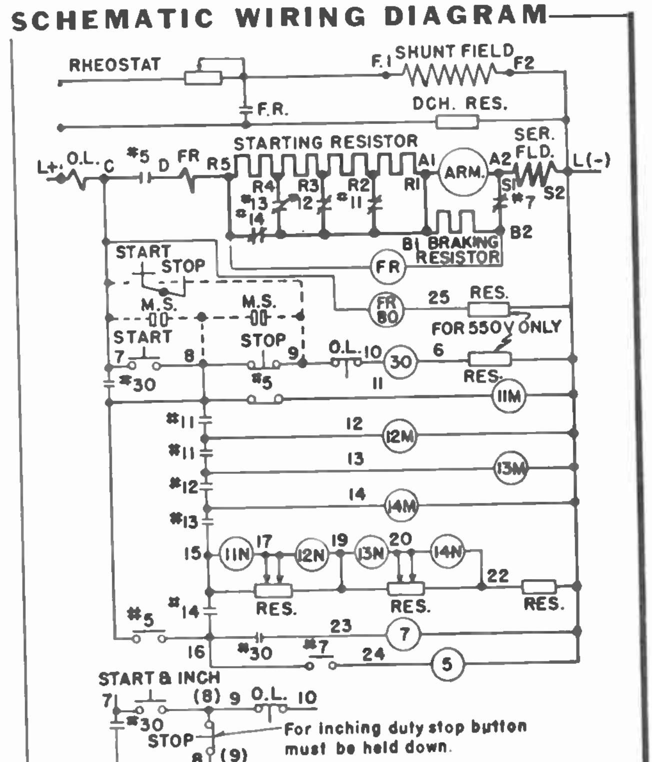
PRESSURE REGULATORS (GAUGE TYPE)—For automatic control of motor-driven pumps, air compressors, etc. Provides high degree of accuracy with visible, built-in gauge. See P.L. 15-066.

FIELD RHEOSTATS—May be used with these starters to obtain the permissible speed variation of standard constant speed motors. See P.L. 14-515.

MASTER SWITCHES—Type N-106, shipper rod operated, may be used instead of Pushbuttons. They will provide low voltage protection. See P.L. 15-100.

MAGNETIC NON-REVERSING TIMESTARTER FOR CONSTANT AND ADJUSTABLE SPEED MOTORS
WESTINGHOUSE CLASS 8522-F

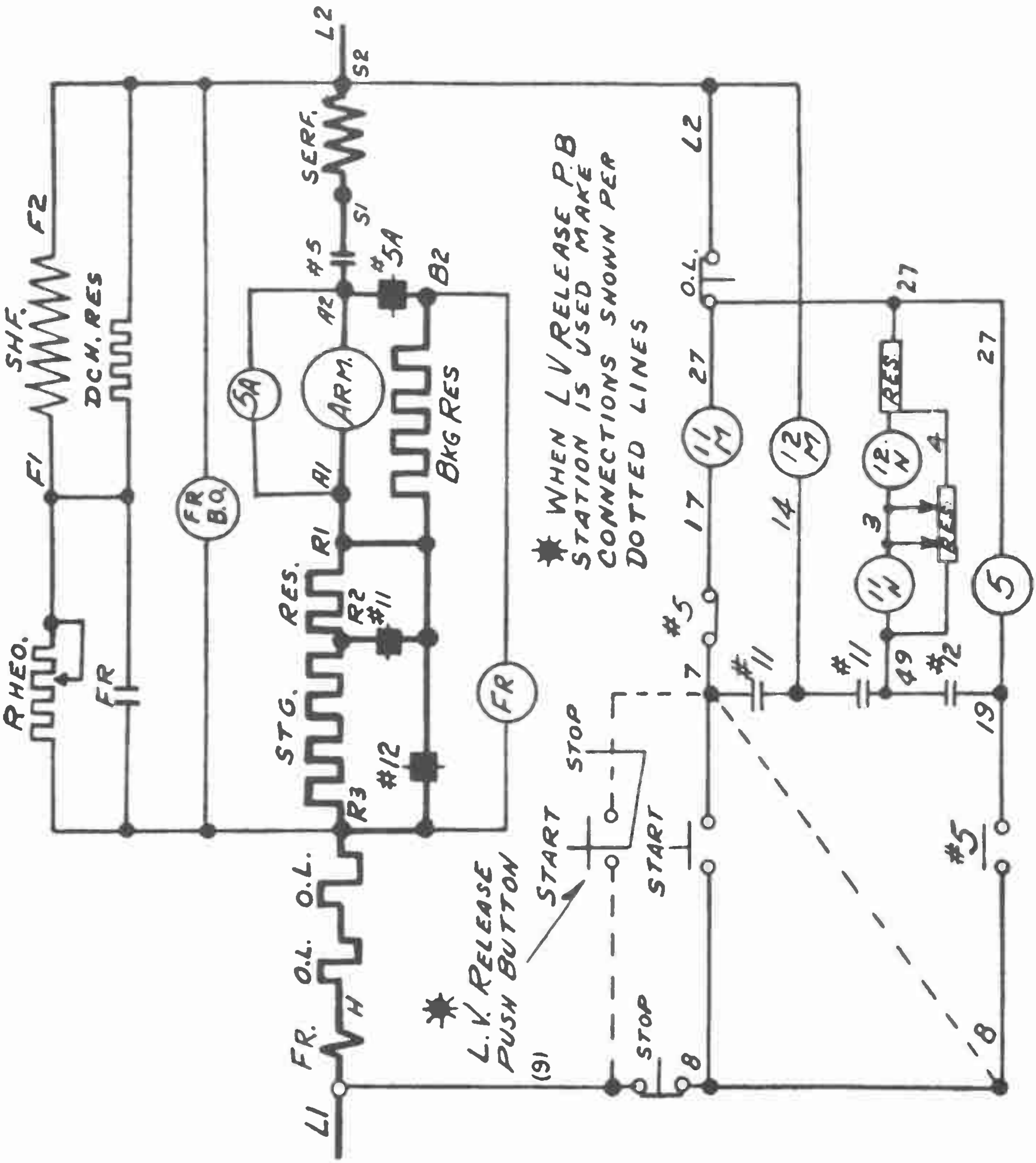
SCHEMATIC WIRING DIAGRAM



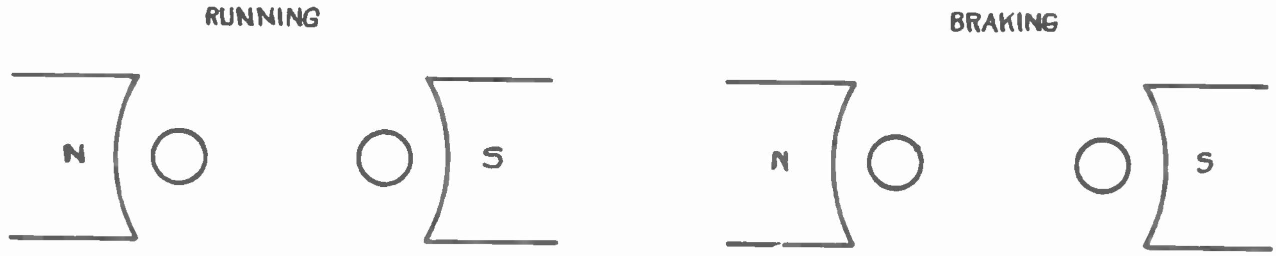
Typical Diagram for Class 8522-F Timestarter With Five Points Acceleration

MAGNETIC ACCELERATING TIMESTARTER WITH THREE-POINT ACCELERATION

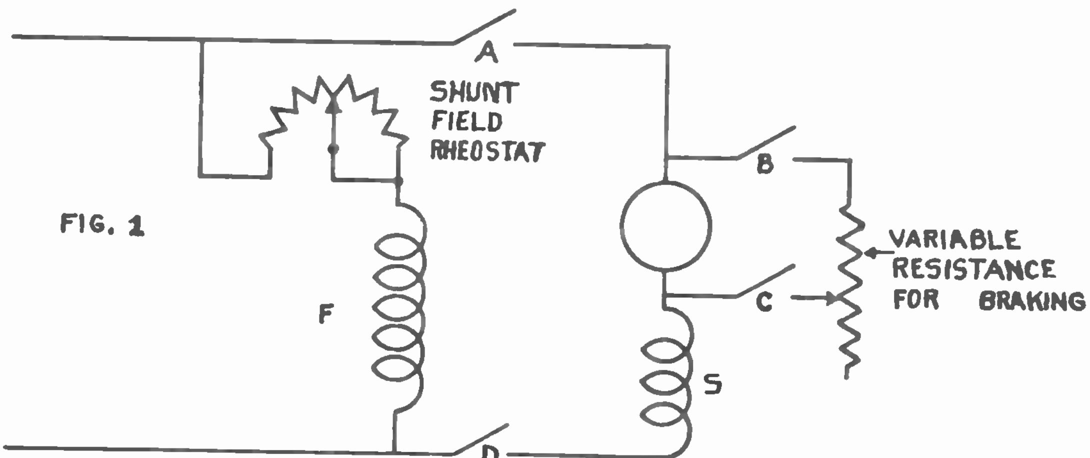
WESTINGHOUSE CLASS 8522-F



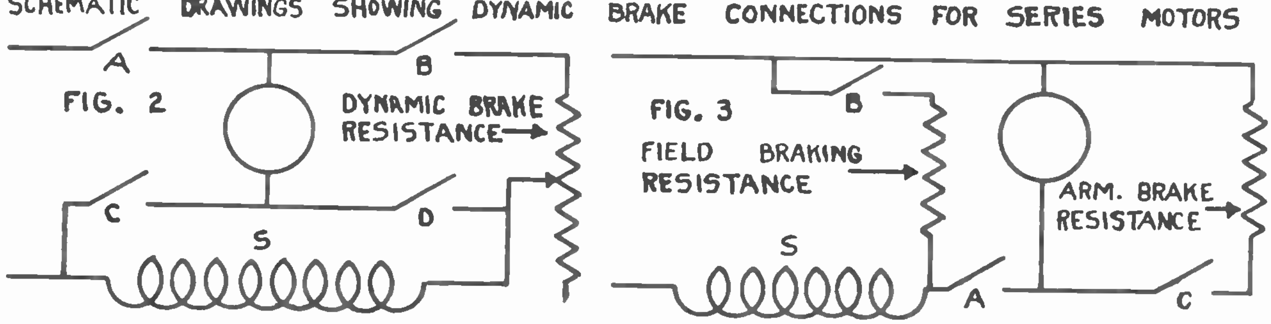
DYNAMIC BRAKING



IN FIGURES 1, 2 & 3 SWITCHES A & D ARE CLOSED AND B & C ARE OPEN WHEN RUNNING. SWITCHES B & C ARE CLOSED AND A & D OPEN WHEN BRAKING



SCHEMATIC DRAWINGS SHOWING DYNAMIC BRAKE CONNECTIONS FOR SERIES MOTORS



The above diagram in Fig. 1 shows the connection used in dynamic braking, using a compound motor. Fig. 2 shows similar connections for a series motor.

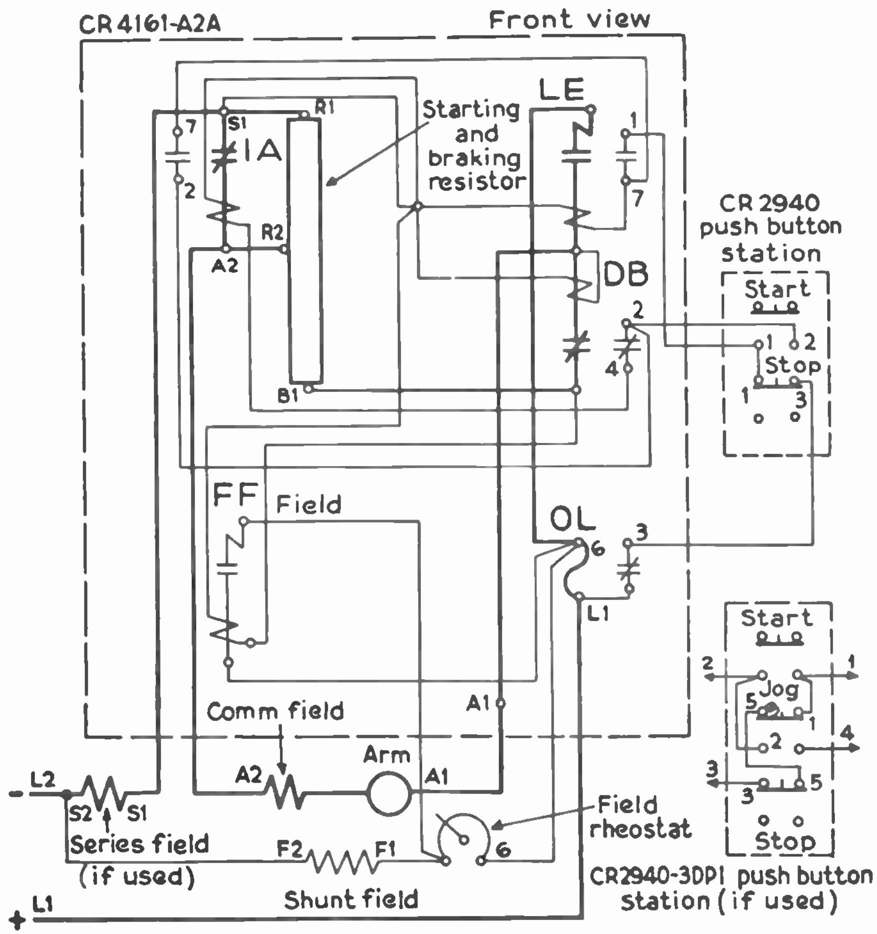
When the source of supply is shut off from a motor, the armature will continue to turn or coast because of its momentum. Any load connected to the motor will also continue to operate. In cases where motors must be stopped quickly, this momentum may be used to generate energy for dynamic braking.

If the shunt field of the motor is excited during the coasting period, the motor will act as a generator and the armature will generate EMF until it stops. By connecting a suitable resistance in the armature circuit, as shown above, the generated armature EMF will cause the armature current and the armature poles to reverse. The reversed armature poles, reacting with the field poles, will now tend to reverse the armature rotation and this action will result in stopping the motor and load.

This form of braking provides a quick, smooth, magnetic form of braking that has many advantages over mechanical methods.

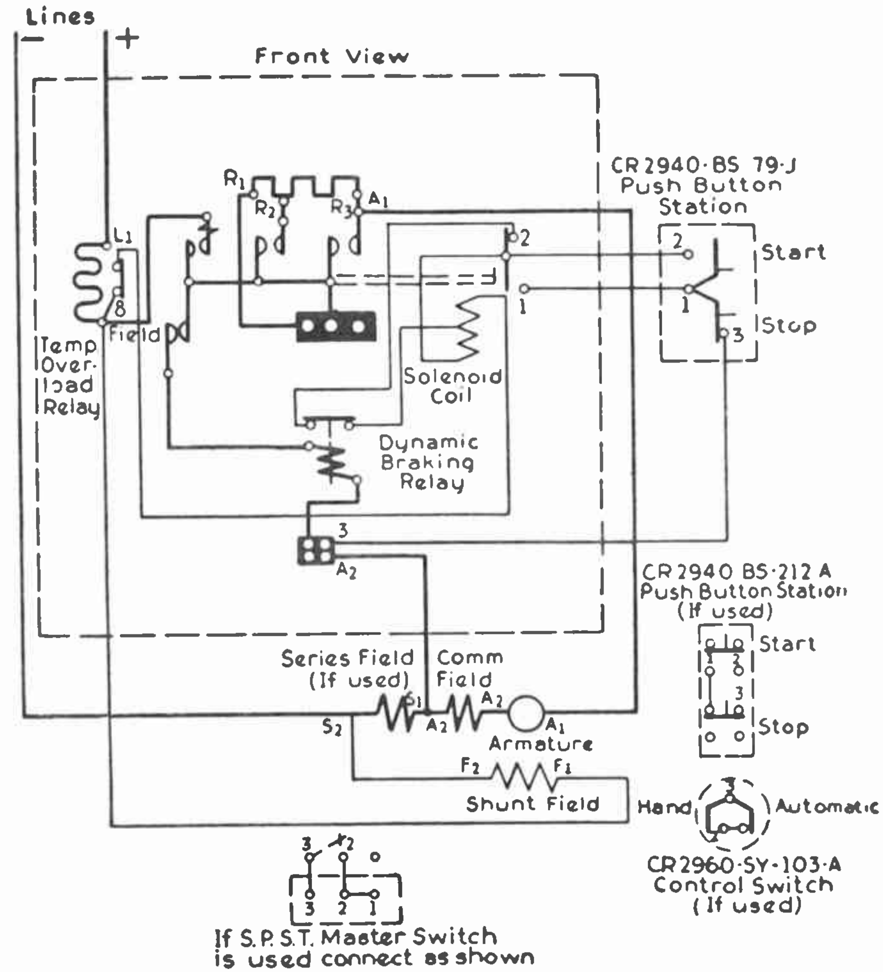
MAGNETIC CONTROLLER WITH DYNAMIC BRAKING

GENERAL ELECTRIC CR 4161



MAGNETIC CONTROLLER WITH DYNAMIC BRAKING

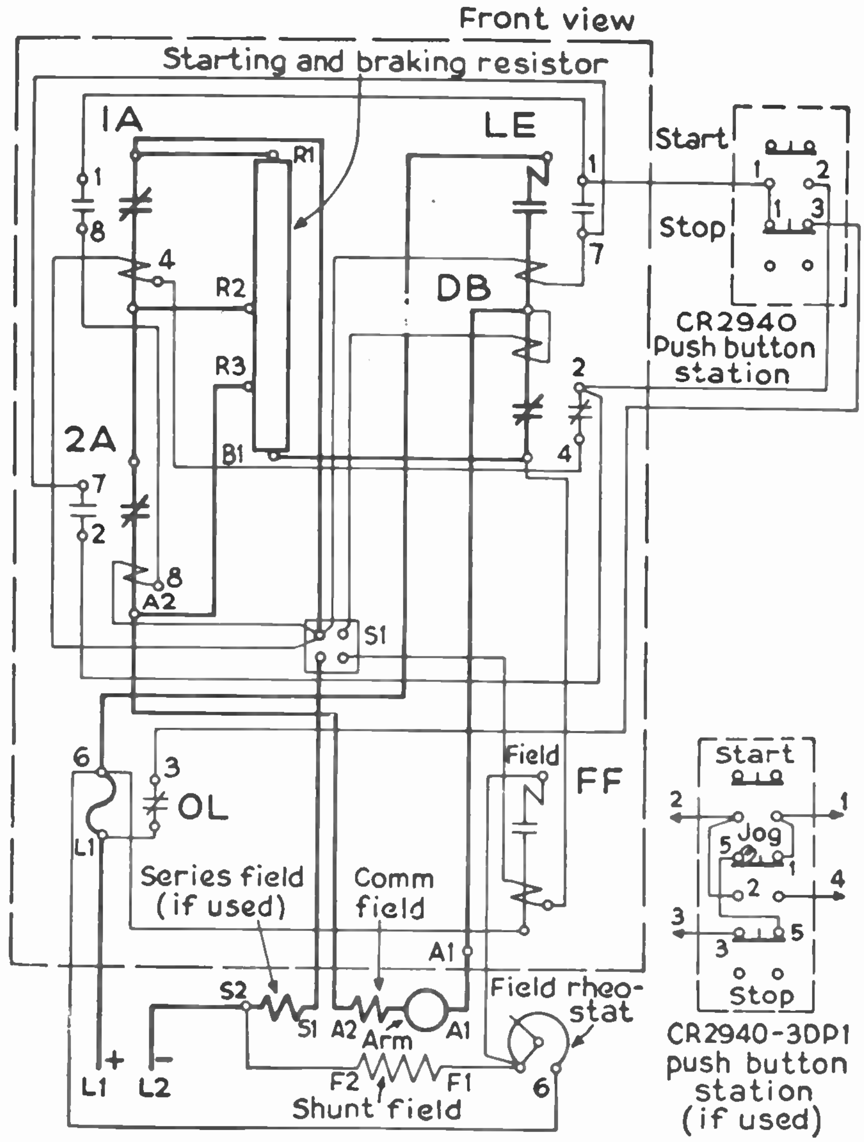
GENERAL ELECTRIC CR 4066



MAGNETIC CONTROLLER

For shunt-wound or compound-wound adjustable speed motors.
Dynamic braking.
Non-reversing.

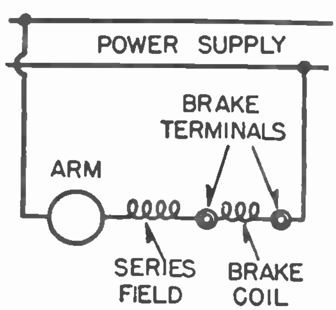
GENERAL ELECTRIC CR 4161



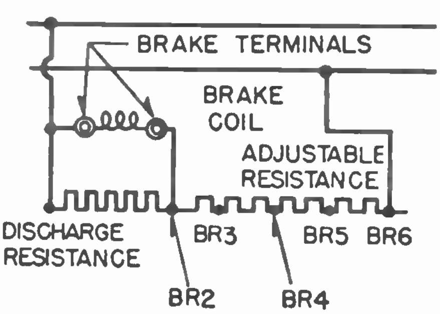
DIRECT-CURRENT MAGNETIC BRAKE

When magnet is energized the brake shoes clear the wheel carried on the shaft, and when de-energized the shoes are applied against the brake wheel by compression spring. Brake wheel usually is mounted on the extended motor shaft.

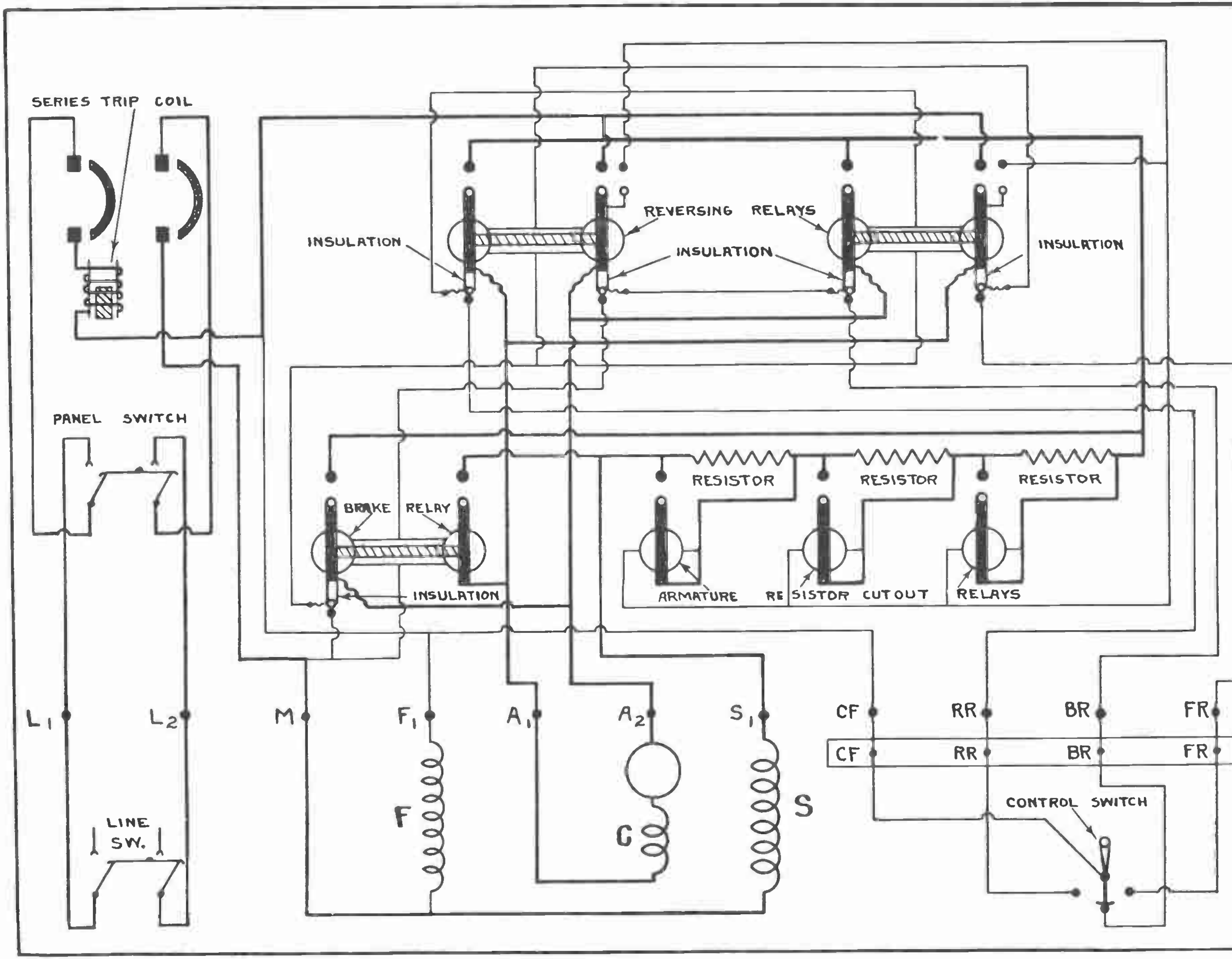
WESTINGHOUSE



Series Brake



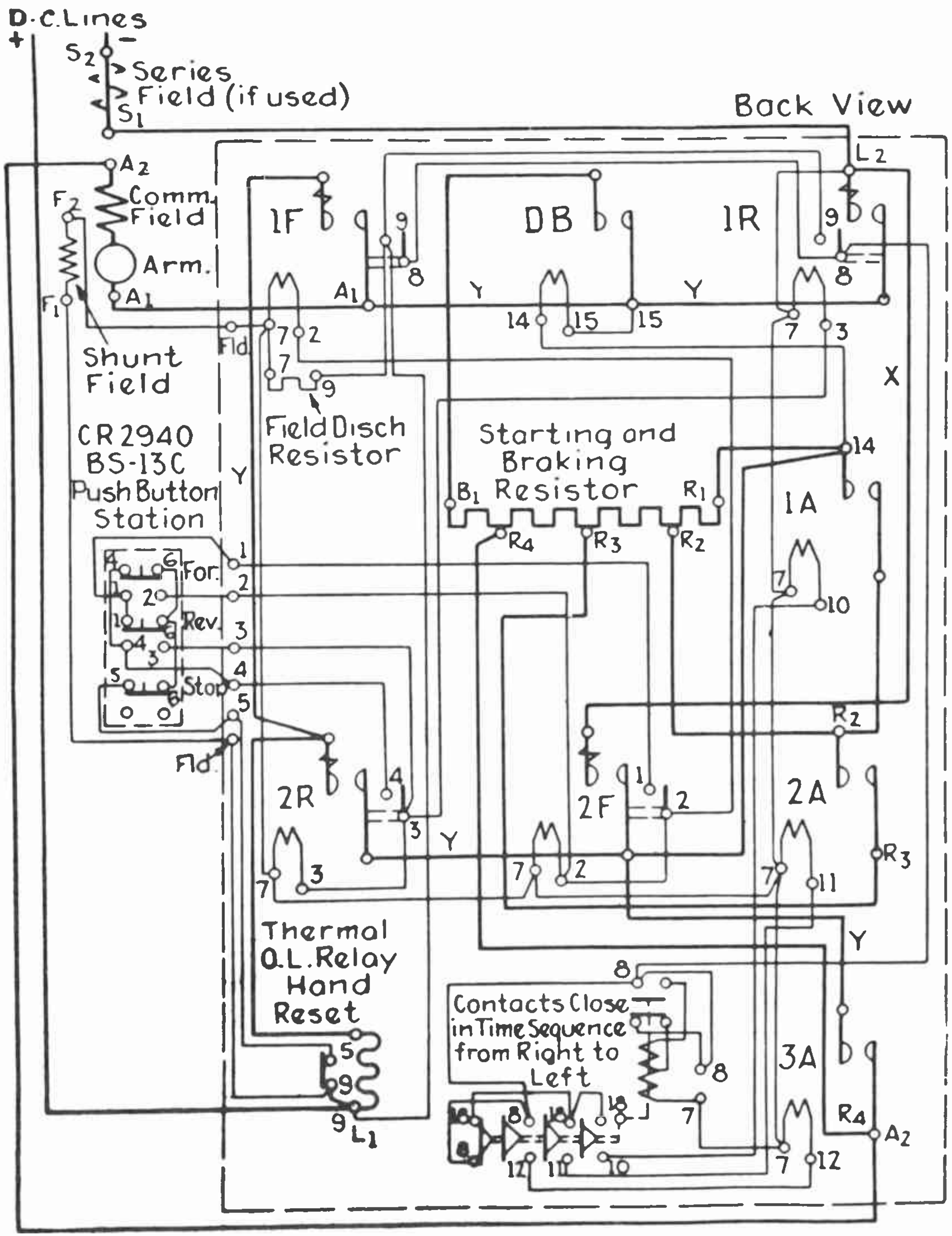
Shunt Brake



MAGNETIC CONTROLLER

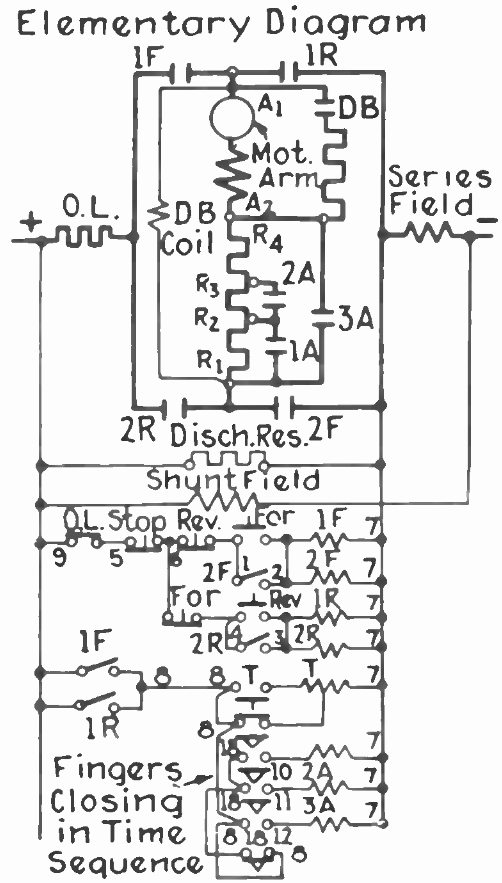
FOR STARTING, REVERSING AND DYNAMIC BRAKE DUTIES

MAGNETIC CONTROLLER, REVERSING AND DYNAMIC BRAKING. GENERAL ELECTRIC CR 4068



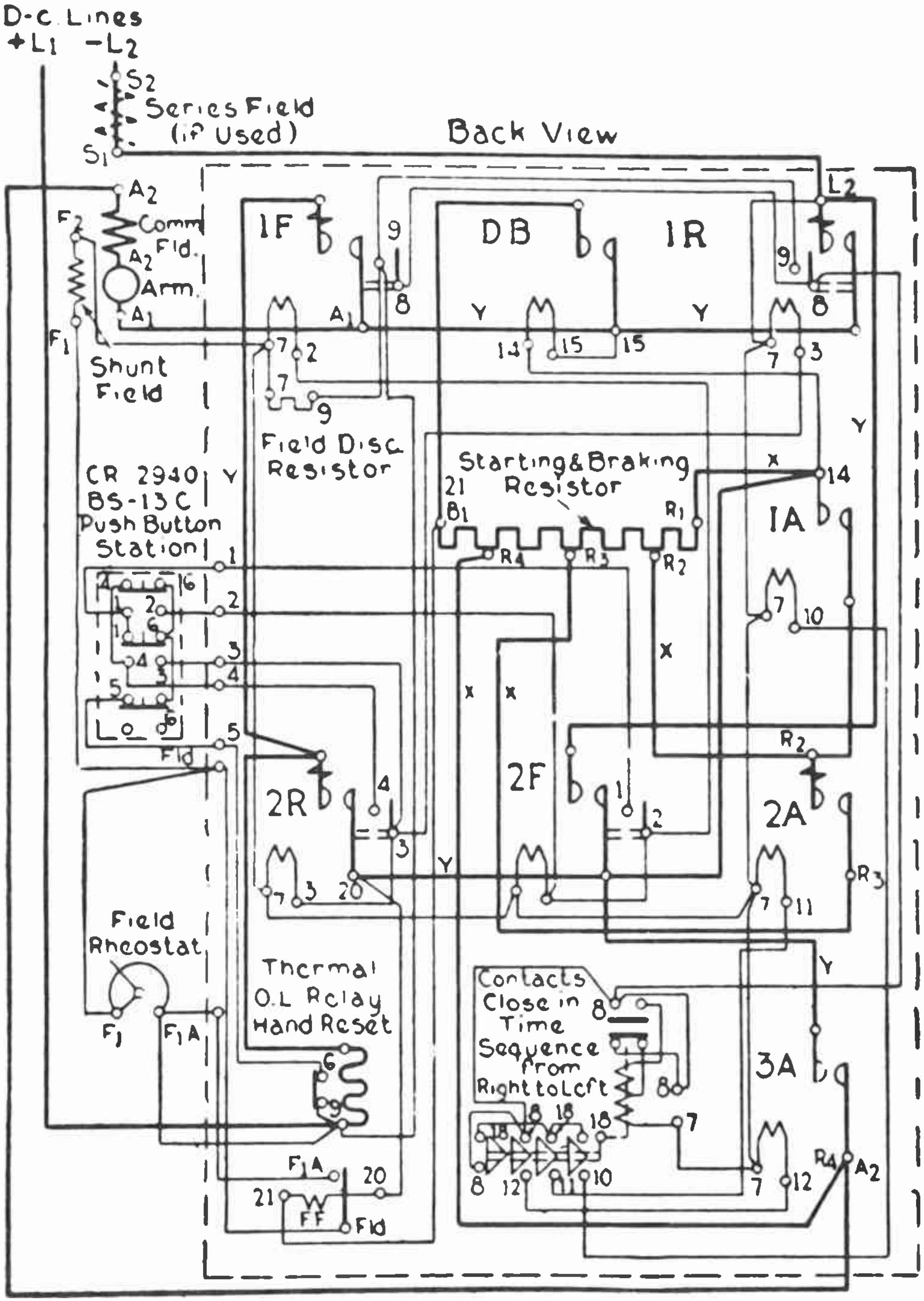
Mechanical Interlock between Contactors 1F-DB-1R and 2F-2R

If Series Field is used, connect F2 to S2 instead of as shown



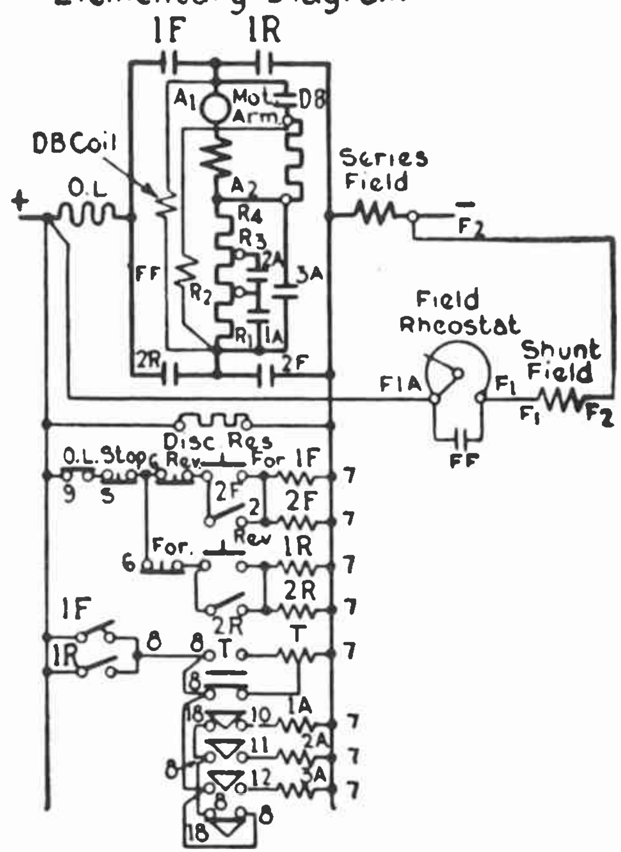
MAGNETIC CONTROLLER, REVERSING, FOR SHUNT-WOUND OR COMPOUND-WOUND ADJUSTABLE SPEED MOTORS

GENERAL ELECTRIC CR 4168



Note: If Series Field is used Connect F2 to S2 Instead of as Shown

Elementary Diagram

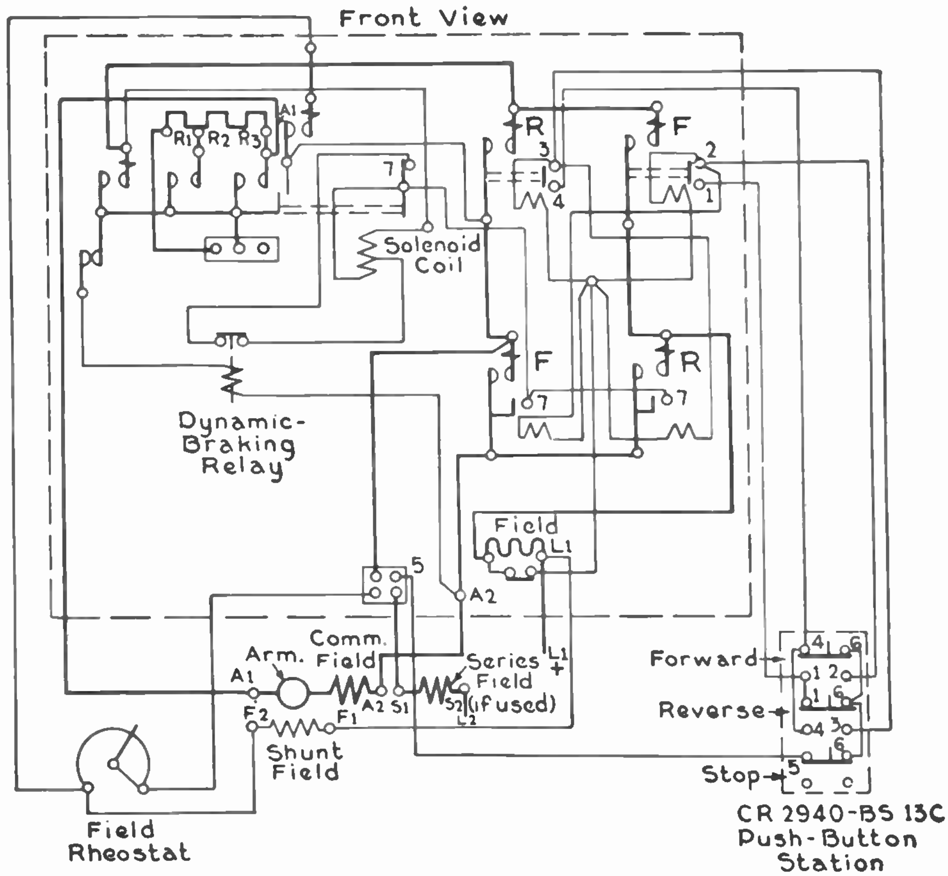


Mechanical Interlock Between Contactors if -DB-1R and 2F-2R

REVERSING MAGNETIC STARTER

For shunt wound or compound wound adjustable speed motors.

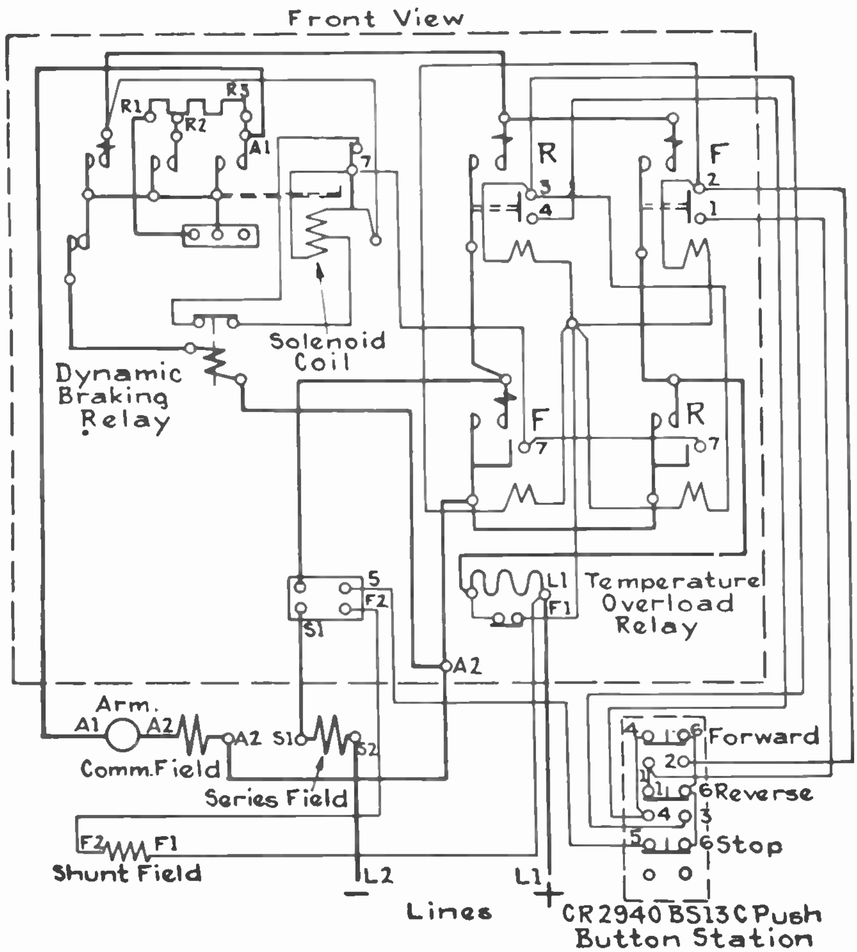
GENERAL ELECTRIC CR 4168



REVERSING MAGNETIC CONTROLLER

For shunt wound or compound wound constant speed motors.

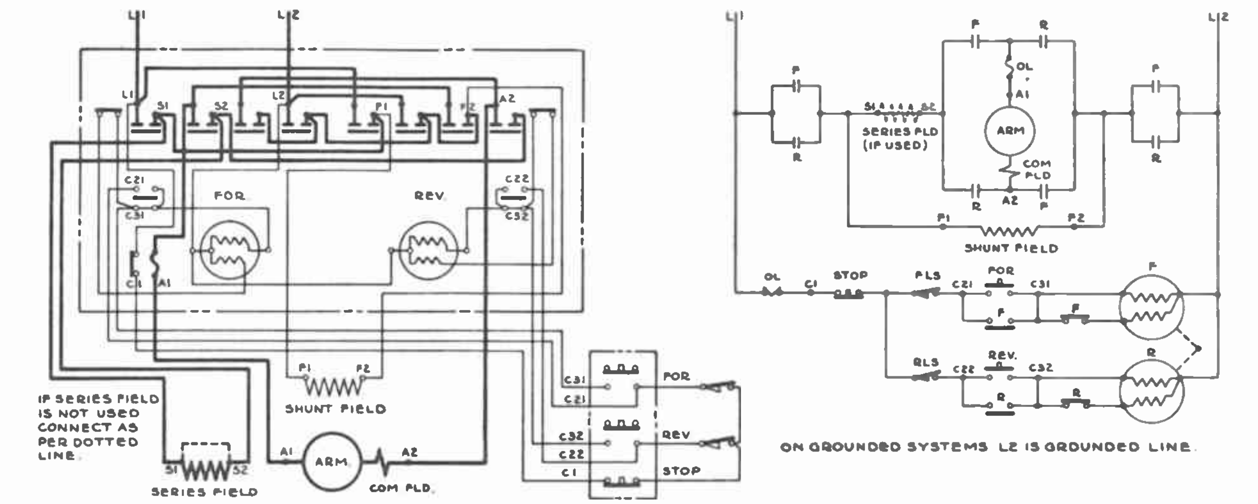
GENERAL ELECTRIC CR 4068



D

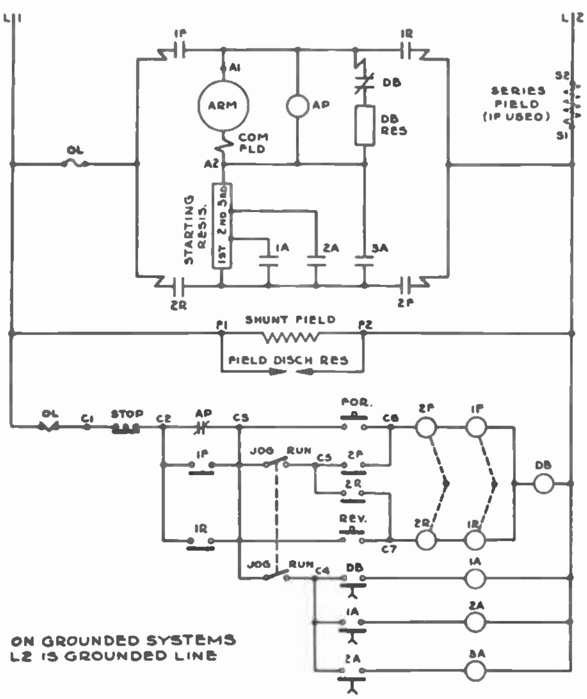
WIRING DIAGRAMS

D. C. REVERSING LINE VOLTAGE STARTERS — CLASS 7732

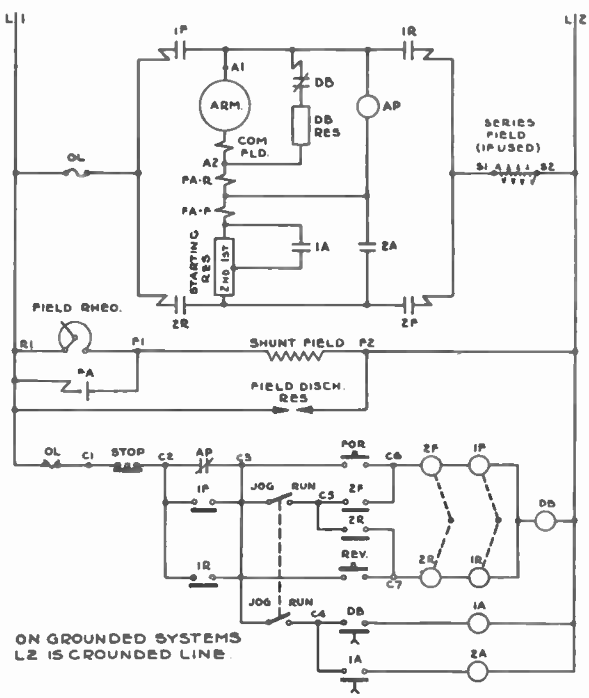


LINE DIAGRAM AND WIRING DIAGRAM FOR CLASS 7732, TYPE S-4 D.C. REVERSING LINE VOLTAGE STARTER

D. C. REVERSING TIME LIMIT ACCELERATION STARTERS — CLASSES 7735, 7736



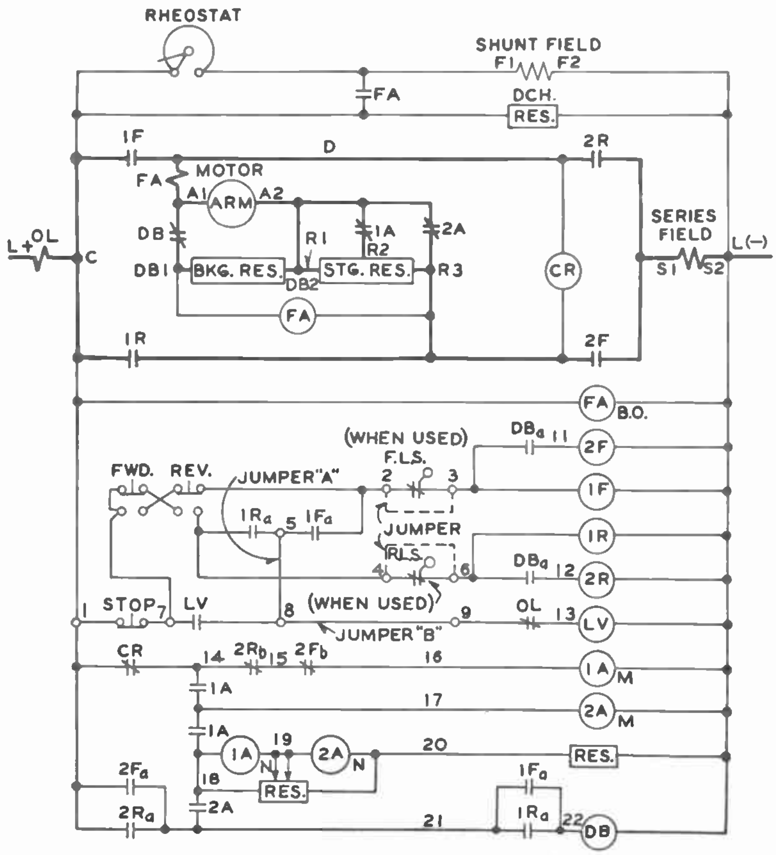
LINE DIAGRAM FOR CLASS 7735 D.C. TIME LIMIT ACCELERATION REVERSING STARTER WITH FOUR POINTS OF ACCELERATION.



LINE DIAGRAM FOR CLASS 7736 D.C. TIME LIMIT ACCELERATION REVERSING STARTER WITH THREE POINTS OF ACCELERATION.

1748-B13

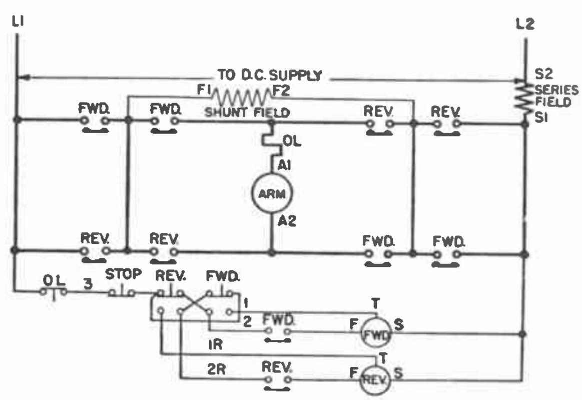
SCHEMATIC WIRING DIAGRAM



Typical Diagram for Class 9022-F Timestarter with Three Points Acceleration

WESTINGHOUSE

SCHEMATIC WIRING DIAGRAM

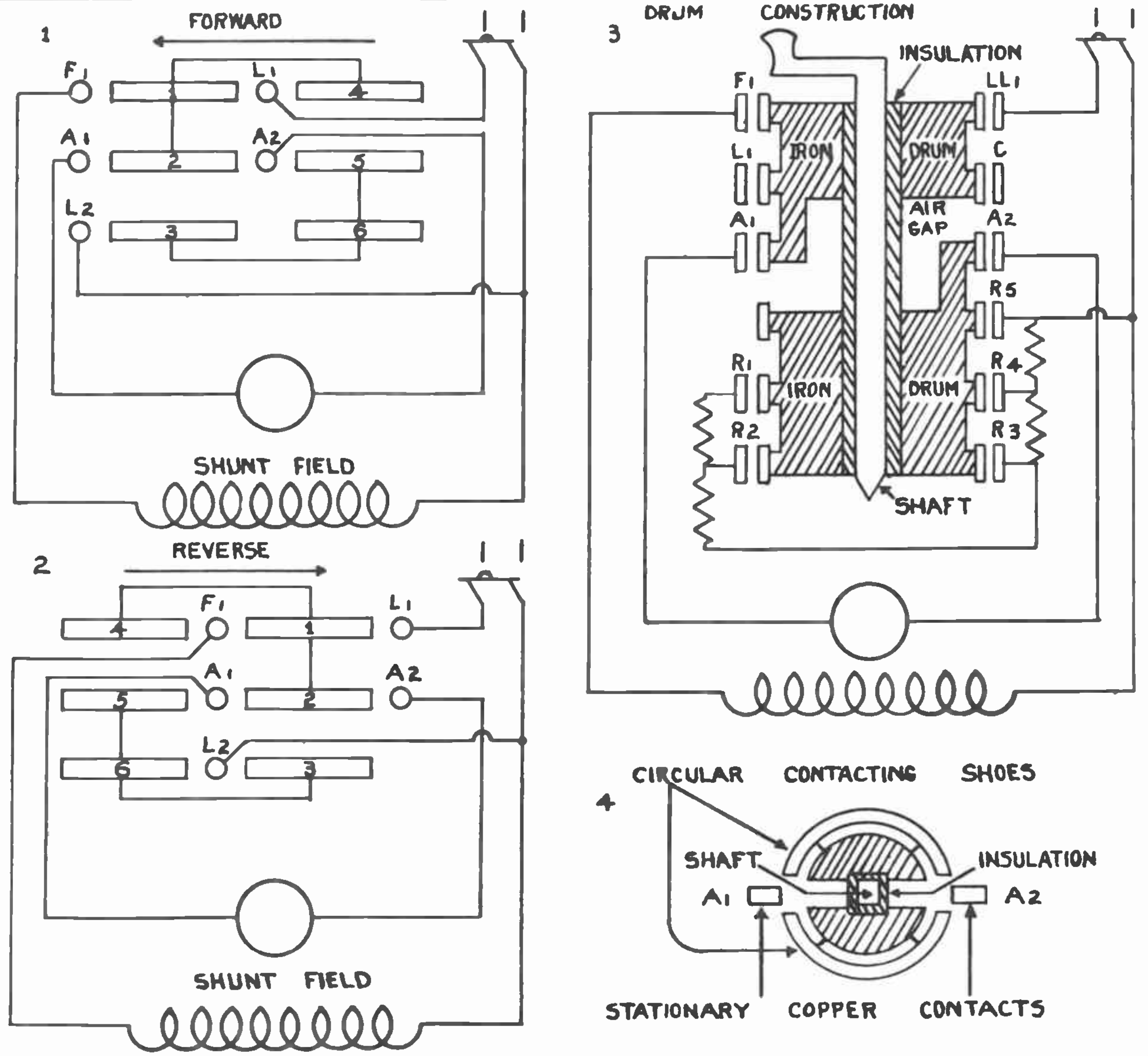


WESTINGHOUSE

REVERSING LINESTARTER FOR COMPOUND-WOUND MOTORS

WESTINGHOUSE CLASS 8503

DRUM CONTROLLERS



Drum controllers are used extensively in the operation of D.C. motors where they must be started, stopped, reversed, and have their speed varied, as on street cars, electric trains, hoists, cranes, etc.

The name is derived from their shape and the manner of mounting contacts on a round iron drum. The cylindrical arrangement of the contacts allows the drum to be rotated part of a revolution in either direction, and brings into connection one or more stationary contacts with the iron drum. The iron drum serves as a mechanical support for the shoes and forms a part of the conducting path.

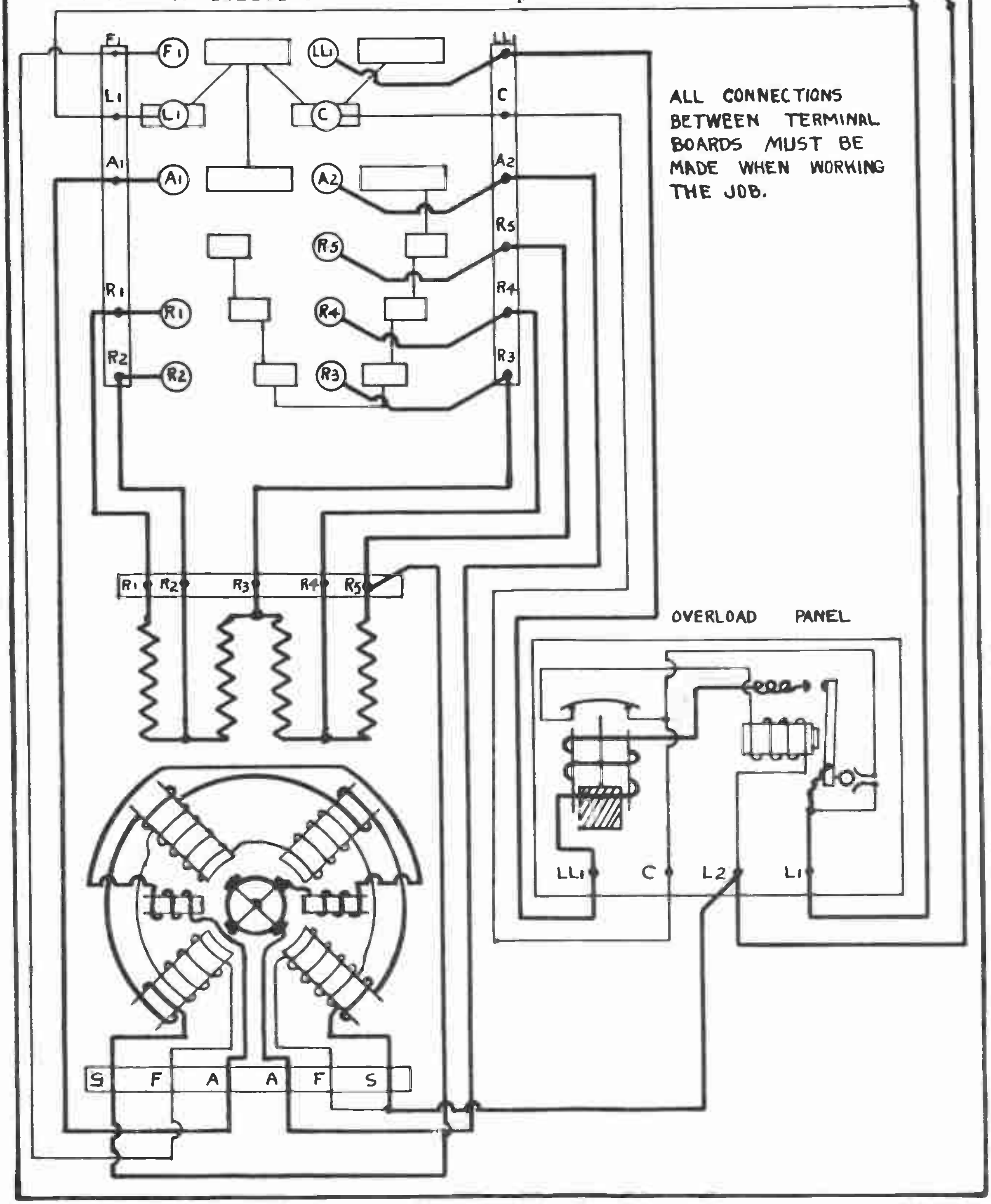
A drum controller, designed for reversing duty, is divided into two parts, completely insulated from each other and from the shaft by fibre insulation.

When the controller in Fig. 2 is in running position, current will flow from positive line to stationary contact "L_1" (Called "contact finger") and enter the iron drum at circular shoe #1, and then flows through the iron drum to shoe #2, which is connected to "A_2", completing the circuit through the armature. The return circuit for the armature is from "A_1" to Shoe #5, through iron drum to shoe #3, which is connected to "L_2".

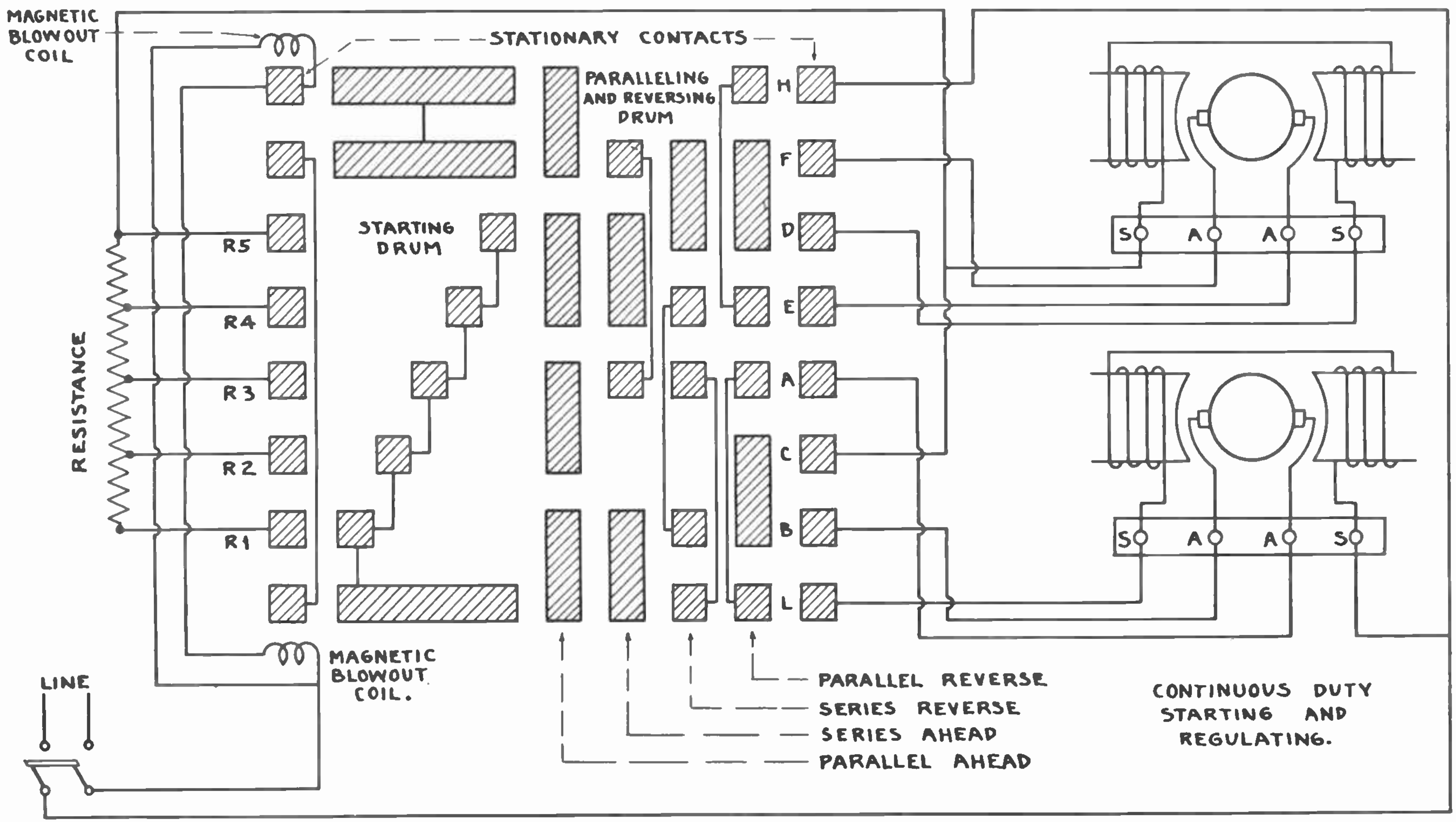
Drum controllers are very rugged and will give excellent service with a minimum of maintenance. The contact fingers and bars may be replaced when burned or worn. Drum controllers may be equipped with auxiliary contacts that close when the drum is in the "OFF" position. These contacts are used to complete a dynamic brake circuit or to operate relays for overload protection.

DRUM CONTROLLER WITH OVERLOAD PANEL

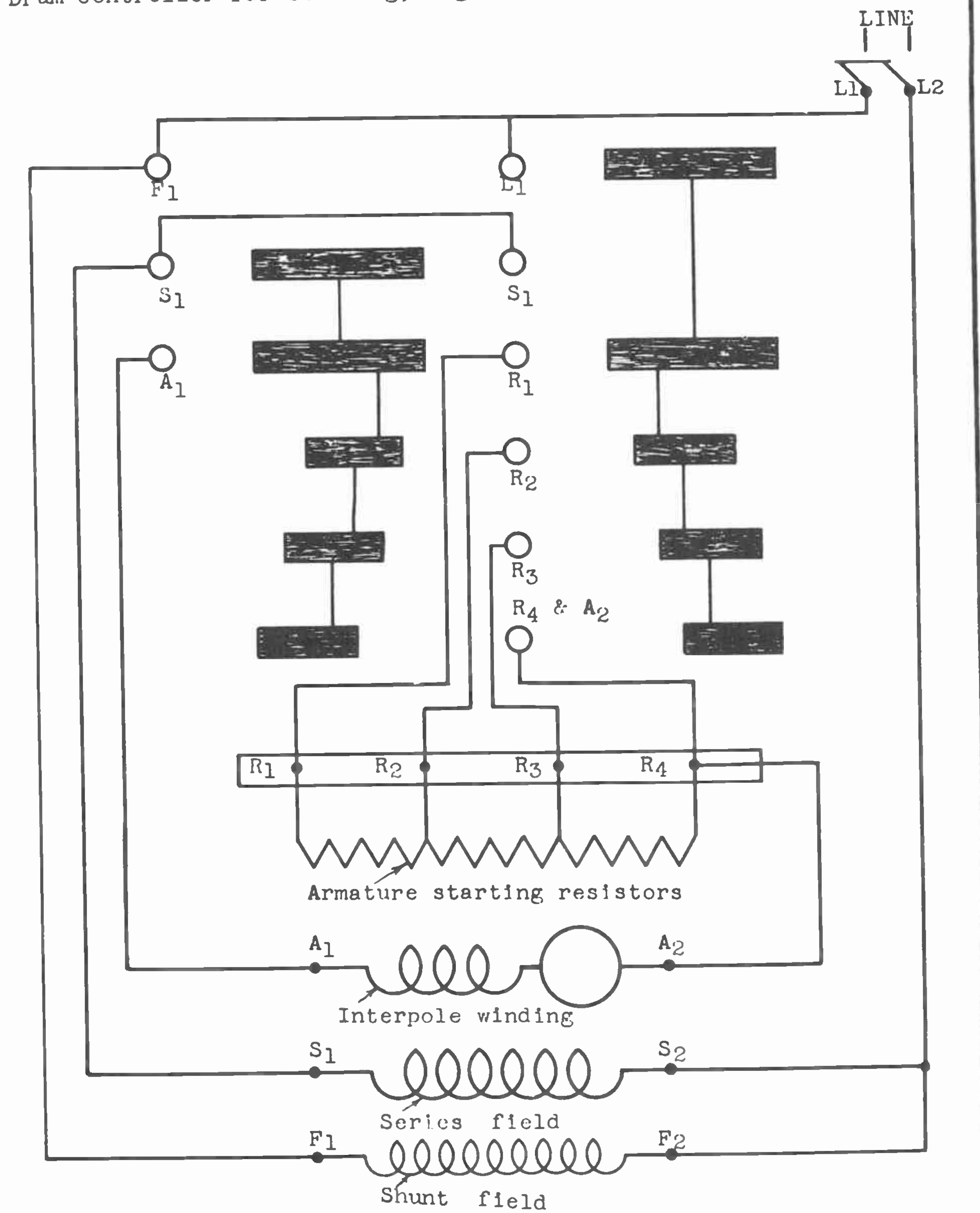
This diagram illustrates how an overload panel is used to protect the motor against overload and "no voltage" conditions, by using contacts "L1" and "C" to complete the relay circuit when the controller is in the "off" position.



DRUM CONTROLLER & SERIES MOTORS.

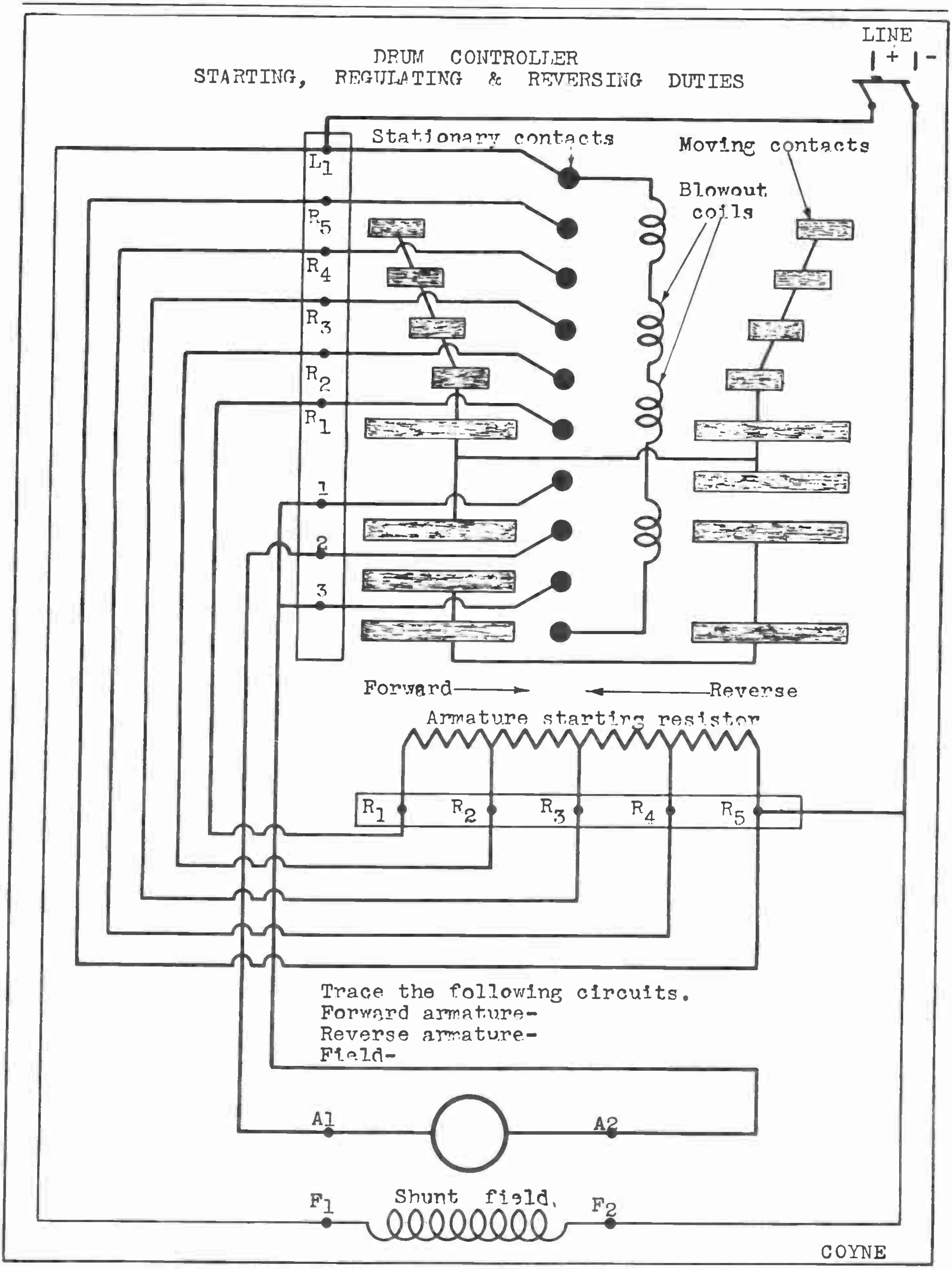


Drum controller for starting, regulating and reversing duties.

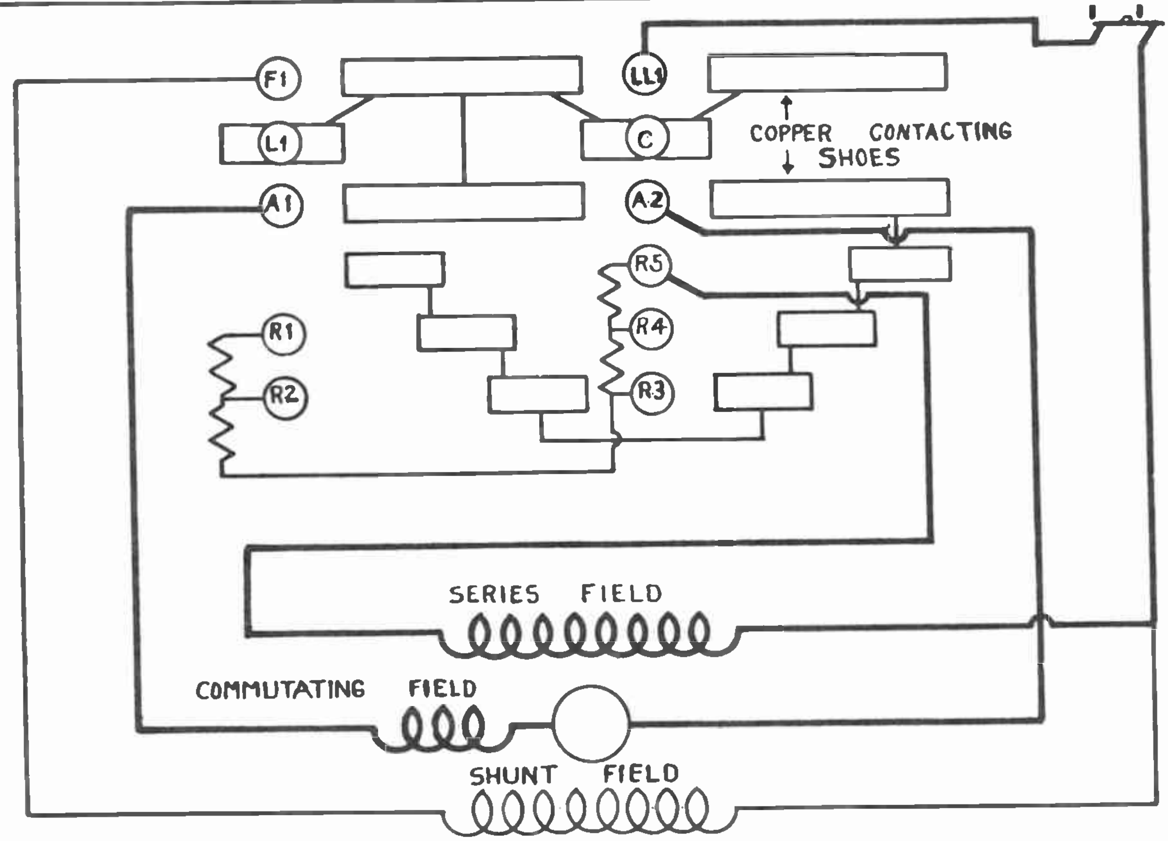


Trace forward armature, reverse armature and field circuits. Draw the terminal board on the diagram and test and identify the terminals. Do not show the terminals connected. Make all connections as shown if a compound motor is used. If shunt motor is used connect S_1 to L_2. If series motor is used omit F_1 connection.

COYNE


DRUM CONTROLLER
STARTING, REGULATING & REVERSING DUTIES
LINE
+
-
Stationary contacts
Moving contacts
Blowout coils
L_1
R_5
R_4
R_3
R_2
R_1
1
2
3
Forward
Reverse
Armature starting resistor
R_1 R_2 R_3 R_4 R_5
Trace the following circuits.
Forward armature-
Reverse armature-
Field-
A1
A2
F_1
Shunt field
F_2
COYNE

DRUM CONTROLLER USED FOR DYNAMIC BRAKING



This diagram shows a compound motor controlled by a drum controller having auxiliary contacts for dynamic braking.

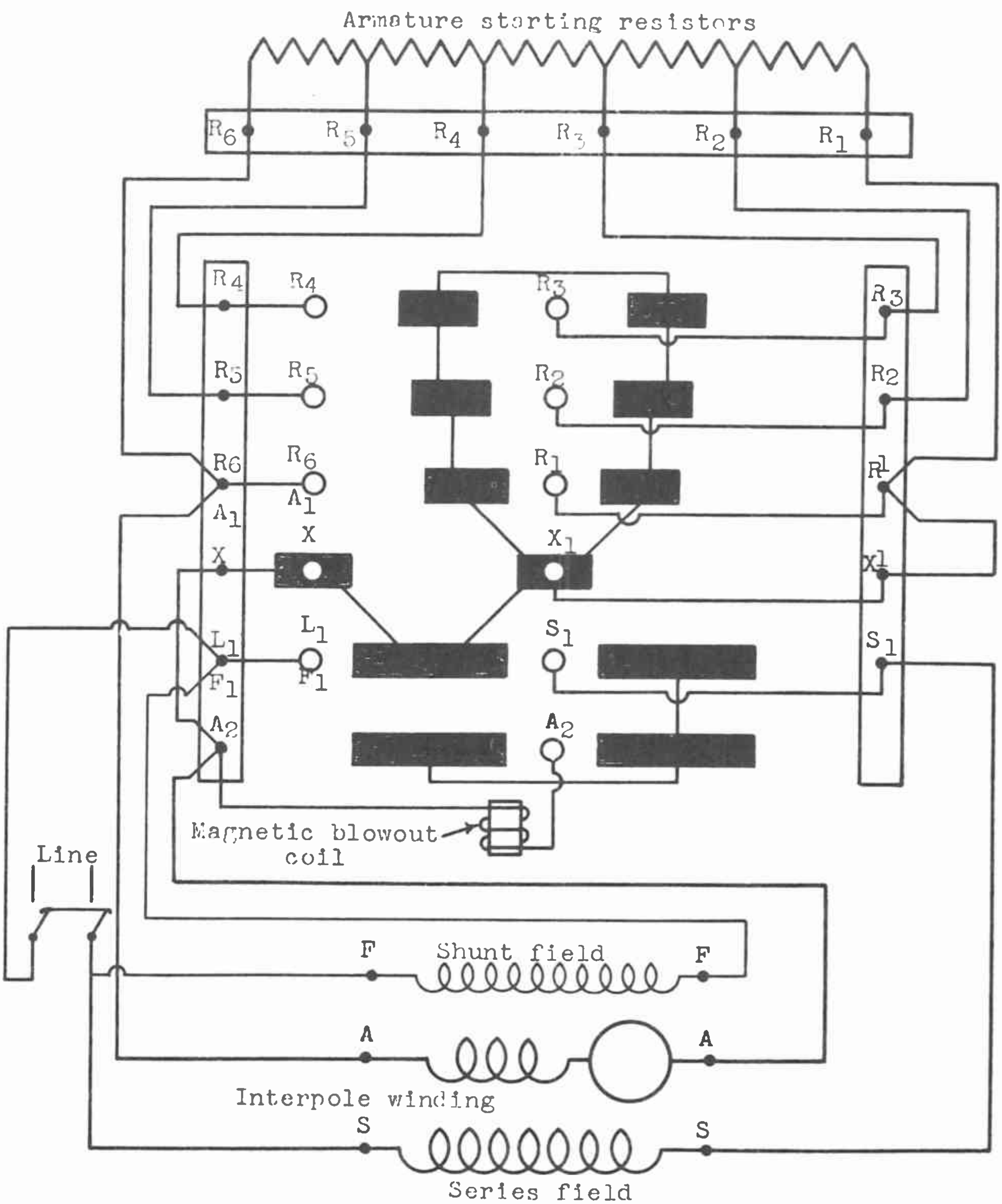
Advantages of this type of braking are: no mechanical wear, less maintenance, economical, effective and, although powerful, will not damage the motor is properly applied.

Caution must be used, when applying dynamic braking, to prevent an overload of current through the armature. This is accomplished by connecting a resistance in series with the armature braking circuit, or by decreasing the field strength to lower the CEMF generated.

Dynamic braking is known as "regenerative braking," when the current generated by the CEMF is fed back into the power line. By leaving the armature connected to the line and over-exciting the field, the CEMF becomes greater than the line voltage. This means that the motor will now act as a generator and will help to carry the line load. This method is used on electric trains which run down long grades. In some systems, as much as 35% of the power used is generated in this manner.

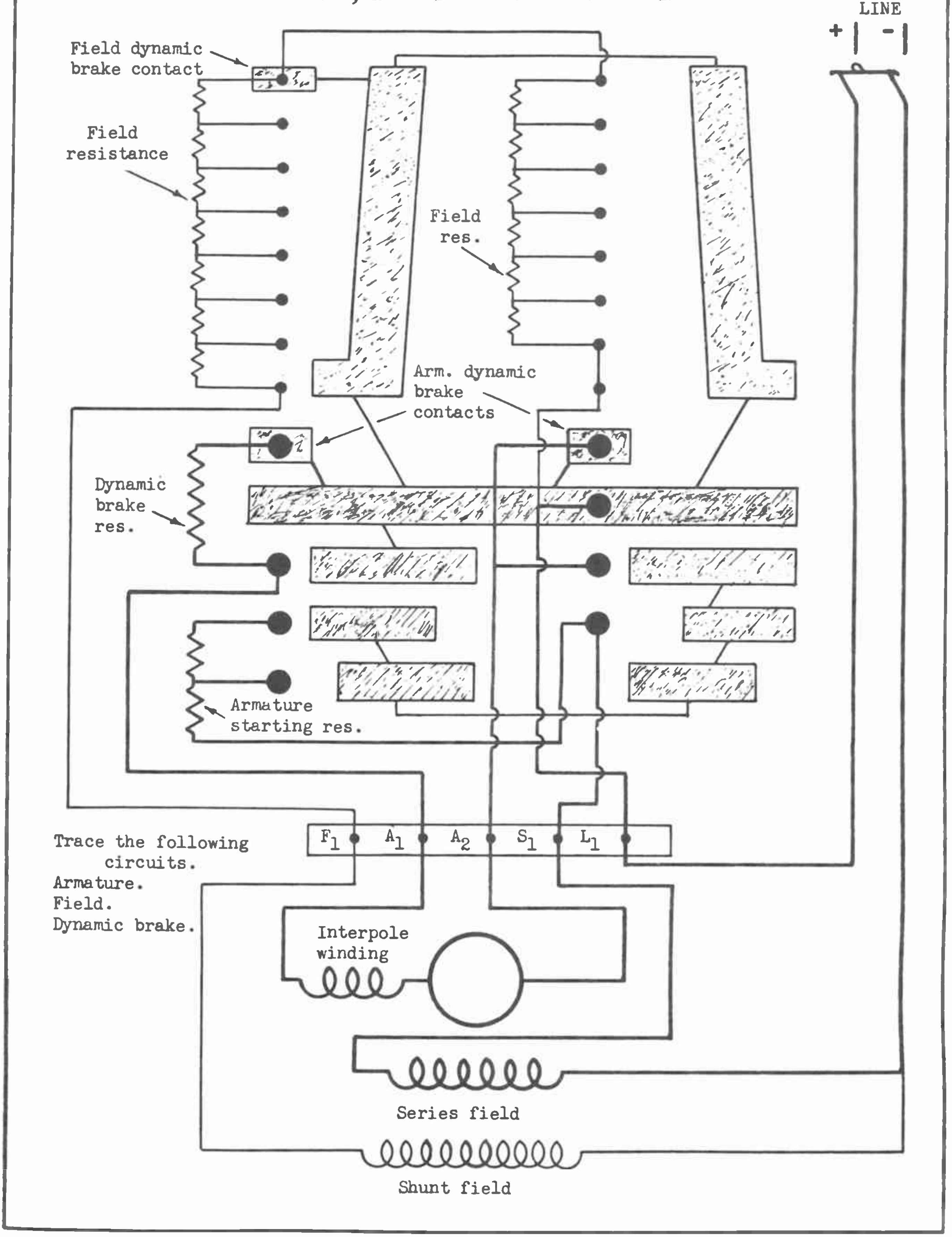
Dynamic braking, or regenerative braking, is only effective when the armature is rotating. Therefore, where it is necessary to hold a load which tends to revolve after brought to a stop, some form of magnetic or mechanical brake must be used in conjunction with dynamic braking.

DRUM CONTROLLER
STARTING, REGULATING, REVERSING AND DYNAMIC BRAKE DUTIES.

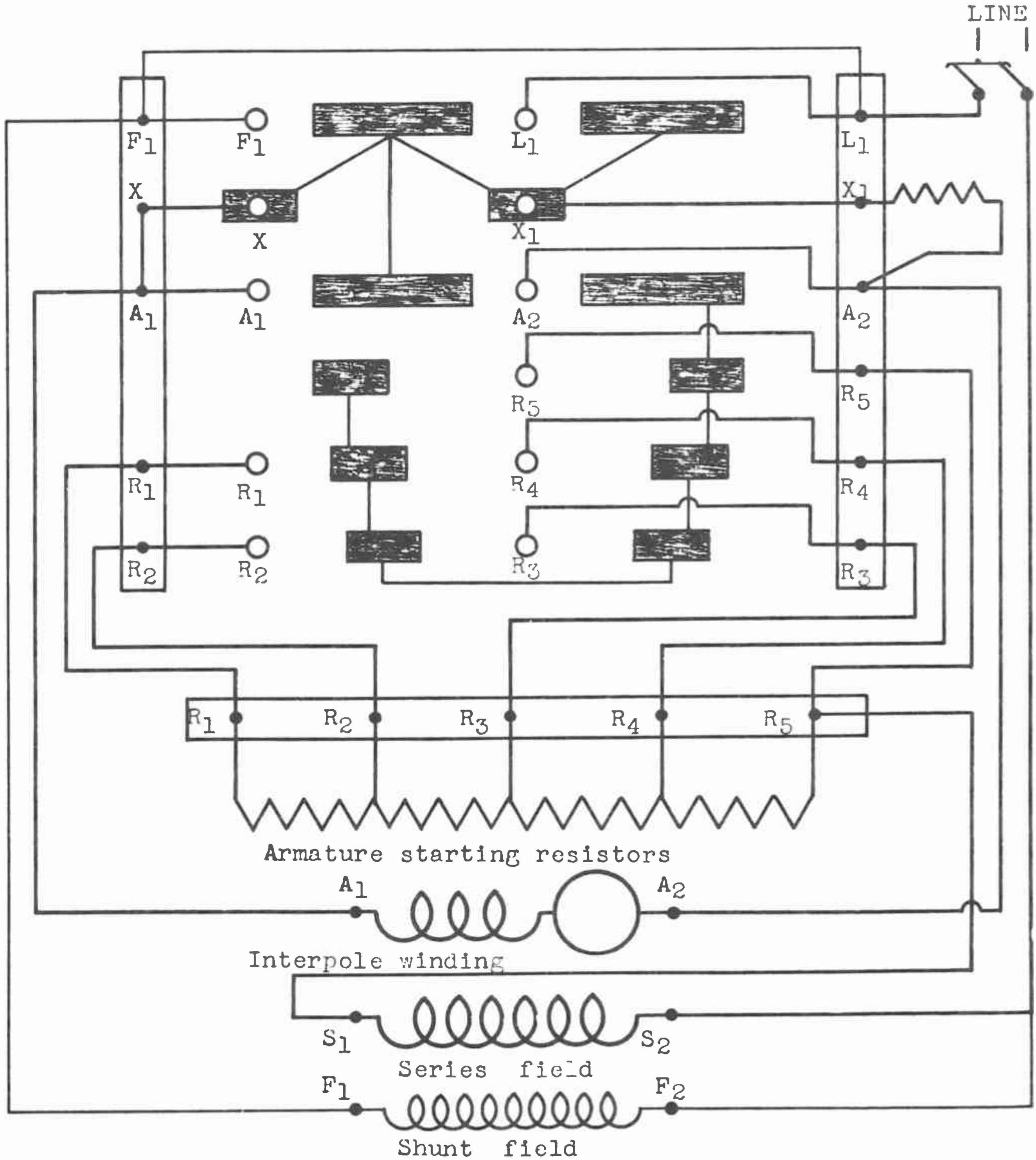


Trace armature, field and dynamic brake circuits.

STARTING, REVERSING AND REGULATING DUTIES



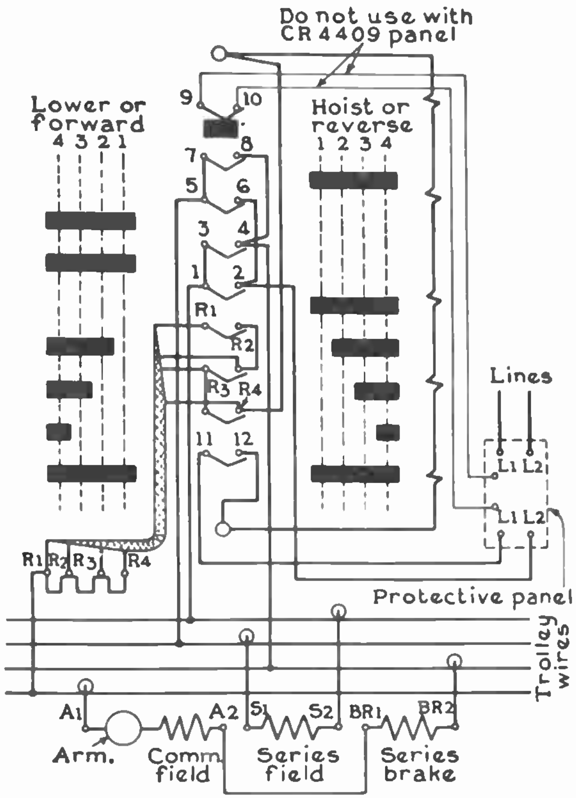
Drum controller for starting, regulating, reversing and dynamic brake duties.



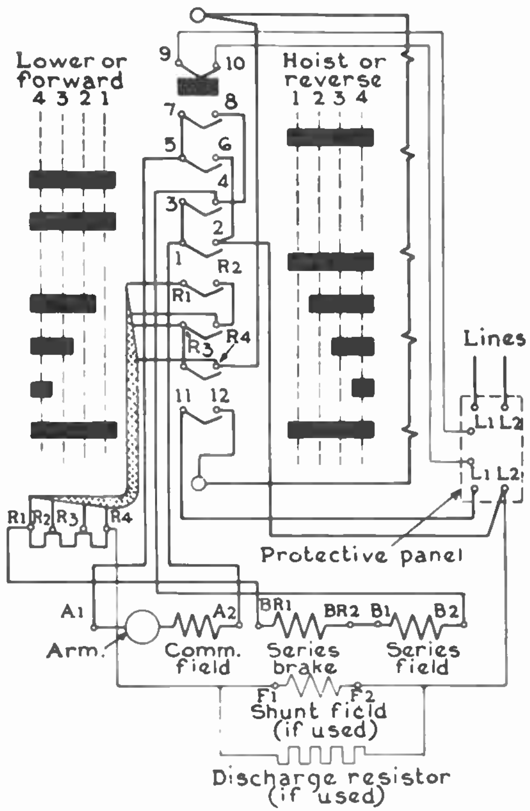
Trace armature, field and dynamic brake circuits. Draw the terminal board on the diagram and test the terminals to identify them. Do not show the terminal board connected. Make all connections as shown for a compound motor. If shunt motor is used connect R_5 to L_2. If series motor is used omit F_1 connection.

COYNE

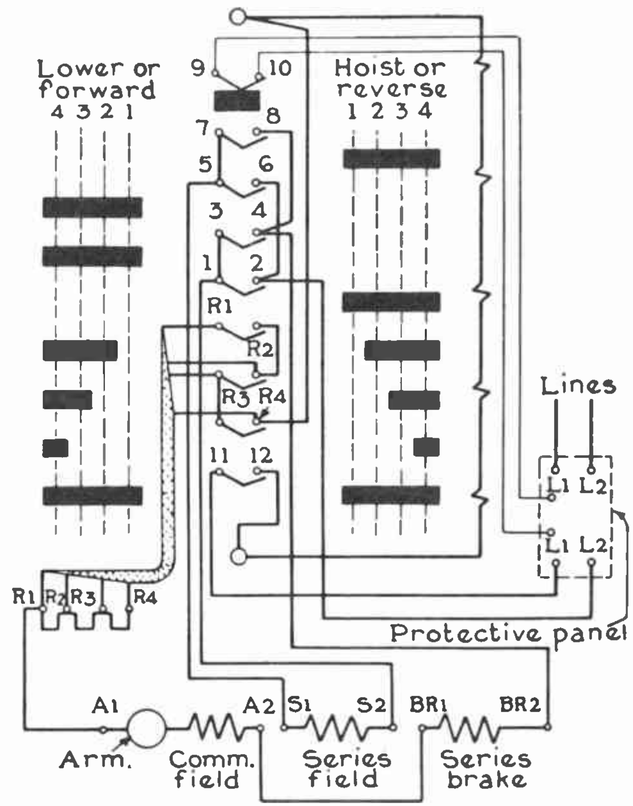
CAM-TYPE DRUM SWITCHES



For series motors only



For shunt and compound motors

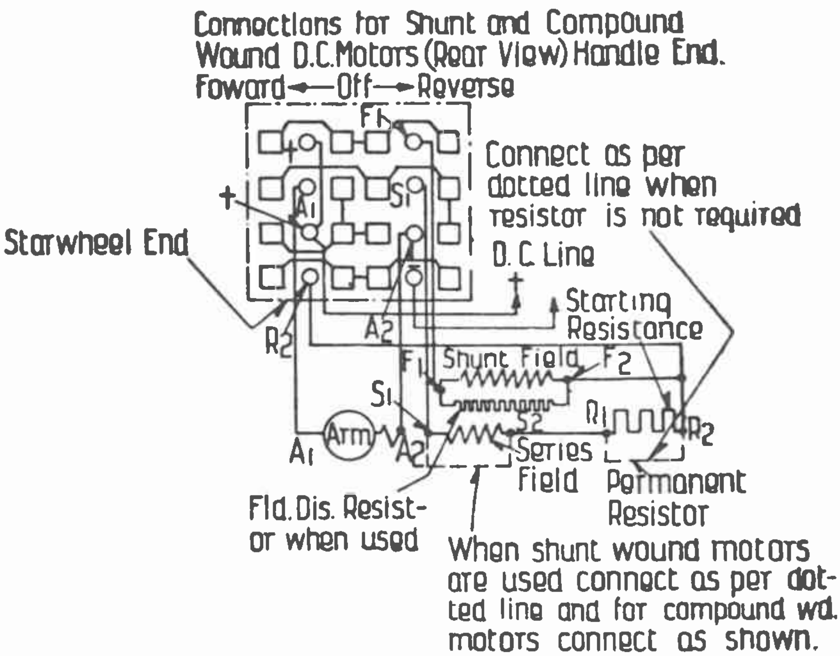


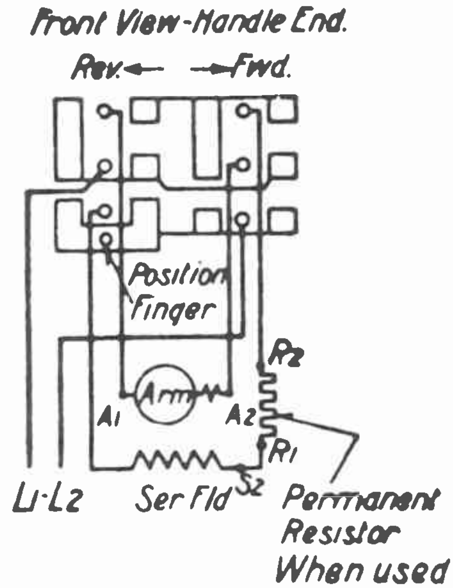
For series motors with traveling cranes

GENERAL ELECTRIC CR 3108 Contacts are cam closed and cam opened. For starting and/or speed regulating. Off position contact can be used (1) with a protective panel to provide undervoltage and overload protection, or (2) with a dynamic braking resistor to provide quick stop.

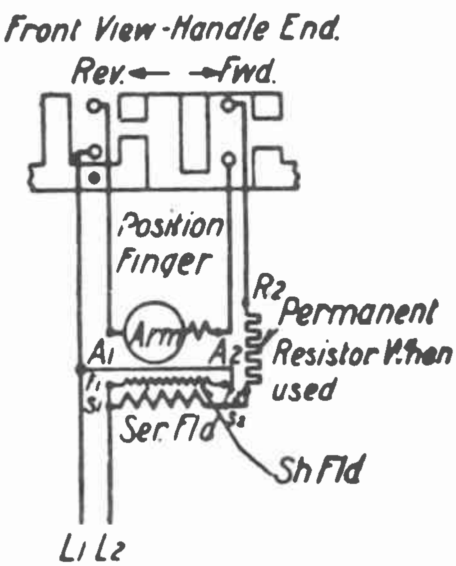
DRUM REVERSING SWITCHES

WESTINGHOUSE



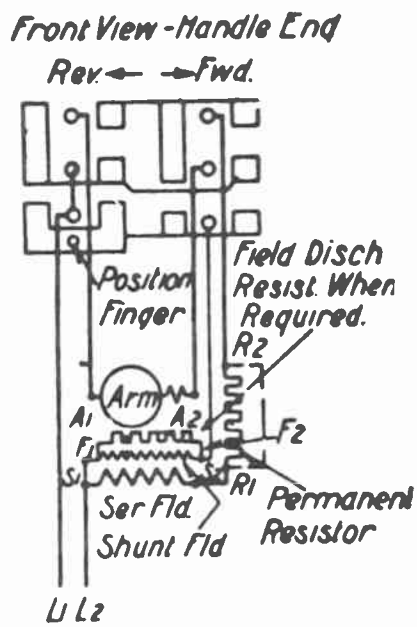


With D C Motor, series winding, with or without permanent resistor



With D.C.Motor, shunt, series or compound winding, with or without permanent resistor.

When field discharge resistor is used, connect to F1 & F2

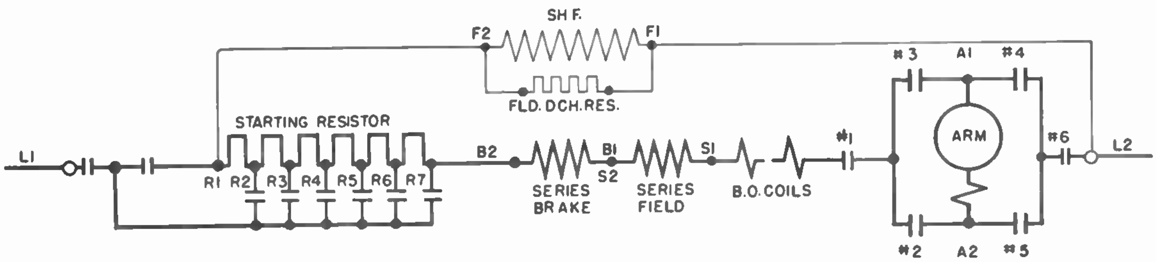


With D.C Motor, shunt, or compound winding, with or without permanent resistor.

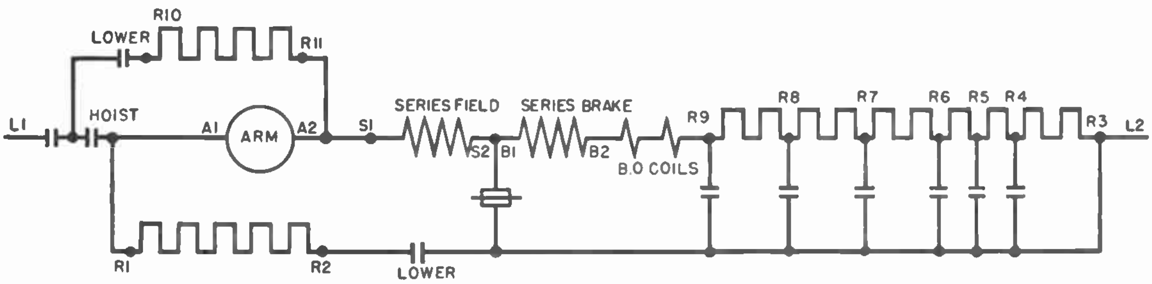
When field discharge resistor is used, connect to F1 & F2.

DRUM CONTROLLERS AND DRUM REVERSING SWITCHES WESTINGHOUSE

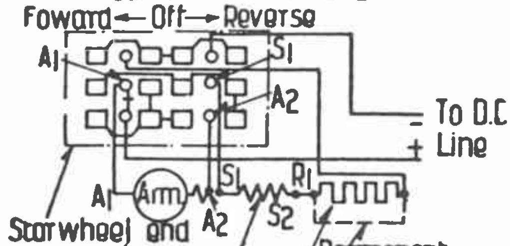
CLASS 8300 CONTROLLERS



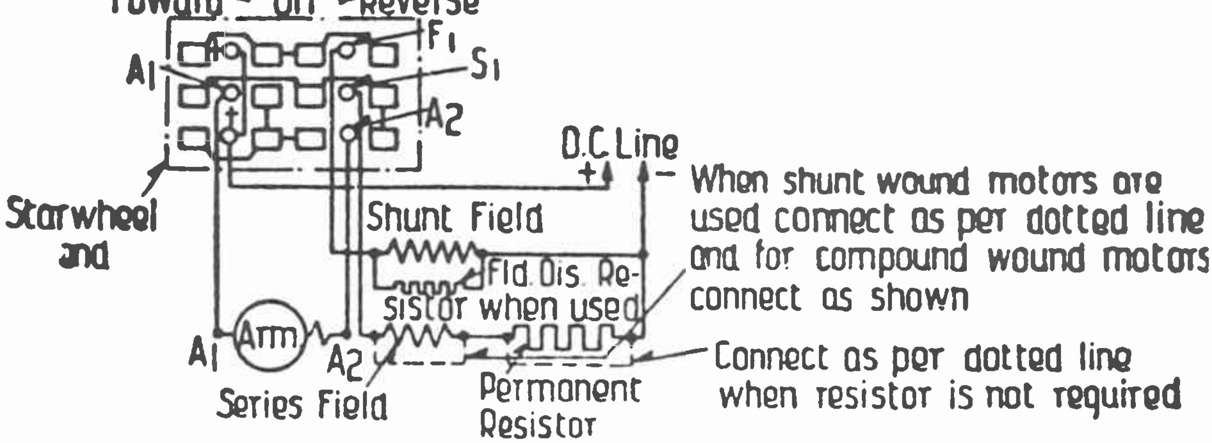
CLASS 8400 CONTROLLERS



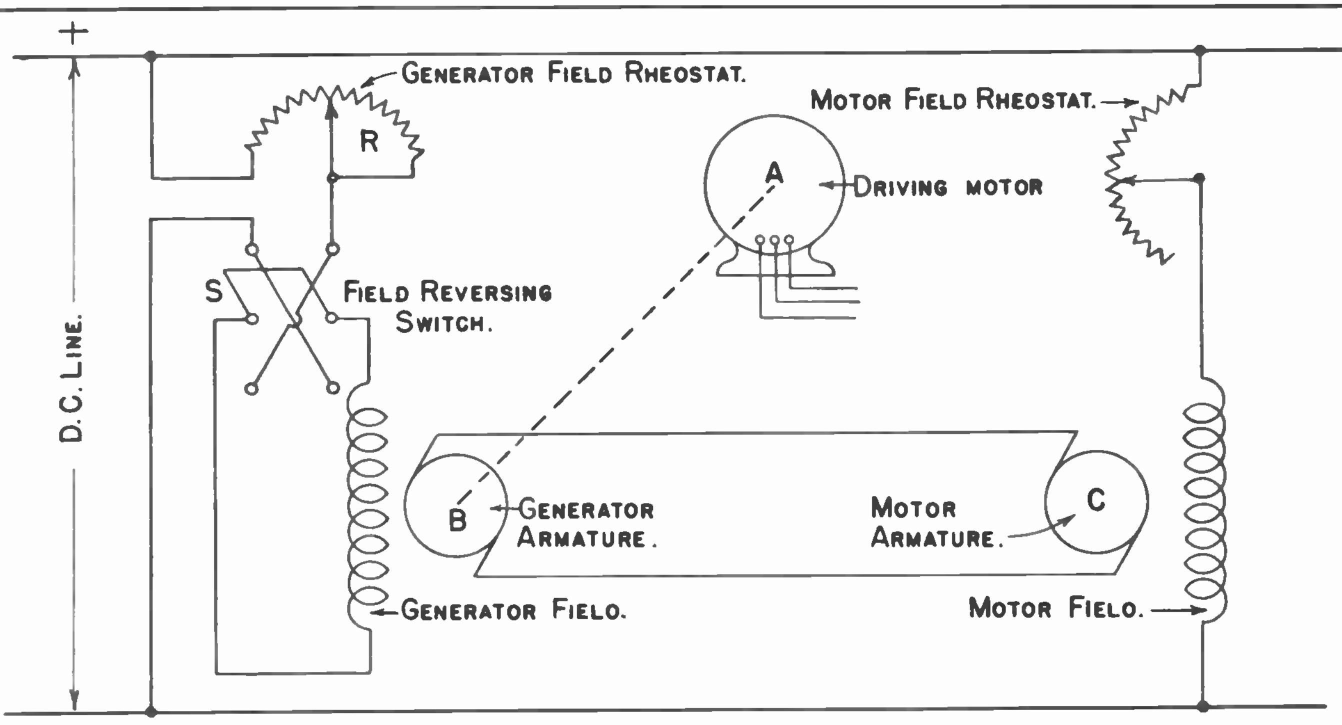
Connections for Series Wound D.C. Motor
Rear View-Handle End
Foward ← Off → Reverse



Connections for Shunt and Compound Wd.
D.C Motor Rear View-Handle End
Foward ← Off → Reverse



VARIABLE VOLTAGE CONTROL.



The variation in speed obtainable by field control on the ordinary D.C. motor will not, in the average case, exceed 4 to 1 due to the sparking difficulties experienced with very weak fields. Although the range may be increased by inserting resistance in series with the armature, this can be done only at the expense of efficiency and speed regulation.

With constant voltage applied to the field, the speed of a D.C. motor varies directly with the armature voltage; therefore, such a motor may be steplessly varied from zero to maximum operating speed by increasing the voltage applied to its armature. The sketch shows the arrangement of machines and the connections used in the Ward Leonard type of variable voltage control designed to change speed and reverse rotation. The constant speed D.C. generator (B) is usually driven by an A.C. motor (A) and its voltage is controlled by means of rheostat R. Note that the fields of both generator (B) and driving motor (C) are energized from a separate D.C. supply or by an auxiliary exciter driven off the generator shaft. Thus the strength of the motor field is held constant, while the generator field may be varied widely by rheostat R.

With the set in operation generator (B) is driven at a constant speed by prime mover A. Voltage from B is applied to the D.C. motor (C) which is connected to the machine to be driven. By proper manipulation of rheostat R and field reversing switch S the D.C. motor may be gradually started, brought up to and held at any speed, or reversed. As all of these changes may be accomplished without breaking lines to the main motor, the control mechanism is small, relatively inexpensive, and less likely to give trouble than the equipments designed for heavier currents.

The advantages of this system lie in the flexibility of the control, the complete elimination of resistor losses, the relatively great range over which the speed can be varied, the excellent speed regulation on each setting, and the fact that changing the armature voltage does not diminish the maximum torque which the motor is capable of exerting since the field flux is constant.

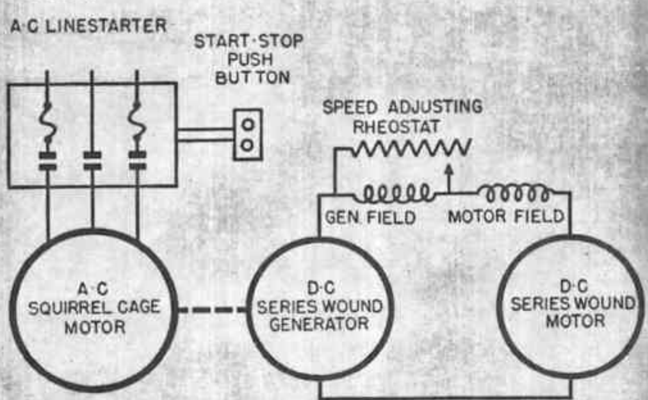
By means of the arrangement shown, speed ranges of 20 to 1—as compared to 4 to 1 for shunt field control—may be secured. Speeds above the rated normal full load speed may be obtained by inserting resistance in the motor shunt field. This represents a modification of the variable voltage control method which was originally designed for the operation of constant torque loads up to the rated normal full load speed.

As three machines are usually required, this type of speed control finds application only where great variations in speed and unusually smooth control are desired. Steel mill rolls, electric shovels, passenger elevators, machine tools, turntables, large ventilating fans and similar equipments represent the type of machinery to which this method of speed control has been applied.

WESTINGHOUSE A-C ADJUSTABLE SPEED DRIVE

METHOD OF OPERATION

The schematic diagram illustrates the simplicity of the A-C adjustable speed drive. To start the drive, it is only necessary to press the "start" button which closes the linestarter, brings the motor generator up to speed and starts the D-C driving motor. This method of starting acts as a magnetic cushion to prevent shocks on gears while accelerating. The speed of the D-C driving motor can be set by changing the setting of the generator field rheostat. When all of the resistance is in the rheostat, the generator voltage and motor speeds are at their maximum value. As the resistance in the rheostat is reduced, the generator voltage is lowered and the motor operates at a slower speed.



Once the rheostat has been set for the desired speed, the drive can be started and stopped without touching the rheostat. The driving motor will come up to the set speed when the "start" button is pressed.

The motor will carry its rated horsepower at rated speed (usually 1750 Rpm.) continuously without exceeding 40°C. temperature rise. The units are suitable for continuous operation from 1750 Rpm. to 175 Rpm. at constant torque (horsepower varies directly proportionate with the speed.

Since the generator voltage decreases with a decreasing load, the series motor cannot overspeed at light loads or no load.

SPEED MAINTAINED FROM COLD TO HOT OPERATION

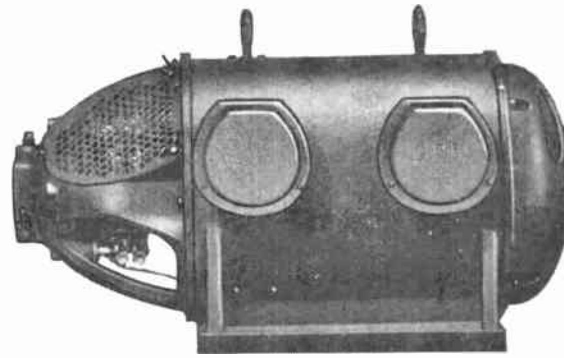
It is an inherent characteristic of shunt wound machines that as the shunt fields heat up the speed of the machine will increase as much as 10% or more. With the series type machine used in this drive, there is practically no change in speed from cold to hot operation.

SPEED MAINTAINED WITH LOAD VARIATIONS

Once the desired speed has been obtained by setting the rheostat, it will be maintained within reasonably close limits regardless of variation in load or temperature changes. If the load increases, the motor will draw more current which, in turn, increases the generator field strength and raises the generator voltage. This compensates for the drooping speed characteristics of the series wound motor and keeps the motor rotating at the same speed regardless of load. Likewise, if the load falls off, the generator voltage decreases and the motor continues to operate at its set speed.

Thus the adjustable speed drive combines the desirable high torque characteristics of a series motor with the flat speed characteristics of a shunt wound machine.

EQUIPMENT INCLUDED



MOTOR GENERATOR—The motor generator set is of the 2-bearing unit type standard horizontal construction, easily mounted in any convenient location. It operates at 1750 Rpm. insuring long life of the bearings, commutators, and brushes. Bearings and brushes are readily accessible for inspection and maintenance and it is not necessary to dismantle the unit to get at the bearings.

ALTERNATE EQUIPMENT

Manual reversing and dynamic break in the "off" position can be supplied. Inching service with control interlock to assure slow speed can be furnished.

Speed ranges, other than 1750 to 175 Rpm. are possible by the selection of a slower speed D-C drive motor or by the substitution of a gearmotor.

Motor generators can be supplied for 25 and 50 cycle operation but may be of the two-unit coupled type.

A Totally-Enclosed Fan-Cooled motor, Splash-proof motor, or motor with semi-enclosing covers may be substituted for standard open D-C driving motors.

A 'De-ion" Combination Linestarter (circuit protective device and motor starter) can be used in place of the standard linestarter.

WESTINGHOUSE A-C ADJUSTABLE SPEED DRIVE

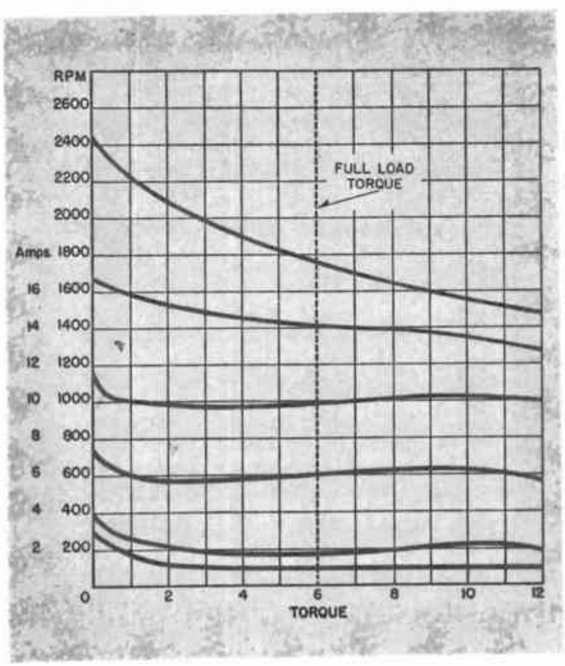
D-C DRIVE MOTOR—The drive motor is the standard, open, Type SK motor which has been proved through years of severe service under all sorts of operating conditions. It is equipped with sealed-sleeve bearings which seal oil in—foreign matter out. Standard speed supplied is 1750 Rpm.

Other enclosure types (see alternate equipment), and other speeds, including gearmotors, can be supplied if desired at additional cost.

RHEOSTAT—The generator field rheostat supplied is a plate type rheostat. It is provided with an adjustable stop which permits setting the maximum generator voltage at the time of installation and so prevent improper operation of the machine. This rheostat may be mounted on the wall, machine or any location convenient to the operator. Hand wheel permits adjustment of setting desired.

LINESTARTER AND PUSHBUTTON—The linestarter supplied as part of this drive is a standard Class 11-200 across-the-line magnetic starter. It has bi-metallic overload protection and "De-ion" arc quenchers. It may be operated by standard "start" "stop" pushbutton mounted in a convenient location. If desired, however, the "start" "stop" can be built into the door of the linestarter to further simplify installation.

SPECIFICATIONS—A-C. ADJUSTABLE SPEED DRIVES



Typical Speed-Torque Curves

STARTING TORQUE—High starting torque is inherent in series motors at minimum speed setting. For example, a 10 HP. drive will develop 600% of its full load running torque.

HORSEPOWER RATING—These drives are available in ratings from 1 to 15 HP. inclusive, and can be supplied to operate from 208, 220, 440 or 550 volts, two or three-phase, 60 cycle power supply.

SPEED RANGE—A 10:1 speed range can be obtained by a single rheostat. That is, a 1750 Rpm. machine down to a 175 Rpm. before or during operation. Motors with slower full speeds, or gearmotors, can also be used giving the same 10:1 speed range.

TEMPERATURE LIMITS—The motor will carry its rated HP. at rated speed (1750 Rpm.) continuously without exceeding a 40°C. temperature rise. The units are suitable for continuous operation from 1750 Rpm. to 175 Rpm. at constant torque (HP. varies directly proportional with the speed). At slow speeds, the temperature will be somewhat higher than 40°C. due to reduced ventilation but will not exceed a safe value.

OVERLOAD PROTECTION—The thermal overload relay in the A-C linestarter provides protection to the drive against high power and systematic overloads at normal operating speeds. In addition, the D-C motor is equipped with a thermoguard which protects the windings against overheat on overloads at any speed. The thermoguard is mounted directly on the motor winding and at unsafe temperature opens the linestarter circuit removing the motors from the line. This permits the motor to develop heavy overloads for short periods of time or carry sustained overloads for a long time without danger of damaging the winding.

Regulex Control

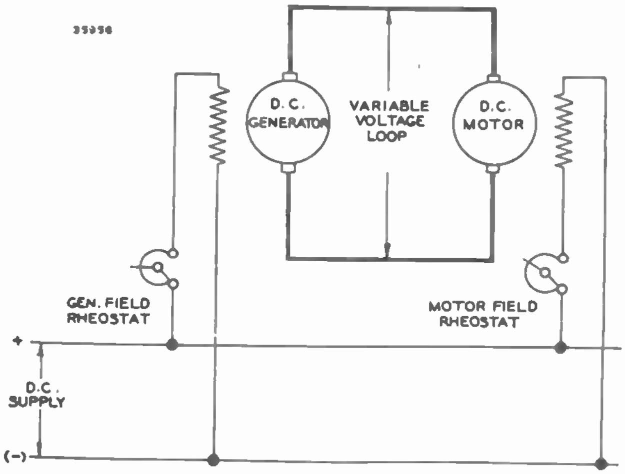


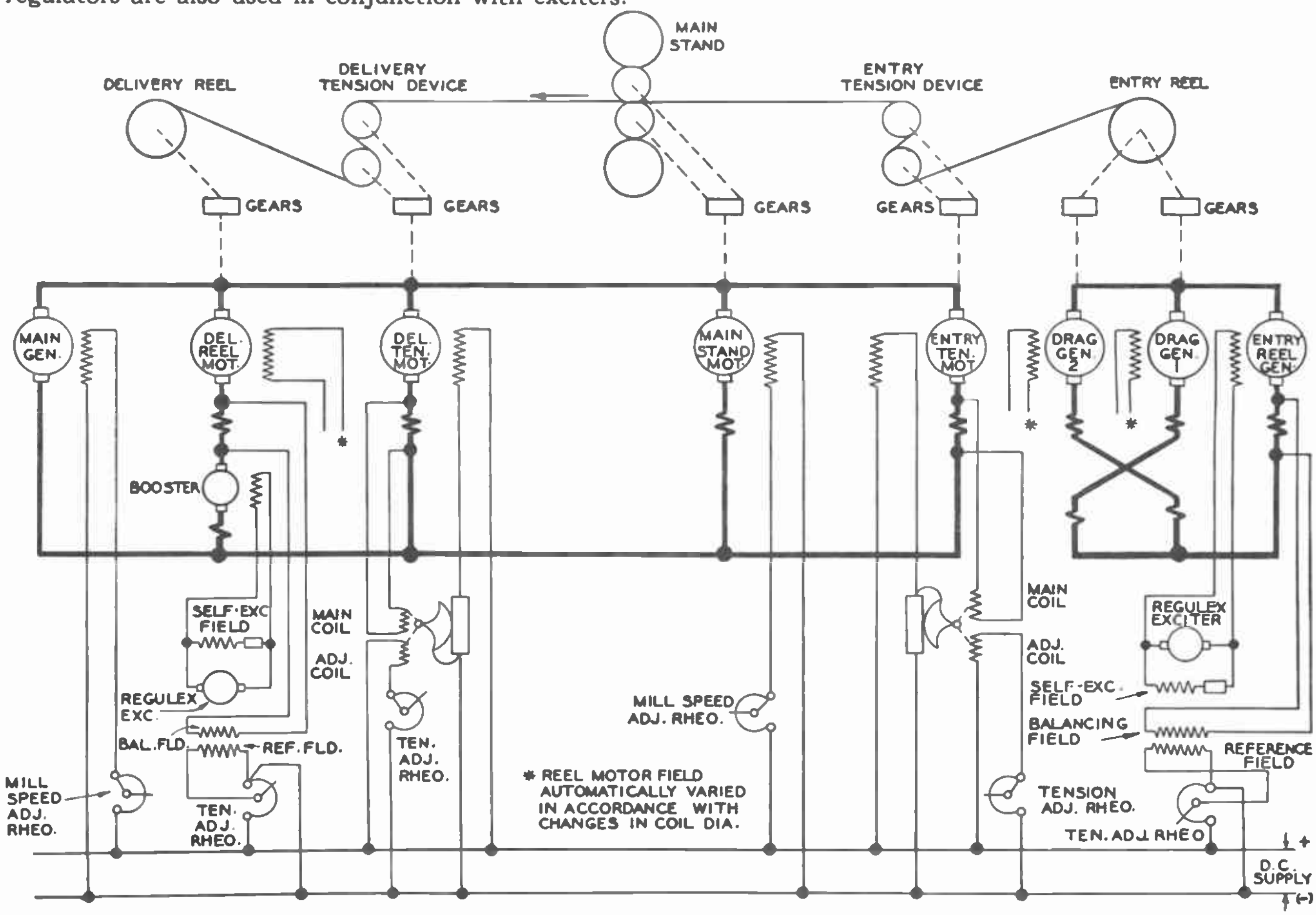
Diagram of basic variable voltage system.

Most main drives have their generators and motors separately excited. The variable voltage control may be manual or automatic. *Regulex* exciters automatically control the drive motor performance of constant or predetermined speed, tension, power, acceleration, deceleration, position, reversing, current limit, etc., or combinations of these functions. *Rocking-Contact* voltage, current, speed or tension regulators are also used in conjunction with exciters.

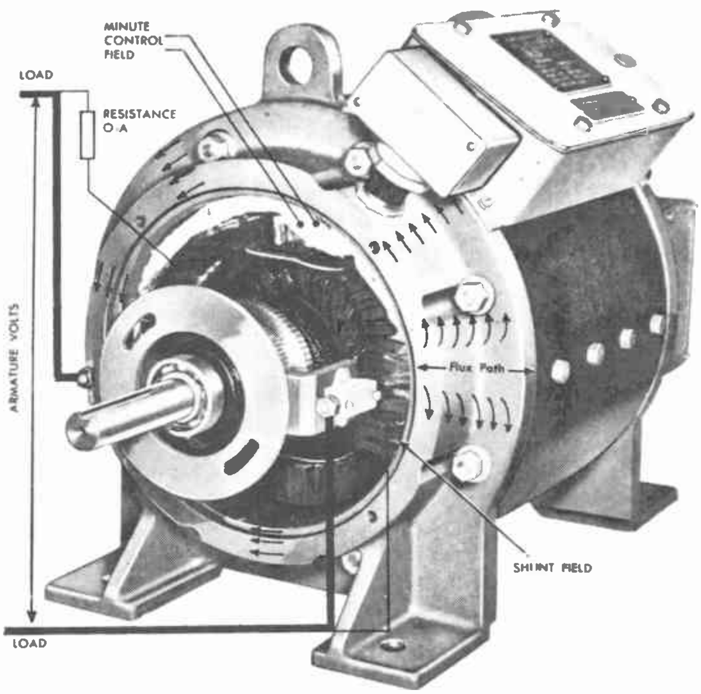
Temper Mill Control

TEMPER MILLS take the steel coils from the annealing furnace and roll the steel under tension to produce the desired mirror surface finish and temper. The entry reel is used to provide back tension and usually a tension roll device provides delivery tension. The strip is then recoiled by the delivery reel.

Regulex exciters are used for accurate reel tension control and *Regulex* exciters, *Rocking-Contact* regulators or tensionmeters control tension between stands.



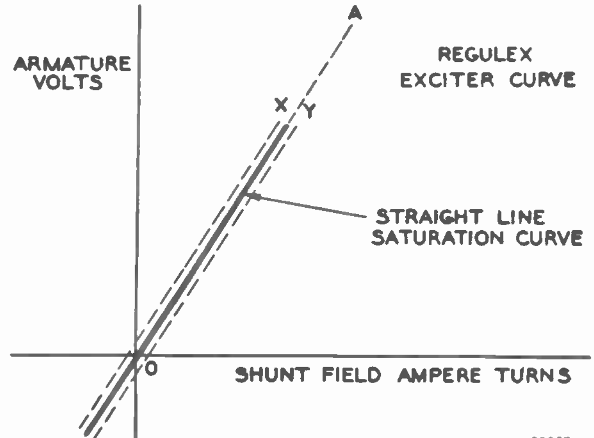
Schematic diagram of temper mill control, illustrating Regulex tension control on the entry and delivery reels, and Rocking Contact regulator control on the tension rolls.



Regulex exciter with end bell removed to show armature, brush rig, shunt field, control field, and large flux path.

Regulex Exciter

Now suppose the flux path is made large enough so that there is *no saturation* (within rated voltage range.) If this is done the saturation curve becomes a *straight line* as shown below. And suppose the field rheostat is replaced by a resistor set to give field resistance line *O-A*. *The field resistance line is set to fall directly on top of the straight line saturation curve.* Now you have one form of *Regulex* exciter (Fig. left). The shunt field always supplies enough ampere-turns to produce whatever particular operating voltage exists.

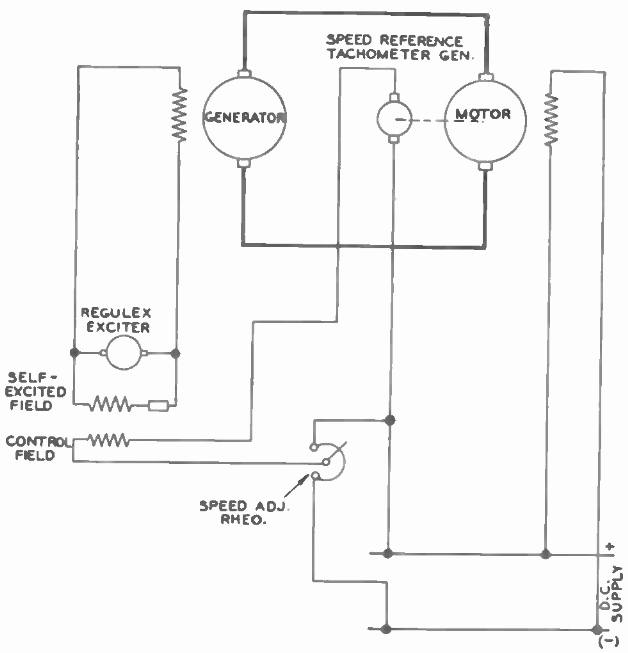


Straight line characteristic of the Regulex exciter.

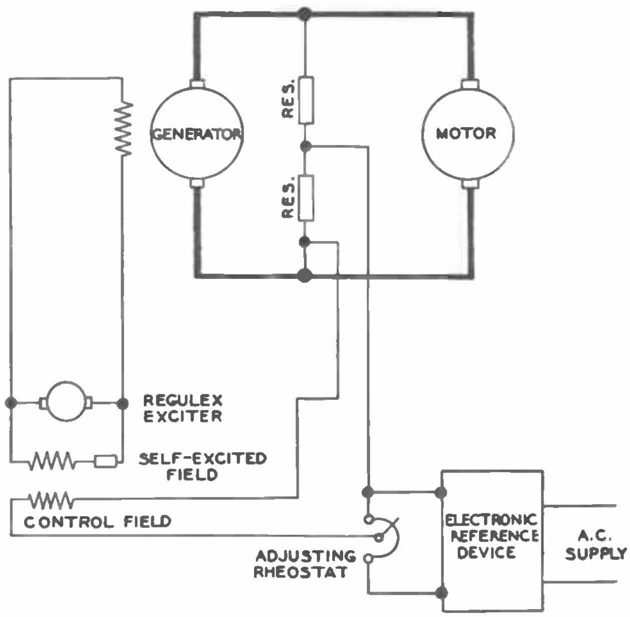
Paper and Rubber Mill Control

The *Regulex* exciter finds wide application in paper, rubber, textile and other process mills where close control of speed, tension, acceleration and position are required. A few typical applications are single motor paper machine drives, paper reeling machines, paper and rubber calenders and textile bleaching lines.

In these applications the *Regulex* exciter improves quality of product by more accurately controlling the speed, increases versatility of driven machine by permitting wider speed range, gives a more uniform product with less waste by controlling tension, and steps up production by cutting acceleration and deceleration time.



Schematic diagram showing Regulex speed control frequently used on calender drives. Generator voltage is varied to hold constant motor speed by balancing tachometer voltage against d-c reference through adjusting rheostat.



Schematic diagram of very accurate speed control at any given load by generator voltage regulation over wide speed range.

Regulex Control

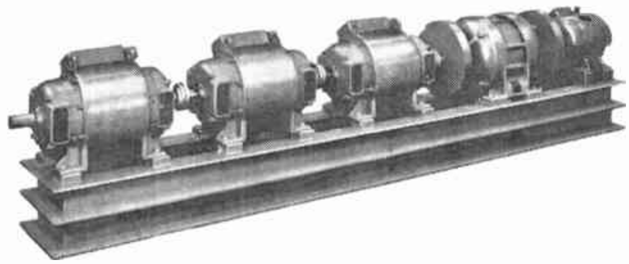
Arc Furnace Control

Regulex control on arc furnaces provides a sensitive, accurate means of manually or automatically regulating electrode position. The speed and accuracy of response of the *Regulex* generator permits fast meltdown, low electrode consumption and a high degree of power economy. Maintenance is low because relays and contactors are eliminated.

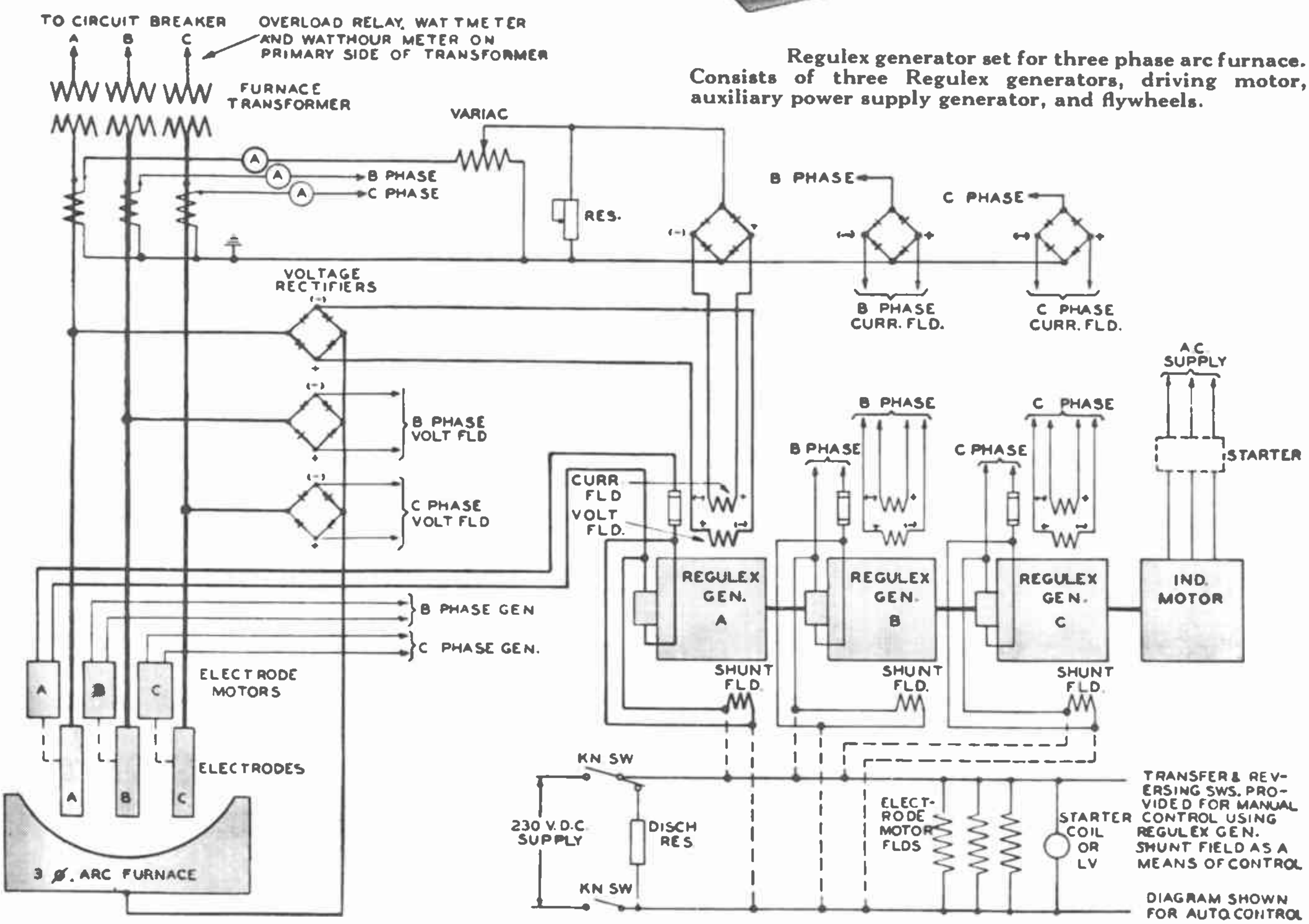
Each separately excited electrode motor is connected directly to its individual *Regulex* generator in the variable voltage system as shown. Reversing operation of the electrode motor is controlled by the relative strength of the current field and the voltage field in the *Regulex* generator. The current field and voltage field are in opposition to one another. The strength of the current field is proportional to the arc current and the strength of the voltage field is proportional to the arc voltage. When the correct arc current and voltage exist these fields are balanced and there is no output voltage on the *Regulex* generator and consequently no power supplied to electrode motor. As soon as conditions become unbalanced, these field strengths are no longer equal and the *Regulex* generator instantly applies an amplified voltage to the electrode motor to raise or lower the electrode and return arc conditions to normal.

The amount of forcing on the electrode motor is proportional to the amount of unbalance, giving continuous, smooth and stepless regulation with regenerative braking so that the electrode motor comes to a quick stop as soon as there is balance again. No brakes are needed.

The *Regulex* set consists of a-c driving motor and three *Regulex* generators (one for each electrode motor on three phase furnaces). An auxiliary generator can be supplied on the set for auxiliary d-c power around the furnace if desired. Flywheels may also be added to provide the highly desirable feature of automatically raising the electrodes out of the bath on a power failure to the furnace.



Regulex generator set for three phase arc furnace. Consists of three Regulex generators, driving motor, auxiliary power supply generator, and flywheels.



Schematic diagram of Regulex control on three phase arc furnace.

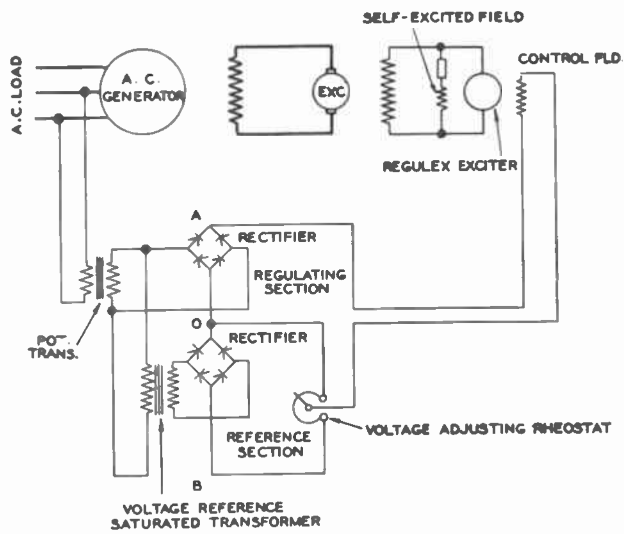
Regulex Control

Generator Voltage Regulation

One of the most important applications of the *Regulex* exciter is to hold accurate, constant voltage output on alternators, generators, and synchronous condensers in power plants. Here the *Regulex* exciter is used as an exciter supplying excitation to the generator or in the case of large generators, the *Regulex* exciter replaces the pilot exciter.

The a-c generator voltage is stepped down by a potential transformer whose secondary voltage is connected to two circuits: One, the regulating section consisting of a full wave rectifier giving a d-c voltage across *O-A* proportional to a-c generator terminal voltage. The second is the reference section, consisting of a voltage reference saturated transformer and full wave rectifier giving a substantially constant voltage *O-B*. These two voltages are in opposition to one another through potentiometer connected voltage adjusting rheostat. Thus the resultant or differential voltage acting through the *Regulex* control field causes the *Regulex* exciter to supply correct excitation to the generator to hold constant generator voltage.

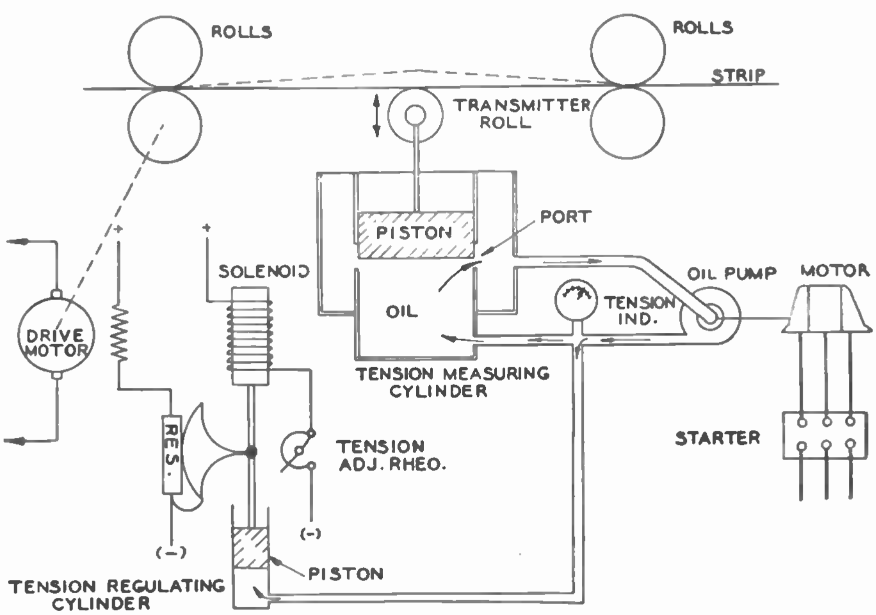
When the generator terminal voltage is normal, voltage *O-A* just equals reference voltage *O-B* and the *Regulex* exciter output is constant at the required value. However, if generator terminal voltage changes for any reason, the voltage that is applied to the control field is proportional to the amount of unbalance between *O-A* and *O-B* and the speed of excitation forcing action varies accordingly. By this means maximum corrective effort is applied in the correct direction for large generator voltage changes and field forcing tapers off as conditions return to normal. In this way generator voltage returns to normal smoothly without overshooting.



Schematic diagram of Regulex exciter accurately controlling output voltage on a-c generator in power plant.

The speed of voltage recovery on the generator is practically instantaneous because the rapid response of the *Regulex* exciter eliminates time delay in the circuit.

For d-c generators, the rectifiers and transformers are eliminated and a d-c source is used as a reference.



Regulating and indicating tensiometer diagram.

Electronic Synchronizer, Type XT

The more important features of the device are:

1—A "lock-out" feature that prevents the Synchronizer from energizing the switching mechanism's closing coil unless the frequency difference is less than a selected amount. This "lock-out" frequency difference is readily adjustable.

2—The phase angle in advance of synchronism at which the closing coil of the switching mechanism is energized, is adjustable so that the Synchronizer can be used with various switching mechanisms having different closing times.

3—The XT Synchronizer imposes a burden of only five volt-amperes on its source of supply This low energy consumption is important, particularly when the power source is limited such as condenser-bushing potential devices

4—The XT Synchronizer is provided with its own power pack, consisting of a transformer, rectifier tube (Type UX 280), and the necessary condensers and reactors to give a smooth source of direct current. This power pack eliminates the need of any *B* batteries, which would have to be periodically replaced. It is appropriately called a *B* Eliminator and is used only when 250 volts direct current is not available.

The Synchronizer can be used either when the switching mechanism it controls is the first tie between two sources to be connected, or when another tie between the two sources already exists. Examples of the former are: (a) synchronizing a generator to another generator, (b) synchronizing a generator to a power system, and (c) synchronizing two separate systems. Examples of the latter are (a) synchronizing two lines of the same system, and (b) synchronizing two systems already connected at some other point. In other words, the Synchronizer is applicable in almost all synchronizing applications. The switching mechanism should be a circuit breaker taking from .5 to 1.0 seconds to close.

OPERATION

To perform its functions the XT Synchronizer shown in Fig. 41, employs two interlocking relays indicated as relay II and relay III in Fig. 42. Relay

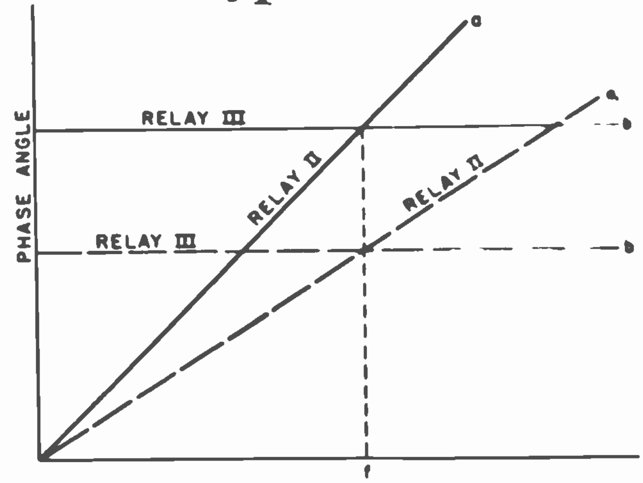


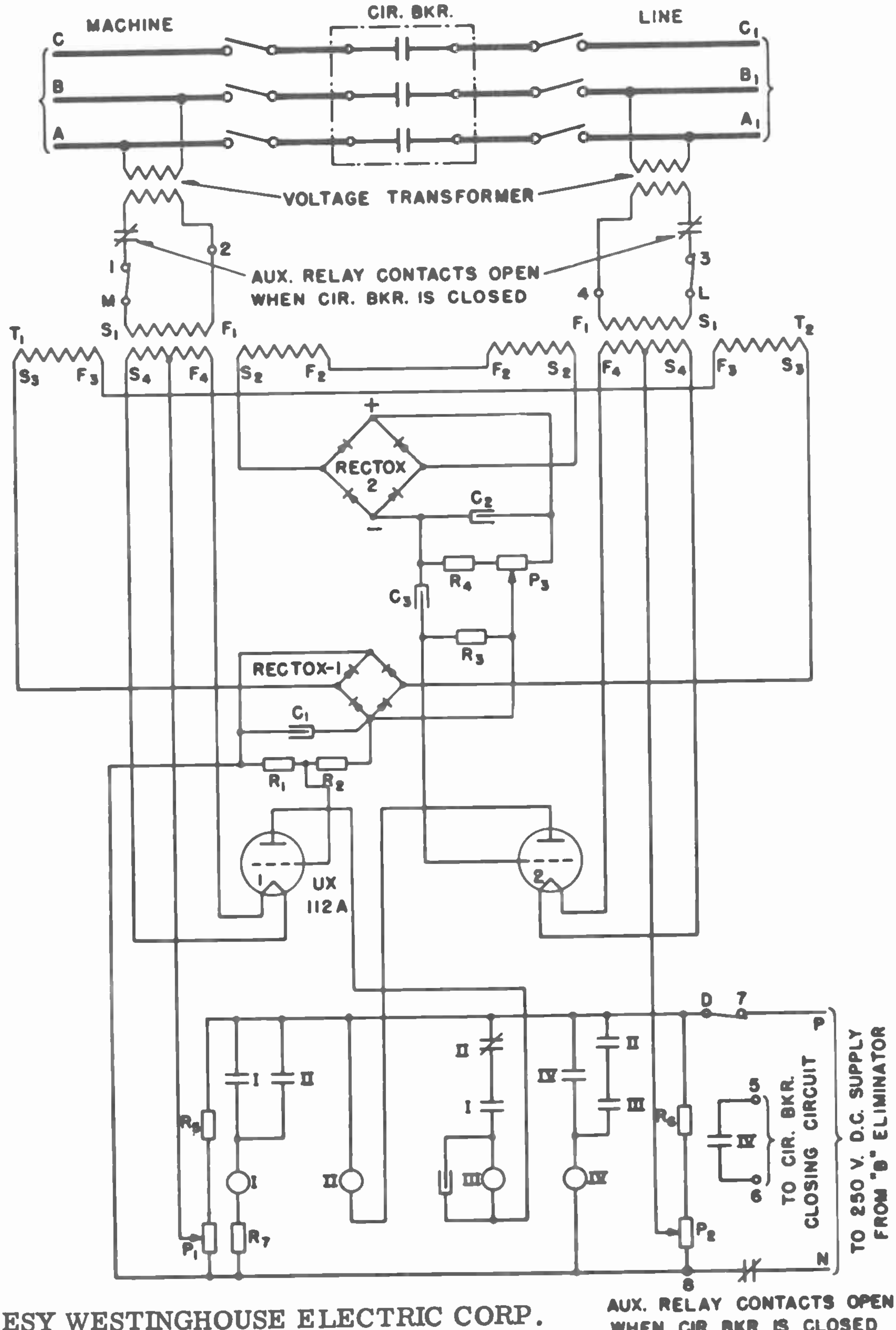
Figure 42—Graph Illustrating the Operation of the Control Relay of Synchronizer

III operates and closes its contacts at a fixed point in advance of synchronism, the closing characteristic being independent of the frequency difference as illustrated by line *b*, while relay II closes its contacts at a point in advance of synchronism proportional to the frequency difference and phase angle according to line *a* of Fig. 42. An interlock between relays II and III is arranged so that another relay, IV, which is energizing the breaker closing coil, is closed only if relay III is operated before relay II is closed. Under these conditions, this relay combination has the characteristic required of the ideal Synchronizer. Then *f* in the figure is the selected lock-out frequency difference as given by the intersection of line *a* and *b*.

The closing characteristic of relay II is adjustable. It can be made to operate at various angles of phase separation for the same frequency difference by changing the setting of a control potentiometer. In order to use the Synchronizer with switching mechanisms having different closing times, it is necessary to adjust the control potentiometer and thereby change the slope of line *a* of Fig. 42. The greater the slope of line *a*, the slower the switching mechanism with which the Synchronizer is used.

When the slope of line *a* is changed, the lock-out frequency will change unless the operating angle of relay III is altered. Therefore, to keep the same lock-out frequency, the operating point of relay III must be altered at the same time the control potentiometer of relay II is changed. In Fig. 42 the dashed lines a_1 and b_1 represent the characteristics of the relay when the Synchronizer is used with a switching mechanism faster than the one that would be used corresponding to the relay characteristics as shown by the solid lines *a* and *b*.

The schematic diagram of the automatic Synchronizer, Fig. 43, shows, in addition to relays II and III and breaker-closing relay IV, also an intermediate relay I. The function of relay IV is to interpose a time delay corresponding to one phase rotation before allowing the Synchronizer to take control, and thus prevent synchronizing until condenser C_3 (the action of C_3 will be explained later) has assumed the charge corresponding to the instantaneous phase-angle displacement and frequency difference. The sequence of relay operation when the Synchronizer is given control,



COURTESY WESTINGHOUSE ELECTRIC CORP.

Schematic Diagram of XT Synchronizer

The first time the phase-angle displacement is zero, relay II operates, and "make" contacts of relay II energize relay I, which operates and seals itself in. As long as relay II remains energized its "break" contacts prevent relay III operating. However, because the frequency of the two systems is different, relay II becomes de-energized as the systems separate in phase angle. Then, as the phase-angle separation passes 180° and begins to decrease toward 0°, relay III becomes energized. (This is true if the lock-out frequency is greater than the frequency difference; otherwise relay II operates first and prevents relay III from being energized.) Relay II then becomes energized after relay III. The instant the contacts of relay II close, relay IV becomes energized and seals itself in. It is significant that capacitor C_4 stores sufficient charge to keep relay III energized for a short interval after the break contacts of relay II open its circuit. This interval allows relay IV time to operate.

When the circuit breaker is closed, the automatic Synchronizer is disconnected from the 250-volt control circuit by means of an auxiliary relay, which is operated by auxiliary contacts on the switching mechanism. Because relay IV can operate and close the circuit breaker only if both relay II and relay III are closed, the device is made inoperative by failure of either of the electronic tubes. Faulty synchronizing because of tube failure is, therefore, prevented.

Tube 1 is in series with the coil of relay III and tube 2 is in series with the coil of relay II. Therefore, the operation of the relays discussed above, is dependent upon the current conductivity of the tubes
The automatic Synchronizer is connected to the condenser-bushing potential device or potential transformers on the two systems to be paralleled. (The secondary voltage of this potential device must be 110.) This is done by two transformers, the secondaries of which are connected to give a dark-lamp beat voltage across Rectox banks 1 and 2. The a-c components of the rectified voltage are smoothed out by condensers C and C The Rectox output voltage is, therefore, essentially a pulsating d-c voltage varying according to a sine-wave between zero and maximum at a frequency equal to the frequency difference between the two systems to be paralleled.

Tube 1 (type UX-112-A) is connected in series with the coil of relay III across a 250-volt, d-c supply circuit; the d-c voltage being obtained from the *B* Eliminator. By means of the potentiometer P_1, the grid is supplied with a constant negative bias that can be varied by changing the potentiometer setting. In addition to this bias, a negative bias equal to one-half of the d-c voltage across Rectox 1 is applied to the grid. This bias is a maximum when the phase-angle displacement between the system voltages is across resistor R_3, the magnitude of this voltage drop being proportional to the frequency difference.

The voltage drop across R_3 is connected to give a positive bias to the grid of tube 2 when C_3 is discharging. A preset constant negative bias is applied to the grid of this tube by means of the potentiometer P_2, and a varying negative bias is obtained from resistors R_1 and R_2 across the terminals of Rectox 1. It is this varying negative component that introduces the effect of phase-angle separation on the operation of relay II. Potentiometer P_2 is so adjusted that the negative grid bias obtained from the potentiometer is just low enough to operate relay II at zero phase-angle displacement when the frequency difference is zero. For any definite fre-
180 degrees. When the phase-angle is reduced, the negative bias on the grid is reduced until a point is reached where the total negative bias on the grid is low enough to allow relay III to close its contacts. By adjusting the potentiometer, the operating characteristic for relay III can be located at any phase-angle position between zero and 40 degrees.

The proportional advance characteristic of relay II is obtained through the combined action of condenser C_3, resistor R_3, resistors R_1 and R_2, potentiometer P_2 and the voltage across Rectox 2. As previously stated the d-c output voltage of the Rectox is pulsating at a rate proportional to the frequency difference between the two systems to be paralleled. The voltage across the condenser C_3 when the frequency difference is zero is equal to the output voltage of the Rectox 2. If the two systems differ in frequency by a definite amount, and if the phase-angle displacement is changing from 180 degrees toward zero, then the voltage across the terminals of the Rectox and the voltage across condenser C_3 are decreasing, but the voltage across the condenser is higher than the Rectox voltage by an amount dependent upon the frequency difference. The discharge current from the condenser will produce a voltage drop
quency difference the grid of tube 2 has a definite positive bias that reduces the total negative bias (composed of an adjustable component from P_2 and a varying component from R_1 and R_2) on the grid, and relay II, therefore, operates at an advance phase-angle position. The amount of this phase advance is proportional to the instantaneous frequency difference

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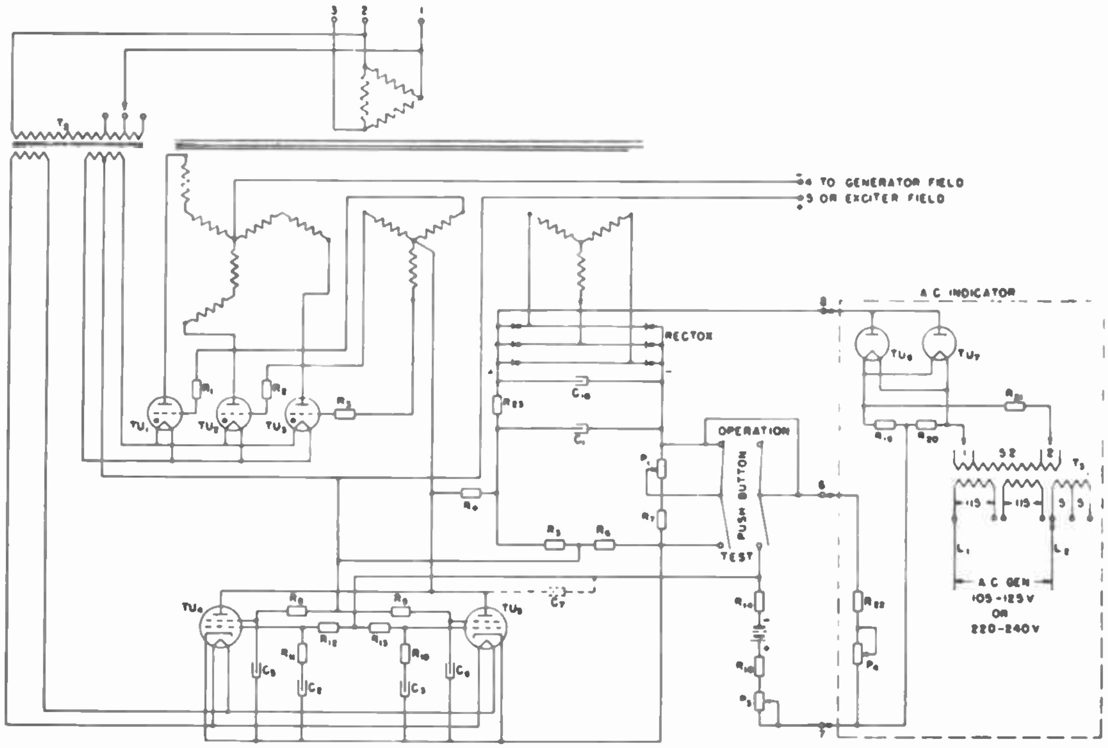

Figure 56—Schematic Diagram of DT-5 Regulator Used to Regulate an A-C Generator

A comparison of Fig. 60 of this section and Fig. 55 of the section on the DT-5 voltage regulator shows that, with the elimination of capacitor C_{10} and resistor R_{23} and the addition of two capacitors (C_{25}, C_{26}) and a resistor (R_{30}), the two devices are the same. These additional elements constitute an anticipatory circuit, which, in conjunction with the anti-hunt circuit, provides the highly sensitive, quick-response speed regulation.

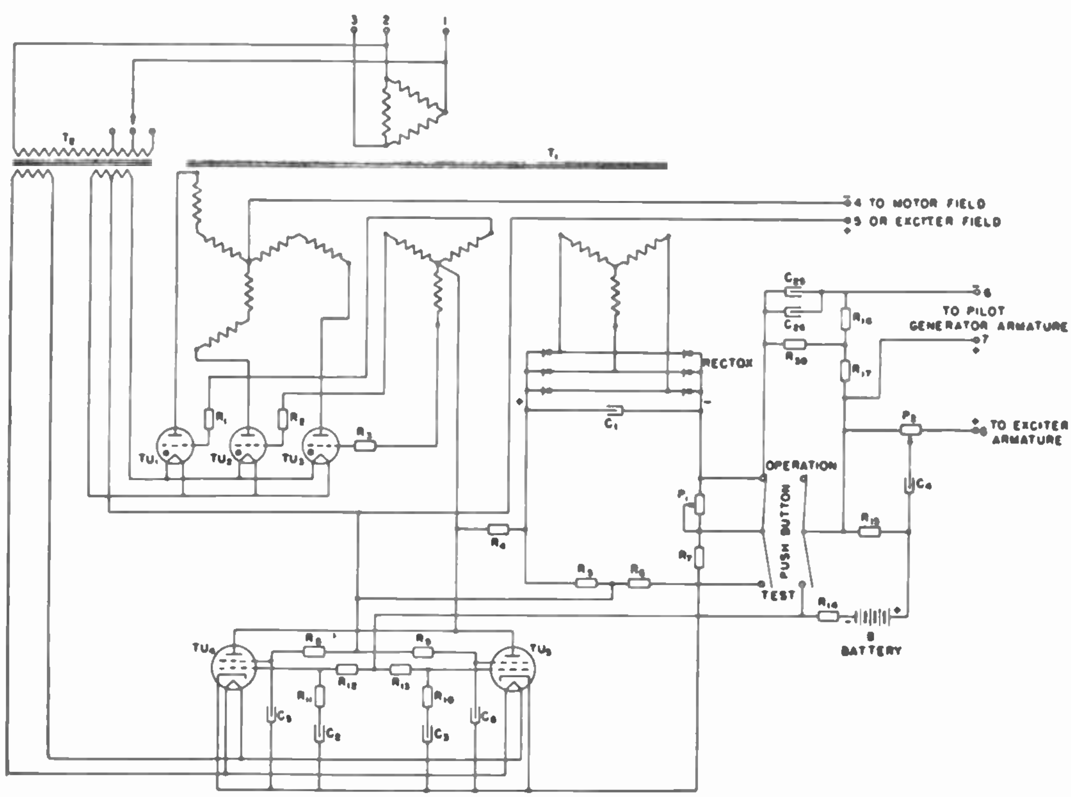

Figure 60—Schematic Diagram of DT-3 Speed Regulator

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The Mot-O-Trol provides a wide speed range by armature voltage control as well as by field control. The armature voltage-control speed range can be as high as 50 to 1. The obtainable field-control speed range can be from 2 to 1 up to 4 to 1 (special motors), giving a potential maximum (in special cases) of 200 to 1.

The speed of the motor is varied in a smooth and stepless way by means of a small potentiometer unit. The speed is automatically regulated so that, for a particular setting of the speed-control potentiometer, it remains essentially constant for all torques between no load and full load.

The Mot-O-Trol provides an automatic current limit and time delay acceleration of the motor whereby the motor is smoothly accelerated to the operating speed corresponding to the setting of the speed control potentiometer by simply depressing a pushbutton. The starting current never exceeds the predetermined limit, which is fixed by the setting of the current-limit control potentiometer. This is adjustable and is normally set for 150 to 200 per cent of rated motor current.

The Mot-O-Trol provides for the dynamic braking of the motor. When the *Stop* pushbutton is pressed, the motor is quickly stopped by dynamic braking. The intensity of braking action is adjustable.

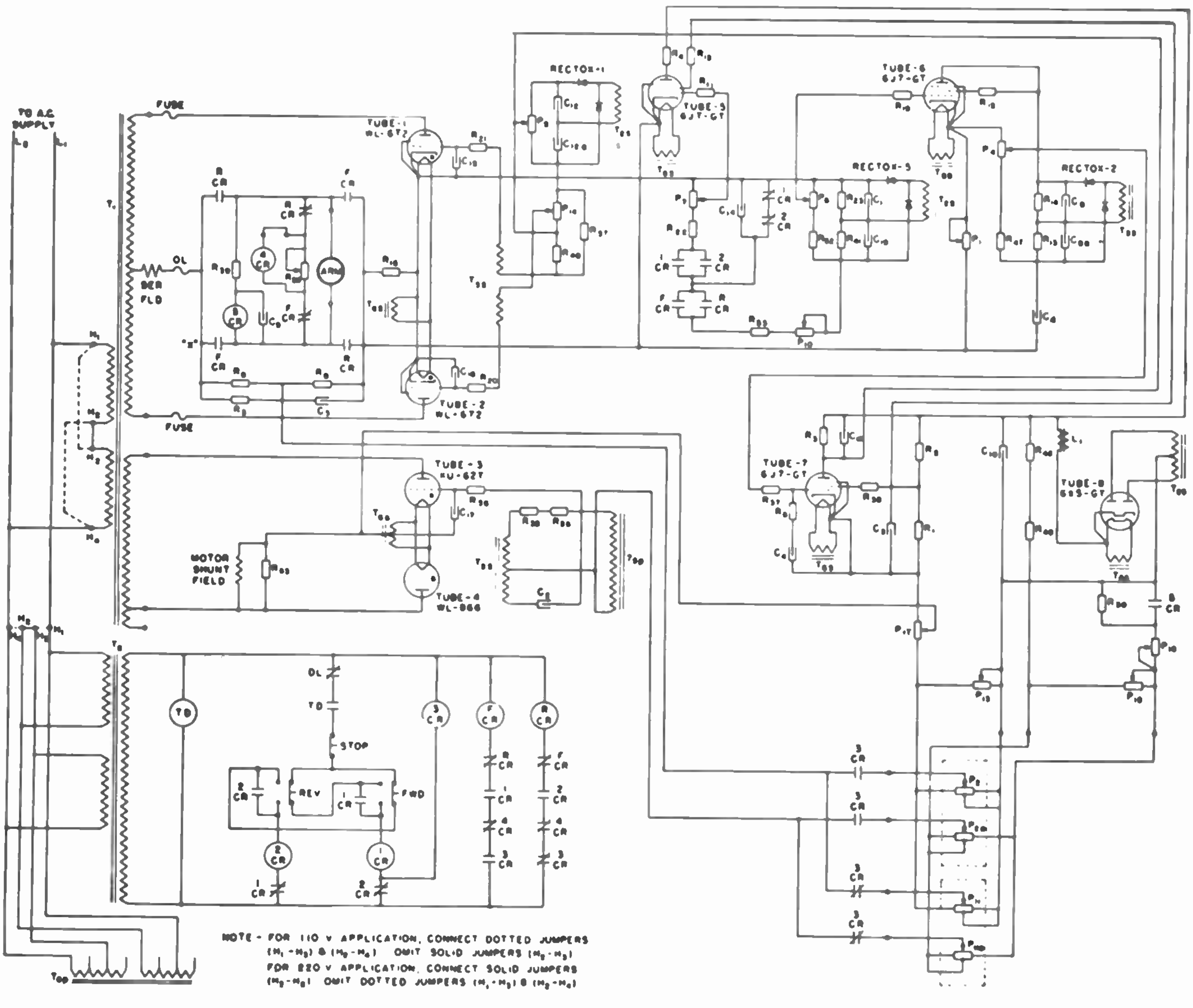

Figure 68 Schematic Diagram of Type MRF-11 Mot-O-Trol Equipment

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THEORY OF OPERATION (Refer to Fig. 79)

Each individual timing circuit of the NEMA Type 3B, functions electrically the same as the timing circuit of the NEMA Type 1A. The sequence of the timing function is as follows: When the foot switch is closed, 1CR relay is energized, energizing the head solenoid of the welding machine with contacts $1CR_a$ and starting the timing period of the first timing function or "squeeze" time with contacts $1CR_b$. $1CR_c$ then parallels the foot switch to effect the non-beat operation.

After an interval of time determined by the setting of potentiometer P_1, relay 1TD is energized due to the conduction of tube 1 and the Weld-O-Trol ignitor circuit is initiated by contacts $1TD_a$. Contacts $1TD_b$ start the timing of the second timing circuit or "weld" time.

After an interval determined by the setting of potentiometer P_4, relay 4TD is energized by the conduction of tube 4. This de-energizes relay 1TD, thus stopping the flow of current through the Weld-O-Trol. Contacts $4TD_b$ parallel contacts $1TD_b$ to prevent tube 4 from ceasing conduction, and contacts $4TD_c$ start the timing of the third or "hold" time circuit. Note that the solenoid of the welder is kept energized until the end of "hold" time.

After an interval determined by the setting of potentiometer P_4, 5TD relay is energized by the conduction of tube 5. Contacts $5TD_a$ parallel contacts $4TD_c$ to prevent the tube from ceasing conduction. Contacts $5TD_d$ de-energize relay 4TD, while contacts $5TD_c$ de-energize relay 1CR, allowing the head of the welding machine to rise. Contacts $5TD_b$ start the timing function of the fourth or "off" time circuit if switch S_2 is closed. The head of the welding machine remains open during the timing interval of the "off" time circuit. When 6TD relay is energized by the conduction of tube 6, contacts $6TD_a$ de-energize 5TD relay which allows the circuit to go through another sequence of operation if the foot switch has remained closed. If switch S_2 is open, 5TD remains energized until the foot switch is opened.

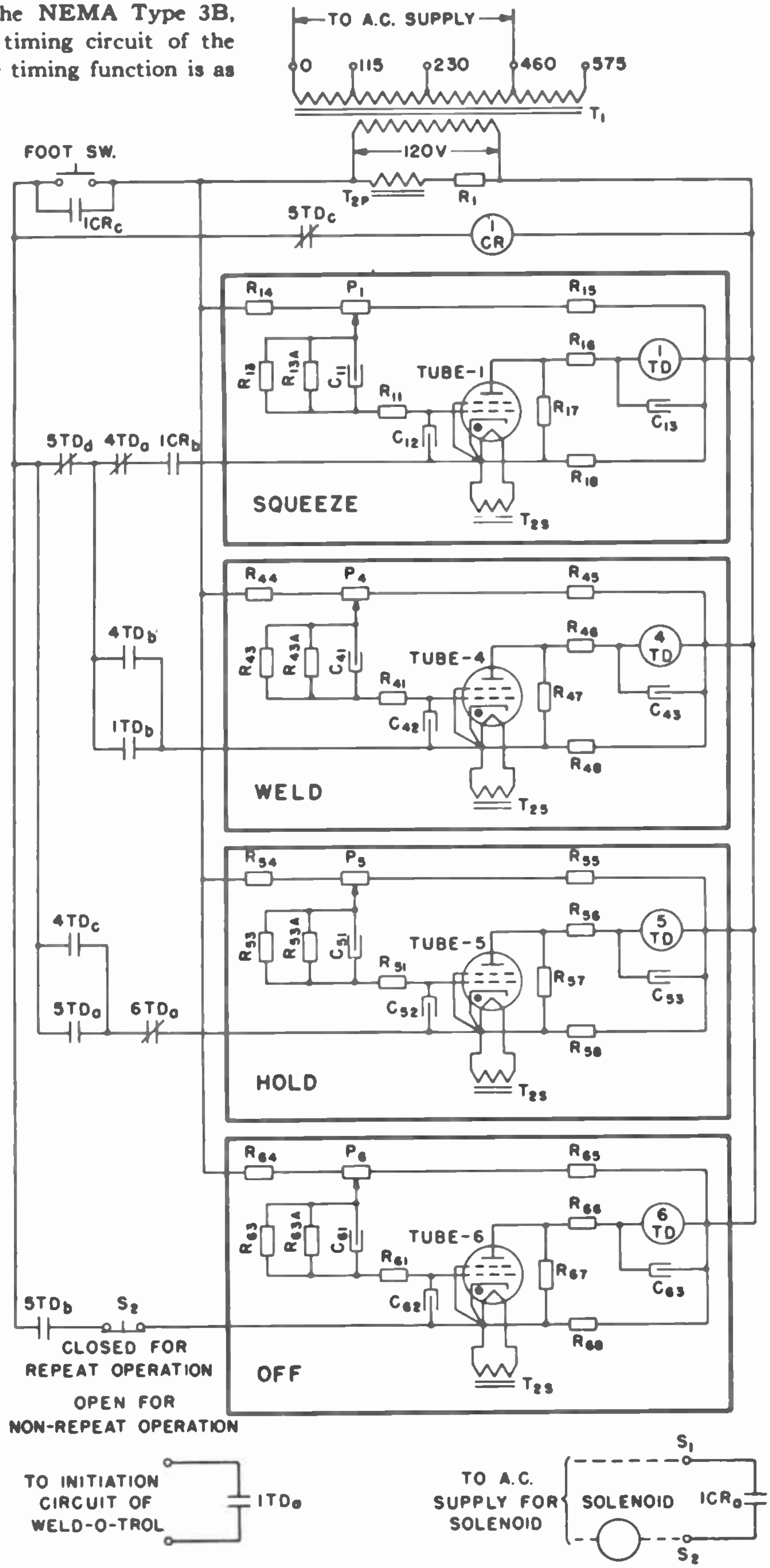


Figure 79—Schematic Diagram of 3B Timer

NEMA Type 7B Sequence Timer

The NEMA 7B is a sequence timer, timing only the functions of the electrodes of the welding machine and leaving the timing of the weld periods to the SP-15C. A NEMA Type B and a 15C timer when used together, perform the functions of the NEMA 3B timer except the timing of the welding time is synchronous precision timing in the case of the SP-15C whereas the weld timing performed by the 3B is nonsynchronous timing. The NEMA 7B consists of three timing functions similar to the timing circuits used in the NEMA 1A; namely, "squeeze", "hold" and "off". It also contains a solenoid contactor for energizing the head solenoid of the welding machine and is equipped with the non-beat feature. The mechanical construction of the NEMA 7B is identical to that of the NEMA 3B with the exception that it contains one less timing function.

THEORY OF OPERATION
(Refer to Fig. 82)

The operation of the NEMA Type 7B is identical to that of the NEMA Type 3B except 1TD relay, when energized at the end of squeeze time, permits the SP-15C timer to go through its sequence instead of energizing the ignitor circuit of the Weld-O-Trol directly. At the end of the timing period of the SP-15C, 2CR relay coil in the 7B timer is energized by tube 2 of the SP-15C timer (see Figure 81). The contacts of 2CR relay allow 5TD relay to become conductive after a timing interval determined by the setting of potentiometer P_4. The "off" time function allows the sequence to repeat after a preset interval as determined by the setting of potentiometer P_6. It should be noted that should the SP-15C timer fail to energize the 2CR relay coil, the sequence of the 7B timer cannot continue.

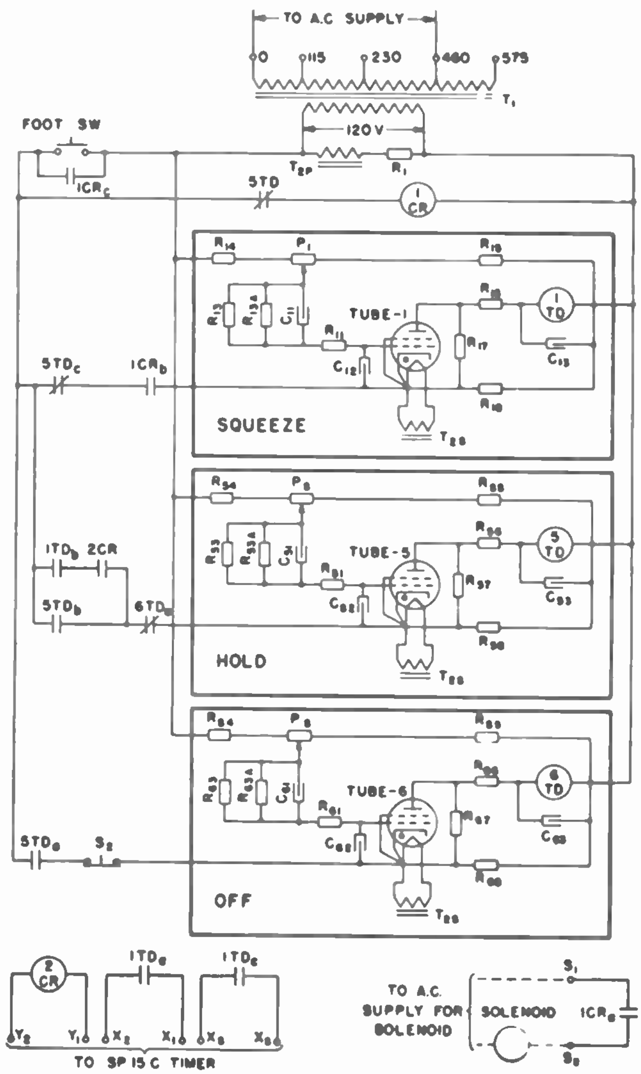


Figure 82—Schematic Diagram of 7B Timer

COURTESY WESTINGHOUSE ELECTRIC

Heat Control Attachment

Welds of good metallurgical properties and appearance require control of weld current as well as the time of welding. The heat control is an electronic device for adjusting the welding current over a continuous range without shutting off the power. It is usually used in conjunction with widely spaced transformer taps.

It will be recalled that the Ignitrons of the Weld-O-Trol are insulating until a current pulse is passed through the ignitor. If this pulse occurs late in the cycle, welding current will flow only during a small portion of the half cycle, thus reducing the net heating. The heat control attachment controls the phase position of the ignitor current pulses, and, thereby, through the Weld-O-Trol, the power delivered to the welding transformer.

The current pulses in the heat control are regulated by two Thyratrons whose grids are phase controlled. The phase can be adjusted to give satisfactory operation as low as 40% heat for 220-volt operation or 20% heat for 440-volt operation. The term "heat" in resistance welding means per cent maximum rms current. Phase control of the Thyratrons is accomplished by means of a resistance-inductance circuit with a potentiometer to obtain the variation desired.

Metal Wall Thickness Measurement from One Side by the Ultrasonic Method

BRANSON ULTRASONIC CO.
DIV. OF BRANSON INSTRUMENTS, INC.

This article discusses the principles of metal wall thickness measurement from one side and an instrument for making such measurements. The selection of quartz crystal and range, accuracy, and limitations of the method are covered.

THE NEED for an instrument which will measure wall metal thickness nondestructively when only one side is accessible is widespread. Practical applications include measurement of tanks, ship hulls, pipes and tubes, and many types of pressure vessels where it is required to determine the extent of metal thinning due to erosion or corrosion. Several different methods have been used. These include measurement of potential drop, measurement of back-scattered radiation from a radioactive source, electromagnetic methods, ultrasonic pulse methods, and the ultrasonic resonance method. The ultrasonic resonance method to be described in this paper is the most recent and, although it does have limitations, it is the method most widely used at the present time because of its inherent simplicity, accuracy, reliability, and wide range. In addition to thickness measurements, instruments operating on the ultrasonic resonance principle also have proved useful for flaw detection applications.

PRINCIPLES

THE ULTRASONIC resonance principle of thickness measurement depends upon two fundamental characteristics of sound waves. First, they travel through metal at a velocity that is a function of its density and of its elastic constants. This velocity is not appreciably influenced by wide variations in temperature. For the commonly used steels, the sound velocity is essentially independent of the chemical composition, previous heat treatment, internal stresses, and the electrical or magnetic properties.

The relationship is expressed by

$$V=\left[\frac{E}{\rho}\left(\frac{1-M}{(1+M)(1-2M)}\right)\right]^{1/2}$$

when V is the velocity of longitudinal waves in centimeters per second; E is the Young's modulus in dynes per square centimeter; ρ is the density in grams per cubic centimeter; and M is Poisson's ratio.

In the second place, sound waves are reflected by interfacial surfaces separating two materials such as metal and water that have different acoustical impedances. Standing waves can be set up within the wall of a pipe, or within a metal plate, just as standing waves are set up within the air column of an organ pipe, as shown in Figure 1. The frequency of the standing waves depends upon the thickness of the material and the velocity of sound in the material, just as the frequency of the organ pipe depends upon its length and the velocity of sound in air.

The fundamental frequency at which thickness resonance will cccur is given by the relation

$$f_1=V/2t$$

where f_1 is the frequency in cycles per second; V is the velocity of sound in the material in inches per second; and t is the thickness in inches. This relation is correct for the case where the work piece has a higher impedance than that of the materials on its opposite faces—and this is the practical case.

Thickness resonance occurs also at all harmonics of the fundamental frequency such as

$$f_2=2f_1,\ f_3=3f_1 \ldots f_n=nf_1$$

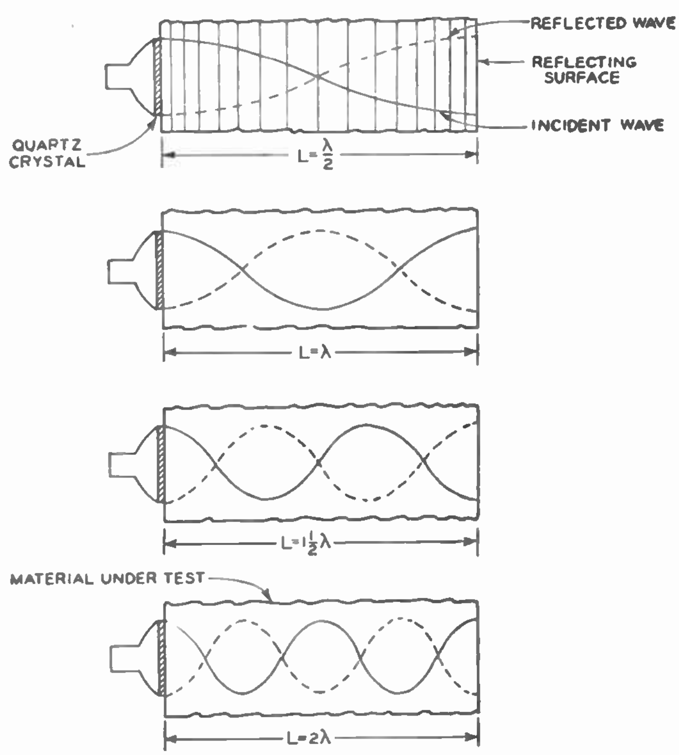
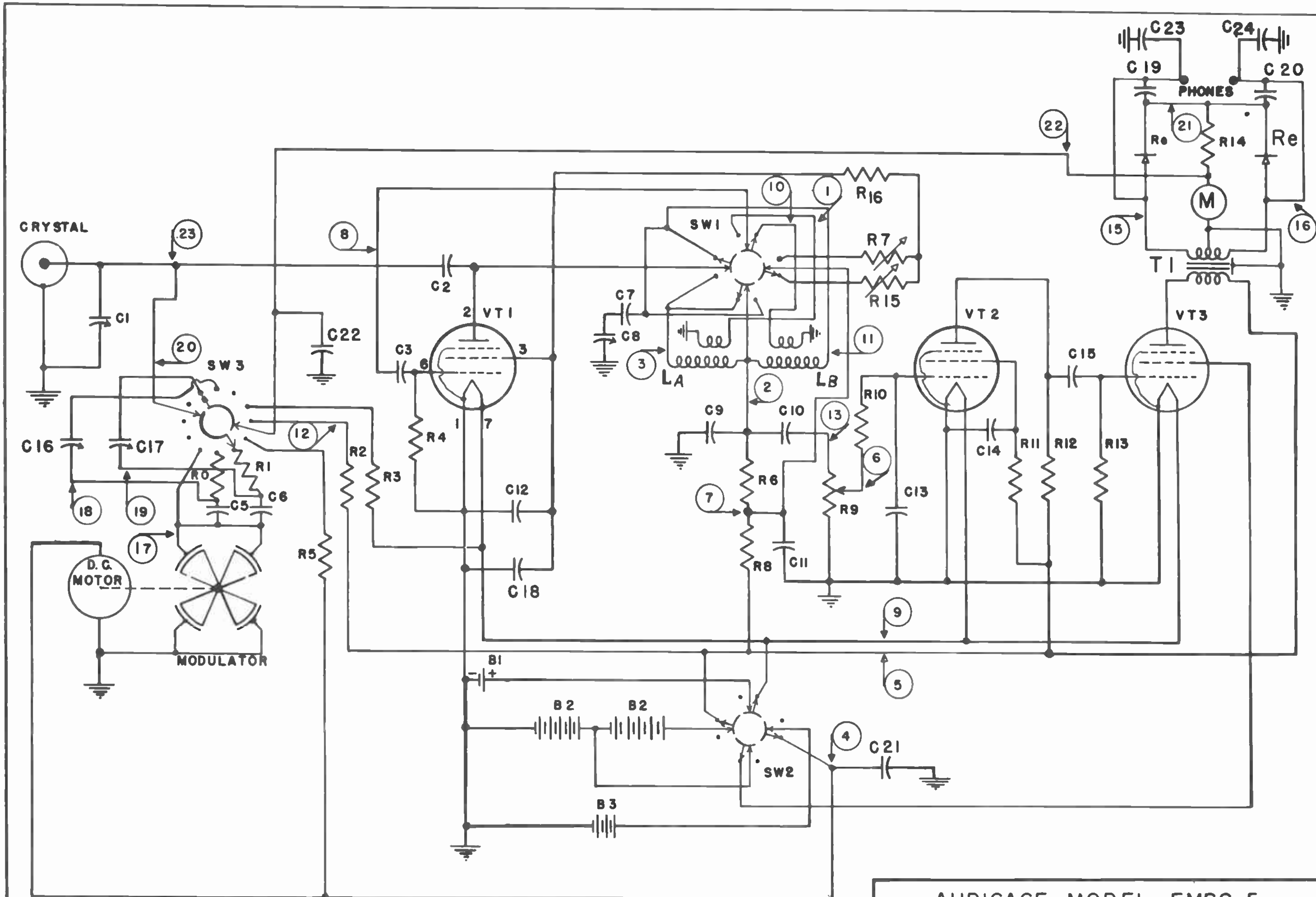


Figure 1. Representative standing-wave patterns of ultrasonic vibrations in material

Full text of a conference paper presented at the AIEE Winter General Meeting, January 22–26, 1951, New York, N. Y. Recommended by the AIEE Committee on Electronics.
N. G. Branson is with Branson Instruments, Inc., Stamford, Conn.



CIRCLED NUMBERS INDICATE CIRCUIT LOCATIONS OF CORRESPONDING TERMINALS IN SUBPANEL LAYOUT DRAWING

AUDIGAGE MODEL FMSS-5

SCHEMATIC CIRCUIT DIAGRAM

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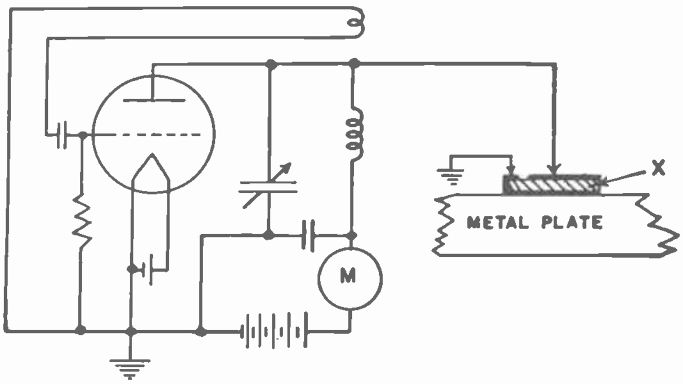


Figure 2. Basic circuit for a variable-frequency ultrasonic thickness tester

The frequency difference between two adjacent harmonics is numerically equal to the fundamental frequency. When the fundamental frequency is known, the thickness can then be determined from the equation $t = V/2f_1$.

When two adjacent harmonic frequencies are known, the equation used is

$$t = \frac{V}{2(f_n - f_{n-1})}$$

The instrument under discussion performs two functions—the transmission of sound waves of known frequencies into the material and the detection of the presence of standing waves. A basic circuit, shown in Figure 2, comprises a variable-frequency self-excited oscillator that generates an alternating voltage which is applied to an X-cut quartz crystal. When the crystal is held against the material to be tested, with a film of oil or other suitable coupling fluid between the crystal and the work, an ultrasonic wave is transmitted into the material. If the oscillator is tuned to a frequency that is an integral multiple of the fundamental frequency of the wave in the thickness of the material, there will be a sharp increase in the amplitude of the vibration in the part of the wall directly under the crystal. This is a resonant condition and because of the internal damping in the material there will be an increase in the energy dissipated. The effect on the oscillator is the same as adding a resistive component across the inductance-capacitance circuit and a sharp increase in the plate current of the oscillator will result.

The increase in oscillator plate current due to thickness resonance may exceed 100 per cent under ideal conditions. Under many practical conditions the change in plate current at resonance may be only a fraction of one per cent. Increased sensitivity over the circuit shown in Figure 2 is then necessary and is obtained by frequency-modulating the electronic oscillator over a small frequency increment. The result will be pulses of current in the oscillator plate circuit when the average oscillator frequency is tuned to the frequency at which a thickness resonance occurs. These current pulses are produced at an audio-frequency rate and are amplified by conventional methods. A schematic circuit diagram used for a portable battery-operated type of instrument is shown in Figure 3. Thickness resonance is indicated by an audible tone in the head-phones and increased deflection of an output meter.

The frequency at which resonance occurs is read on a calibrated scale and converted to thickness by use of a concentric conversion scale provided on the instrument panel. This scale is adjustable to the sound velocity in the type of metal to be measured. In the case of harmonic resonance indications, the fundamental resonance is equal to the frequency difference between two adjacent harmonic frequencies. By using harmonic resonance indications it is practical to use a 2- or 3-to-1 frequency range for measurements over a thickness range of 100-to-1, or more.

Other types of instruments,[2] designed to frequency-modulate over a 2-to-1 frequency range, apply the amplified output to the vertical plates of a cathode-ray oscilloscope to provide direct reading indications.

THICKNESS RANGE AND ACCURACY

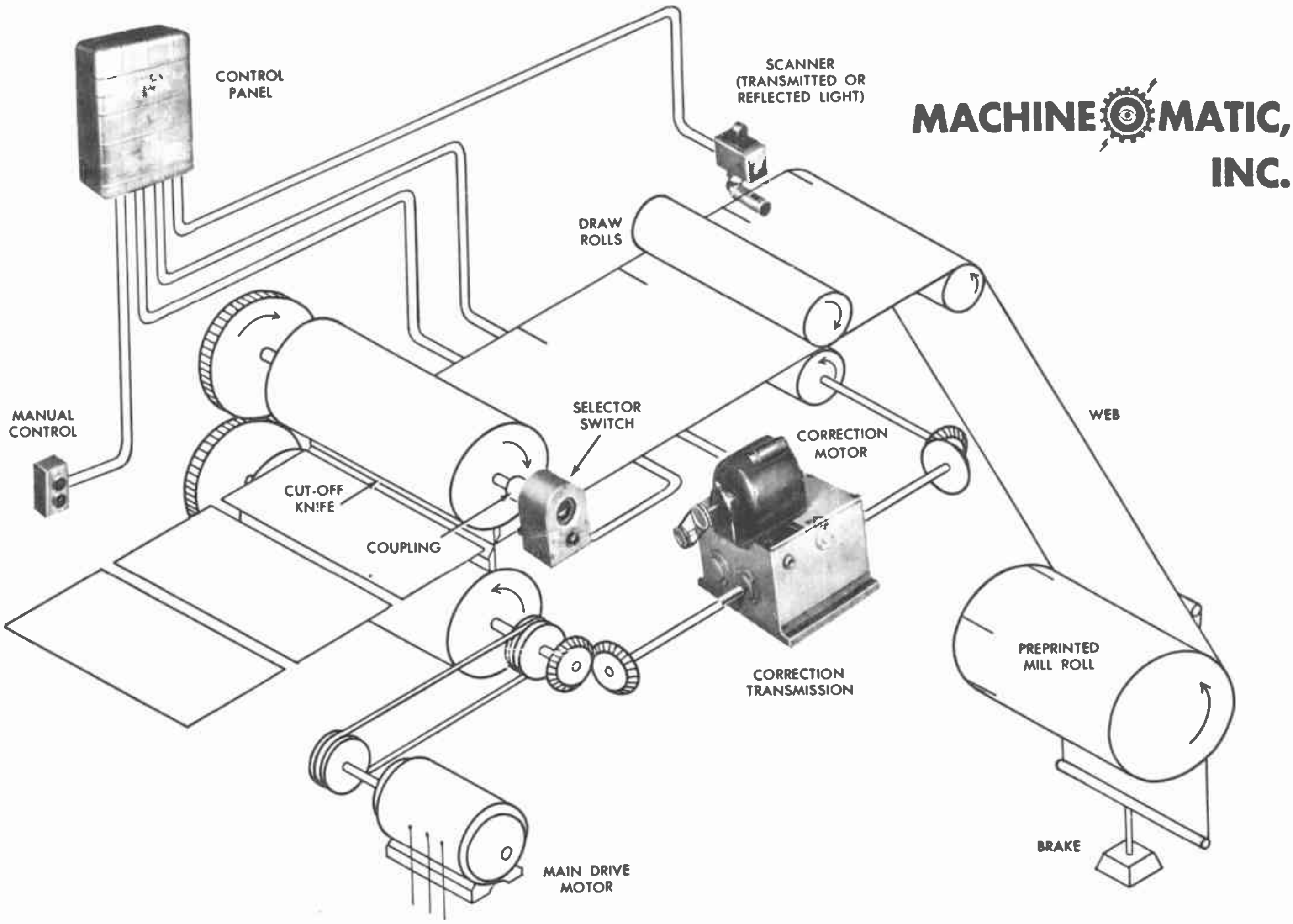
LOW FREQUENCIES (long wavelengths) are suitable for thick specimens and rough surfaces. High frequencies permit the use of smaller crystals and the measurement of thin materials, provided the work piece is sufficiently smooth and homogeneous.

The minimum thickness of material which can be measured depends upon the ultrasonic frequency which it is possible to use. On materials such as steel, aluminum, and glass, with smooth parallel surfaces, it is possible to use ultrasonic frequencies of 20 megacycles or higher, and measure thicknesses of 0.005 inch, or less. However, many materials will absorb the acoustic energy very rapidly at such frequencies with the result that there will be no thickness resonance indications. Certain types of cast iron, for example, can be measured at frequencies below one megacycle but no detectable resonance effect can be observed at higher frequencies. In general, most metal thicknesses of 1/16 inch or more can be measured. By using harmonic resonance indications it is sometimes possible to measure thicknesses of several feet. It is common practice to measure heavy-walled pressure vessels with wall thicknesses of several inches by using harmonic resonances.

Accuracies within one per cent generally can be obtained when it is possible to use the fundamental or the lower harmonic indications. On materials of 1/2 inch or more, where it is necessary to use higher harmonics, accuracies of 2 to 3 per cent can be realized.

FLAW DETECTION

SINCE ULTRASONIC waves are reflected at any discontinuity, it is possible to apply the same principles used for thickness measurement to certain flaw detection applications. One type of commercial equipment which is used to detect cracks in rails within the joint bar area is shown in Figure 4. The complete equipment, including self-contained power supply, weighs only 11 pounds and the condition of the rail is indicated by the audible tone produced in headphones. In this equipment, the frequency is modulated over a range which includes many resonance peaks and results in an audible tone with a frequency which is proportional to the distance from the top of the rail to the first discontinuity. Other applications include the detection of laminar flaws in metal plates and hydrogen blisters in pressure vessels.



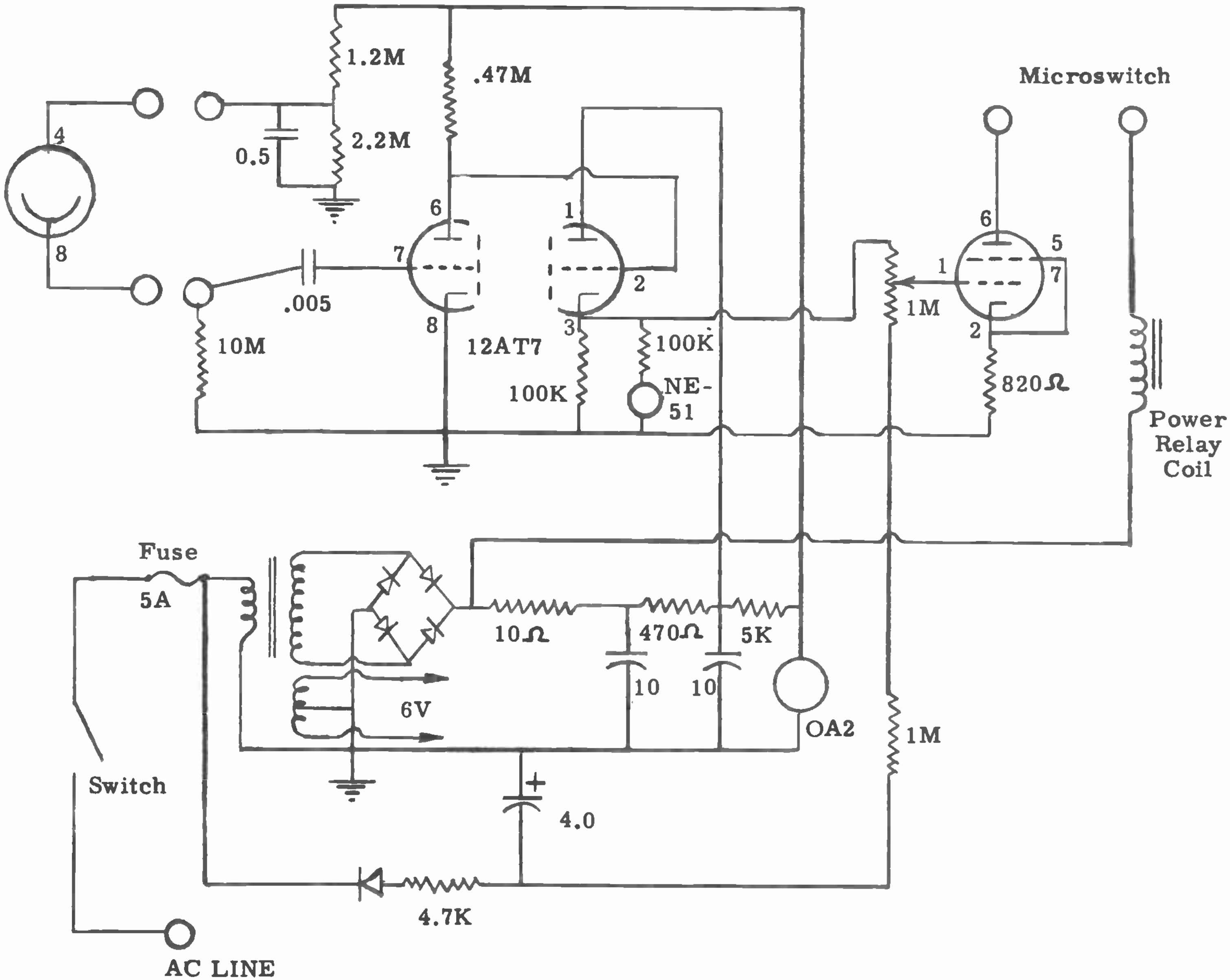
TWO-WAY CORRECTION

The method used is to have a photo electric cell in conjunction with a selector switch detect the errors and transmit the information to a correction motor, which in turn operates the "correction transmission" to make the needed mechanical adjustment. The above illustration shows a typical application. A frequent variation of this is to install the transmission so that it repositions the knife instead of advancing or retarding the feed rolls as illustrated.

The "Brain" of the unit determines if the register is correct or in what direction correction is needed, its simple design is the secret of its efficiency, versatility and extreme accuracy. A wiring method which requires it to handle only milliamps of current eliminate all possibility of arcing.

There is a choice of two types, the standard selector switch which corrects any error no matter how large. and the "Skip Print" which is used when a clear path for the register mark cannot be provided and part of the design itself is used for a register mark.

Photo Electric Scanner: The "electric eye" designed for this type of operation is capable of receiving 2500 impressions per minute. Will react to either transmitted or reflected light, will respond to any color or surface height variation and can be arranged to give a signal by going from light to dark or from dark to light. These features make its use possible in instances where a regular printed mark cannot be provided.



MACHINE O MATIC
MODEL 90

<u>Terminals</u>

- Phototube P4
- Phototube P8
- Lamp
- Lamp
- Microswitch
- Microswitch
- AC Line
- Ground

Basic Facts About Magnetic Amplifiers

A SATURABLE REACTOR is an inductor with a saturable ferromagnetic core, utilizing the nonlinear magnetization curve of a ferromagnetic material. In its simplest form a reactor consists of a closed magnetic core linked by two windings, Figure 1. The gate winding, connected in series with the load and a source of ac power, constitutes a variable impedance. The effective impedance of the gate winding can be varied by a current injected into a second winding, the control winding. Thus the load current and power to the load can be controlled.

If the reactor is wound on a core of ferromagnetic material with a magnetization curve as shown in Figure 2, the inductance of the power winding will vary as a function of the dc-magnetization level set by the control signal.

With the circuit shown in Figure 1, undesirable ac voltages are induced in the control winding. Unless a high impedance is in series with this winding, the reactor behaves like a transformer with short-circuited secondary. Moreover a control winding of many turns would result in high induced voltages with accompanying insulation problems.

These difficulties can be avoided by using the three- or four-legged reactors shown in Figure 3. With these balanced arrangements, there is no net voltage of fundamental frequency induced in the control winding. Thus, insulation and short-circuiting problems do not arise.

The two coils, N_g, can be in parallel but this type of connection results in a longer time constant. This discussion will be limited to the series connection

By the use of rectifiers and positive feedback arrangements, high-gain high-performance magnetic amplifiers can be constructed around the basic saturable reactor element. The saturable reactor alone, Figure 4, can be used also in many applications that don't need high gain. Combinations of these basic elements can give the phase-reversible output to operate an induction-type control motor in a positioning system. One arrangement used this way, Figure 5, is known as a saturable transformer.

Other aspects of the basic reactor are that the output can be rectified to supply dc to the load, and additional control or bias windings can be used to add or subtract several input signals.

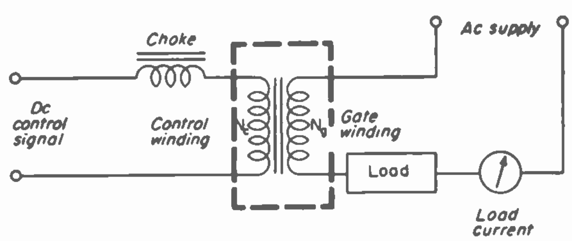
PERFORMANCE CHARACTERISTICS

When wound on a high-permeability core, the saturable reactor of Figure 3 is a constant current device that tends to produce an average ac current directly proportional to the dc control current, I_c. This relationship can be expressed.

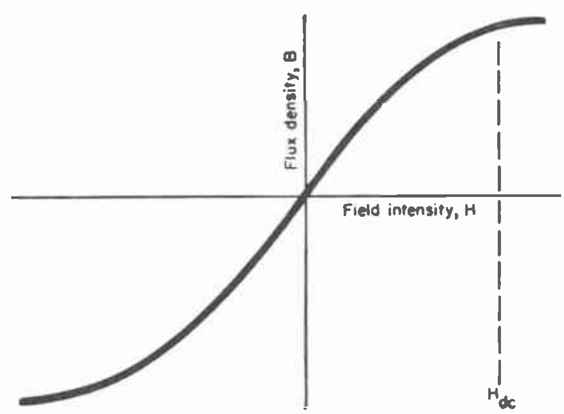
$$N_c I_c = N_g I_g \qquad (1)$$

This equation is exact for idealized materials having the magnetization characteristics shown in Figure 6 and is closely approached by practical reactors wound on high grade cores. Thus, if the gate winding turns are equal to the control turns. the load current equals the control current, Figure 7. The output current of a saturable reactor in its linear region is almost independent of the load and is not sensitive to the polarity of the control signal.

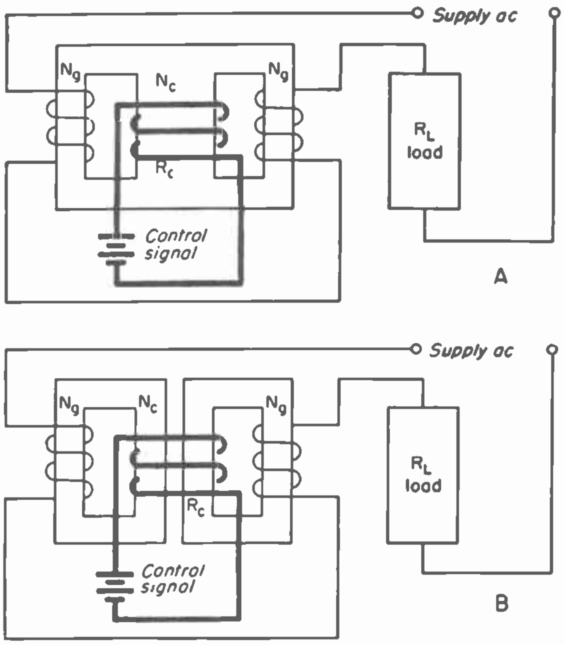
The power gain, K, of a magnetic amplifier is, by definition, the change in load power divided by the change in control power required to produce it.



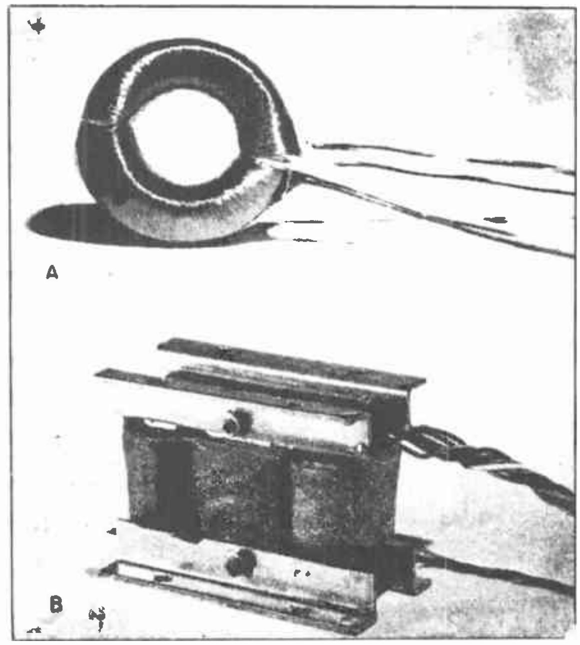
Elementary saturable reactor. DC control signal regulates impedance of gate winding and power to load. Fig. 1



Normal magnetization curve of silicon steel, neglecting hysteresis. Shows how incremental permeability, and hence inductance, will vary as operating point on curve. Fig. 2



Balanced reactor designs. Three-legged, (A), and four-legged, (B), insure cancellation of fundamental frequency. Fig. 3



Toroidal reactor, (A) and three-legged reactor, (B). These are the basic building blocks of magnetic amplifiers. Fig. 4

$$K = \frac{\text{Load power change}}{\text{Signal power change}}$$

$$K = \frac{(\Delta I_g)^2 R_2 k_f^2}{(\Delta I_c)^2 (R_f + R_c)} \quad (2)$$

where

R_2 = load resistance
R_f = external forcing resistor in series with control winding
R_c = control winding resistance
k_f = form factor of load voltage. (varies from 1.1 at full output to about 1.5 at low output values)
ΔI_g = load current change
ΔI_c = control current change

The output response of a series-connected saturable reactor to a change in control current is practically instantaneous. But because the control winding is an inductive element, there is a time lag between the application of a voltage to the control circuit and the flow of control current. The time constant, T, is proportional to the effective control winding inductance, L_c, divided by the total resistance of the control circuit.

$$T = \frac{L_c}{R_f + R_c} \quad (3)$$

Increasing the resistance in the control circuit proportionately reduces the time constant. This applies until the time constant approaches the period of the supply voltage.

Since an increase in the control circuit resistance reduces the time constant, it is possible to improve amplifier response within limits by increasing the value of the forcing resistor, R_f. Although this sacrifices some power gain, the ratio of power gain to time constant remains constant.

In a given reactor, power gain is proportional to ac supply frequency. The time constant is expressed, therefore, in cycles of supply voltage rather than in seconds. This leads to a widely used figure of merit for magnetic amplifiers; the ratio of power gain to time constant measured in cycles. For a simple series saturable reactor this ratio is about four.

The wave form of the gate current or load voltage of a saturable reactor is nonsinusoidal except at the fully saturated condition, Figure 8. This distortion is most pronounced with sharply saturating square loop core materials and is inherent in saturable reactor operation. Prior to saturation the output current is essentially the magnetization current of the cores and therefore is small. When the core flux reaches saturation, the core inductance drops nearly to zero, and almost full supply voltage appears across the load for the rest of the half cycle.

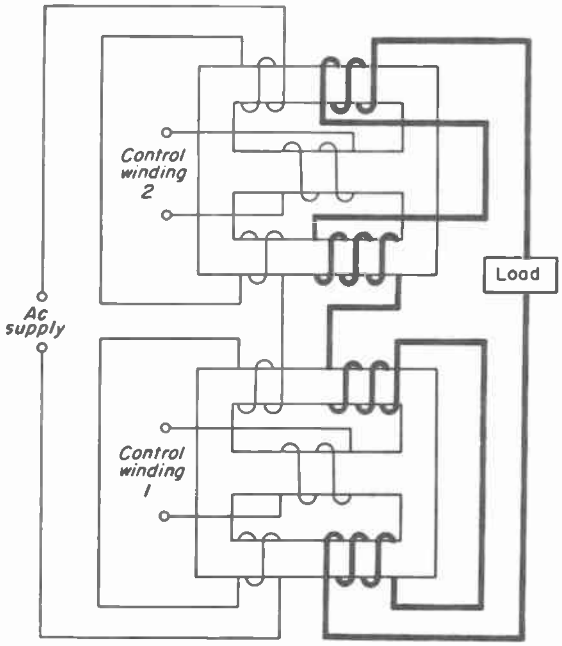
FEEDBACK TECHNIQUES

A positive current feedback increases the power-gain-to-time-constant ratio of a simple saturable reactor. The load current is rectified and fed back to a winding that is concentric with the control winding. Therefore, the signal current required to produce a given load current is reduced.

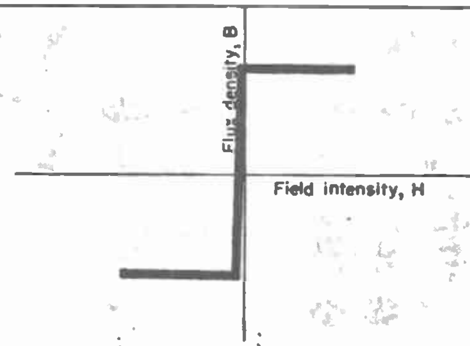
Figure 9 shows a magnetic amplifier with a feedback winding. The expression relating control ampere-turns to load ampere-turns now becomes:

$$N_g I_g = N_c I_c + N_f I_g \quad (4)$$

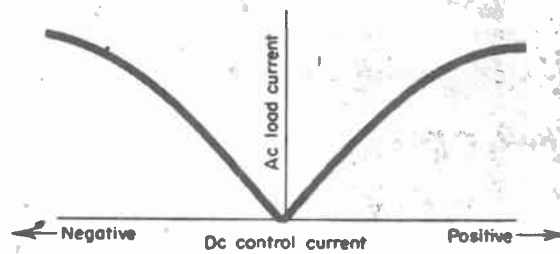
where N_f equals the number of feedback turns. The



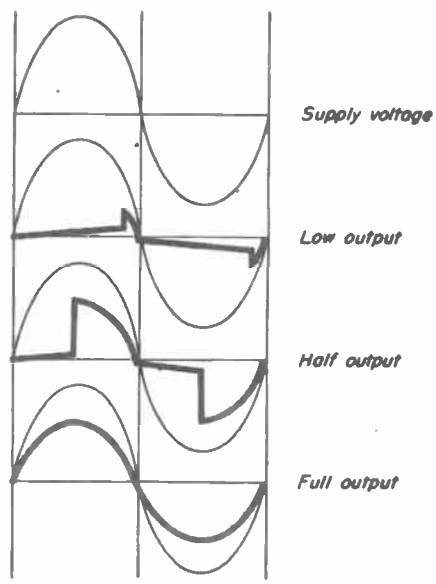
Saturable transformer. Output phase reverses depending on which control winding is energized. Fig 5



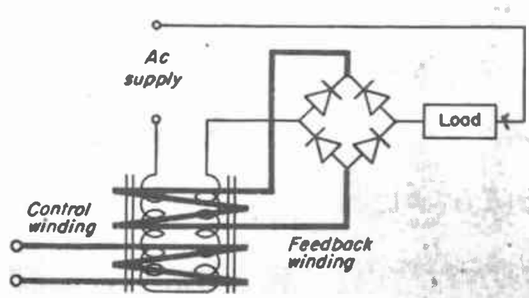
Idealized magnetization curve. Small change in field intensity makes large change in flux density. Fig. 6



Transfer characteristics of reactor. Load current varies with magnitude of signal but not with polarity. Fig. 7



Load current of saturable reactor at various firing angles. Load is resistive. Fig. 8



Amplifier with external feedback. Rectified load current adds to the control signal to increase gain. Fig. 9

ampere turns gain, m, becomes

$$m = \frac{N_g I_g}{N_c I_c} \quad (5)$$

where

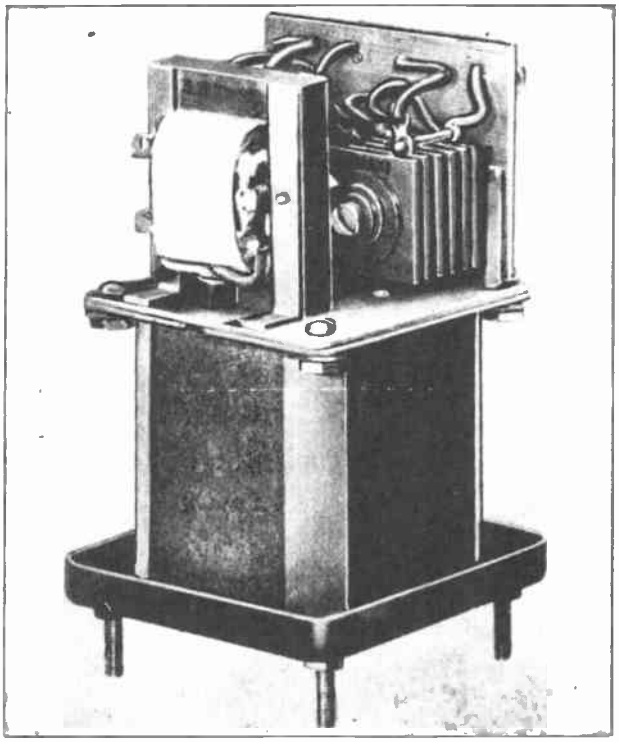
$$m = \frac{N_g}{N_g - N_f} \quad (6)$$

Thus, the use of N_f feedback turns per core increases the power gain by a factor m^2. On the other hand, the time constant is increased by a factor of only m. The figure of merit with feedback is increased also by a factor of m, and the ratio of power gain to time constant in cycles is approximately $4m$.

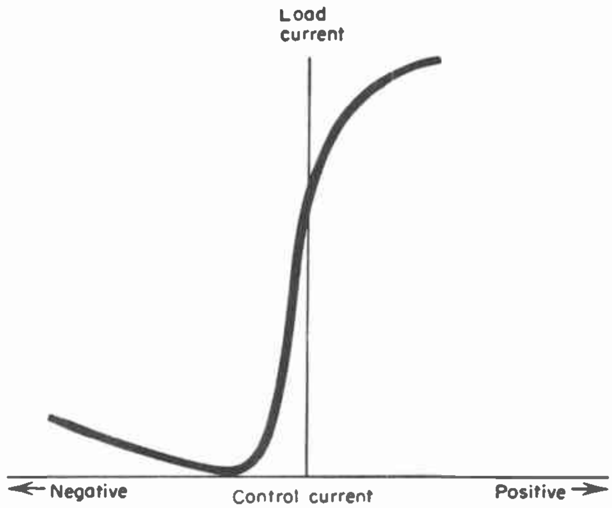
The above relationships, based on idealized core materials and perfect rectifiers, indicate that when N_f equals N_g the gain of the amplifier will be infinitely high. This is not true since with practical core materials, when N_f equals N_g the signal current must supply the magnetomotive force necessary to saturate the core. The effective feedback is reduced also by any leakage in the rectifiers.

In practical magnetic amplifiers, Figure 10, typical usable values of m are between 100 and 1,000, resulting in figures of merit up to several thousand per cycle. The addition of feedback makes the amplifier polarity sensitive, since the gain is high when the feedback is aiding the control signal and low when bucking, Figure 11.

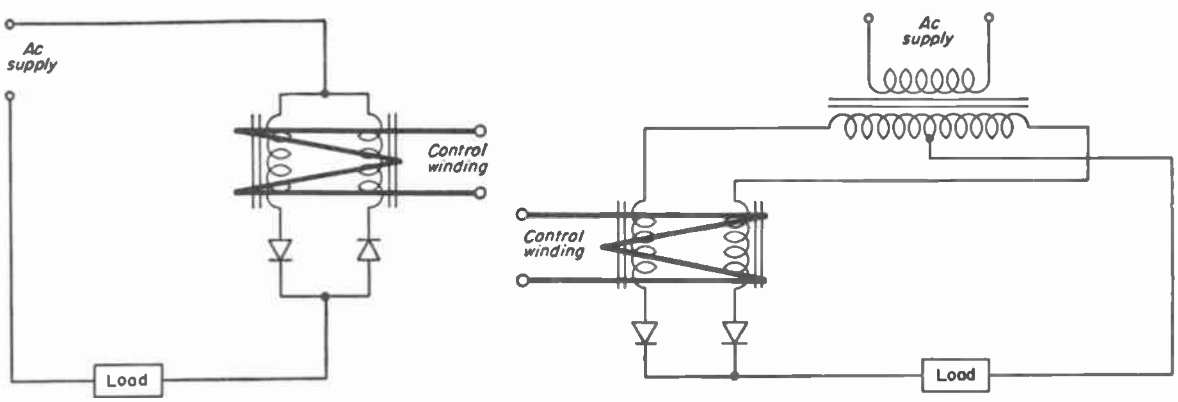
Self-saturation gives as good performance as the 100 per cent feedback arrangements. In self-saturation circuits high gains and high figures of merit come from use of rectifiers in the gate winding. Reversed current flow is prevented and control can be obtained by supplying only sufficient control



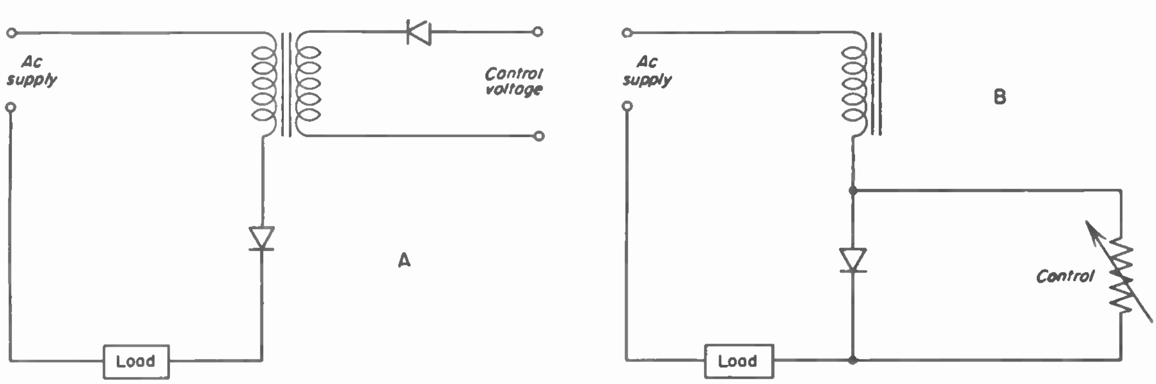
Commercial version of a hermetically-sealed, push-pull adjustable magnetic servo amplifier. Fig. 10



Output versus input characteristic for a magnetic amplifier with external feedback. Unit is polarity sensitive. Fig. 11



Self-saturating circuits. (A) shows a doubler circuit for ac output, while (B) shows a full-wave circuit for dc output. Fig. 12



Reset circuits. (A) shows a basic half-wave amplifier of the flux resetting type. (B) is a half-wave magnetic amplifier with variable resistance control. Fig. 13

ampere-turns to saturate the core. Figure 12 shows two typical circuits.

RESET CIRCUITS

Magnetic amplifier circuits have been developed that have response times of one-half to one cycle of the carrier supply. These consist of half-wave, self-saturating elements so arranged that the output delivered to the load during the gating half cycle is determined by the level to which a voltage signal has preset the core flux during the preceding "reset" half cycle. Effectively decoupling the control and gating circuits combines both power gain with fast response. Either ac or dc control signals can be used.

Circuits of this type, Figure 13, are useful in many applications. Fast response and possible circuit simplicity are advantages. But the maximum power gains are lower than in the feedback and self-saturating types previously described.

Reset circuits can be constructed with one-half the number of core loops required for the more conventional circuits. For example, a phase-reversing ac output can be got with a single pair of toroidal cores. However, voltages of fundamental frequency are induced in the control circuits of the half-wave amplifiers, and precautions must be taken to prevent the flow of excessive currents caused by these induced voltages. This can be done with blocking rectifier arrangements or high impedance control circuits.

Power gains of 100 to 1,000 per stage can be obtained with the flux resetting type of amplifier. The gain is generally lower than that of the conventional circuits, because the control circuit must supply enough energy to reset the core flux once per cycle of the supply.

SERVO APPLICATION FACTORS

The simple saturable reactor is suitable for many applications where a high ratio of power gain to time constant is not necessary. This type is smaller, simpler, and cheaper than high-performance reactors with feedback and should, therefore, be used where its characteristics fit the application. Many control systems, however, demand high-gain, fast-response amplifiers to combine accuracy with stability and suitable performance under dynamic conditions.

Sensitivity

Present day commercial magnetic amplifier circuits are suitable for operation from signal sources able to supply input power of the order of 10^{-8} watts. Laboratory models are sensitive to 10^{-14} watts, but these are not ready for production. Signal power of 10^{-8} watts or more can be obtained from many of the commonly used transducer elements such as synchros, resistance potentiometers, tachometers, generators, tuned circuits with normal-size components, and phototubes.

Where the minimum signal level is lower than 10^{-8} watts, vacuum tube or transistor preamplifiers can be used in combination with magnetic amplifier output stages. This permits the high amplification of low level signals in combinations that still exhibit the basic advantages of magnetic amplifier systems.

Time Constant

Feedback circuits with a reasonably high gain per stage are available with time constants not exceeding a few cycles of carrier frequency. In most servo and regulator applications, time delays of this magnitude have no significant effect on system performance. Usually time lags associated with portions of the system external to the amplifier, such as the inertia of a mechanical system or the electrical time lag of an inductive element, are the primary limitations on system performance.

Servo Stabilization

In servo and regulating systems using magnetic amplifiers, the stabilization techniques commonly used in electronic systems are applicable.

Compensating networks to introduce phase lead or lag are suitable in magnetic amplifier systems. The relatively low impedance levels usually encountered with magnetic amplifiers may result in large capacitance values in R-C networks. Recent improvements in low-voltage high-microfarad capacitors have made such networks practical. Also useful are networks using inductive elements specially designed to operate with magnetic amplifiers.

Damping signals proportional to the rate of change of the output or to higher order derivatives are frequently used to improve servo system performance. Magnetic servo amplifiers are well suited to this technique because the stabilizing signal can be fed into separate control windings with no problems of isolation or mixing.

Viscous or friction dampers also can improve servo system stability in magnetic amplifier systems.

Isolation

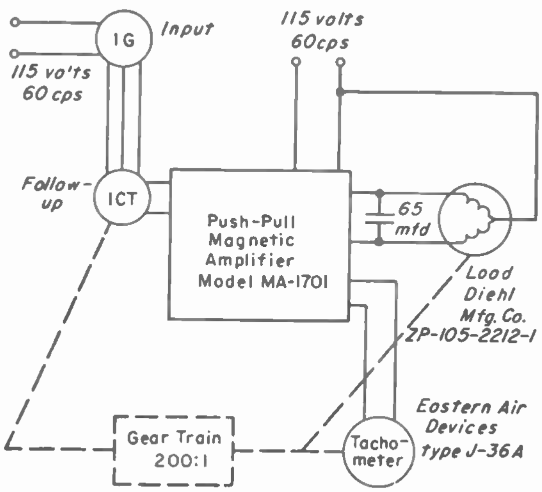
Since the control windings of a magnetic amplifier are separated from each other and from the load circuit windings, problems of electrical isolation and grounding are minimized. Multiple control signals can be used and the polarity of an input signal is easily reversed.

Figures 14 and 15 show typical servo applications of magnetic amplifier circuits.

MEDIUM-POWER POSITIONING SERVO SYSTEM FIG. 14

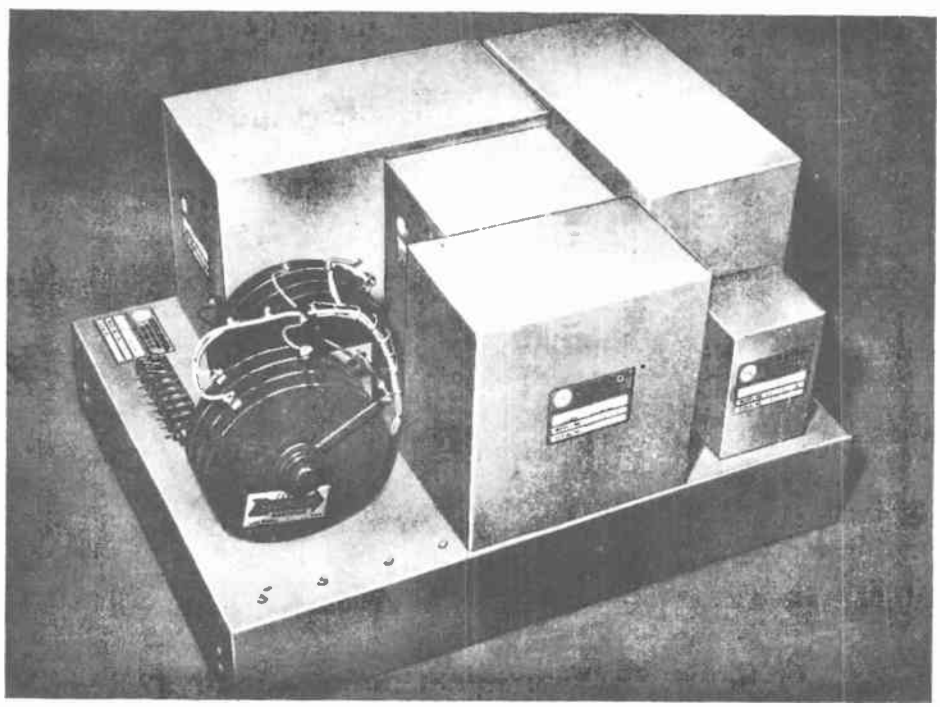
SYSTEM SPECIFICATIONS

Magnetic Amplifier Characteristics	Model MA-1701
Output Power	650 w
Supply	115 v, 60 cps, single phase.
Size	$10\frac{3}{8}$x$20\frac{1}{4}$x$8\frac{3}{4}$ in. high
Weight	90 lb
Stabilization	Rate feedback from tach.
Servo System Characteristics	
Motor	Diehl Type ZP105-2212-1 low inertia two-phase servo motor. Mechanical power output 200 w
Synchro input	1G
Synchro follow-up	1CT
Motor to synchro gear ratio	200
Static accuracy	1 deg (1 v RMS)
Velocity constant	80 deg per sec per deg
Natural frequency	approximately 2 cps



Schematic of servo system.

Magnetic amplifier element.



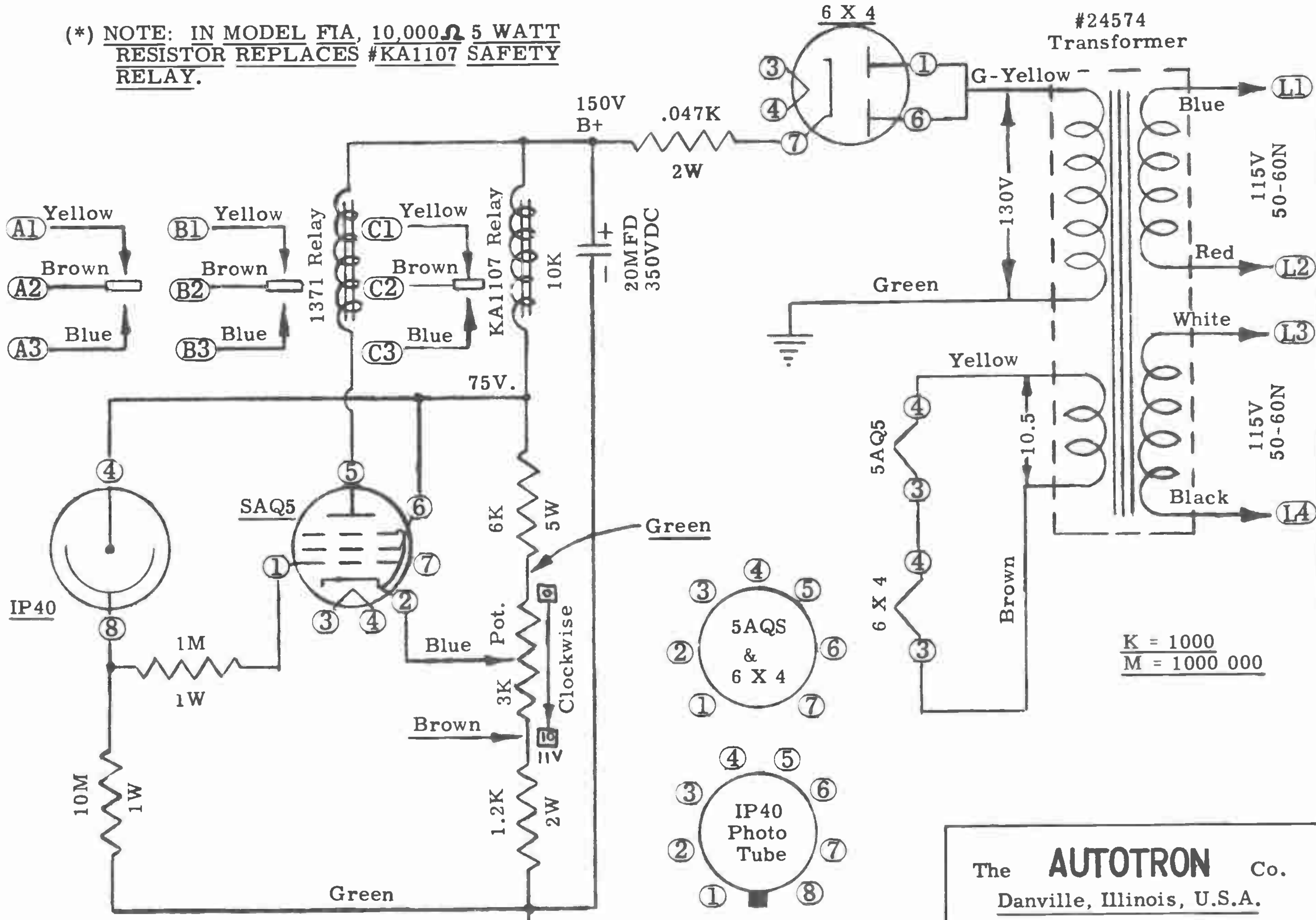
Magnetic amplifier controls a two-phase induction servomotor capable of delivering 200 watts to the load shaft. The synchro follow-up system produces an alternating current error signal with a magnitude proportional to the angular displacement between the output and input shaft positions, and a phase angle of either 0 deg or 180 deg with respect to the supply, depending on the direction of the displacement.

This signal is fed to a phase-sensitive demodulator that gives a dc output proportional to the magnitude of the ac input signal with a polarity depending on the phase of the input signal. The demodulator output drives a two-stage magnetic amplifier that supplies a phase-reversible voltage to the control windings of the motor. Thus the load shaft is driven to a position corresponding to input shaft position.

The dc permanent-magnet tachometer coupled to the motor produces a signal proportional to the speed of the output shaft. This speed signal is fed into a winding of the preamplifier unit to damp the system for stable operation.

Servo systems of this type have been used in antenna training systems, stable platform drives, and machine tool controls.

(*) NOTE: IN MODEL FIA, 10,000Ω 5 WATT RESISTOR REPLACES #KA1107 SAFETY RELAY.



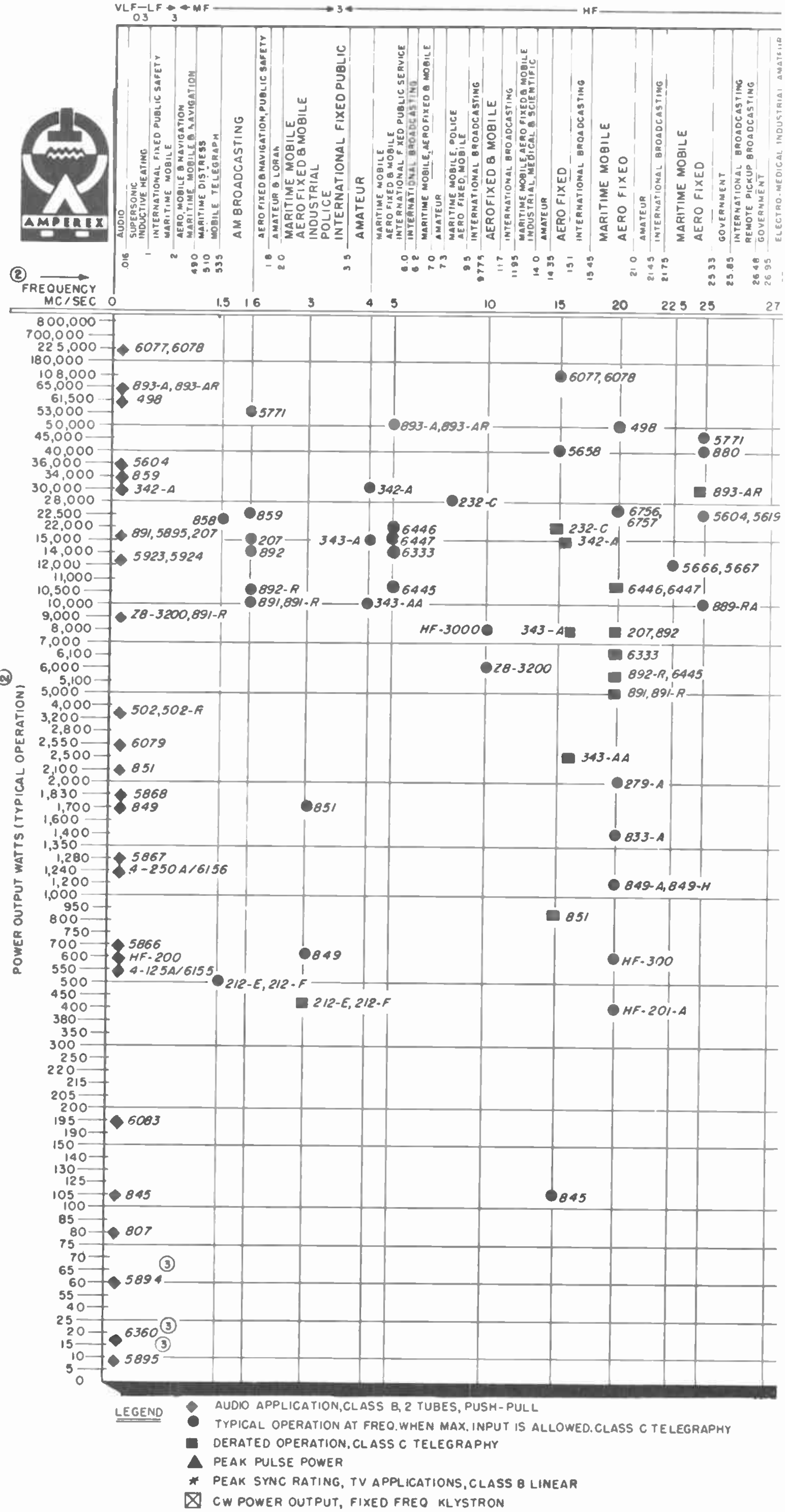
TUBE BASE CONNECTIONS BOTTOM VIEW

NOTE: VOLTAGES SHOWN ARE BASED ON 117 VAC LINE VOLTAGE AND PLATE RELAY ENERGIZED.

The **AUTOTRON** Co.
Danville, Illinois, U.S.A.

Model: FIARW & FIA (*)
PHOTOELECTRIC CONTROL

AMPEREX POWER TUBE CHART



INFORMATION FOR USE

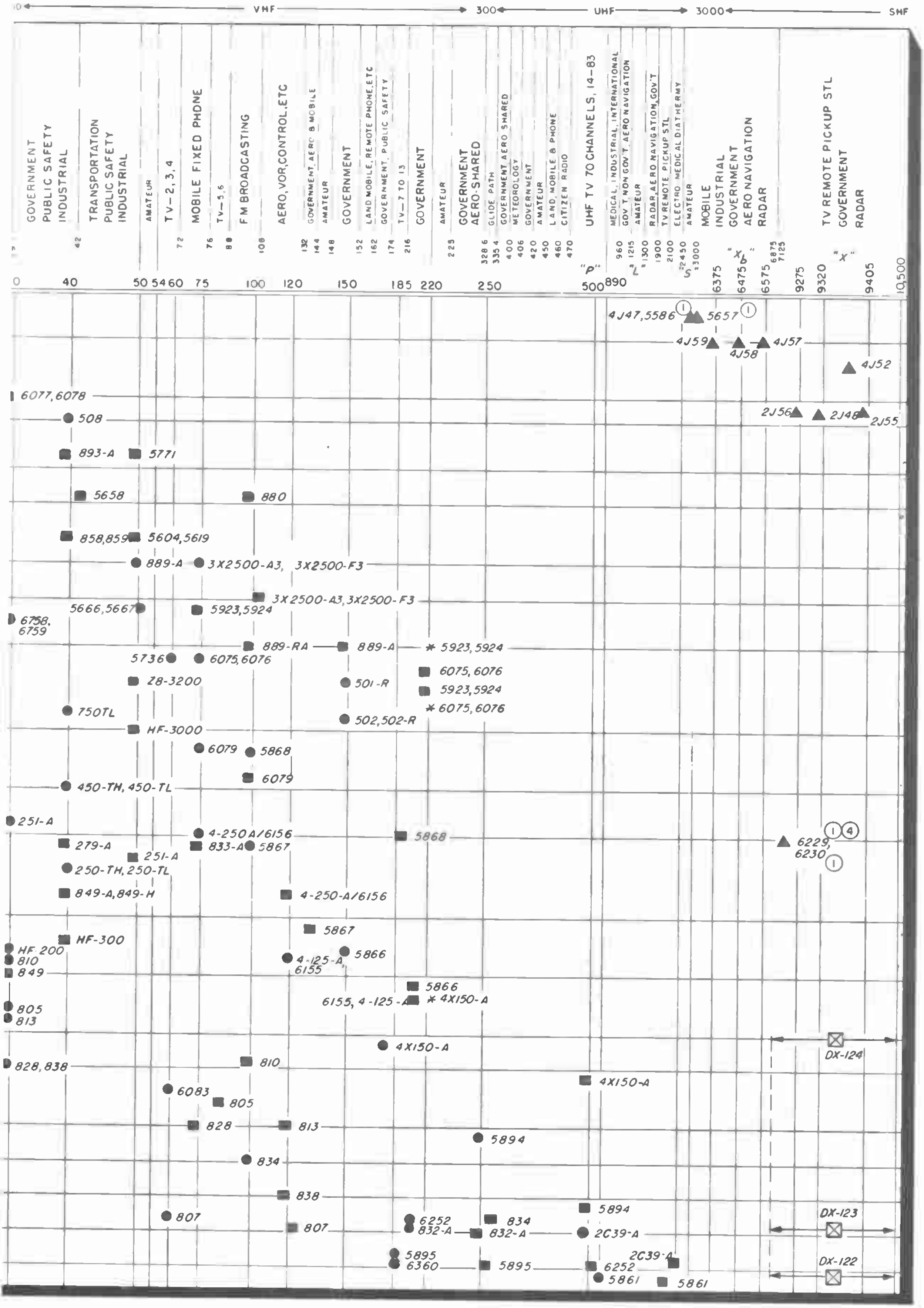
1. Locate the application as a point on the chart by selecting the power, frequency and class of operation. Single tubes which meet these requirements are found above, and to the right of this point. When a derated condition (violet square on chart) is given for a particular tube in addition to the maximum input point (red circle on chart) for the same tube, that tube is applicable if a line between these two points passes anywhere to the right and above the required application. Usually a number of tubes may thus be located to satisfy the required condition. In addition, combinations of two or more lower power tubes either in push-pull or parallel may be found which will meet the power and frequency requirements.

2. The choice of the particular tubes which best meet the requirements will usually necessitate reference to the detailed data sheets for the candidates taken from the chart inasmuch as other factors such as available power supply, type of cooling, physical size of tube, capacities, etc., may influence the decision. These data sheets are available upon request.

3. It should be understood that the typical operation point at frequency for maximum input does not necessarily demonstrate the maximum power output capability for the tube at that frequency. Therefore, a tube may still be applicable even though the point falls slightly below the required power. Such a tube should also be considered as a possibility and further inquiry made.

4. A rough estimate of the power output capabilities of a tube under class B linear conditions and plate modulated, class C conditions may be made by multiplying the following factors by the class C telegraphy power output (red circle on chart):

Class B, linear . . . . approx. 35%
Class C, plate modulated . approx. 50%



NOTE:

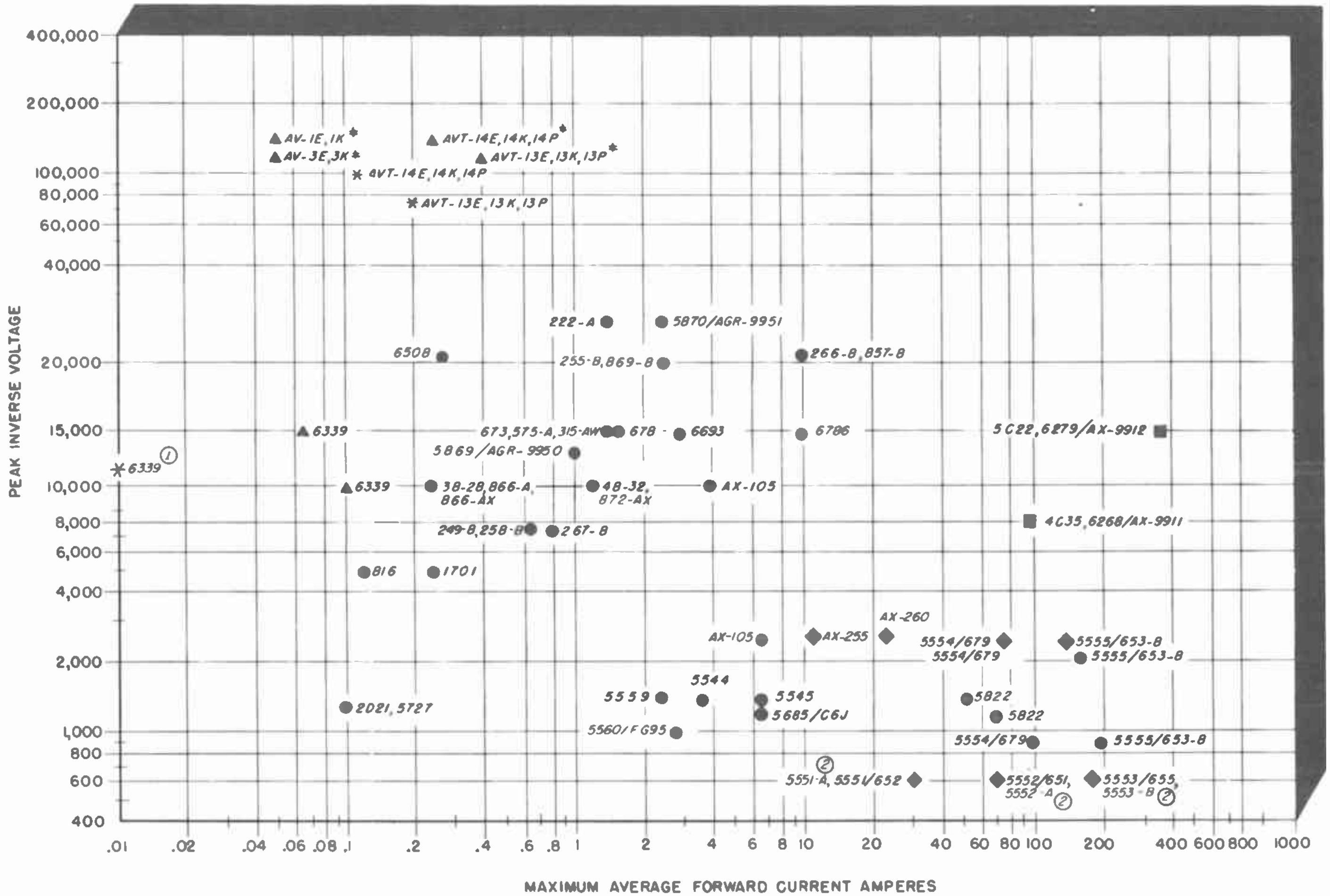
1. TUNABLE TYPE MAGNETRON, APPROX. CENTER FREQ.
2. THIS CHART IS NOT TO SCALE.
3. ONE TUBE ONLY
4. TENTATIVE POWER RATING

AMPEREX RECTIFIER, THYRATRON & IGNITRON CHART

(FOR INCREASED INTERMITTENT DUTY RATING, CONSULT DATA SHEET.)

LEGEND

- ● Peak inverse voltage, Max. average Forward Current-Rectifier or Controlled Rectifier Service.
- ◆ Welder Control Service R.M.S Voltage
- ▲ Oil Immersed Operation
- ✳ Air Insulated Operation
- ■ Peak Forward Anode Voltage, Peak Anode Current
- ╪ Pulse width 6 Microseconds, Max. For these tubes, the Forward Currents are Load Current Values in a Four-Tube, Single-Phase Bridge Circuit.



NOTES:

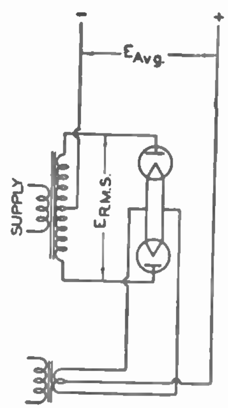
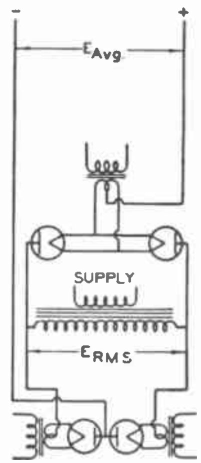
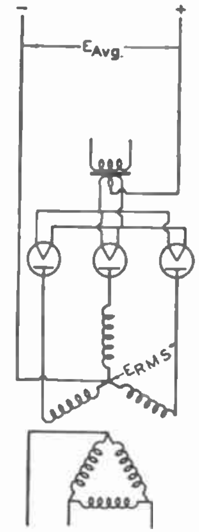
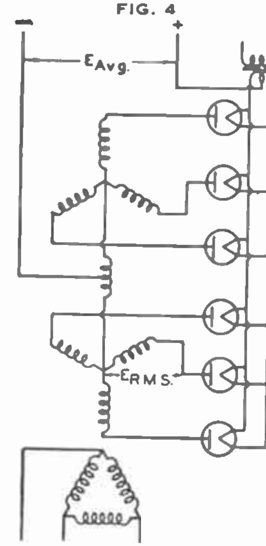
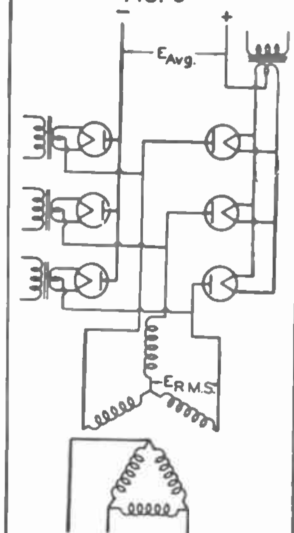
(1) WITH AUXILIARY COOLER

(2) THERMOSTATIC CONTROL IGNITRON

AMPEREX

This chart gives maximum continuous ratings and will serve as a guide for tube selections for a particular application. The choice of the tube which best meets the requirements will usually necessitate reference to the detailed data sheet. Other factors such as ambient temperature, peak currents, type of cooling, physical size of tube, frequency, associated circuitry, etc, may influence the decision. Increased ratings for intermittent service may be obtained from data sheets, available upon request.

Below are given typical rectifier circuits and the associated calculation factors.

RECTIFIER CIRCUIT	SINGLE PHASE FULL-WAVE 2 TUBES	SINGLE PHASE FULL-WAVE 4 TUBES	THREE PHASE HALF-WAVE	THREE PHASE DOUBLE-Y	THREE PHASE FULL-WAVE
Conditions assumed for following relations 1. Sine-Wave Supply 2. Balanced Phase Voltages 3. Zero Tube Drop 4. Pure Resistance Load 5. No Filter Used NOTE: All rectifier filaments supplied by single phase transformers, with secondaries insulated for voltages greater than the Maximum Peak Inverse Voltage.	FIG. 1 	FIG. 2 	FIG. 3 	FIG. 4 	FIG. 5 
E Average	$.450\ E_{rms}$ $.318\ E_{max}$	$.900\ E_{rms}$ $.636\ E_{max}$	$1.170\ E_{rms}$ $.827\ E_{max}$	$1.170\ E_{rms}$ $.827\ E_{max}$	$2.34\ E_{rms}$ $1.65\ E_{max}$
E Inverse	$3.14\ E_{avg}$	$1.57\ E_{avg}$	$2.09\ E_{avg}$	$2.09\ E_{avg}$	$1.045\ E_{avg}$
I Average	$.636\ I_{max}$	$.636\ I_{max}$	$.827\ I_{max}$	$1.91\ I_{max}$	$.955\ I_{max}$
Ripple Frequency	2 X Supply Freq.	2 X Supply Freq.	3 X Supply Freq.	6 X Supply Freq.	6 X Supply Freq.
Ripple Voltage (Rms)	48.3%	48.3%	18.3%	4.2%	4.2%
† Ratio $\frac{\text{Secondary Kva}}{\text{D.C. Output-Kw}}$	1.57	1.11	1.48	1.48	1.05
† Ratio $\frac{\text{Primary Kva}}{\text{D.C. Output-Kw}}$	1.11	1.11	1.21	1.05	1.05

† These ratios assume that a choke input filter is used to maintain the output current substantially constant.

MAINTENANCE REFERENCE SHEET

POWER OSCILLATOR TUBES

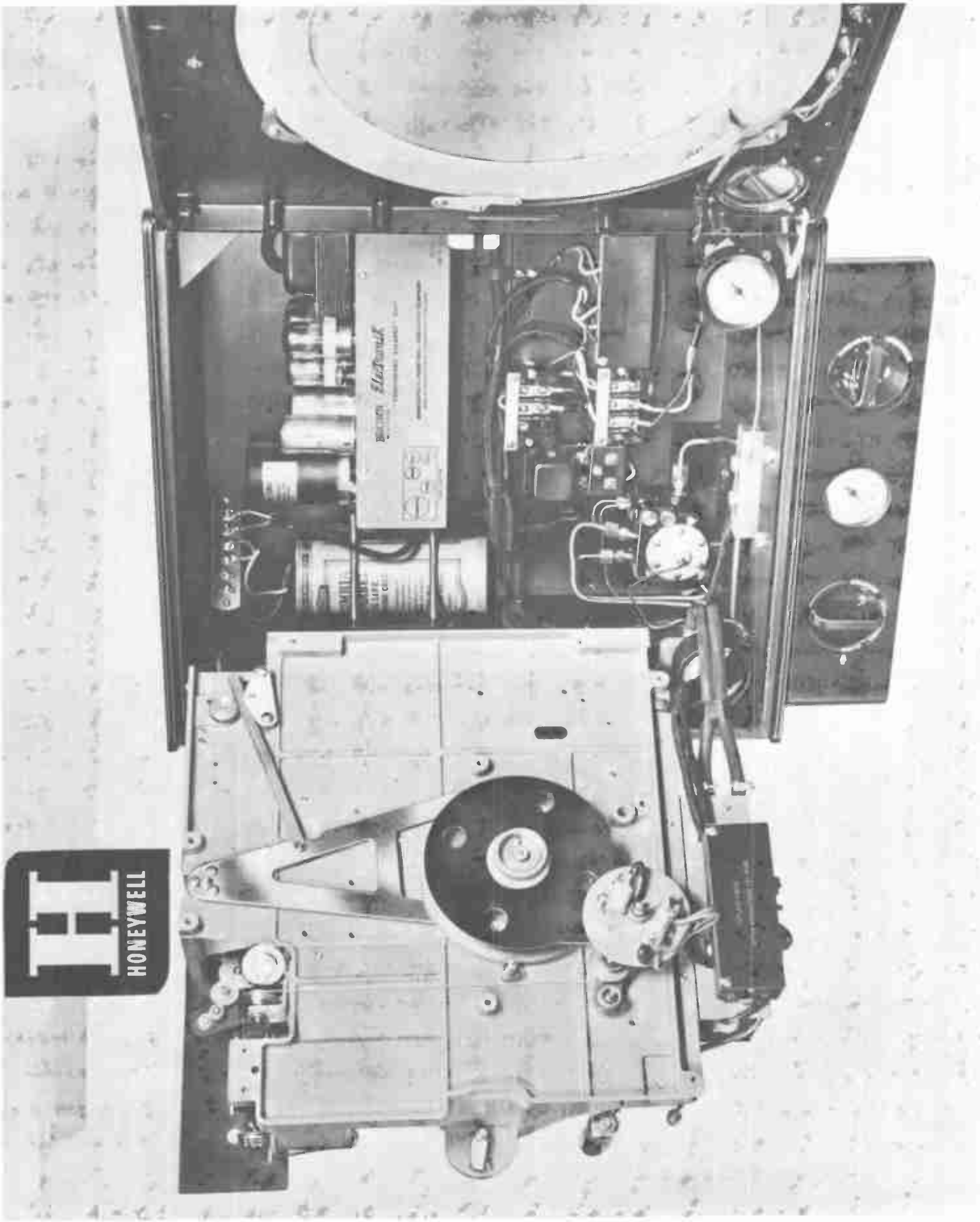
TROUBLE	CAUSE	PREVENTIVE OR CURATIVE MEASURES
1. *Filament Burn-Out* (See photograph at left)	a. Filament voltage too high	1a. Filament voltage should be checked regularly at tube terminals with an accurate voltmeter Tubes should be operated at constant voltage throughout life (not at constant current). Line voltage should not vary more than 5%. If it does vary more, a voltage regulator for the tube filaments will generally pay for itself by reducing tube replacements.
	b. Excess grid dissipation causes gas evolution which results in a power arc capable of burning out filament	1b. Tube currents and voltages should be checked against maximum ratings in tube data sheets. Equipment should be adjusted to suggested conditions given by manufacturer of equipment. (Check no-load adjustment of oscillator, grid-current maximum should not be exceeded). Excessively high grid current settings reduce power generally.
	c. In tubes with multistrand filaments, when one strand is broken, others can burn out due to unequal current division. Types: 889, 5666, 5604, 5619, 880, 3X2500, 5771	1c. Set up such tubes in equipment and check filament current at correct voltage upon receipt, to check for filaments broken in shipment.
	d. Normal end of life	1d. Record number of hours on running time meter when tube is installed and when the tube is removed. Life is reckoned on the basis of filament hours. Record as well—date of installation, tube serial number, manufacturer, and where obtained, equipment number and type.
2. *Punctured or "Sucked In" Anodes* (See photograph at left)	a. Overloading or poor load matching shown by plate current too high, grid current too low	2a. Maintain operating conditions as set up by equipment manufacturers. Never operate with grid current or plate current beyond maximum tube ratings. Operation at manufacturer's typical plate current but below corresponding grid current may result in low efficiency. This will produce excessive plate dissipation.
	b. Insufficient water flow. Low pressure, closed pipes, dirty filters c. Water failure	2b. & c. Check water filters regularly—check water flow and water pressure interlocks regularly. Use large enough water pipes in installation to insure enough pressure when all equipment in plant is on. Rated water or air flow must be started before any voltage is applied and continued for 5 minutes after voltage is removed.
	d. Scale on anode due to hard water	2d. Water that shows a hardness of more than 10 grains per gallon, or a specific resistance of less than 4000 ohms per cubic inch, should not be used. A well-designed distilled water recirculating system will eliminate hard water problems and may save on total water flow requirements. Tube should be removed immediately, if any hissing indicating boiling is heard. Scale can be removed from anodes by carefully dipping the anode in 10% solution of hydrochloric acid. Protect glass-to-metal seals. Acid should then be washed away thoroughly.
	e. Failure of blowers—(air-cooled types)	2e. An air-flow interlock should be included in the design of air-cooled equipment and should be checked regularly for correct operation.
	f. Air filters clogged—(air-cooled types)	2f. Air filters should be changed or cleaned regularly.
3. *Gassy Tubes* Blue flashes in tube. Circuit breaker opens when high voltage is applied.	a. Tubes taken off shelf and high voltage immediately applied	3a. Tubes held as spares should be installed in equipment where they are to be used and the following schedule followed every 3 to 6 months. I. Light filament for 30 minutes at rated conditions. II. Operate tube at reduced anode voltage (½ to ⅔ full) for 15 minutes. III. Operate tube at full voltage conditions for 15 minutes. This will keep the tube hard indefinitely. Use older tubes before new tubes—to take advantage of guarantee period. This schedule should be followed whenever a new tube is installed in equipment.
	b. Mismatch of oscillator to load	3b. See 2a.
	c. Excess grid dissipation	3c. See 1b.
	d. Parasitics (oscillations at frequencies other than normal). Grid or plate currents too high with no load power	3d. Use lossy lead in grid circuits, small capacitors directly from plate or grid terminal to filament terminals.
	e. Low filament voltage or low emission	3e. Age in as in 3a or see 8 below. If necessary, return to factory for repair.
	f. Lack of cooling water or air	3f. See 2e and 2f. May be possible to age in as in 3a. Note: Cooling should not be turned off after tube is shut down until all elements are cooled to black.
	g. Mechanical damage	3g. See 5c.

TROUBLE	CAUSE	PREVENTIVE OR CURATIVE MEASURES
4. *Broken Filaments*	a. Excess shock in handling during shipment or later b. Starting current limit exceeded on tungsten filament types c. Excess mechanical vibrations	4a. Examine cartons carefully for external damage upon receipt. Handle tubes carefully in cartons. Tubes should always be shipped with external anode down. Store tubes in original cartons as packed. Check filaments for continuity with ohmmeter immediately on receipt from the carriers. If possible, check in actual equipment as in 1c and 3a. Report all damaged tubes to carrier immediately. 4b. Check operation of starting current limiting device (high reactance transformer or resistance and cut out relay). 4c. Check shock mounting of tubes for vibration due to associated machinery. Isolate or damp out the vibrations that reach the tube.
5. *Broken Envelopes*	a. Star crack—hit by sharp object b. Overheated — excess dissipation, or cooling failure c. Tube shocked excessively on installation or during storage in shipment	5a. Remove tube from equipment when doing any heavy work in equipment. 5b. See 2a, b, c, e. 5c. A vacuum power tube is a fragile device which has glass parts and some types may have several soft, copper seals to allow for expansion and contraction. In a typical tube there are 250 square inches of glass with 14psi outside pressure and inside pressure of ½ x 1/100,000,000 of the outside pressure. While the manufacturer designs and makes the tube for utmost strength considering limitations of materials, care must be used in installing. See a.
6. *Melted or Warped Grids*	a. Parasitic oscillations b. Oscillator with too much drive c. Filament voltage too low causes low tube emission increasing grid dissipation for normal grid current	6a. See 3d. 6b. See 1b. Always operate within tube ratings including no-load condition. 6c. See 1a.
7. *Glass-to-Metal Seal Failure*	a. Excess torque or tension during installation b. Lifting heavy external anode tubes by glass envelope c. Inadequate seal cooling. Seal temperatures too high d. Parasitic oscillations due to unusual load or drive adjustments e. Poor filament and grid contacts	7a. & b. Use torque or small-handle wrench when tightening filament and grid connectors. Use no more force than is necessary to make good contact. Always pick up external anode tube by anode or radiator. Insert tubes in water jackets carefully. During installation, examine water jacket for leaks and gasket for proper seal. 7c. Use sufficient air as recommended by manufacturer. If in doubt, check seal temperature with Tempilac or Tempilstic. Use heat radiating connectors. 7d. See 3d. 7e. Make good contact with adequate connectors. Keep contacts clean and in good condition.
8. *Low Emission*—First shown in oscillator by drop in grid current and efficiency with time. Test by temporarily boosting filament voltage 10% when circuit is adjusted for normal operation. If grid and plate currents increase 10% or more, tube has insufficient emission.	a. Tungsten filaments—filament voltage too low b. Thoriated tungsten I. Filament voltage too high II. Filament voltage too low III. Excess grid dissipation causing back bombardment of cathodes (both released gas and electrons) IV. Any of causes for gassy tubes	8a. & b. I & II. Measure power-line variation and adjust filament transformer tap so that rated filament voltage ranges are not exceeded. Thoriated tungsten filaments—nominal ±5%. By adding 5% to the nominal filament voltage for pure tungsten filaments, the life is approximately halved and the emission is doubled. Reducing the voltage 5% results in doubling the filament life and halving the emission. III. See 1a. IV. See 3.
9. *Punctured Glass Envelopes*	a. Inadequate cooling—Glass temperature too high b. High-frequency parasitics c. External deposits, dirt on glass	9a. Sufficient clean air flow should be available to keep glass and seal temperature within ratings. check glass or metal envelope with temperature sensitive lacquer Tempilaq. Ambient air temperature may be too high or proper free air circulation may be obstructed. 9b. See 3d. 9c. All external glass should be kept clean and free of dust, dirt and chemical deposits. Use a clean rag with industrial alcohol to periodically wipe the envelope clean. Make sure equipment is off and glass envelope is cool to the touch. Air filters should be maintained.

10. Shorts	a. Grid filament shorts—caused by excess grid dissipation which can warp grids b. Rough handling in shipping c. Excess or resonant vibration	10a. See 1b. 10b. See 4a. 10c. See 4c.
11. Flash Arcs	a. Installing tubes without operating at reduced power input b. Failure of other elements or insufficient transient suppression—causing high transient voltages	11a. See 3a. 11b. Repair equipment and check out before replacing tubes.
12. Low Power Output	a. Low emission b. Load not adjusted properly c. Parasitic oscillation using some of input power d. Grid drive adjusted too low under loaded conditions e. Power supply problem	12a. See 8. 12b. See 2a. 12c. See 3d. 12d. Increase drive adjustment. 12e. Check rectifier tubes—line fuses—transformers.

POWER RECTIFIER TUBES – MERCURY VAPOR TYPES

13. Arc Back	a. Improper operating temperature b. Insufficient preheat time after installation to distill mercury off of anode and top of bulb c. Filament voltage too high or too low d. Radio-frequency pick up e. Excess peak current due to overloads in circuit	13a. Maintain condensed mercury or ambient temperatures according to tube manufacturing recommendations in tube data sheets. Cooling, if used, should be directed at base of rectifiers. Ventilation of cabinet should be adequate. Plate voltage should be delayed for the specified filament preheat time. Check time delay circuits against stopwatch occasionally. 13b. Store and handle mercury vapor tubes with anodes up to minimize mercury deposition on anodes. Operate filaments only for 30 minutes or until there are no mercury droplets above the bottom of the tube. Tube should then be operated at ½ full anode voltage for 15 minutes. Next, voltage should be brought up to full slowly. If arcing occurs, reduce voltage slightly until tube operates clear. Continue "aging up" the tube to full voltage. 13c. See 1a. 13d. Shield tubes from r-f fields. 13e. Use quick-acting circuit breakers. Allow rectifiers to run with plate voltage off for 5 to 10 minutes after a severe overload.
14. Open Filaments (See photograph)	a. Arc back b. Filament voltage too high c. Filament starting current too high on larger types d. Too frequent turning off and on of filament voltage	14a. See 13. 14b. Filament voltage should be maintained ±5%. See 1a. 14c. See 4b. 14d. See 15b.
15. Punctured Envelope	a. Dirt or dust on envelope b. Insufficient preheat time. Too low a condensed mercury-temperature can puncture the bulb Mercury droplets on bulb near anode can cause breakdown of the glass	15a. See 9c. 15b. Wait time recommended in data sheets before applying plate voltage. Maintain automatic time delays. Allow tube to run with filament on only for at least 30 minutes after first installing new tube to distill mercury into base of tube.


HONEYWELL

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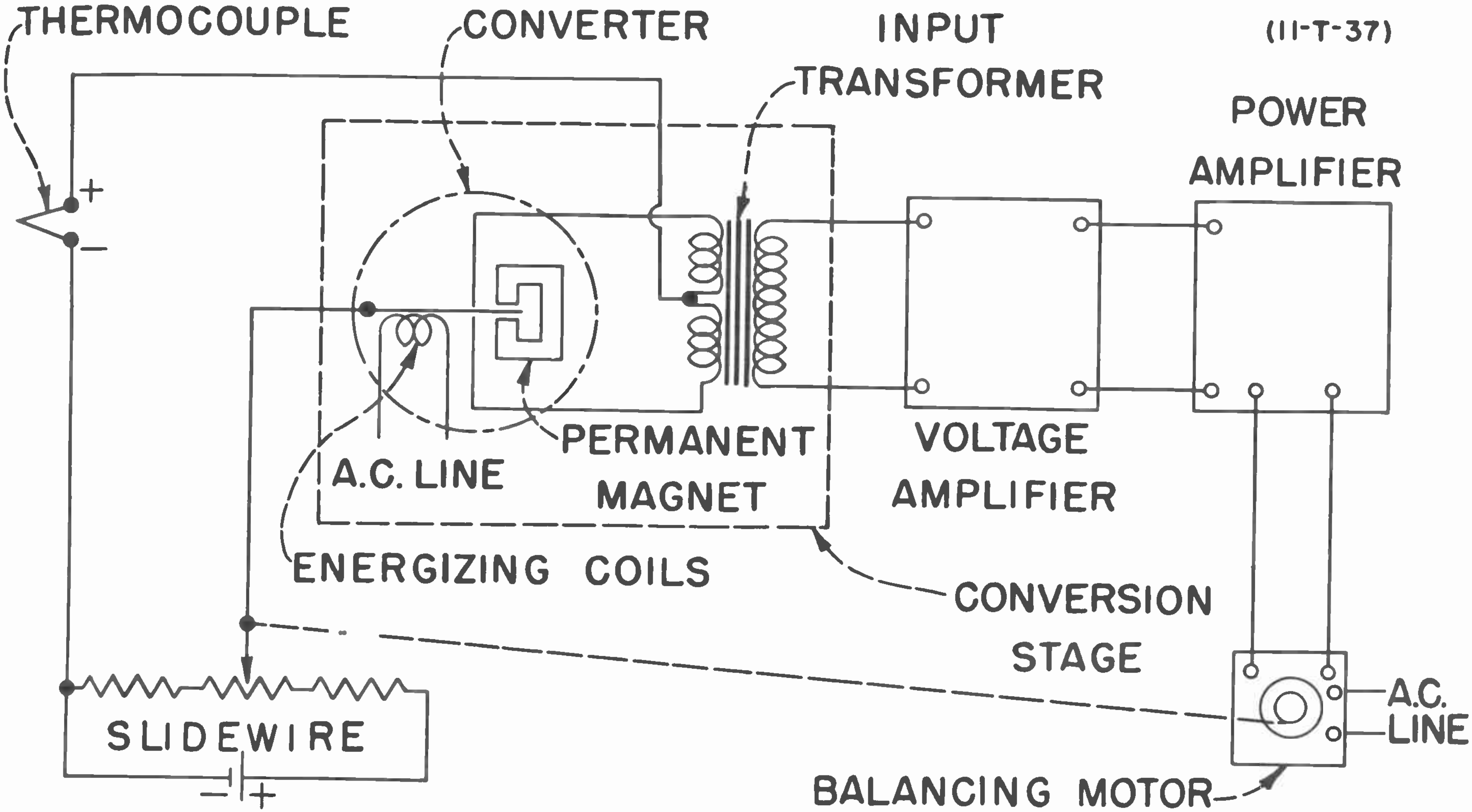
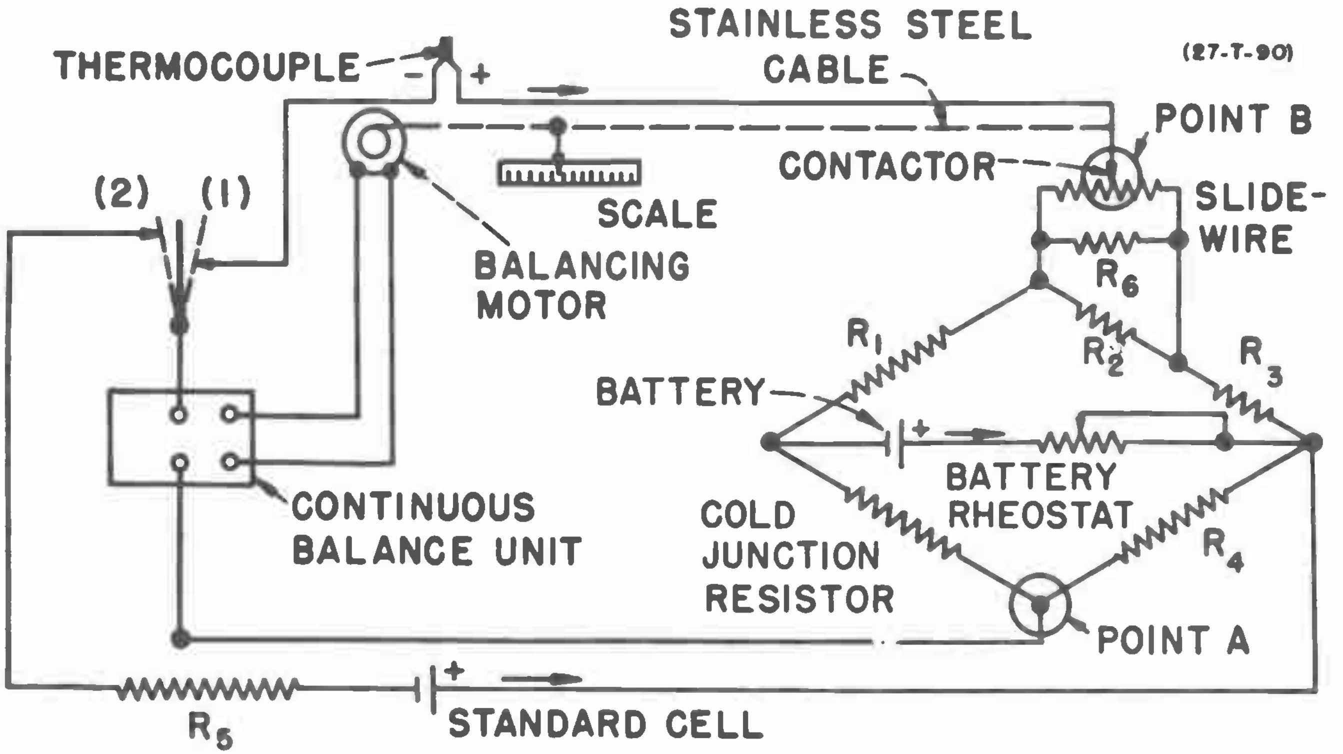
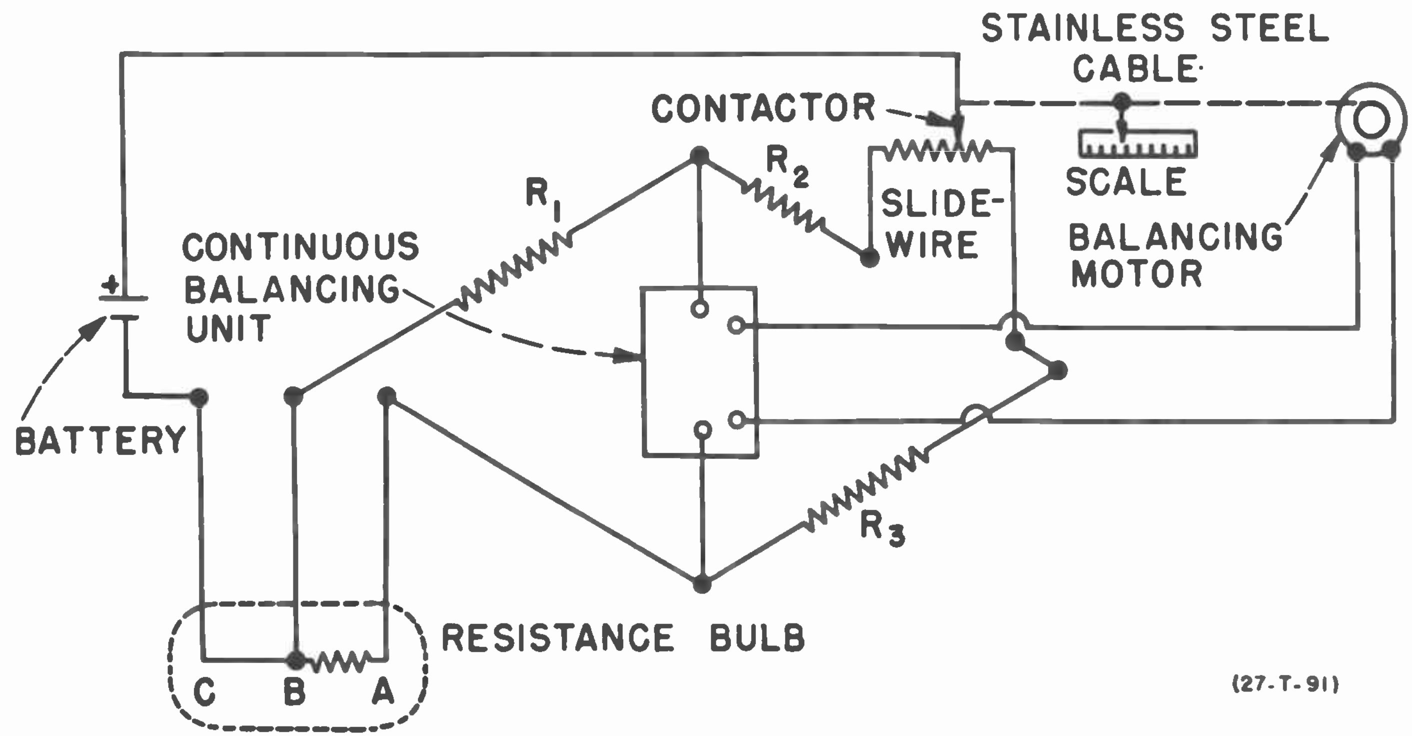


MINNEAPOLIS Honeywell
Industrial Division

SCHEMATIC DIAGRAM OF BROWN CONTINUOUS BALANCE SYSTEM

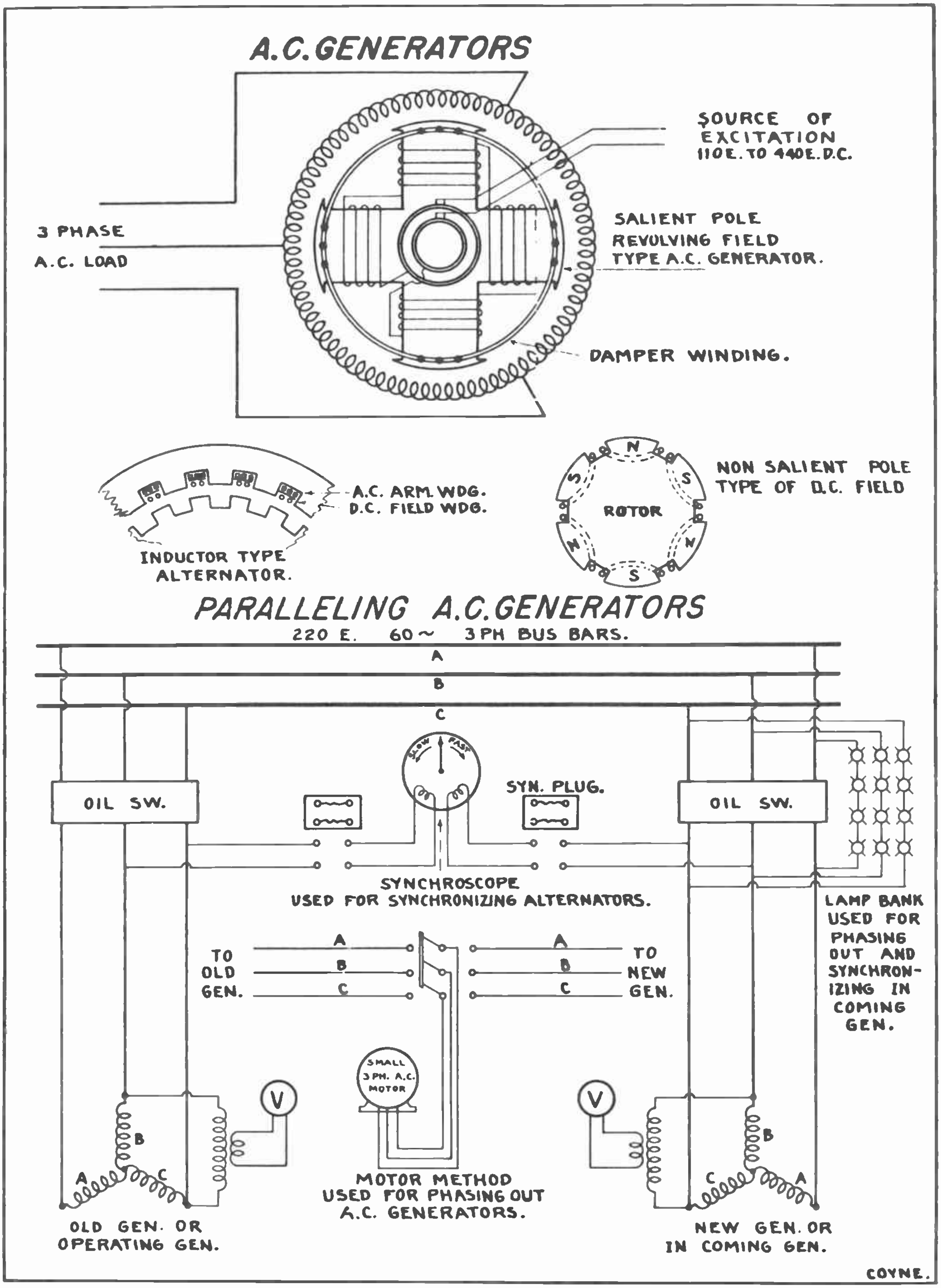


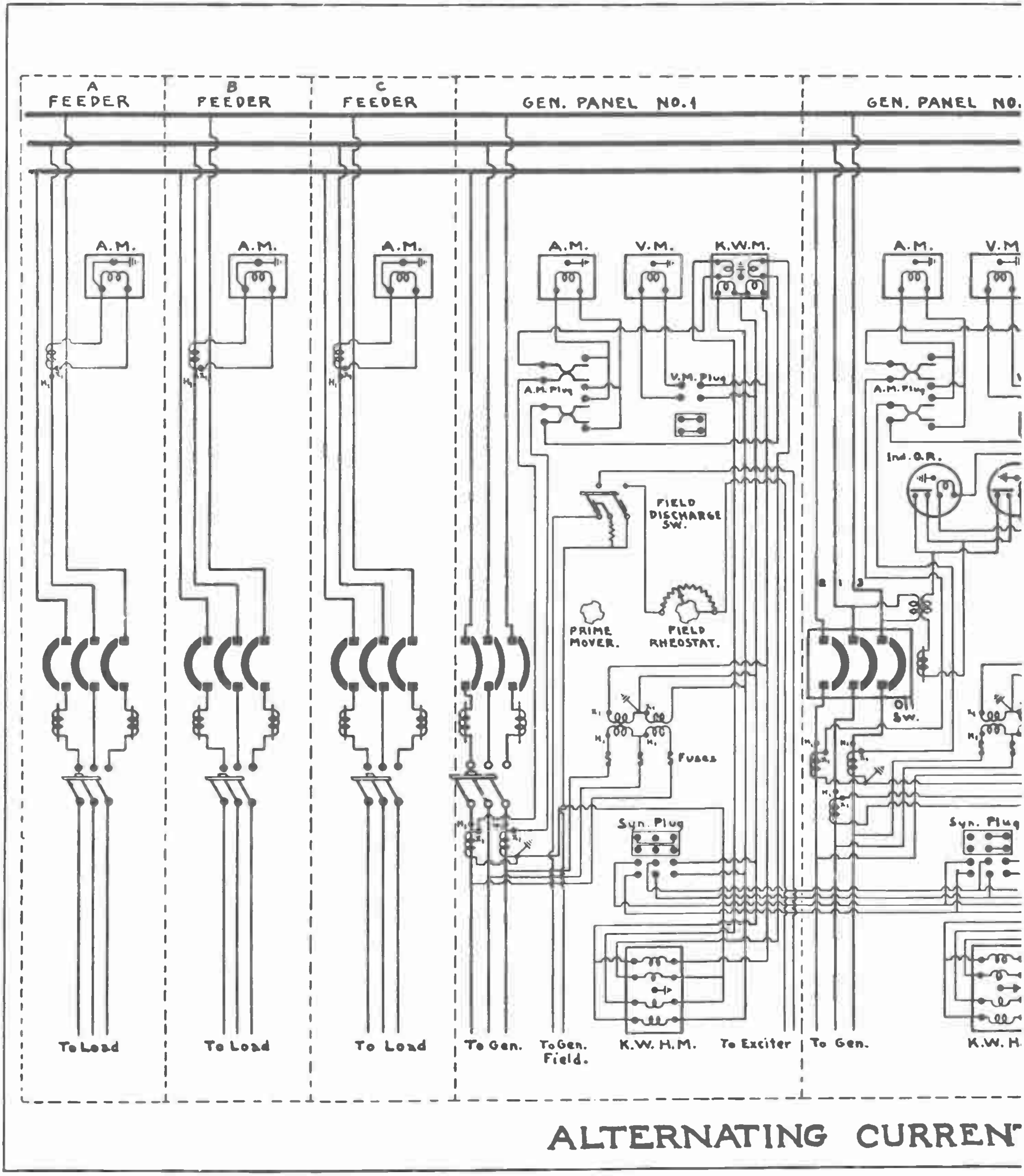
MINNEAPOLIS - HONEYWELL REGULATOR CO. BROWN INSTRUMENTS DIVISION PHILADELPHIA, PA., U. S. A.	DRAWN AS	DATE	ISSUE NO.	APP.	SEMI-SCHEMATIC STANDARD POTENTIOMETER CIRCUIT	DRAWING NO. 27-T-90
	APPROVED	SCALE				



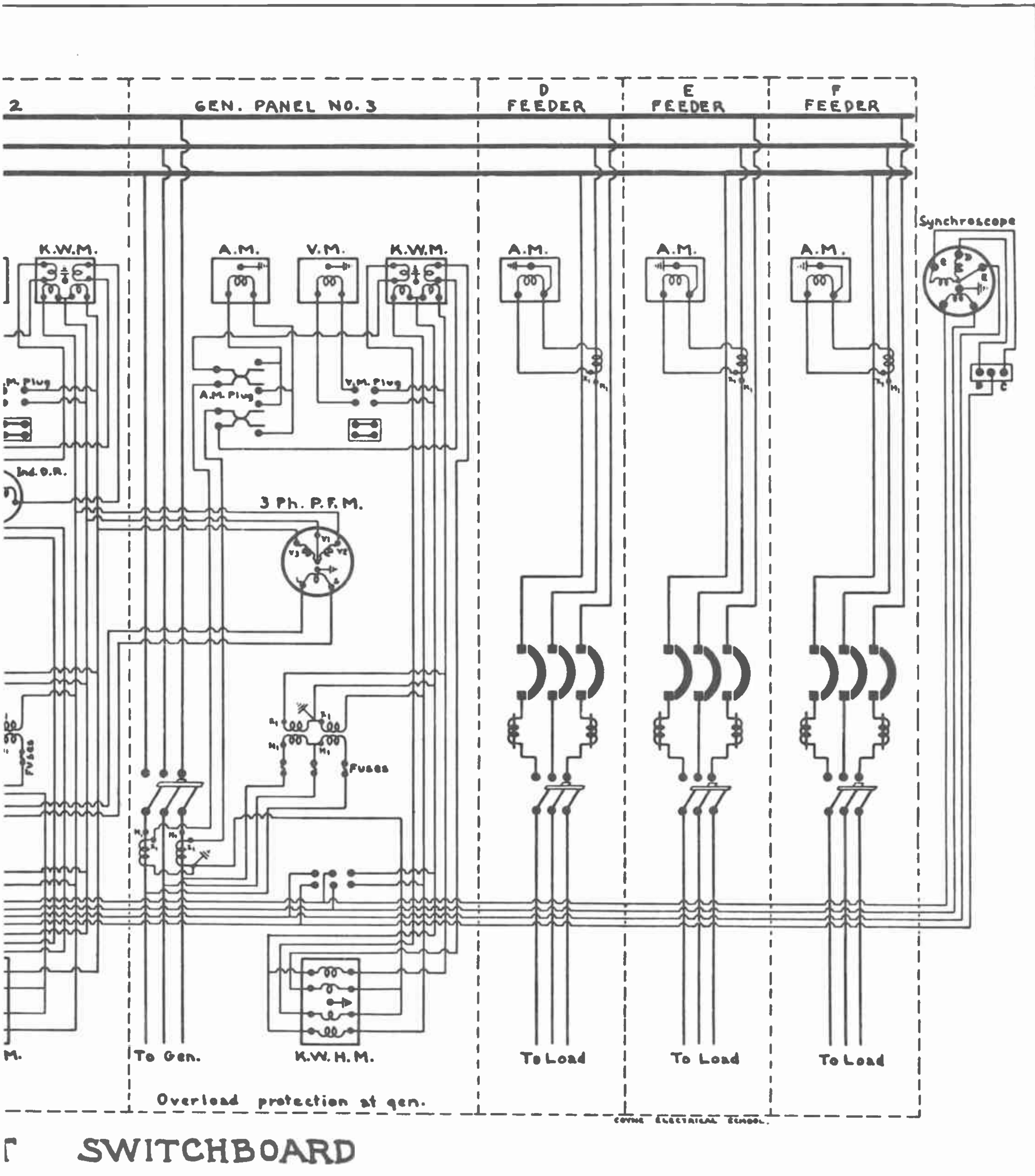
(27-T-91)

MINNEAPOLIS - HONEYWELL REGULATOR CO. BROWN INSTRUMENTS DIVISION PHILADELPHIA, PA., U. S. A.	DRAWN A S APPROVED	DATE SCALE	ISSUE NO.	APP.	SEMI-SCHEMATIC RESISTANCE THERMOMETER CIRCUIT	DRAWING NO. 27-T-91

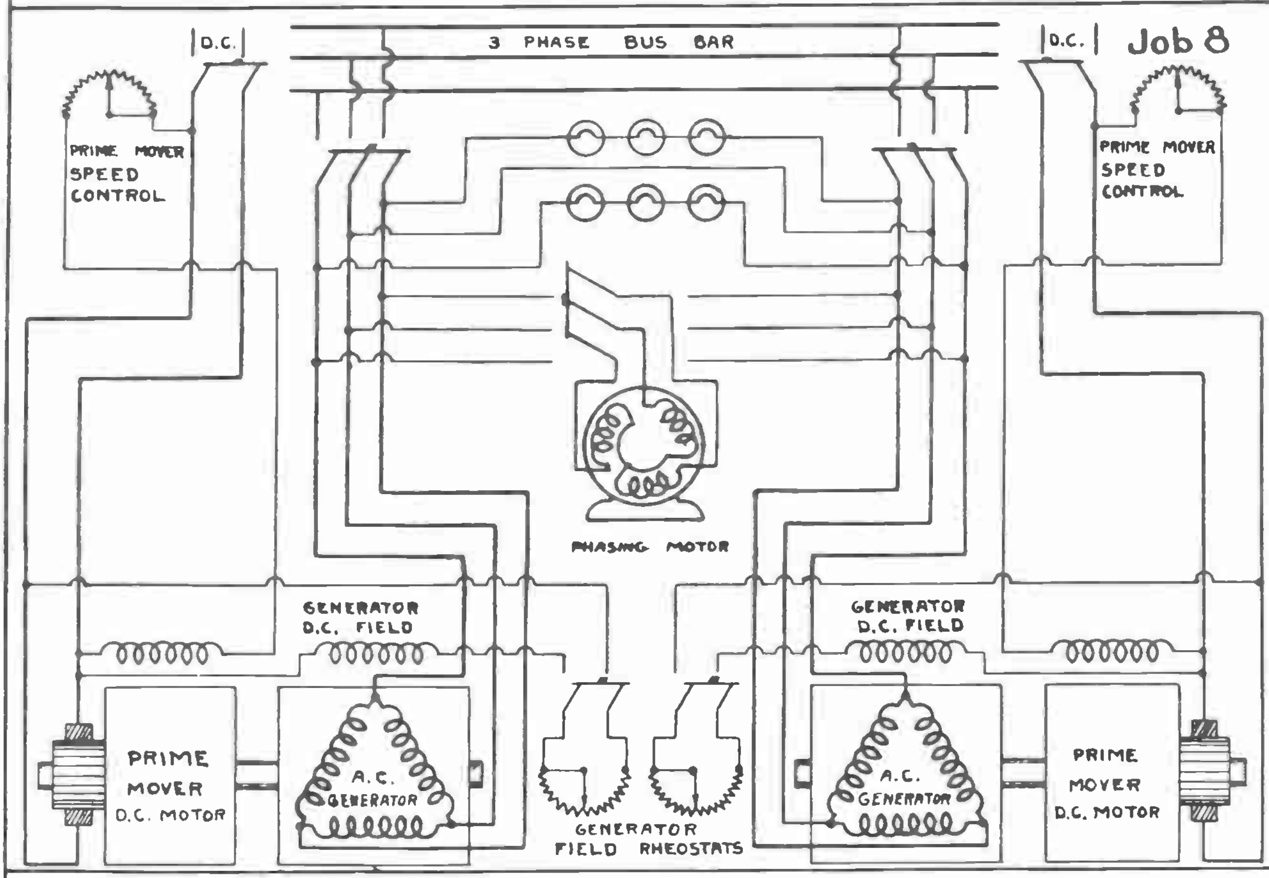

A.C. GENERATORS
SOURCE OF EXCITATION 110E. TO 440E.D.C.
3 PHASE A.C. LOAD
SALIENT POLE REVOLVING FIELD TYPE A.C. GENERATOR.
DAMPER WINDING.
A.C. ARM. WDG.
D.C. FIELD WDG.
INDUCTOR TYPE ALTERNATOR.
N
S
ROTOR
NON SALIENT POLE TYPE OF D.C. FIELD
PARALLELING A.C. GENERATORS
220 E. 60 ~ 3 PH BUS BARS.
A
B
C
SLOW
FAST
OIL SW.
SYN. PLUG.
OIL SW.
SYNCHROSCOPE USED FOR SYNCHRONIZING ALTERNATORS.
LAMP BANK USED FOR PHASING OUT AND SYNCHRON-IZING IN COMING GEN.
TO OLD GEN.
TO NEW GEN.
SMALL 3 PH. A.C. MOTOR
V
MOTOR METHOD USED FOR PHASING OUT A.C. GENERATORS.
OLD GEN. OR OPERATING GEN.
NEW GEN. OR IN COMING GEN.
COYNE.



ALTERNATING CURREN


2
GEN. PANEL NO. 3
D FEEDER
E FEEDER
F FEEDER
K.W.M.
A.M.
V.M.
K.W.M.
A.M.
A.M.
A.M.
Synchroscope
A.M. Plug
V.M. Plug
Ind. O. R.
3 Ph. P.F.M.
Fuses
Fuses
M.
To Gen.
K.W.H.M.
To Load
To Load
To Load
Overload protection at gen.
SWITCHBOARD

PHASING OUT, SYNCHRONIZING AND PARALLELING OF A.C. GENERATORS



TO OPERATE SATISFACTORILY WHEN SWITCHED IN PARALLEL, A.C. GENERATORS MUST FULFILL THE FOLLOWING REQUIREMENTS:

1. The machines must be designed for the same voltage and frequency. They need not have the same speed or the same power rating.
2. The generators must have similar operating characteristics as far as voltage regulation is concerned in order to assure proper division of load.
3. The machines must be correctly connected together, or "phased out."

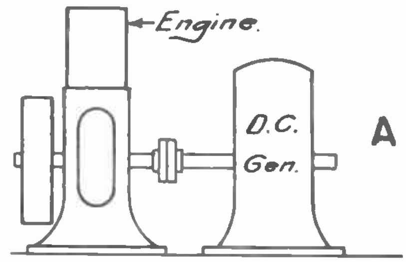
The paralleling switch must be closed at the instant when the generator frequencies are very nearly equal, and when the voltages are exactly equal and in direct opposition to each other. These conditions exist when the voltmeters read alike and the synchronizing lamps are out. Under such circumstances, the generators are said to be in synchronism - this is the instant at which the paralleling switch must be closed.

"Phasing out" may be effected by strings of lamps, or a three-phase motor, connected as indicated. If the generators are properly connected, all lights will go out together, and the phasing motor will run in the same direction on either machine. Should the action of the lamps or the operation of the motor indicate an improper connection, interchange any two leads of the new machine. It is important to note that the strings of lights or the phasing motor - whichever is used - must be symmetrically connected with respect to the generators if trustworthy indications are to be obtained. The above sketch shows how these devices should be connected.

After the new machine is in parallel, it must be caused to assume its proper share of the load. This can be accomplished by increasing the power input to the prime mover. Varying the field excitation on an A.C. generator will not cause it to pick up or drop load as it does with a D.C. machine. Instead, it merely results in changing the power factor of the machine. Although the new machine has to be "phased out" but once, the synchronizing operation must be repeated each time a generator is paralleled with others.

D.C. GENERATORS.

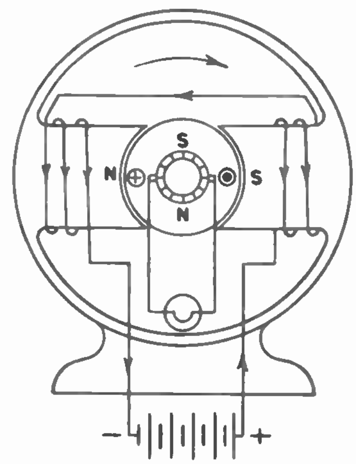
GENERATOR ACTION
An electrical generator is a device designed to change mechanical energy into electrical energy. Note that it does not generate energy, it merely converts it from the mechanical to the electrical form.



A

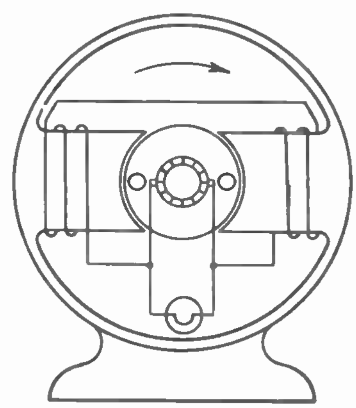
As no conversion device is 100% efficient, the power input to the generator must be greater than the rated generator output. For generators of 5 K W rating or above, a prime mover capable of supplying 1.5 H P for each KW of generator output is usually employed.

SEPARATELY EXCITED GENERATORS
The D. C. Generator produces voltage by rotating conductors through a magnetic field. In Figure B this field is produced by field coils that are energized from a separate source external to the machine. This type of generator may be driven in either direction, for the field excitation is independent. The polarity of the brushes will reverse when the rotation is changed, the positive brush becoming negative and vice versa.



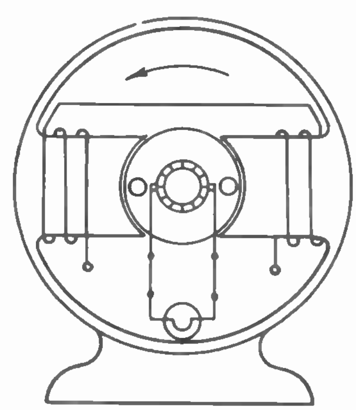
B

SELF EXCITED GENERATOR SHUNT TYPE
In this machine, the energy for the field is obtained from the armature and the generator is self exciting. The field poles retain some magnetism after having once been magnetized, and as the armature is rotated, the conductors cut this residual flux and generate voltage. This voltage is applied to the field, which is in parallel with the armature, and in this manner the field is strengthened. This increased field raises the voltage still further and this action continues until normal voltage is reached. The magnetic polarity set up by the field coils must be the same as the residual magnetism, otherwise the voltage will not build up.



C

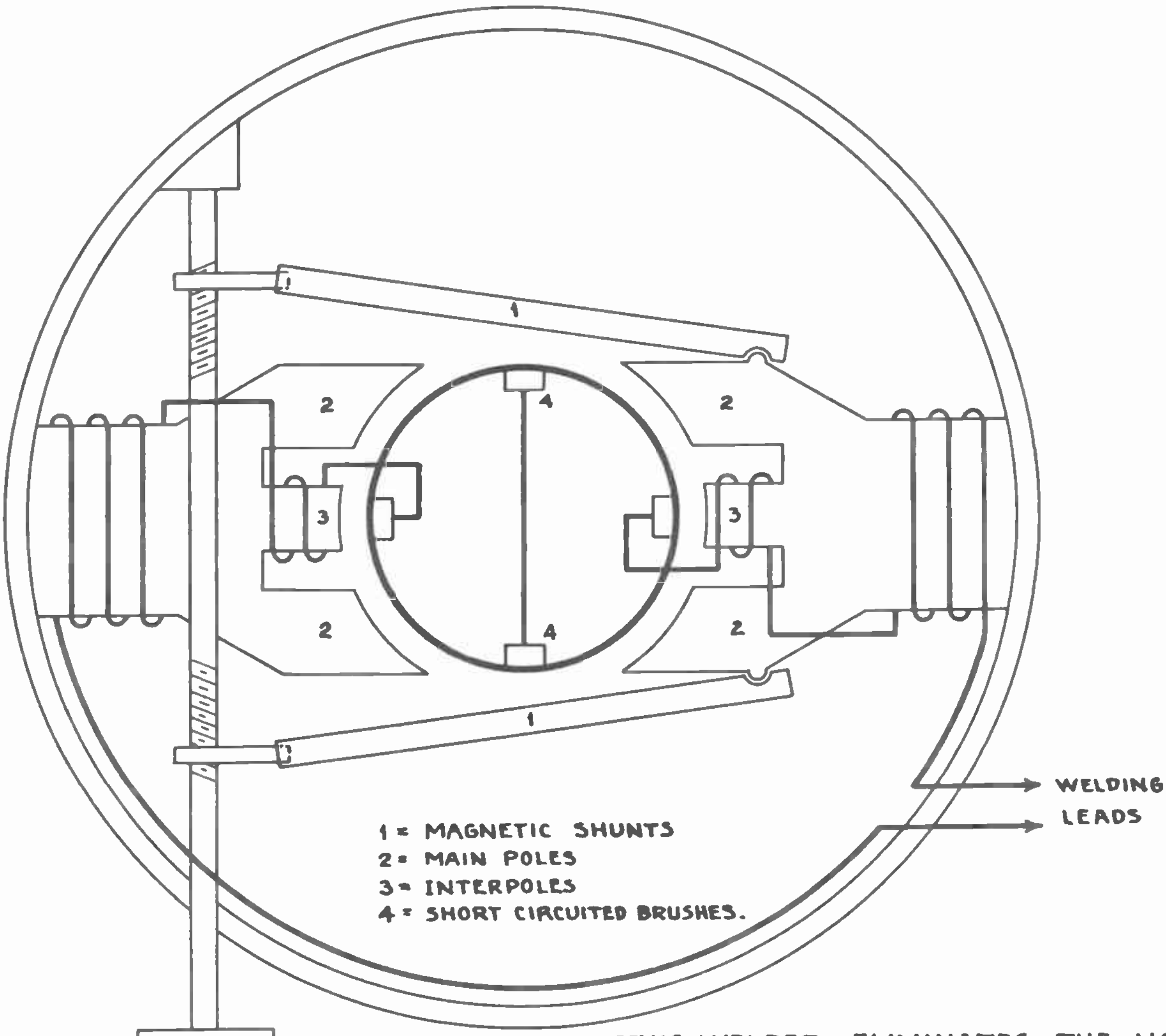
FAILURE TO GENERATE
The self excited type generator may fail to develop normal voltage due to: no residual field magnetism; magnetic effect of field coils opposing residual magnetism; poor brush contact; speed too low; wrong direction of rotation.
When the direction of rotation is changed, the brush polarity reverses and this reverses the current flow through the field coils, causing the coil magnetism to weaken the residual field. Under such conditions, the generator cannot build up a voltage. For operation in the opposite direction, the field leads must be reversed.

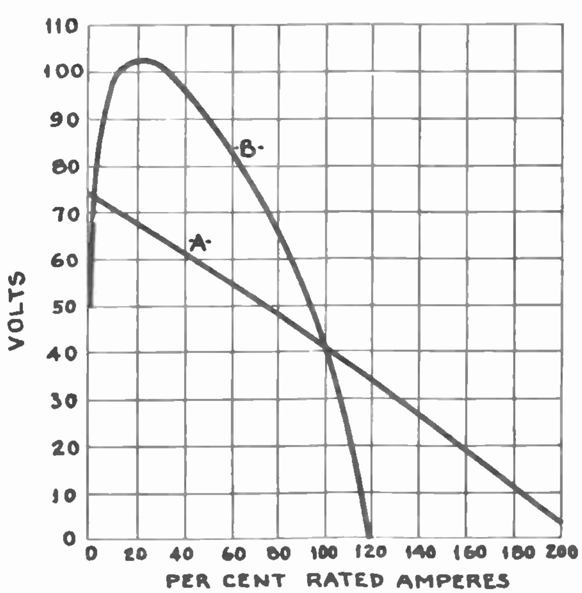


D

SERIES WELDING GENERATOR

CROSS FIELD DESIGN

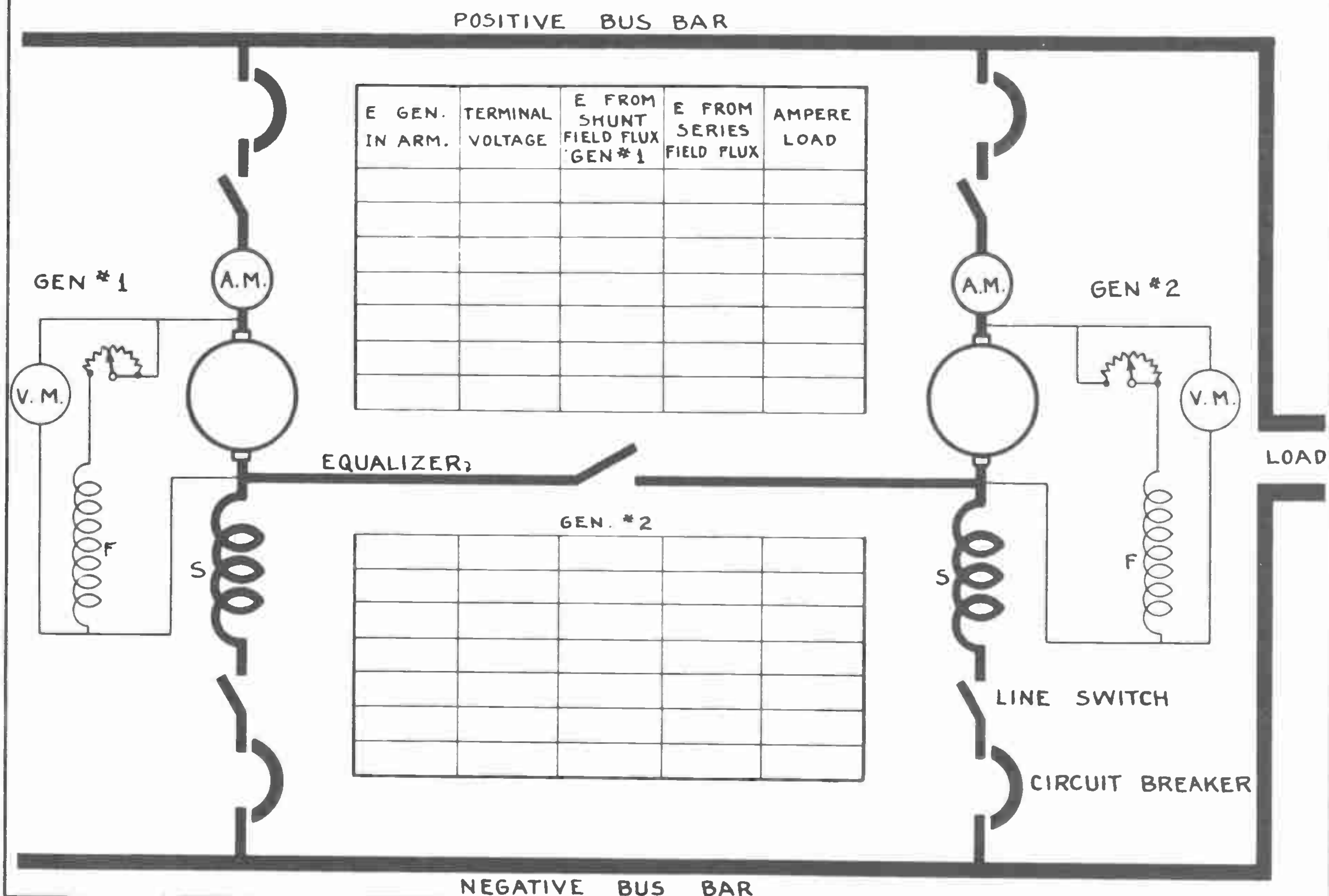




THIS WELDER ELIMINATES THE USE OF A REACTOR, EXCITER, VOLTMETER, AMMETER, METER SWITCHES, FIELD RHEOSTATS, AND FIELD DISCHARGE RESISTANCE. HOWEVER IT OPERATES VERY SATISFACTORILY HAVING FEWER PARTS THAN OTHER TYPES OF WELDING GENERATORS. THE MAINTENANCE COST IS CONSIDERABELY LOWER.

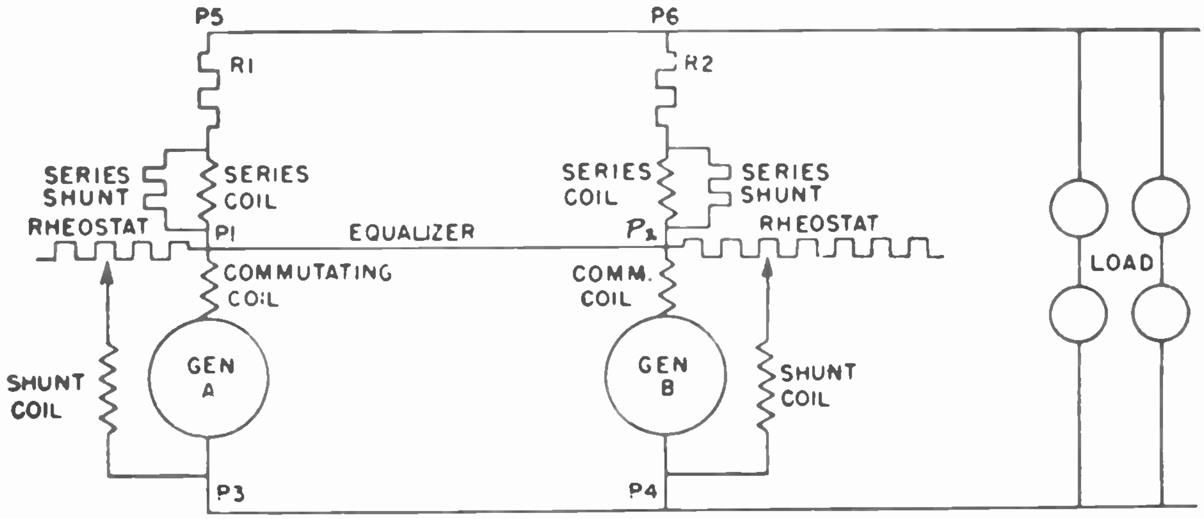
THE VOLT-AMPERE CURVE -A- IS A COMPOSITE, AND THE CURVE AT -B- IS THAT OF ONE OF THE CROSS FIELD WELDING GENERATORS.

PARALLELING D.C. GENERATORS.

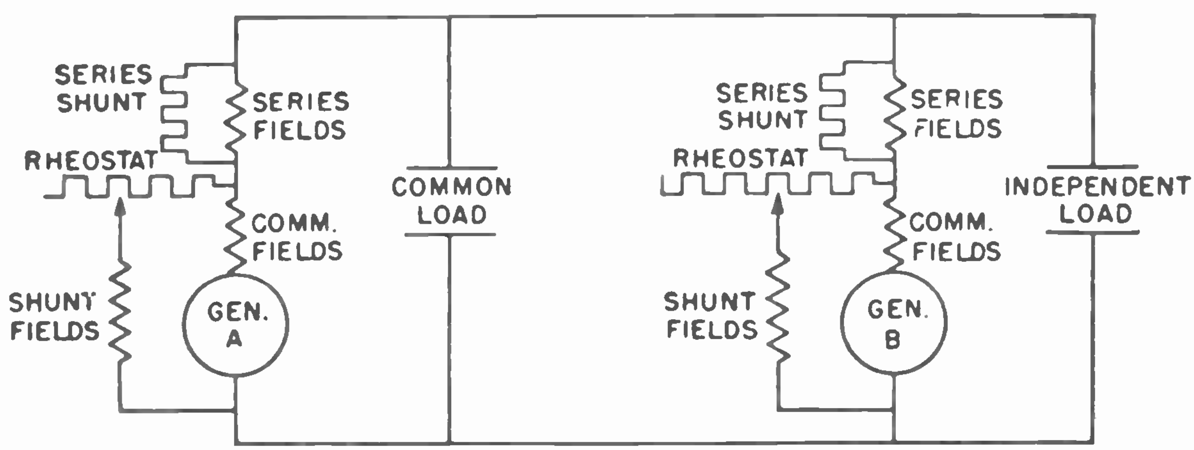


E GEN. IN ARM.	TERMINAL VOLTAGE	E FROM SHUNT FIELD FLUX GEN #1	E FROM SERIES FIELD FLUX	AMPERE LOAD

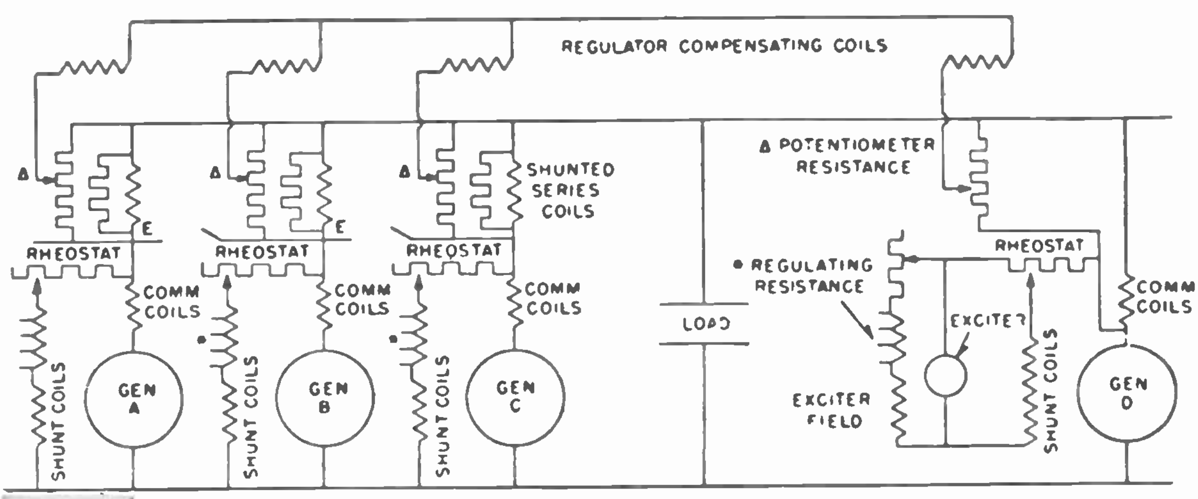
GEN. #2



Connections for Compound Generators in Parallel—Generators Close Together



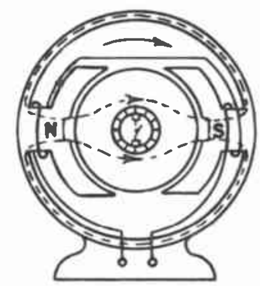
Connections for Compound Generators in Parallel Generators at a Distance



Compound Wound and Shunt Wound Generators in Parallel With Individual Voltage Regulators

AMPLIDYNE GENERATORS.

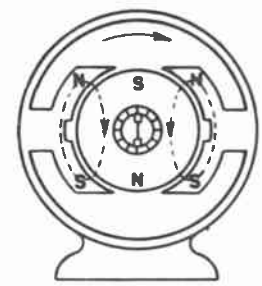
If a D.C. generator designed as shown and operated with a very weak field be driven at constant speed, the main brushes may be short circuited as indicated. This action results in relatively heavy currents in the armature that in turn produce an intense armature cross field with the polarities shown and, if the poles are especially designed to provide a magnetic circuit of low reluctance to this cross field, a strong magnetic field will be developed in the air gap. The armature, rotating in this field, produces a relatively high voltage at right angles to the normal brush axis and if extra brushes are placed as shown, power almost equivalent to the normal rating of the machine may be obtained.



A

SIGNAL FIELD.

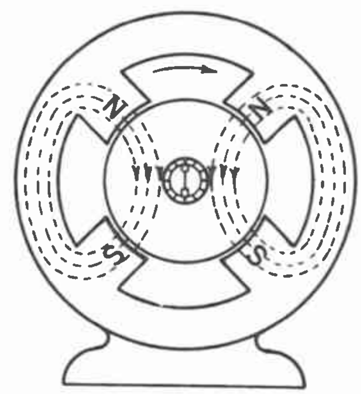
As the operating point for the field magnetism is set on the steep part of the magnetization curve, a small variation in the magnetizing force produced by the field coils will produce a relatively great change in the short circuit current produced by the armature, and this in turn will greatly increase the generated output voltage. Therefore, if special control coils be placed on the poles, and if these coils be fed from a low voltage or low power source, the variations which these coils produce may be caused to reappear in the output circuit in a greatly amplified form. This is the principle of operation of the Amplidyne Generator.



B

CROSS FIELD.

The Amplidyne Generator may be regarded as a two stage electrical power amplifier, and its use is concerned with control situations in which small controlling impulses are employed to handle equipment that demands a large amount of power to operate it. The small control power is fed to the field coils where it effects a relatively high variation in field magnetism; this variation is amplified in the cross field and again in the output circuit. Amplifications of 20,000 to 1 are common and 100,000 to 1 are possible. Thus a variation of one watt in the input control circuit may produce a change in generator output of 20 kilowatts, a range impractical for any electronic amplifier. The range may be extended by the use of a preamplifier using ordinary radio tubes.

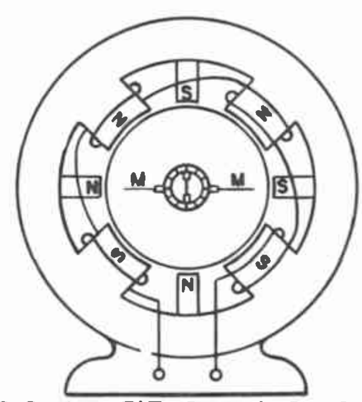


C

SPLIT POLE DESIGN
SHOWING CROSS FIELD.

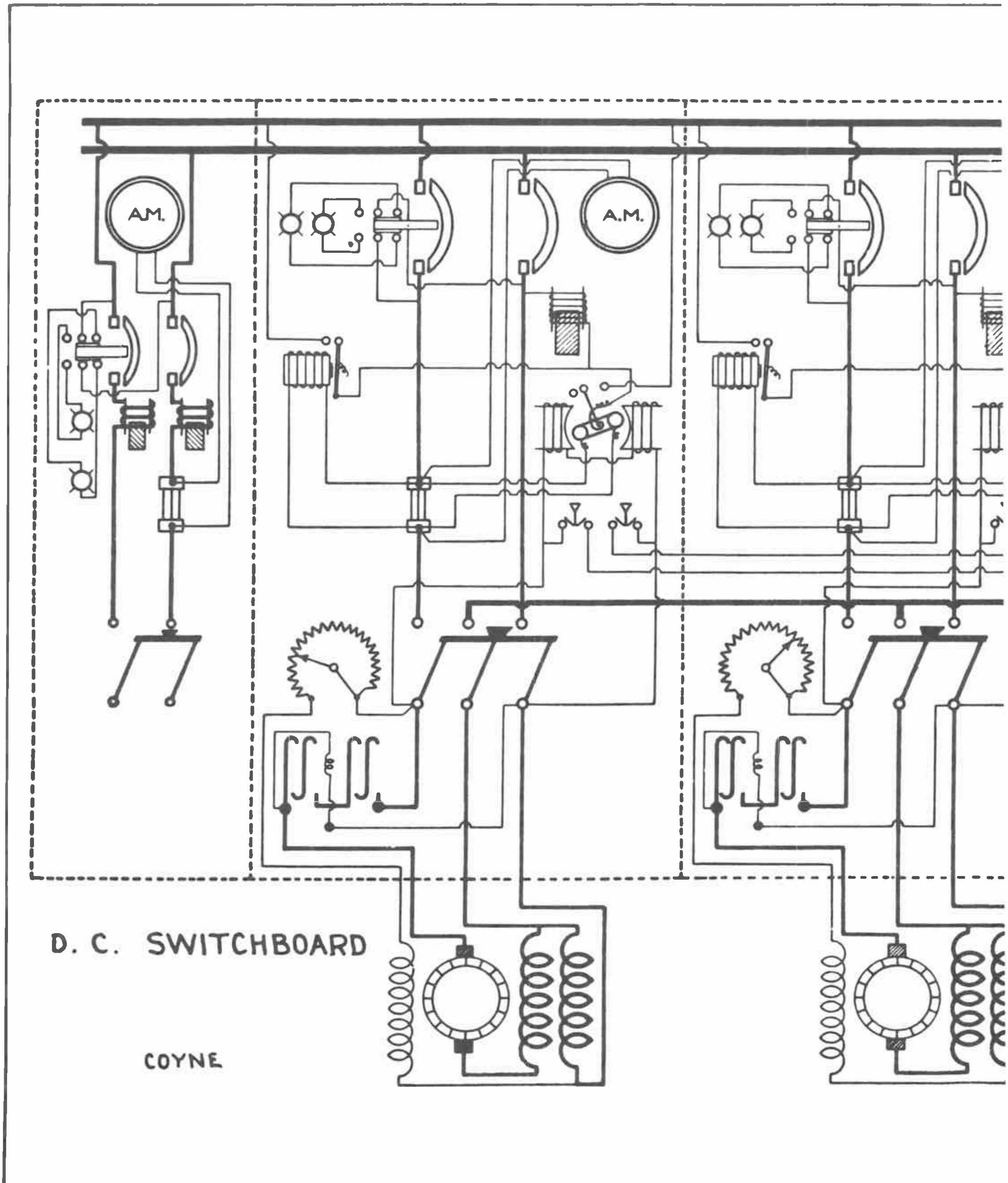
Instead of the split-pole construction shown above, the arrangement indicated in fig. C shows the constructional features of a modern amplidyne unit. Although four poles are shown, adjacent groups are wound with the same polarity, and the machine is therefore a two pole unit.

Figure D shows the construction of an Amplidyne unit using interpoles. Although several field windings are employed in an actual machine, only the signal winding is shown. The brushes M are the output brushes from which the amplified energy is obtained.



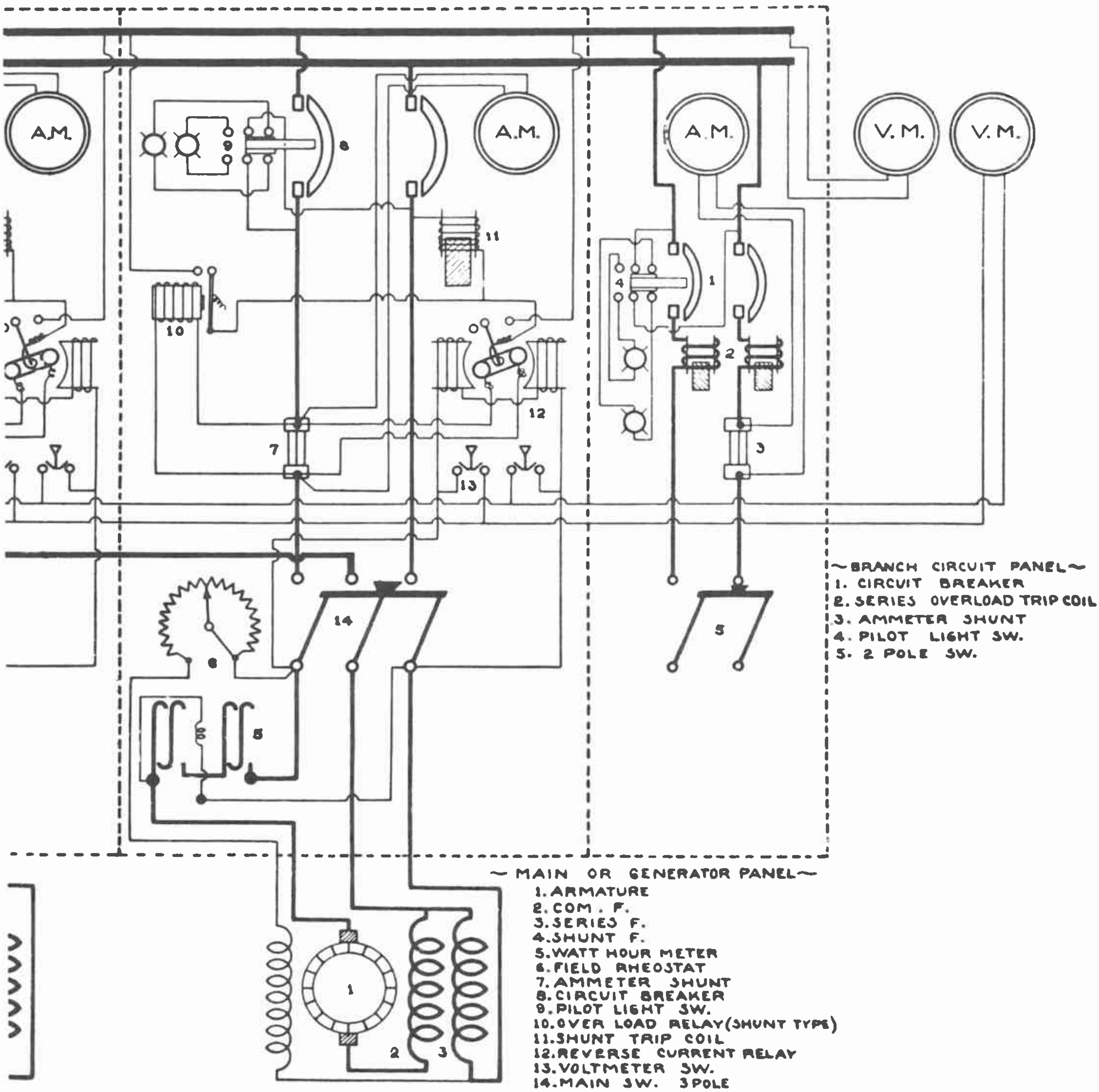
D

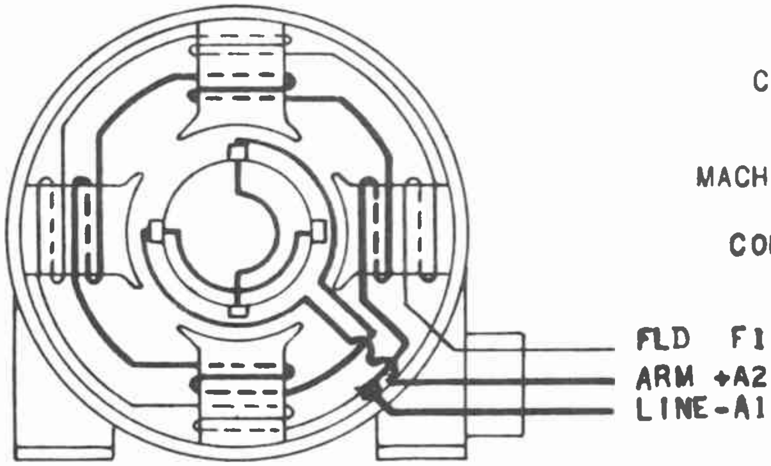
SIGNAL FIELD WINDING.



D. C. SWITCHBOARD

COYNE


A.M.
A.M.
A.M.
V.M.
V.M.
~BRANCH CIRCUIT PANEL~
1. CIRCUIT BREAKER
2. SERIES OVERLOAD TRIP COIL
3. AMMETER SHUNT
4. PILOT LIGHT SW.
5. 2 POLE SW.
~MAIN OR GENERATOR PANEL~
1. ARMATURE
2. COM. F.
3. SERIES F.
4. SHUNT F.
5. WATT HOUR METER
6. FIELD RHEOSTAT
7. AMMETER SHUNT
8. CIRCUIT BREAKER
9. PILOT LIGHT SW.
10. OVER LOAD RELAY (SHUNT TYPE)
11. SHUNT TRIP COIL
12. REVERSE CURRENT RELAY
13. VOLTMETER SW.
14. MAIN SW. 3 POLE



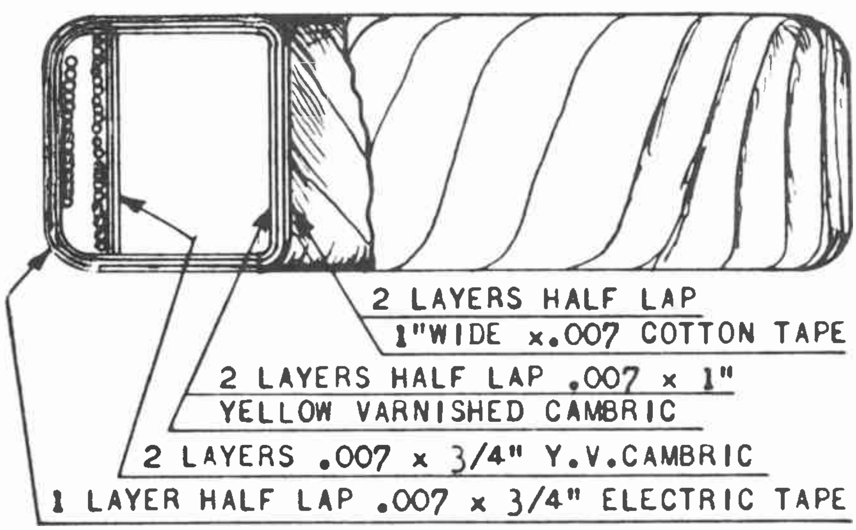
DIRECT CURRENT
GENERATOR
CONNECTION AND WINDING DATA

B-5236

CONNECTION DIAGRAM
MACHINE VIEWED FROM COMMUTATOR END
ROTATION COUNTER CLOCKWISE
COMPOUND NON INTERPOLE GENERATOR

THESE SYMBOLS ARE
STAMPED ON TERMINALS

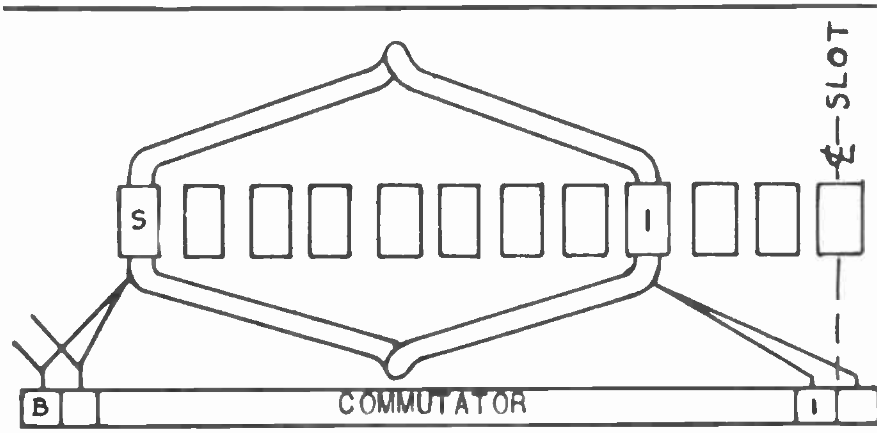
THE PEERLESS ELECTRIC CO.,
WARREN OHIO.



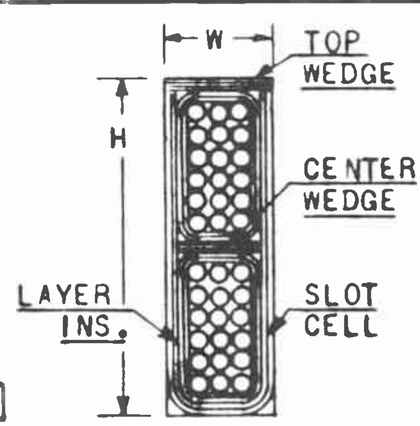
MAIN POLE COIL

TREATMENT OF COMPLETED COIL	
MAIN FIELD	COM.FIELD
DIP IN BB 52V13 VARNISH & BAKE 6 HOURS. AGAIN DIP IN CB 52V13 VARNISH & BAKE 4 HOURS. AFTER ASSEMBLY IN SHELL, BRUSH WITH AIR DRYING VARNISH.	NONE

B-5236



COILS PER SLOT

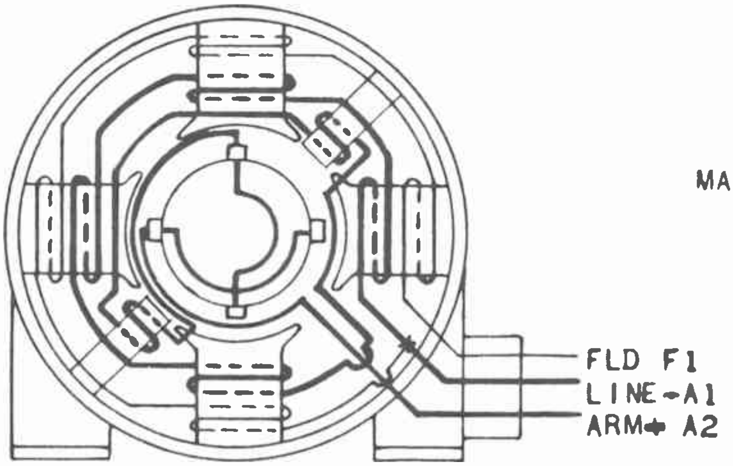


SECTION OF ARMATURE SLOT

TREATMENT OF COMPLETED ARMATURE

1. DIP IN BB 52V13 VARNISH
2. BAKE 4 HOURS AT 260 F.
3. REPEAT 3 TIMES.

INSULATION MATERIALS		
MATERIALS		NAVY SPEC.
SLOT CELL	.002 COPAREX	17-1-10
CENTER WEDGE	.020 COPAREX	17-1-10
TOP WEDGE	.020 COPAREX	17-1-10



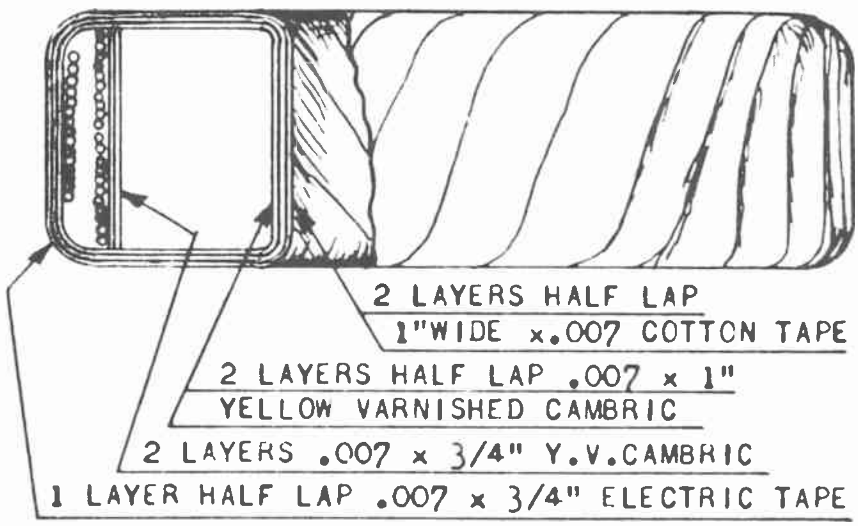
DIRECT CURRENT GENERATOR CONNECTION AND WINDING DATA

B-5237

CONNECTION DIAGRAM
MACHINE VIEWED FROM COMMUTATOR END
ROTATION COUNTER CLOCKWISE
COMPOUND INTERPOLE

THESE SYMBOLS ARE STAMPED ON TERMINALS

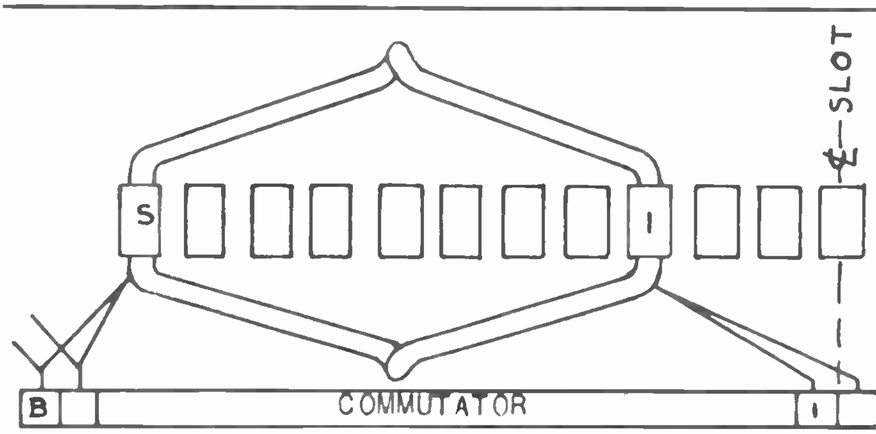
THE PEERLESS ELECTRIC CO.,
WARREN OHIO.



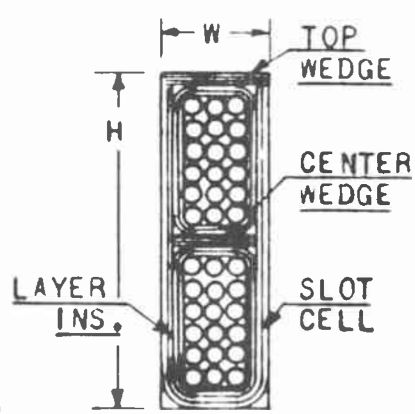
MAIN POLE COIL
COMMUTATING POLE COIL INSULATION SAME AS MAIN POLE COIL

TREATMENT OF COMPLETED COIL	
MAIN FIELD	COM.FIELD
DIP IN BB 52V13 VARNISH & BAKE 6 HOURS. AGAIN DIP IN CB 52V13 VARNISH & BAKE 4 HOURS. AFTER ASSEMBLY IN SHELL, BRUSH WITH AIR DRYING VARNISH.	SAME AS MAIN FIELD

B-5237



COILS PER SLOT

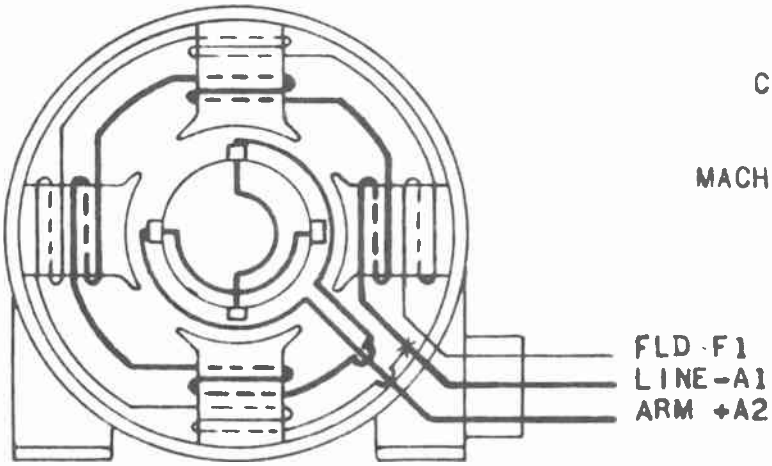


SECTION OF ARMATURE SLOT

TREATMENT OF COMPLETED ARMATURE

1. DIP IN BB 52V13 VARNISH
2. BAKE 4 HOURS AT 260 F.
3. REPEAT 3 TIMES.

INSULATION MATERIALS		
MATERIALS		COIL LAYER INSULATION
SLOT CELL	.002 COPAREX	.007 COTTON TAPE 1/2 LAP.
CENTER WEDGE	.020 COPAREX	
TOP WEDGE	.020 COPAREX	



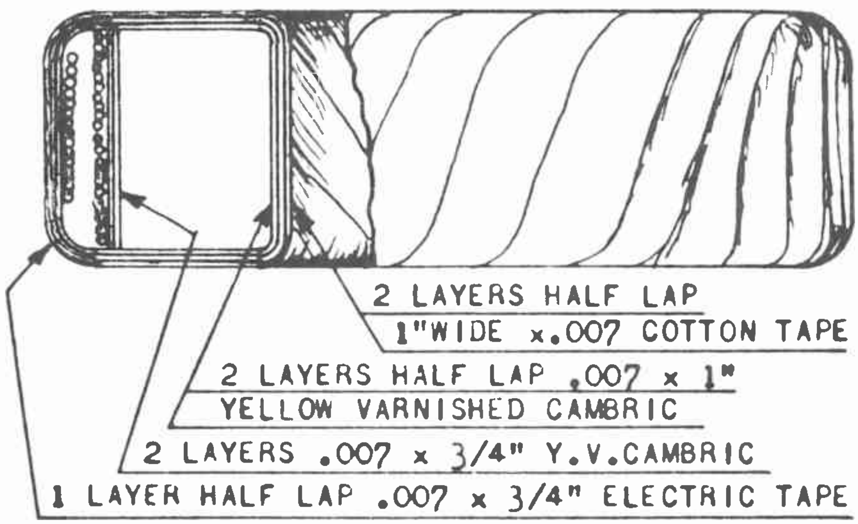
DIRECT CURRENT GENERATOR
CONNECTION AND WINDING DATA

B-5446

CONNECTION DIAGRAM
MACHINE VIEWED FROM COMMUTATOR END
ROTATION CLOCKWISE
COMPOUND NON INTERPOLE

THESE SYMBOLS ARE STAMPED ON TERMINALS

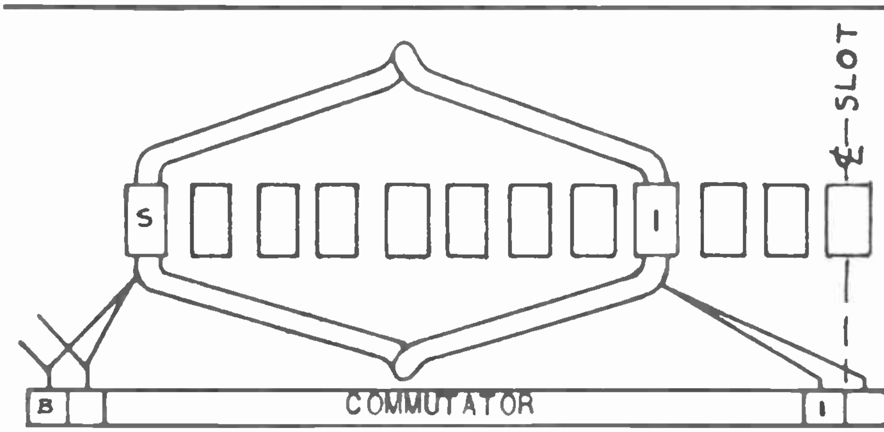
THE PEERLESS ELECTRIC CO., WARREN OHIO.



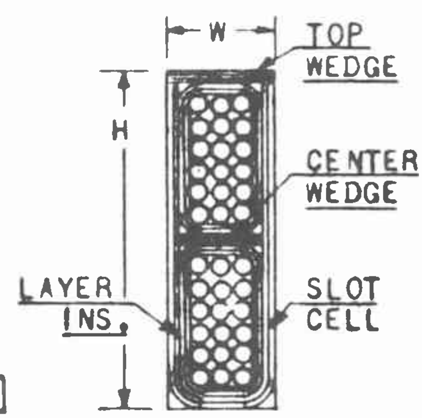
MAIN POLE COIL

TREATMENT OF COMPLETED COIL	
MAIN FIELD	COM.FIELD
DIP IN BB 52V13 VARNISH & BAKE 6 HOURS. AGAIN DIP IN CB 52V13 VARNISH & BAKE 4 HOURS. AFTER ASSEMBLY IN SHELL, BRUSH WITH AIR DRYING VARNISH.	NONE

B-5446



COILS PER SLOT



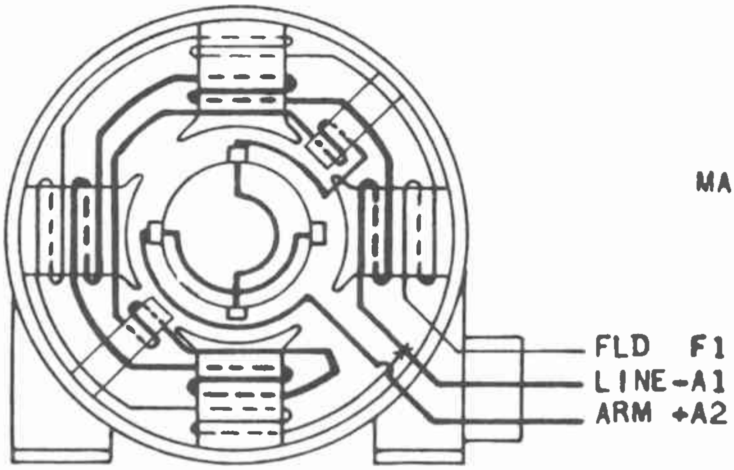
SECTION OF ARMATURE SLOT

TREATMENT OF COMPLETED ARMATURE

1. DIP IN BB 52V13 VARNISH
2. BAKE 4 HOURS AT 260 F.
3. REPEAT 3 TIMES.

INSULATION MATERIALS

MATERIALS		COIL LAYER INSULATION
SLOT CELL	.002 COPAREX	.007 COTTON TAPE 1/2 LAP.
CENTER WEDGE	.020 COPAREX	
TOP WEDGE	.020 COPAREX	



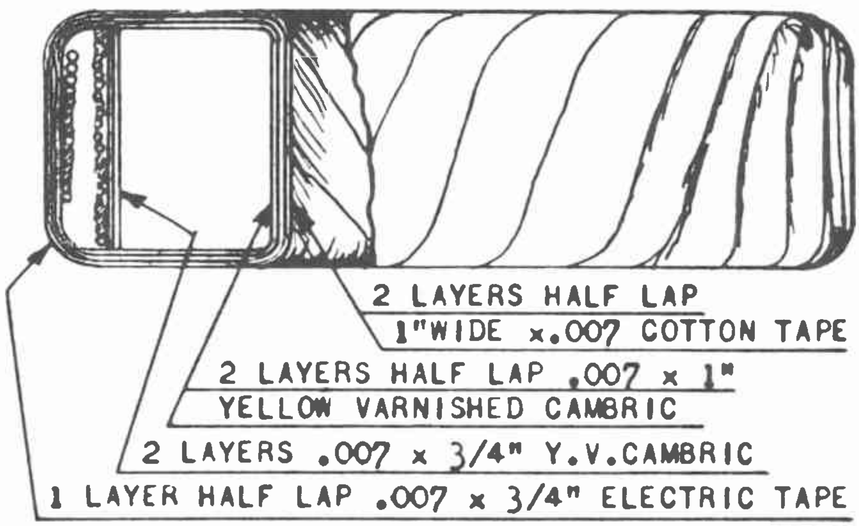
DIRECT CURRENT
GENERATOR
CONNECTION AND WINDING DATA

B-5447

CONNECTION DIAGRAM
MACHINE VIEWED FROM COMMUTATOR END
ROTATION CLOCKWISE
COMPOUND INTERPOLE

THESE SYMBOLS ARE
STAMPED ON TERMINALS

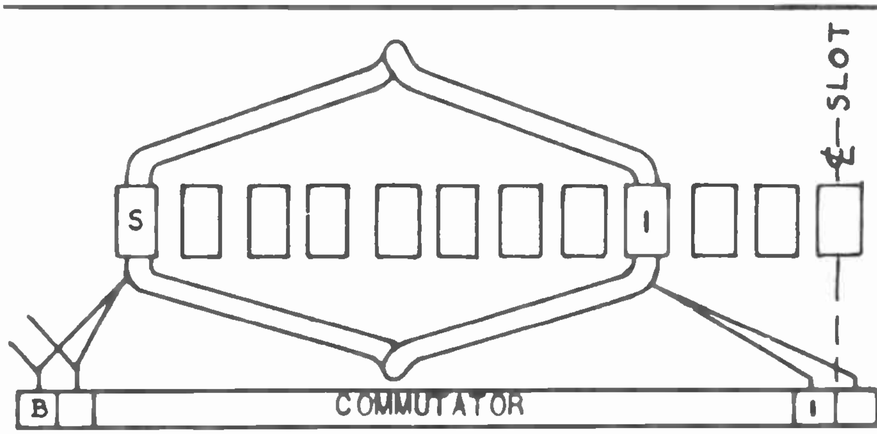
THE PEERLESS ELECTRIC CO.,
WARREN OHIO.



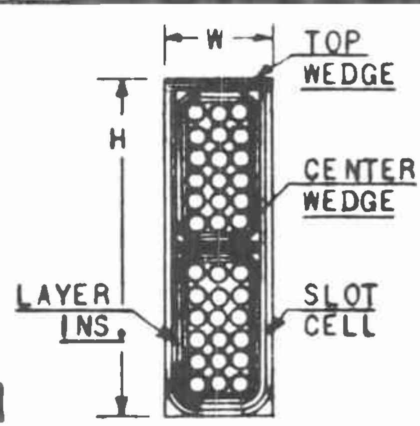
MAIN POLE COIL

TREATMENT OF COMPLETED COIL	
MAIN FIELD	COM.FIELD
DIP IN BB 52V13 VARNISH & BAKE 6 HOURS. AGAIN DIP IN CB 52V13 VARNISH & BAKE 4 HOURS. AFTER ASSEMBLY IN SHELL, BRUSH WITH AIR DRYING VARNISH.	SAME AS MAIN FIELD

B-5447



COILS PER SLOT

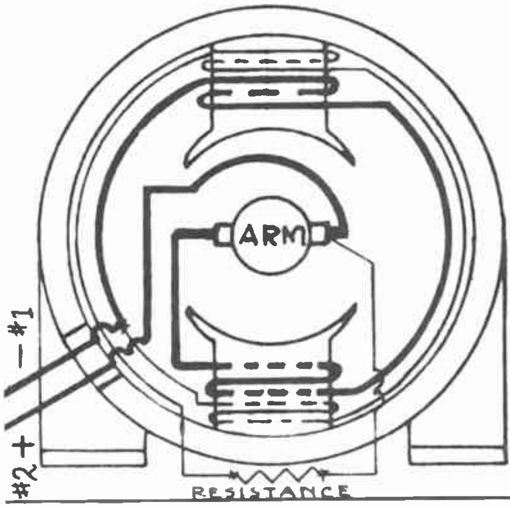


SECTION OF ARMATURE SLOT

TREATMENT OF COMPLETED ARMATURE

1. DIP IN BB 52V13 VARNISH
2. BAKE 4 HOURS AT 260 F.
3. REPEAT 3 TIMES.

INSULATION MATERIALS		
MATERIALS		COIL LAYER INSULATION
SLOT CELL	.002 COPAREX	.007 COTTON TAPE 1/2 LAP.
CENTER WEDGE	.020 COPAREX	
TOP WEDGE	.020 COPAREX	

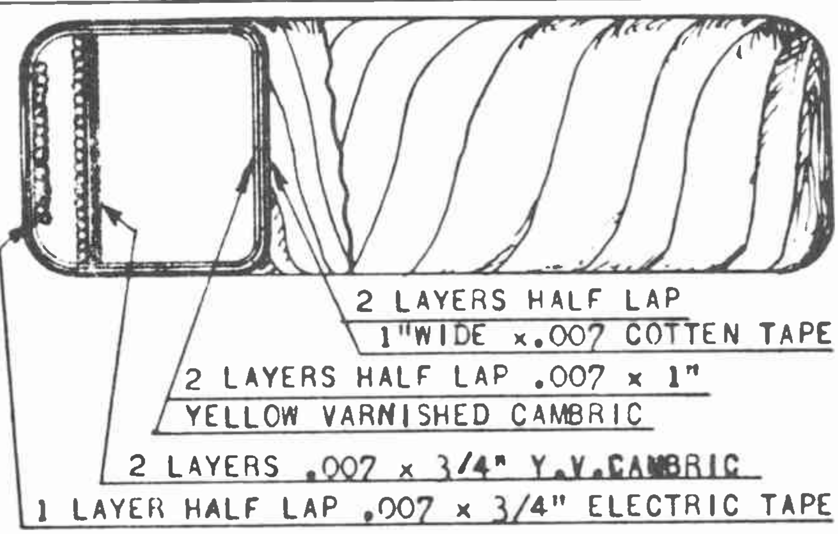


DIRECT CURRENT
EXCITER
CONNECTION AND WINDING DATA

B-5401

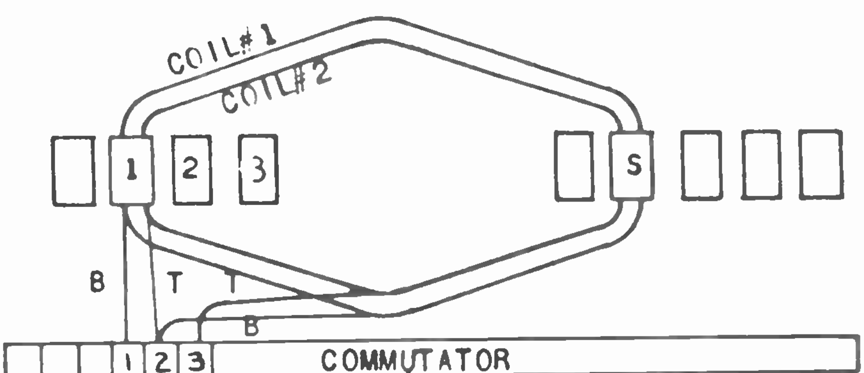
CONNECTION DIAGRAM
MACHINE VIEWED FROM COMMUTATOR END
ROTATION CLOCKWISE
FOR
THE RELIANCE ELECTRIC &
ENGINEERING COMPANY.
THESE SYMBOLS ARE
STAMPED ON TERMINALS

THE PEERLESS ELECTRIC CO.,
WARREN OHIO.

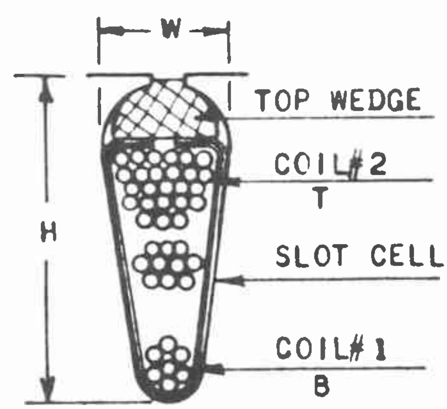


MAIN POLE COIL

TREATMENT OF COMPLETED COIL	
MAIN FIELD	
DIP IN BB 52V13 VARNISH & BAKE 6 HOURS. AGAIN DIP IN CB 52V13 VARNISH & BAKE 4 HOURS. AFTER ASSEMBLY IN SHELL, BRUSH WITH AIR DRYING VARNISH.	



2 COILS PER SLOT



SECTION OF ARMATURE SLOT

TREATMENT OF COMPLETED ARMATURE

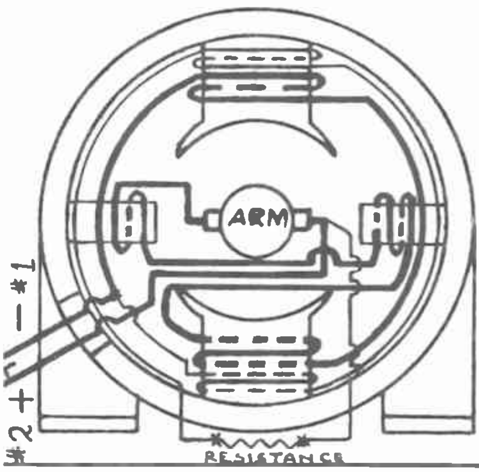
1. DIP IN BB 52V13 VARNISH
2. BAKE 4 HOURS AT 260 F.
3. REPEAT 3 TIMES.

INSULATION MATERIAL		
MATERIALS		NAVY. SPEC.
SLOT CELL	.002 COPAREX	17-1-10
TOP WEDGE	MAPLE	

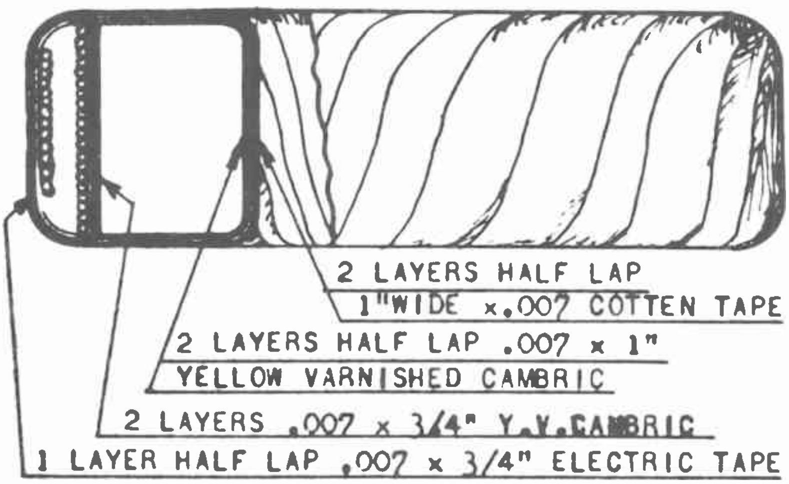
DIRECT CURRENT
EXCITER
CONNECTION AND WINDING DATA

B-5402

CONNECTION DIAGRAM
MACHINE VIEWED FROM COMMUTATOR END
ROTATION CLOCKWISE
FOR
THE RELIANCE ELECTRIC &
ENGINEERING COMPANY
THESE SYMBOLS ARE
STAMPED ON TERMINALS



THE PEERLESS ELECTRIC CO.,
WARREN OHIO.

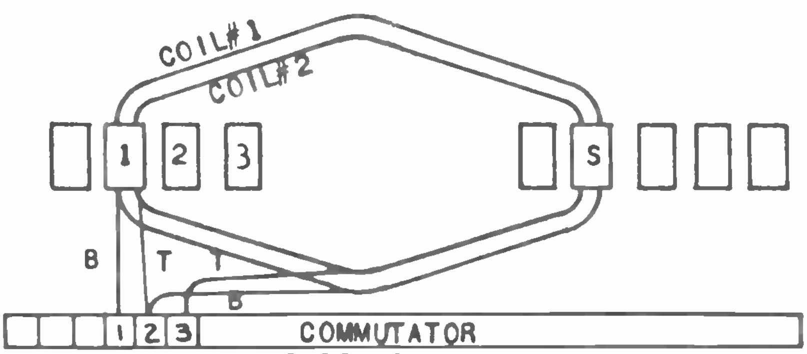


MAIN POLE COIL

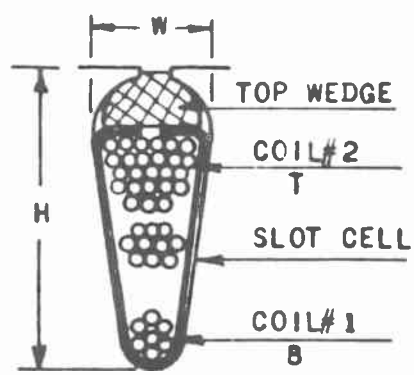
COMMUTATING POLE COIL INSULATION
SAME AS MAIN POLE COIL

TREATMENT OF COMPLETED COIL	
MAIN FIELD	COM. FIELD
DIP IN BB 52V13 VARNISH & BAKE 6 HOURS. AGAIN DIP IN CB 52V13 VARNISH & BAKE 4 HOURS. AFTER ASSEMBLY IN SHELL, BRUSH WITH AIR DRYING VARNISH.	SAME AS MAIN FIELD

B-5402



2 COILS PER SLOT



SECTION OF ARMATURE SLOT

TREATMENT OF COMPLETED ARMATURE

1. DIP IN BB 52V13 VARNISH
2. BAKE 4 HOURS AT 260 F.
3. REPEAT 3 TIMES.

INSULATION MATERIAL		
MATERIALS		NAVY. SPEC.
SLOT CELL	.002 COPAREX	17-1-10
TOP WEDGE	MAPLE	

AMERICAN STANDARD

3.1 D-c GENERATORS

3.105 Connections and Terminal Markings—D-c Generators, Two-Wire

Standard direction of shaft rotation is clockwise facing end opposite the drive.

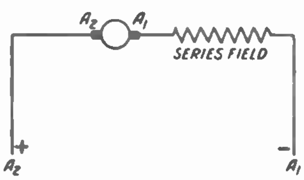


FIG 1 SERIES GENERATOR WITHOUT COMMUTATING POLES

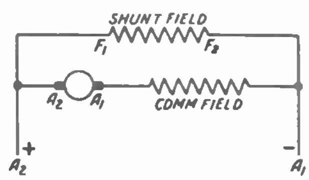


FIG. 2 SHUNT GENERATOR WITH COMMUTATING POLES

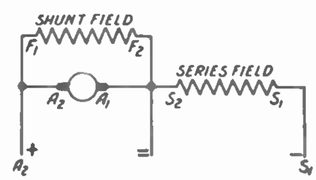


FIG. 3 COMPOUND GENERATOR WITHOUT COMMUTATING POLES

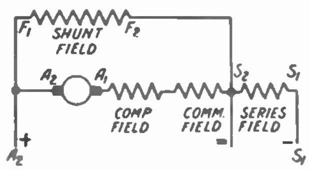


FIG 4 COMPOUND GENERATOR WITH COMMUTATING AND COMPENSATING FIELDS

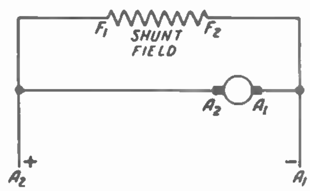


FIG. 5 SHUNT GENERATOR WITHOUT COMMUTATING POLES

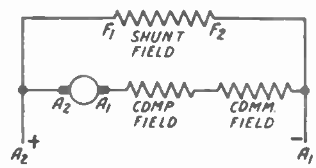


FIG 6 SHUNT GENERATOR WITH COMMUTATING AND COMPENSATING FIELDS

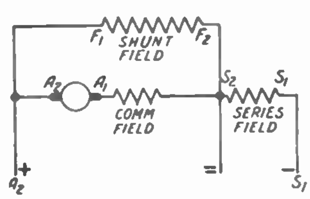


FIG. 7 COMPOUND GENERATOR WITH COMMUTATING POLES

NOTE I—See 1.510 for terminal letters assigned to different types of windings, and 1.130 for the significance of the subscript numerals.

NOTE II—For differential connection of the series fields no change should be made on the field leads or terminal markings on the machine, but the connection of the series field to the armature should be shown reversed.

NOTE III—Commutating and series field windings are shown on the A1 side of the armature, but this location, while preferred, is not standardized. If sound engineering, sound economics or convenience so dictates, these windings may be connected on either side of the armature or may be divided part on one side and part on the other.

3.110 Connections and Terminal Markings—D-c Generators, Three-Wire

Standard phase and rotor rotation is clockwise facing the end opposite the drive.

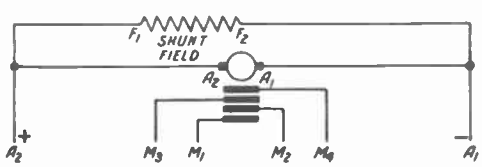


FIG 1 SHUNT GENERATOR WITHOUT COMMUTATING POLES

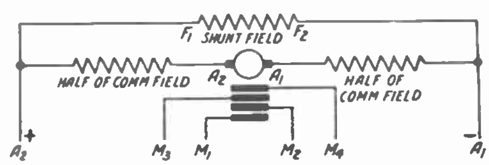


FIG. 2 SHUNT GENERATOR WITH COMMUTATING POLES

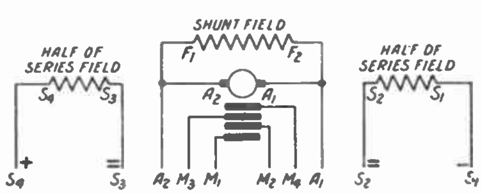


FIG 3 COMPOUND GENERATOR WITHOUT COMMUTATING POLES

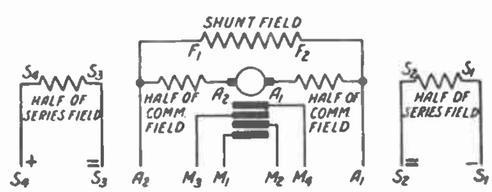


FIG 4 COMPOUND GENERATOR WITH COMMUTATING POLES

NOTE I—See 1.510 for terminal letters assigned to different types of windings, and 1.130 for the significance of the subscript numerals.

NOTE II—If three slip rings are used they shall be marked M_1, M_2, and M_3. If two slip rings are used they shall be marked M_1 and M_2. If one slip ring is used it shall be marked M.

NOTE III—For differential connection of the series fields no change should be made on the field leads or terminal markings on the machine, but the connection of the series field to the armature should be shown reversed.

AMERICAN STANDARD

3.115 Connections and Terminal Markings—D-c Generators for Farm Lighting Plants

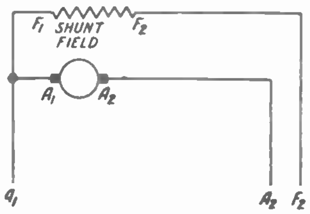


FIG. 1 SHUNT GENERATOR

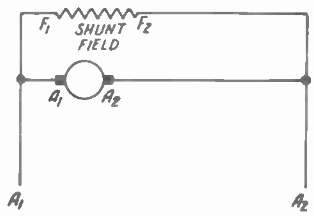


FIG. 2 SHUNT GENERATOR

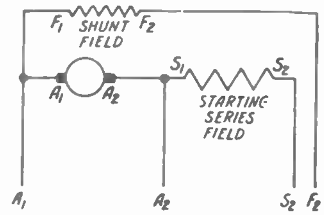


FIG. 3 SHUNT GENERATOR WITH STARTING SERIES FIELD

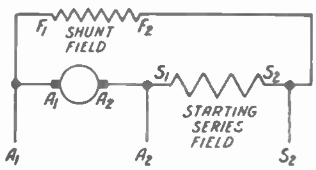


FIG. 4 SHUNT GENERATOR WITH STARTING SERIES FIELD

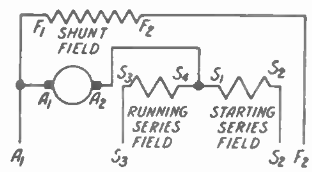


FIG 5 COMPOUND GENERATOR WITH STARTING SERIES FIELD

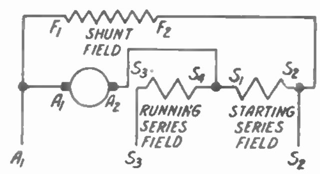


FIG. 6 COMPOUND GENERATOR WITH STARTING SERIES FIELD

NOTE I—The Society of Automotive Engineers cooperated with the National Electrical Manufacturers Association in the preparation of these connections and terminal markings and in securing their approval by the industry.

NOTE II—Standard direction of shaft rotation is counter-clockwise facing the end opposite the drive.

NOTE III—See 1.510 for terminal letters assigned to different types of windings, and 1.130 for significance of the subscript numerals.

Janette Rotary Converters

A CONVERTER should be installed in a clean, dry, well ventilated place, preferably not below 32° F., or above 104° F., in such a manner as to be easily accessible for inspection and cleaning. It should be mounted on a level surface, as near as possible to the device or apparatus it is to operate, in order to minimize voltage drop. In locations where vibration or "running" noise is objectionable, vibration dampening materials can be used between the converter and its base.

WIRING—Be sure the voltage of the power line is the same as the D.C. voltage stamped on the converter nameplate. A wiring connection diagram is shown on page 8. Use conductors large enough to keep voltage drop to a minimum. It is important that the D.C. and A.C. wiring to and from a converter, be made in SEPARATE conduits, both ends of which should be well grounded. All connections should be soldered and the contact prongs of plugs and receptacles checked for fit, because poor contacts may cause arcing and serious interference.

Resistance type D.C. starters should be used with CE12, CE10 and CE10F converters. 1 H.P. for CE12 when wound for 32, 115 and 230 volts; 1 H.P. for CE10 when wound for 32 volts and 1½ H.P. when wound for 115 and 230 volts.

When storage batteries are used as a power supply for low voltage converters, they should have ampere hour capacities approximately 10 times greater than the D.C. ampere ratings of the converters.

GROUNDING: (Converter with filter)—To obtain the best reception from a radio receiver it may be necessary to try various connection combinations for grounding.

A ground wire (preferably stranded) of at least No. 12 B&S gauge should be connected to a water pipe, or equally good ground by means of a suitable clamp. The contact surfaces MUST be clean. Steam pipes or radiators usually are not good for grounding and should not be used unless no better ground is available. The ground wire should be as short as possible.

Separate ground wires should be used for the converter and radio chassis; each unit should have its own individual ground wire.

1. The manufacturers' instructions for grounding the radio receiver should be complied with.
2. Connect the converter leads (or plug) to the D.C. power supply. Connect the radio and start the converter.
3. If reception is unsatisfactory, try connecting a ground wire to the terminal post on the filter box.
4. The yellow wire from the filter box, which is connected to a screw on the frame of the converter before shipment from the factory, is the ground wire from the center of the filter system. Try the reception with this yellow wire disconnected.
5. Try connecting the yellow wire to the ground terminal post on the filter box.
6. Reception sometimes can be improved by changing the D.C. polarity. Reverse the D.C. wires to the converter or the plug prongs (if a plug is used) in the D.C. receptacle.

In the event of trouble a converter should not be tested for grounds until all ground wires in the filter and on the converter frame have been disconnected.

INTERFERENCE—This is often caused by motors, generators, X-Ray machines and similar apparatus. The filter system of the converter is not intended to eliminate such interference, as this can be only eliminated at the source. A set of twin condensers with the center point grounded, connected across the brushes of the unit causing the interference, will usually eliminate this trouble. "Leaky" wiring is very often responsible for interference. A set of twin condensers of 1 mfd. capacity, with a rating of 400 volts D.C., grounded at the center point, connected across the A.C. line at the radio chassis, may reduce this kind of interference. Shielding an ungrounded converter by completely surrounding it with a well grounded copper or galvanized screen, preferably with the interlacing joints soldered, is a good method to use for reducing interference from outside of a converter.

MAINTENANCE

COMMUTATOR—The commutator, collector (slip) rings, brushes and brush holders, should be thoroughly cleaned at regular intervals. Wipe them off with a soft cheesecloth moistened with kerosene or carbon tetrachloride, or blow out the dirt with dry air under pressure. Dirty brushes may stick in their holders and cause sparking at the commutator.

SEASONING—It requires some months of operation for a new commutator to become seasoned. During this period, segments may loosen, causing high or low bars or an eccentric commutator. If this happens, the commutator should be turned in a lathe. An eccentric commutator or slip ring will cause a distinct knocking action on the brushes.

SANDING—A rough commutator can be smoothed by holding No. 00 (or No. 000) sandpaper against it by means of a thin piece of hard wood which has a straight edge. If commutator stones are available, start with a coarse and finish with a fine grain stone. Clean out all dust, especially from the brushes and slots, and see that the brushes move freely in their holders and have sufficient spring tension to hold them in firm contact with the commutator. DO NOT use emery cloth, oil or lubricants on a commutator, or abrasives on collector (slip) rings. IF the rings become blackened, clean with alcohol or carbon tetrachloride.

Fig. 1—Sanding a commutator. The best method is to hold the sandpaper with a strip of hard wood.

TURNING—If the commutator (or slip rings) becomes eccentric, or has high or low bars it should be "turned." Protect the windings from copper chips and dust, by wrapping them with a piece of light canvas or oil cloth. Take light cuts with a fairly sharp (diamond) pointed tool. Use a surface speed of about 300/400 feet per minute for a carbon steel tool or 500/600 f.p.m. for a stellite cutting tool.

R.P.M. = (F.P.M. x 12) ÷ (Diameter in inches x 3.14). F.P.M. = (R.P.M. (lathe) x dia. (commutator) x 3.14) ÷ 12. Undercut the mica to a depth of about .04". If no undercutting tool is available, attach a suitable handle to a hack saw blade and grind off the "set." Be sure that all mica fins along the sides of the slots are removed. It is good practice to slightly bevel the edges of the commutator bars.

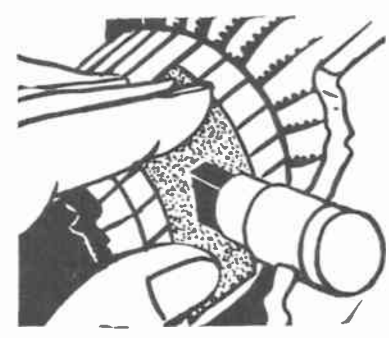


Fig. 2—Sanding in a brush.

SEATING BRUSHES—See that the commutator is smooth before installing new brushes, which should be of a make and grade recommended by JANETTE engineers. Wrap a strip of No. 00 sandpaper firmly around the commutator (or rings) with abrasive side out. Insert brushes and springs into the holders. Oscillate the armature or pull the sandpaper back and forth until brush face conforms to the curve of the commutator or slip ring. When nearly bedded the sandpaper should be pulled only in the direction the armature rotates when running. Clean the dust from brushes, holders, and slots. If possible run the converter for several hours without load to polish the brush faces. Seating brushes can also be done by using a free wearing, fine grain, brush seating stone if the dust is thoroughly cleaned out.

BURNISHING—After "sanding" or "turning" a commutator (or slip rings) should be burnished. The end grain of a small block of hard wood (maple is good) can be held against the commutator with heavy pressure. An oak strip, with several layers of six or eight ounce, hard woven, canvas duck fastened over one end, held against the commutator with heavy pressure is an excellent means of polishing and removing surface deposit. Regular frequent cleaning of the commutator surface with canvas will go a long way in preventing the need for major resurfacing operations.

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LUBRICATION

SLEEVE BEARINGS—CAUTION—Before leaving the factory, oil is drained from the bearings of converters equipped with sleeve type bearings, in order to prevent leakage of the oil during shipment. **Fill bearings before starting the converter for the first time.** Slowly pour about ½ ounce for CE12, or ¾ ounce for CE10, of high grade mineral oil (of approximately 150 viscosity at 100°F. which is within the S.A.E. No. 10 range) into the oil cup on top of each bearing, or until oil appears at the overflow holes. After approximately 1000 hours of operation, more oil should be added. Do not use animal fat, vegetable or heavy cylinder oil. The following oils, or equal, are recommended:

Standard Oil Co. (Indiana), Stanoil No. 15; Socony-Vacuum Oil Co. Gargoyle Vacuoline oil light or Mobiloil Arctic Special; Shell Oil Co. 3647 Albus 27 oil; Sinclair Refining Co., Saline Oil and Texas Co. Ursa oil P-10.

BALL BEARINGS—For ordinary service in ambient temperatures of from 32° to 104°F., the original grease should be sufficient for 9 to 12 months' operation. For severe service and high ambient temperatures, it is advisable to add a small amount of grease every 3 months.

For ambient temperatures above 32°F.: Use a smooth or short fibre ball bearing grease of 250-300 A.S.T.M. worked penetration and containing a refined mineral oil of 250-350 viscosity at 100°F. It should show no separation at 250°F. and must be free from any fillers, grit or other harmful impurities.

For ambient temperatures below 32°F.: Use a smooth or short fibre ball bearing grease of 300-350 A.S.T.M. worked penetration and containing a refined mineral oil of a viscosity not to exceed 200 at 100°F. It must be free from any fillers, grit or other harmful impurities.

DO NOT over-lubricate as this will cause temperature rise on the bearing; may lead to serious heating and/or force grease out of the bearing.

As quietness and life of a ball bearing depends upon cleanliness, use only a CLEAN, high grade grease. CAUTION: Keep the cover on the grease can, removing it only for the short interval that grease is being taken from the can. Do not lay the cover where it can pick up dirt. Make certain that the utensil with which you take the grease from the can is perfectly clean. Avoid the use of a wooden paddle Use instead something with a steel blade like a putty knife, which can be wiped off smooth and clean.

When the housing covers are to be removed wipe them clean of all dirt. After the first year of service and every year thereafter, (oftener if conditions warrant) the old grease should be renewed. Insert a grease solvent, such as kerosene or carbon tetrachloride into the bearings by means of a syringe. Start the converter and allow the solvent to churn for a few minutes, then remove the bearing caps and wash out the bearings. Replace the caps and inject a small amount of light lubricating oil. Allow to churn for a few minutes then drain off. Fill the bearing housings not more than one third to one half full of grease. Ball bearings should not be removed from the housings unless proper tool equipment is available.

GREASES RECOMMENDED

MANUFACTURER	ABOVE 32°F.	BELOW 32°F.
Standard Oil Co. (Indiana)	Stanobar No. 2	Omega
Socony-Vacuum Oil Co.	Gargoyle BRB No. 3	Gargoyle A No. 0
Shell Oil Co.	5472 EXL No. 2	5121 Albida No. 1
Sinclair Refining Co.	AF No. 1	AF No. 1
Texas Co.	Texaco Starfak "M"	Texaco Starfak "L"

U.S. Navy specification 14-L-3B grade B medium grease. (Socony-Vacuum PD288C grease meets this specification)

AUTOMATIC FREQUENCY CONTROL

REGULATION—Converters supplied with manual or automatic control, have capacities of 10% less than the ratings listed in our price sheet. The frequency only is regulated, and the A.C. voltage will follow, almost in direct proportion, the voltage variations of the D.C. power supply. When regulation of both frequency and voltage is required, the A.C. voltage can be controlled by an adjustable transformer, in addition to the frequency control. The capacity must be reduced 10% because of the losses in the transformer. For some applications it is advisable to use a motor generator set when close regulation is necessary.

MODEL DS1X—Automatic frequency control is constructed with a moulded Bakelite disc, steel hub insert, hard commutator copper split slip rings, which are insulated from the Bakelite disc. A split ring is used, which reverses the current each revolution, thereby supplying A.C to the contacts to prevent polarization, roughening and sticking. A set of spring supported contacts on the face of the governor disc, cuts a resistor into the shunt field circuit of the converter when the speed decreases and cuts it out when the speed increases. This interruption frequency, about 100 to 200 per second, is determined by the normal periodic frequency of the contact spring, which is independent of the speed of the converter. This high frequency permits an accuracy of about 60 cycles plus or minus ¾% (approximately ½ cycle), with a plus or minus 7% variation in D.C. input voltage, at a varying load from ⅓ to full load; for 50 cycles plus or minus approximately ¾ cycle.

The contact springs are adjusted roughly for a converter speed of 3600 RPM and closer adjustment may have to be made. If a tachometer indicates higher than 3600 RPM, or if a synchronous clock connected to the A.C. output leads of the converter runs fast, lower the frequency by readjusting the contact spring screws on the governor.

FREQUENCY—To check output frequency when no frequency meter is available, connect a small synchronous electric clock to the A.C. output leads and determine whether this clock runs fast or slow when compared with any available timepiece.

TO INCREASE FREQUENCY back up the small set screw on the outer contact spring on the face of the governor disc and follow up with the set screw on the inner spring contact, until the air gap between the contacts is approximately 1/32". This moves the entire contact assembly towards the periphery of the governor disc, which increases the frequency by increasing the speed of the converter.

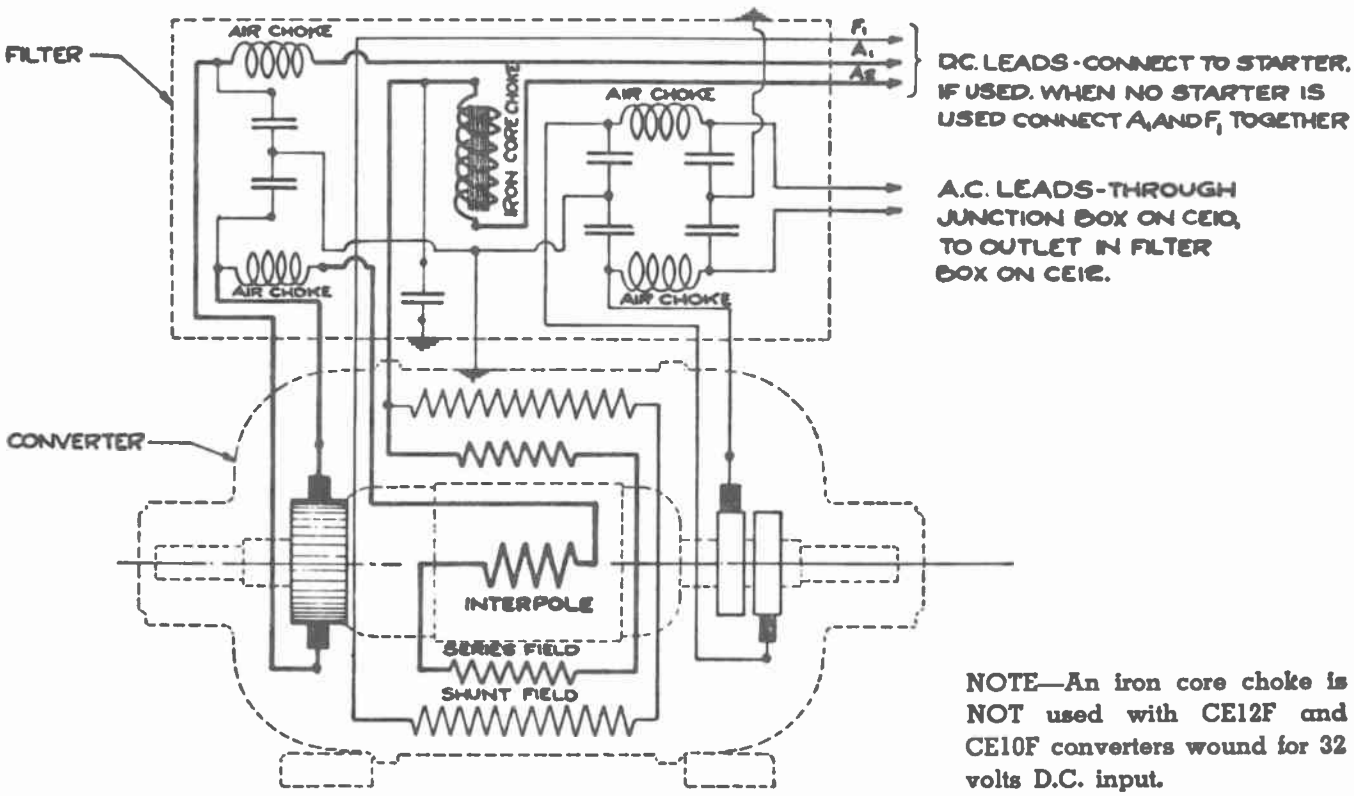
TO REDUCE FREQUENCY screw in the small set screw bearing against the outer spring contact and back up the set screw for the inner contact spring, until the air gap between the contacts is about 1/32". This moves the entire contact assembly away from the periphery of the disc, which decreases the frequency by decreasing the speed of the converter.

PITTING of the contact points may cause erratic governor action. When this happens smooth the points with No. 000 or No. 00 sandpaper. (Do not use emery cloth.) After cleaning the contacts readjust the governor for the correct frequency (speed) as described above.

THE SLIP RINGS on the split back governor disc should occasionally be cleaned with No. 000 or No. 00 sandpaper. (Do not use emery cloth.) Also clean between the rings. Any carbon dust or oil can be removed at this point by using a toothpick. Keep the governor free from any accumulation of dust and oil.

IMPORTANT—Always keep a spare set of brushes on hand for both the converter and governor. Also a spare governor disc assembly. Whenever the spare governor disc is installed, return immediately the other disc to JANETTE MANUFACTURING COMPANY, 556 WEST MONROE STREET, CHICAGO 6, ILLINOIS, with a purchase order to cover repair or replacement. Be sure to give the type and serial number of the converter with which it is used. We do not build electric governors and do not guarantee this apparatus but do supply the best available make.

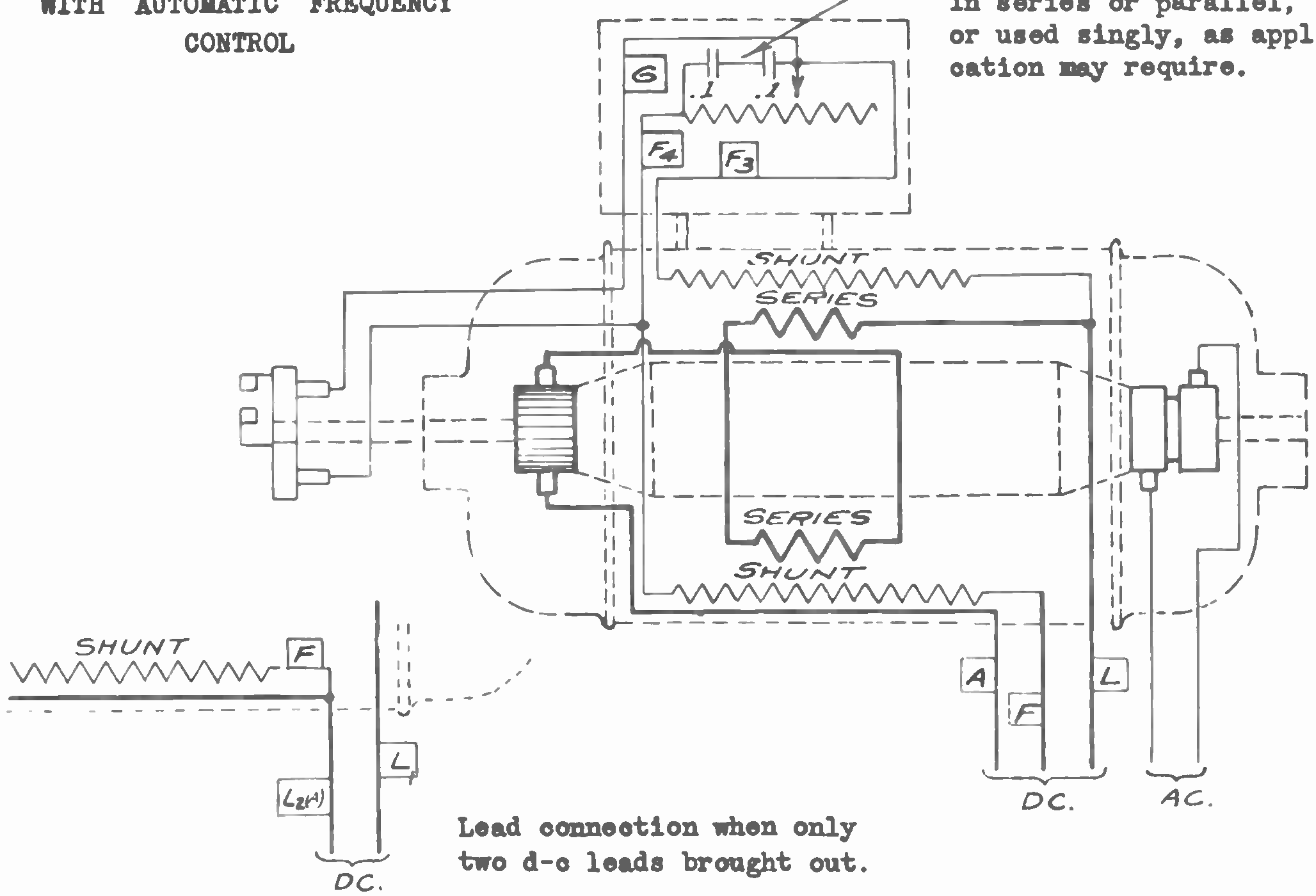
JANETTE ROTARY CONVERTER WITH FILTER



NOTE—An iron core choke is NOT used with CE12F and CE10F converters wound for 32 volts D.C. input.

JANETTE ROTARY CONVERTER WITH WITH AUTOMATIC FREQUENCY CONTROL

Two 0.1 mfd. condensers in series or parallel, or used singly, as application may require.



Lead connection when only two d-c leads brought out.

Janette Rotary Converters

MISCELLANEOUS INFORMATION

CAUTION: When a load consists of a number of radio receivers, which may be turned on or off; where a mixed load such as a motor, radio or lamp are connected to a converter of large capacity; or where the D.C. supply voltage of a converter is subject to abnormal fluctuations, protection should be provided for EACH receiver against high A.C. output voltage. An adjustable resistor such as an Ohmite, Clarostat, Amperite, Vitrohm, etc., can be used. It may also be advisable to use an A.C. voltmeter. An adjustable transformer in the A.C. line is also a good method to use for protecting apparatus from damage by high A.C. voltage.

POWER FACTOR: As the A.C. capacity of a converter is rated in VOLTAMPERES, the POWER FACTOR of the load should be given when ordering. Power factor is the ratio of actual watts (measured by a wattmeter) to the voltamperes (VOLTS × AMPERES). The power factor is obtained by dividing WATTS by voltamperes and is expressed in percent. The power factor is 100% when the volt-amperes and watts are the same. When the watt load is smaller than the volt-amperes, the power factor is less than 100%.

Examples of high power factor loads are heating devices, filament lamps, irons, toasters, radios, amplifiers, etc. Motors, inductive loads, some types of transformers, are medium or low power factor loads. A converter must be wound for the SAME POWER FACTOR as that of the A.C. load it supplies.

NOTE: The two power factor conditions given below apply when the SAME voltampere load is supplied.

HIGH POWER FACTOR CONVERTER and a LOW POWER FACTOR load—The no load will be lower than full load speed; the A.C. output frequency and voltage higher, which causes sparking at brushes and heating of commutator and armature. The high speed may also unbalance the armature and the high cycles cause trouble in the load.

LOW POWER FACTOR CONVERTER and a HIGH POWER FACTOR load—Lower A.C. output frequency and voltage result, which may damage the D.C. windings and injure the apparatus connected to the converter.

GASEOUS ELECTRIC SIGNS: To select a converter, add the VOLTAMPERE ratings stamped on the nameplates of all transformers used and select a converter whose voltampere rating equals or exceeds the total voltamperes of the transformers. Transformers for neon signs are built for both low (40%) and high (85%) power factor.

CAUTION: If a high power factor converter is underloaded or operated from a D.C. supply voltage higher than stamped on the nameplate, or both, overheating or breakdown of the sign transformer and converter may result.

FLUORESCENT LAMPS: A standard converter should be used ONLY when the minimum lamp load at any time is 50% or more of the TOTAL voltampere load. A specially wound converter, with closer voltage regulation than a standard machine, is recommended where lamps may be turned on or off, until the load on the converter is less than 50% of its rated capacity. Any size converter can be supplied for special close voltage regulation but the capacity will be 20% less than listed.

Fluorescent lamps and control auxiliaries are rated in WATTS. The power factor is normally about 60% but when corrected with condensers, 85% to 95%. To obtain volt-amperes, divide watts by the power factor. For example: a 20 watt lamp requires an auxiliary of about 7 watts, or a total load of 27 watts. A bank of 15 lamps would be 405 watts. If the power factor of the lamps is 40%, 405 ÷ .40 = 1012 voltamperes capacity required; if 85% P.F., 405 ÷ .85 = 476 voltampere capacity converter would be required. A 1000 voltampere converter can supply 31 lamps if the power factor of the load is 85%; only 15 lamps if it is 40%.

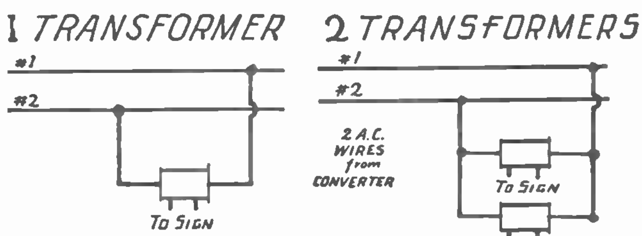
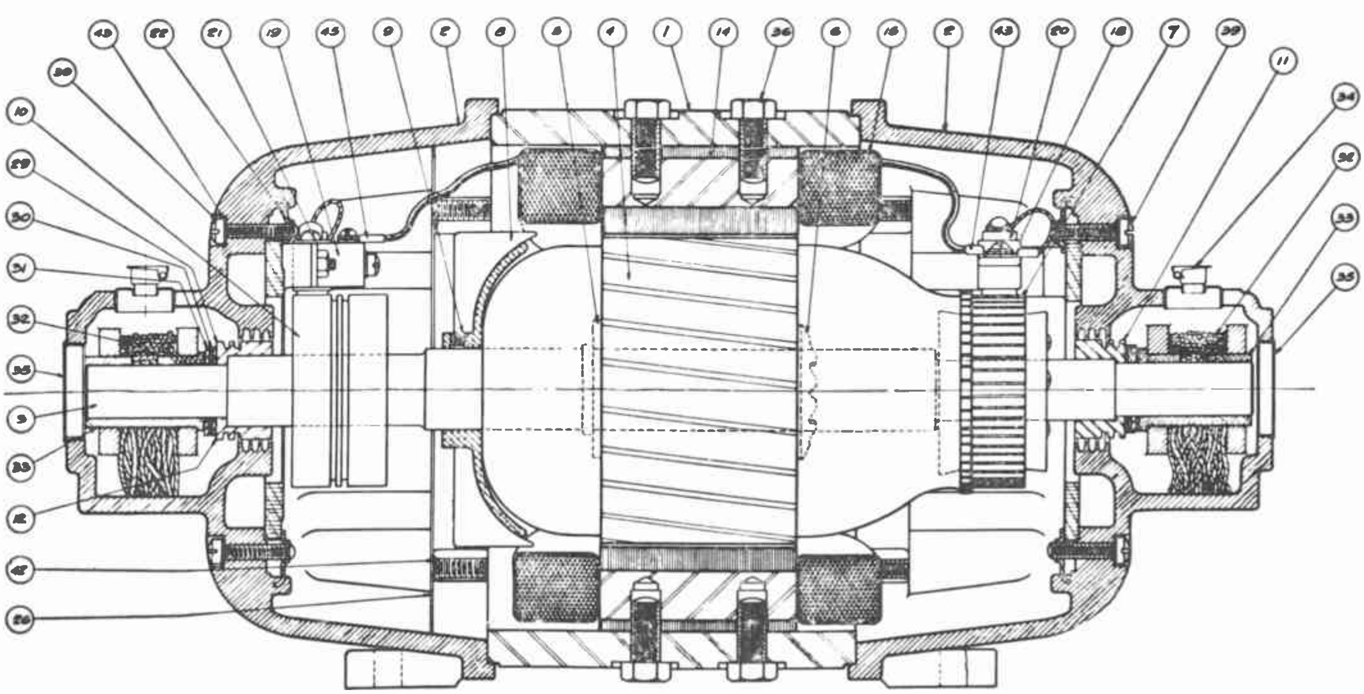


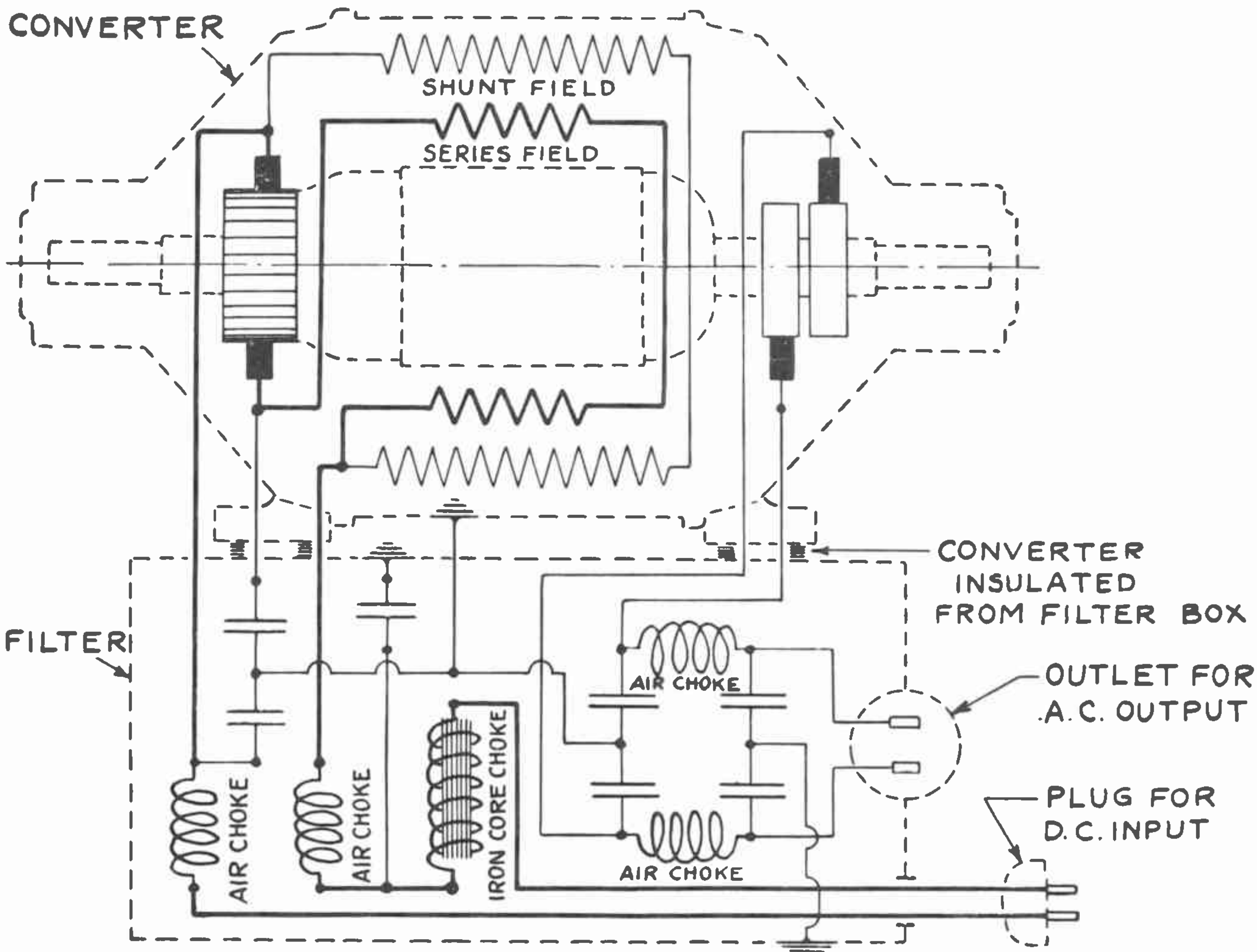
Fig. 4—Connections for electric sign transformers and converters.



CE10

Janette Rotary Converters

CONNECTION DIAGRAM OF CONVERTER WITH FILTER — WD462



NOTE—IRON CORE CHOKE IS OMITTED, also separate D.C. leads are used in place of cord and plug on 6, 12, and 32 volt converters.

AMERICAN STANDARD

3.9 SYNCHRONOUS CONVERTERS

3.905 Connections and Terminal Markings—Synchronous Converters, Two-Wire

Standard direction of shaft rotation is clockwise facing the commutator end.

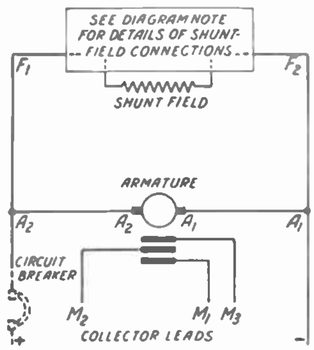


FIG. 1 SHUNT-WOUND THREE-PHASE SYNCHRONOUS CONVERTER WITHOUT COMMUTATING POLES

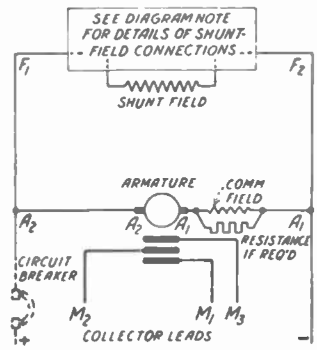


FIG 2 SHUNT-WOUND THREE-PHASE SYNCHRONOUS CONVERTER WITH COMMUTATING POLES

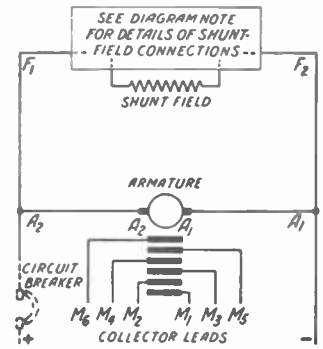


FIG. 3 SHUNT-WOUND SIX-PHASE SYNCHRONOUS CONVERTER WITHOUT COMMUTATING POLES

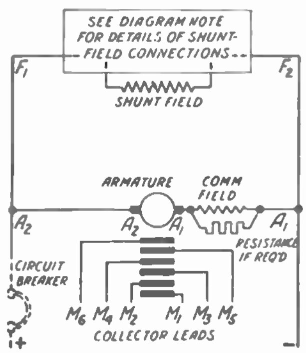


FIG 4 SHUNT-WOUND SIX-PHASE SYNCHRONOUS CONVERTER WITH COMMUTATING POLES

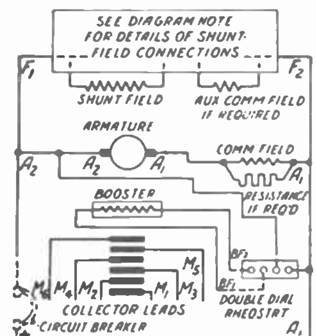


FIG. 5 SHUNT-WOUND SIX-PHASE SYNCHRONOUS CONVERTER WITH COMMUTATING FIELD, AUX. COMMUTATING POLES, & REVOLVING-ARMATURE BOOSTER

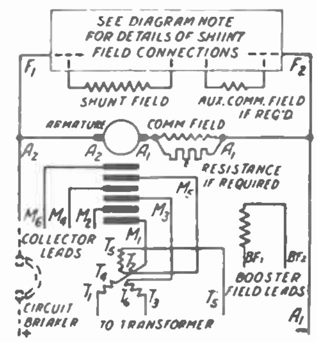


FIG. 6 SHUNT-WOUND SIX-PHASE SYNCHRONOUS CONVERTER WITH COMMUTATING FIELD, AUX. COMMUTATING POLES, & REVOLVING-FIELD BOOSTER

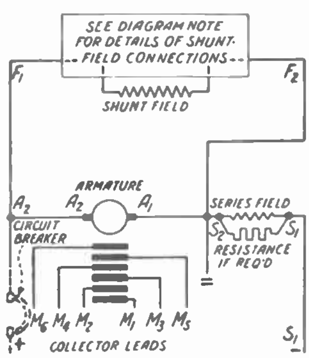


FIG 7 COMPOUND-WOUND SIX-PHASE SYNCHRONOUS CONVERTER WITHOUT COMMUTATING POLES

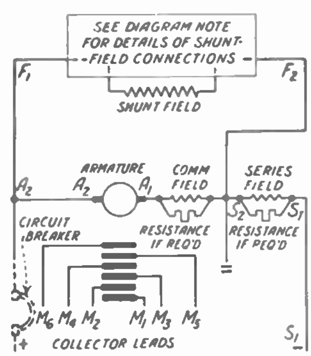


FIG. 8 COMPOUND-WOUND SIX-PHASE SYNCHRONOUS CONVERTER WITH COMMUTATING POLES

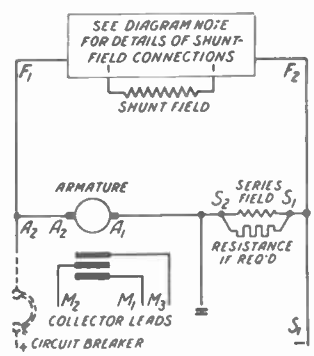


FIG 9 COMPOUND-WOUND THREE-PHASE SYNCHRONOUS CONVERTER WITHOUT COMMUTATING POLES

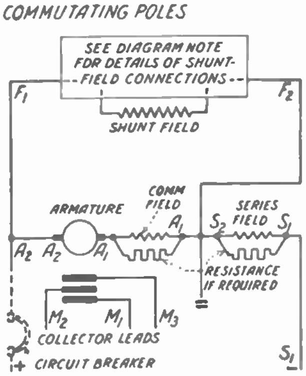


FIG. 10 COMPOUND-WOUND THREE-PHASE SYNCHRONOUS CONVERTER WITH COMMUTATING POLES

NOTE I—Owing to the varieties of shunt-field connections, these diagrams (see 3.915) are shown separately from the other machine connection diagrams in order to simplify and reduce the number of diagrams required. In some cases a shunt-field connection diagram may be used with only one machine diagram. In other cases a machine diagram may be used in combination with any of several shunt-field diagrams. For instance, the shunt-field connections shown in 3.915, diagrams 1, 4, and 6, may be used with several of the machine diagrams given in 3.905 and 3.910.

NOTE II—See 1.510 for the terminal letters assigned to different types of windings, and 1.130 for the significance of the subscript numerals.

3.910 Connections and Terminal Markings—Synchronous Converters, Three-Wire

Standard direction of rotation is clockwise facing the commutator end.

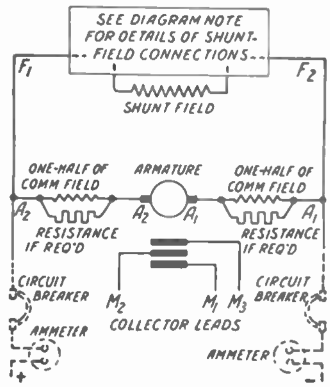


FIG 1 SHUNT-WOUND THREE-PHASE SYNCHRONOUS CONVERTER WITH COMMUTATING POLES

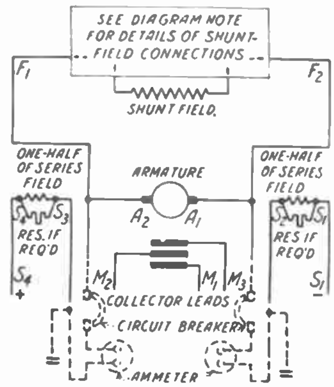


FIG. 2 COMPOUND-WOUND THREE-PHASE SYNCHRONOUS CONVERTER WITHOUT COMMUTATING POLES

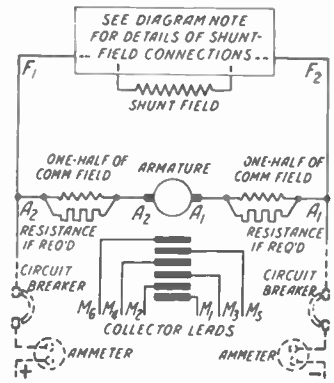


FIG. 3 SHUNT-WOUND SIX-PHASE SYNCHRONOUS CONVERTER WITH COMMUTATING POLES

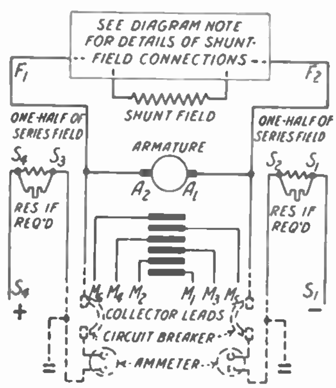


FIG 4 COMPOUND-WOUND SIX-PHASE SYNCHRONOUS CONVERTER WITHOUT COMMUTATING POLES

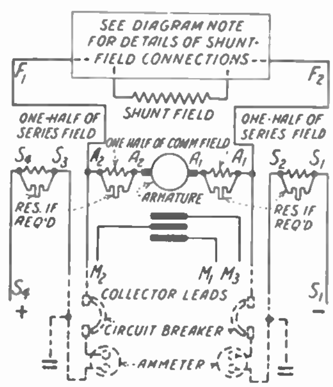


FIG. 5 COMPOUND-WOUND THREE-PHASE SYNCHRONOUS CONVERTER WITH COMMUTATING POLES

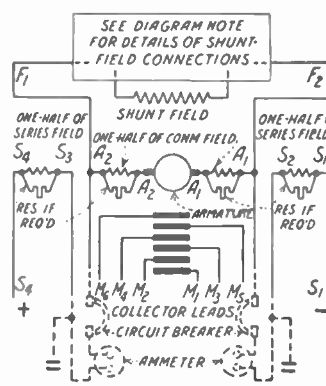


FIG. 6 COMPOUND-WOUND SIX-PHASE SYNCHRONOUS CONVERTER WITH COMMUTATING POLES

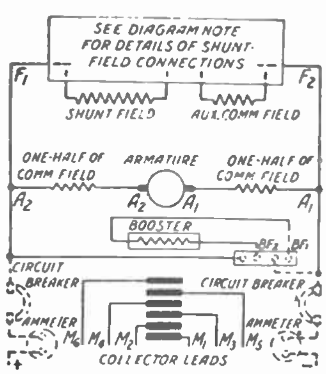


FIG. 7 SHUNT-WOUND SIX-PHASE SYNCHRONOUS CONVERTER WITH COMMUTATING POLES, AUXILIARY COMMUTATING FIELD, AND REVOLVING-ARMATURE BOOSTER

NOTE I—Owing to the varieties of shunt-field connections, these diagrams (see 3.915) are shown separately from the other machine connection diagrams in order to simplify and reduce the number of diagrams required. In some cases a shunt-field connection diagram may be used with only one machine diagram. In other cases a machine diagram may be used in combination with any of several shunt-field diagrams. For instance, the shunt-field connections shown in 3.915, diagrams 1, 4, and 6, may be used with several of the machine diagrams given in 3.905 and 3.910.

NOTE II—See 1.510 for the terminal letters assigned to different types of windings, and 1.130 for the significance of the subscript numerals.

3.915 Connections and Terminal Markings—Synchronous Converter Shunt Fields

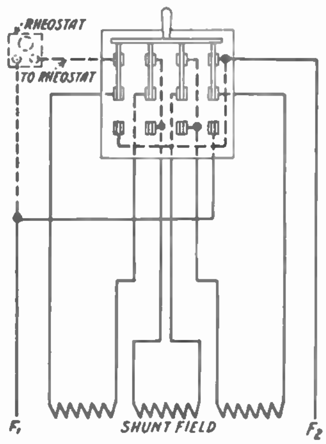


FIG. 1-4 P. D. T. BREAK-UP SWITCH

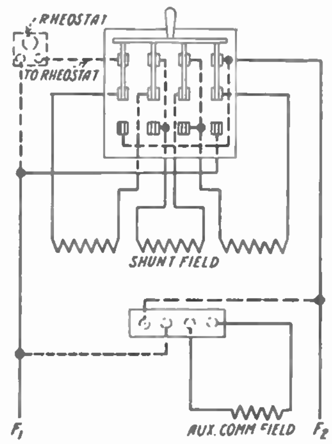


FIG. 2 4 P. D. T BREAK-UP SWITCH WITH AUXILIARY COMMUTATING SHUNT FIELD

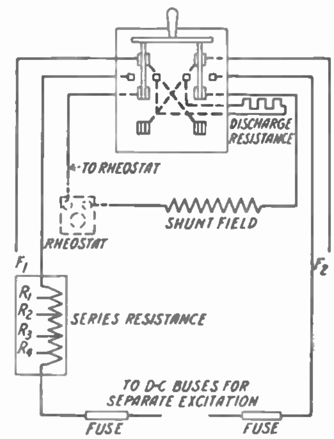


FIG. 3-2 P. D. T FIELD DISCHARGE SWITCH FOR SEPARATE EXCITATION

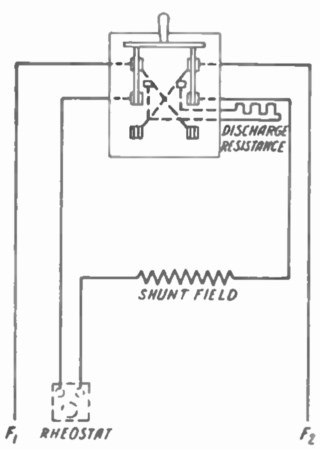


FIG 4-2 P. D. T. FIELD DISCHARGE SWITCH FOR SELF EXCITATION

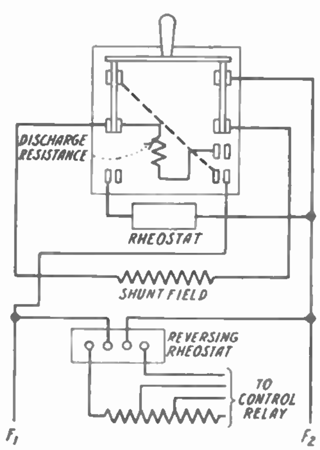


FIG. 5-2 P. D. T DISCHARGE SWITCH WITH AUXILIARY COMMUTATING FIELD SHUNT WITH CONTROL RELAY

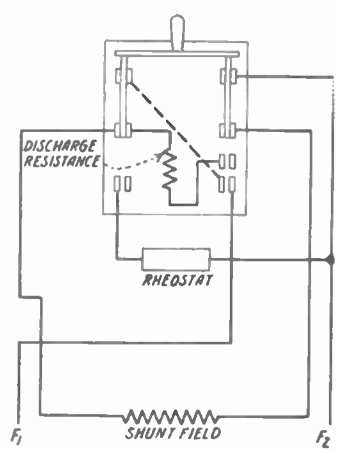


FIG. 6-2 P. D. T. DISCHARGE SWITCH FOR SELF EXCITATION

NOTE—See 1.510 for terminal letters assigned to different types of windings, and 1.130 for the significance of the subscript numerals.

MOTOR-DRIVEN FREQUENCY CONVERTER SET - THE LOUIS ALLIS CO.

CONNECTIONS AND CONTROL

Fig. 4 shows the usual connections and control for a 4-bearing motor-driven frequency converter set. General practice is to use separate switches to connect the motor and frequency converter primary-winding to the normal frequency supply-line. The motor starter may be either the manual or magnetic type. The switch for the converter primary-winding should always be of the magnetic type, with the operating coil connected to the motor side of the motor starter. With this arrangement there is no danger of damage to the frequency converter windings from being left connected to the line when the driving motor is shut down.

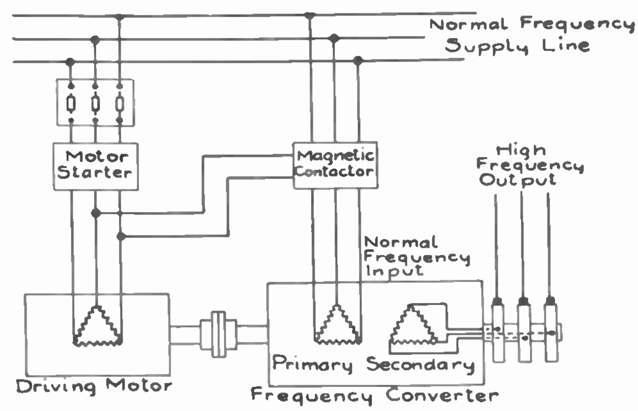


Fig. 4—Wiring and Control Diagram for Motor-Driven Frequency Converter.

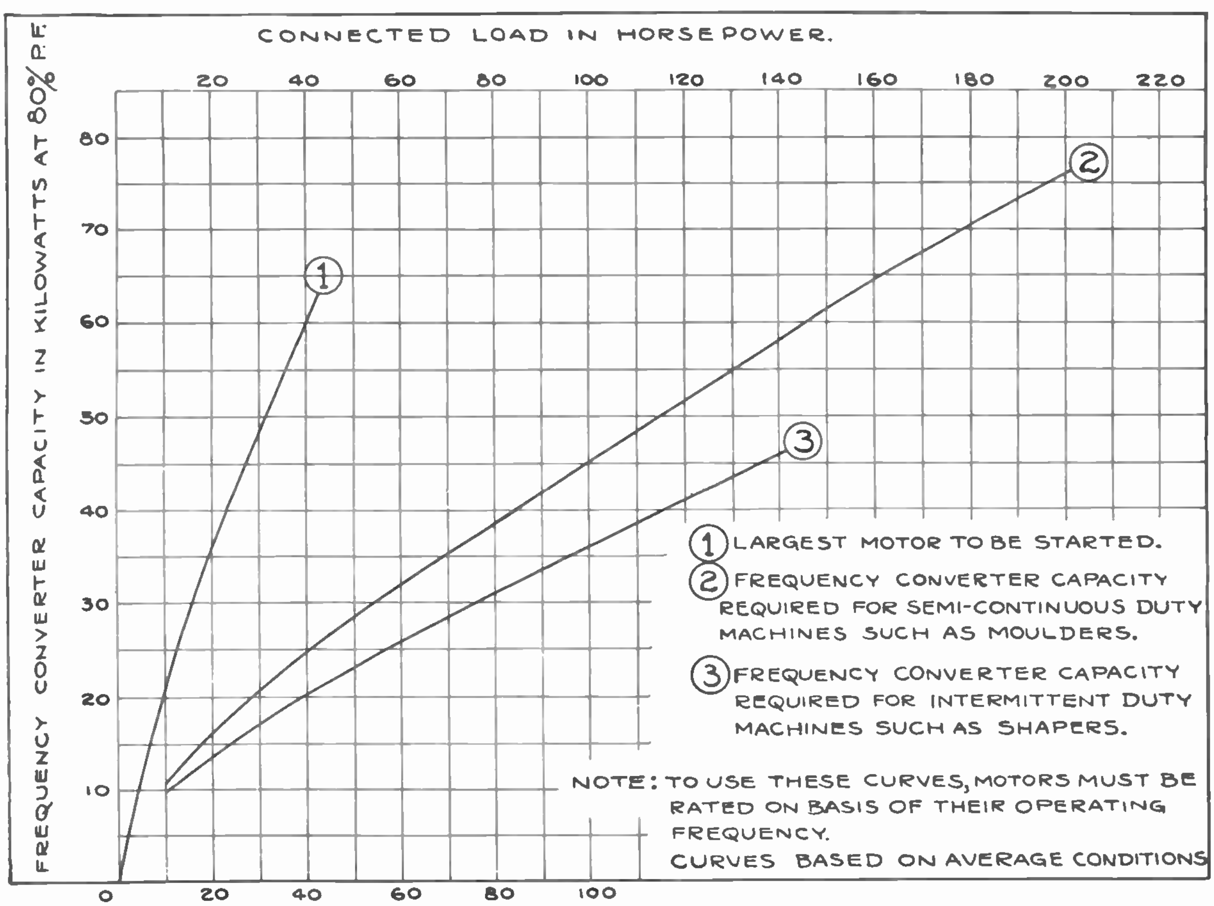
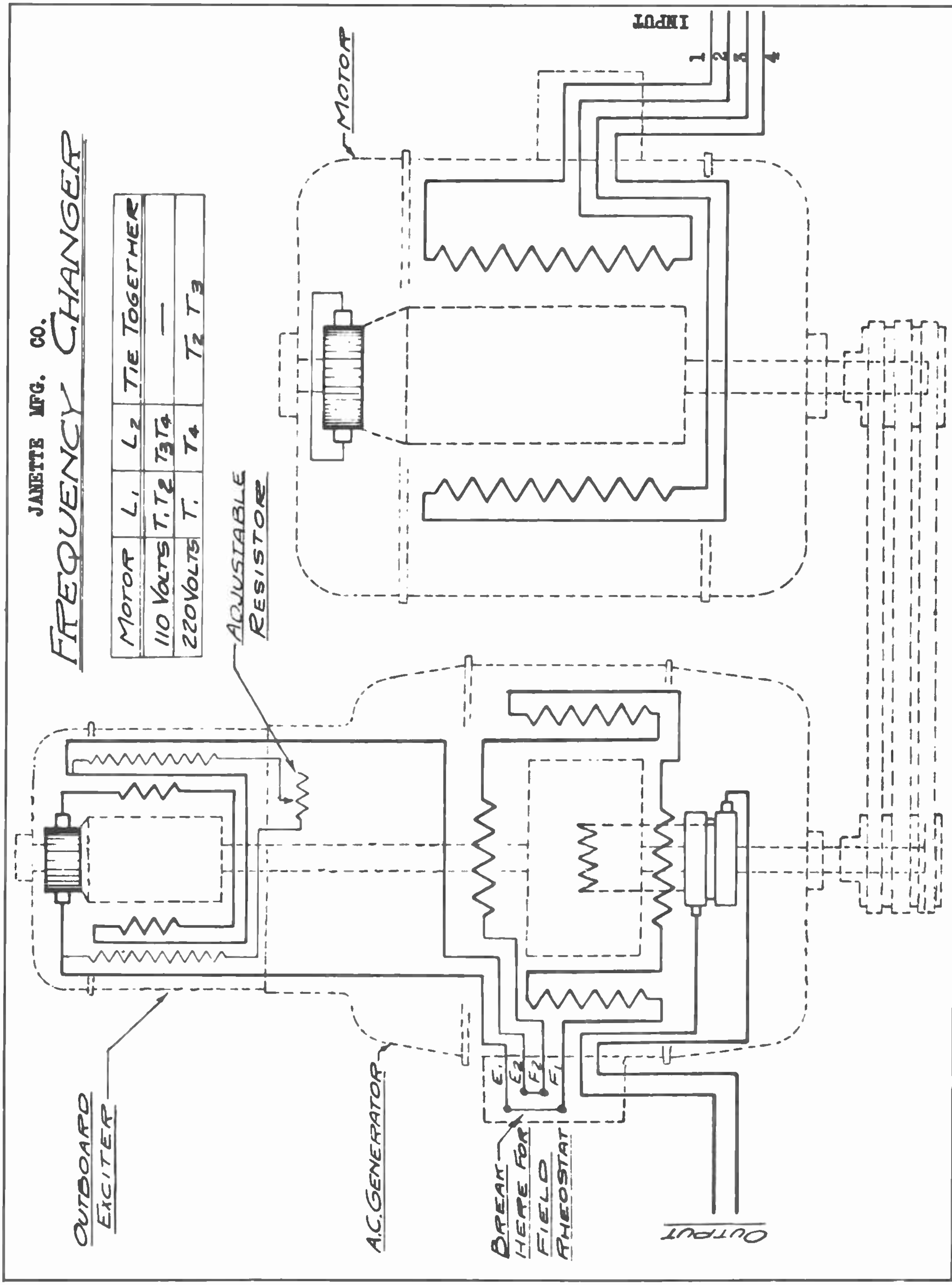
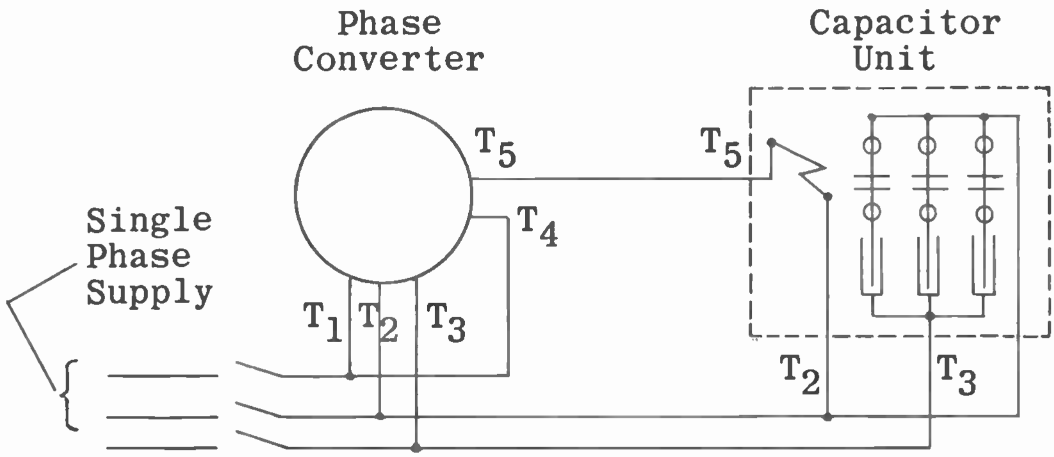


Fig. 5—Curves for estimating capacity of frequency converter required for a given total connected load, also the largest permissible motor to be started.


JANETTE MFG. CO.
FREQUENCY CHANGER
Motor | L1 | L2 | Tie Together
110 Volts | T1 T2 | T3 T4 | —
220 Volts | T1 | T4 | T2 T3
Adjustable Resistor
Motor
Input
1
2
3
4
Outboard Exciter
A.C. Generator
Break Here for Field Rheostat
E1
E2
F2
F1
Output

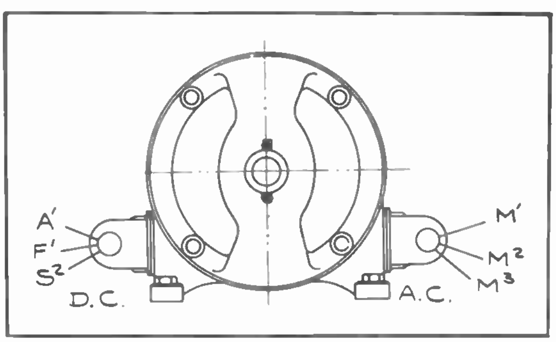
CONNECTION DIAGRAM FOR INDUCTION TYPE PHASE CONVERTER



Converter Should Be Up To Speed Before Connecting to 3 Phase Load

The Louis Allis Co.
Milwaukee, Wis.

Dia.#688



D.C. TO A.C. INVERTED ROTARY CONVERTER

S^2 = To one side of d-c line (S^2 internally connected to A^2-F^2 inside of motor). A'-F' = To other side of d-c line (connection is made through A'-F' on starting box).

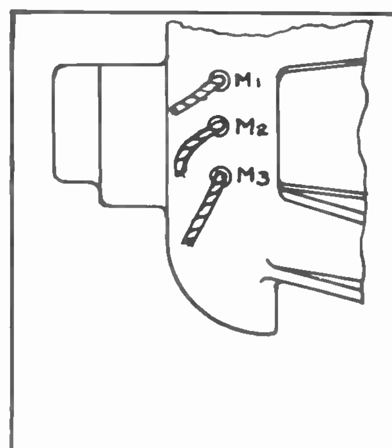
Single phase - M'-M^2

Two phase - Phase 1 = M'-M^3. Phase 2 = M^2-M^4

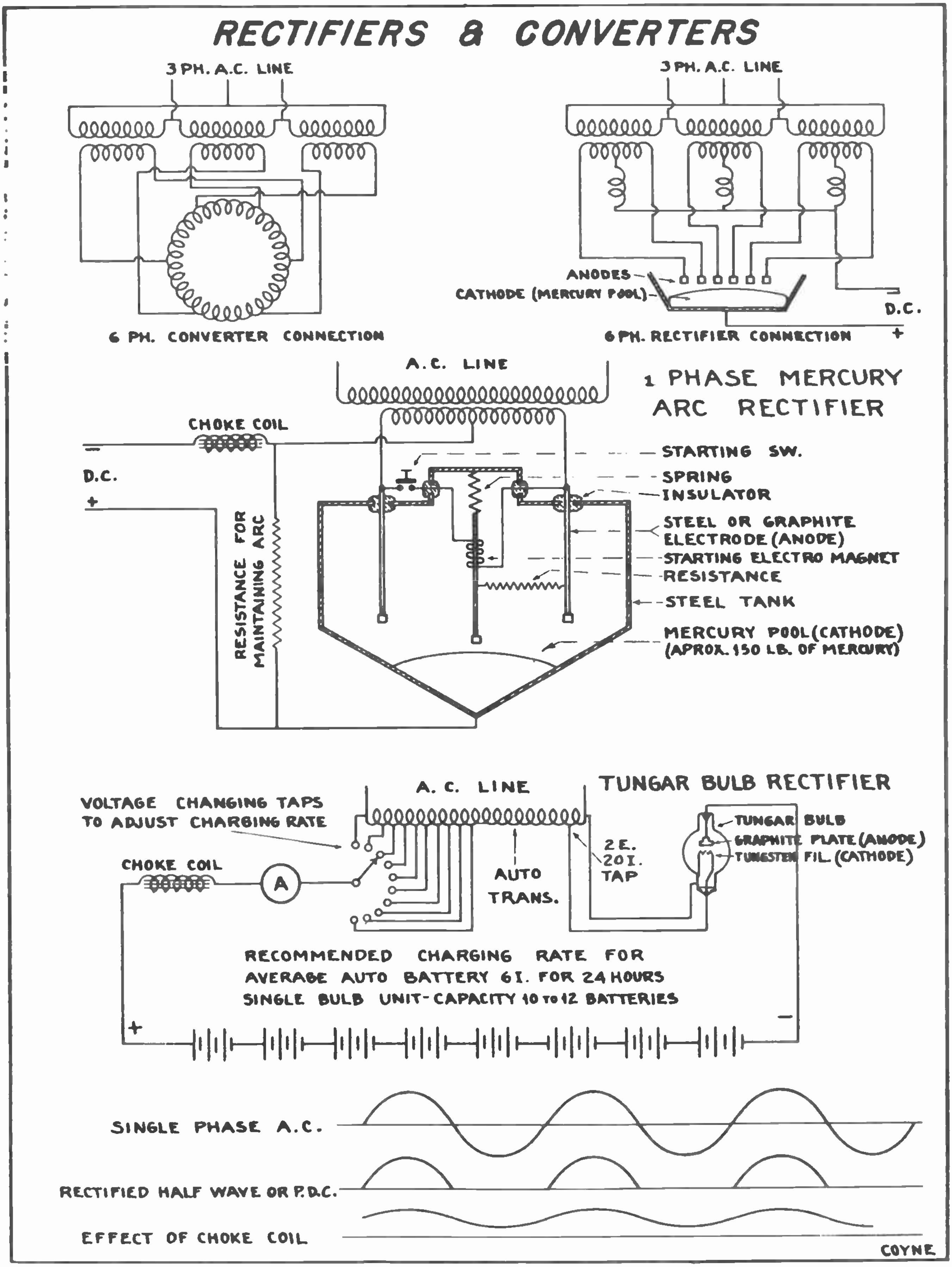
Three phase - M'-M^2-M^3

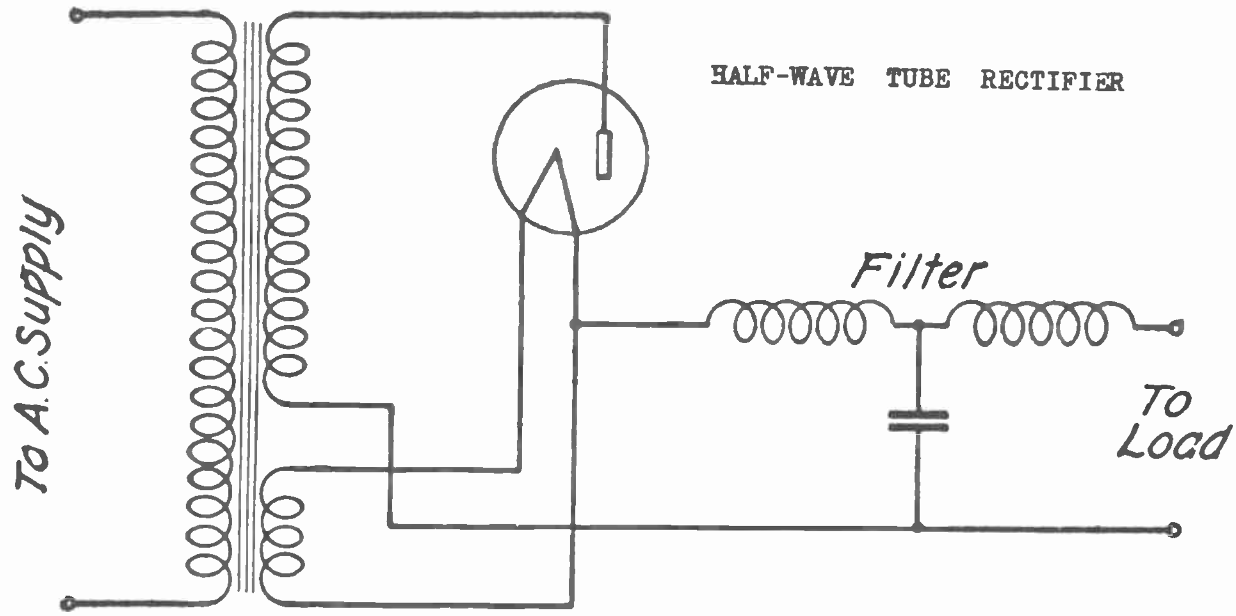
Four phase - Phase 1 = $M'M^2$. Phase 2 = M^2-M^3.
Phase 3 = M^3-M^4. Phase 4 = M^4-M^1

2 OR 3 PHASE WOUND ROTOR OR FREQUENCY CONVERTER

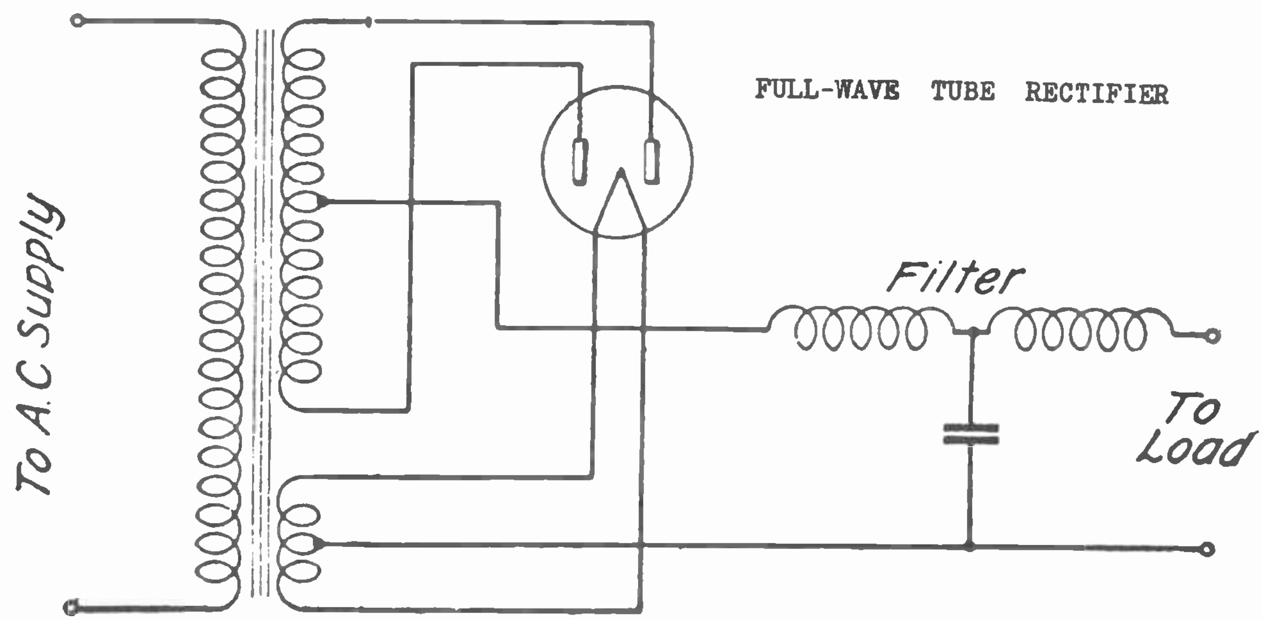


CONNECT M1 - M2 - M3 TO SLIP RING REGULATOR OR STARTER.
STATOR LEAD MARKINGS SAME AS I OR II

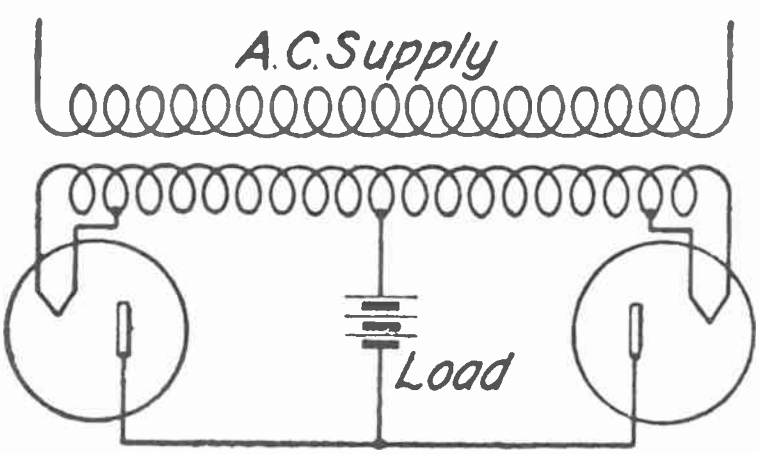

RECTIFIERS & CONVERTERS
3 PH. A.C. LINE
6 PH. CONVERTER CONNECTION
3 PH. A.C. LINE
ANODES
CATHODE (MERCURY POOL)
D.C.
+
6 PH. RECTIFIER CONNECTION
A. C. LINE
1 PHASE MERCURY ARC RECTIFIER
CHOKE COIL
D.C.
−
+
RESISTANCE FOR MAINTAINING ARC
STARTING SW.
SPRING
INSULATOR
STEEL OR GRAPHITE ELECTRODE (ANODE)
STARTING ELECTRO MAGNET
RESISTANCE
STEEL TANK
MERCURY POOL (CATHODE) (APROX. 150 LB. OF MERCURY)
A. C. LINE
TUNGAR BULB RECTIFIER
VOLTAGE CHANGING TAPS TO ADJUST CHARGING RATE
CHOKE COIL
A
AUTO TRANS.
2 E. 20 I. TAP
TUNGAR BULB
GRAPHITE PLATE (ANODE)
TUNGSTEN FIL. (CATHODE)
RECOMMENDED CHARGING RATE FOR AVERAGE AUTO BATTERY 6 I. FOR 24 HOURS
SINGLE BULB UNIT-CAPACITY 10 TO 12 BATTERIES
+
−
SINGLE PHASE A.C.
RECTIFIED HALF WAVE OR P.D.C.
EFFECT OF CHOKE COIL
COYNE



HALF-WAVE TUBE RECTIFIER



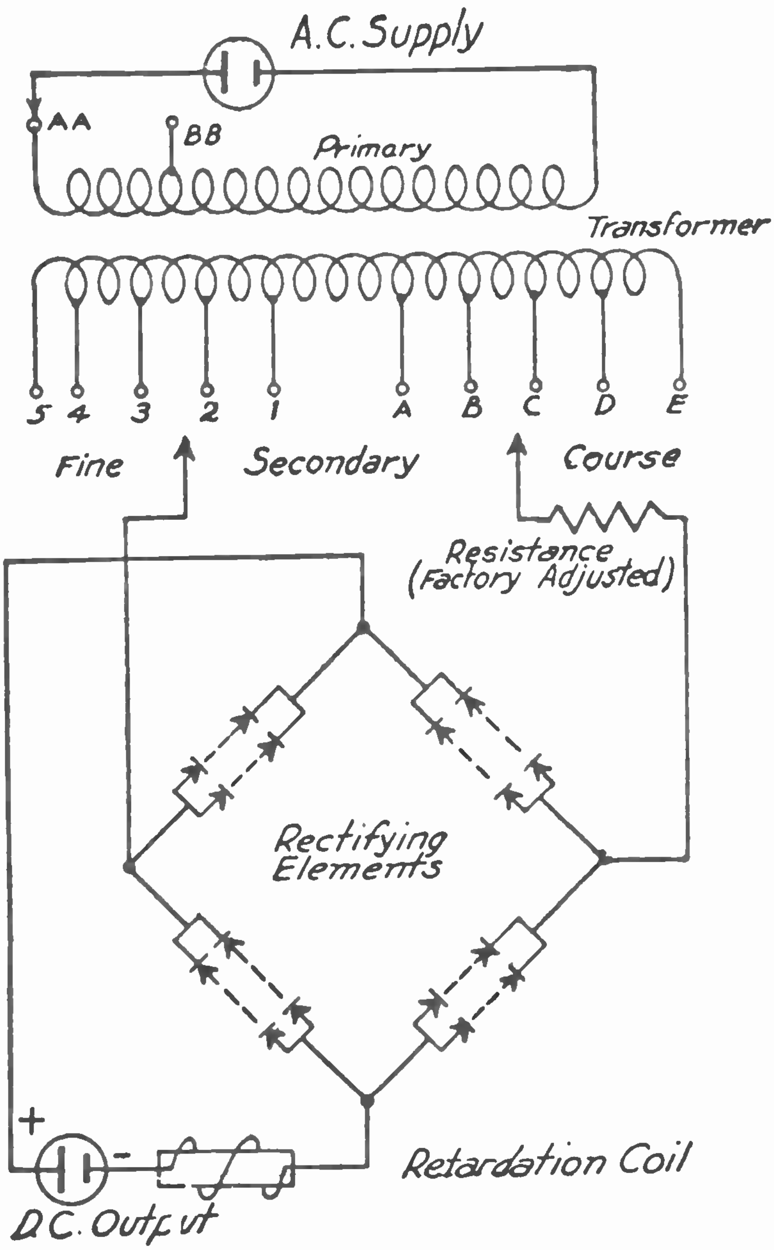
FULL-WAVE TUBE RECTIFIER



FULL-WAVE TUNGAR RECTIFIER

FOR BATTERY CHARGING

Other gas-filled tubes of generally similar performance and characteristics may be used in this circuit.

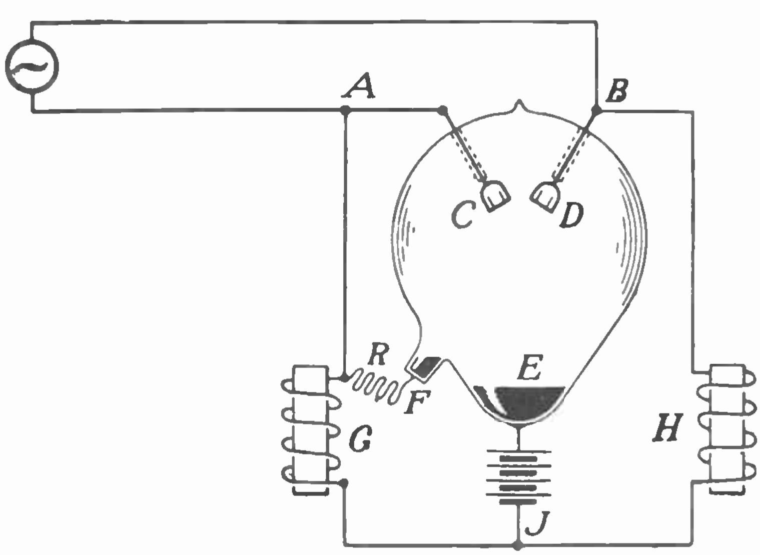


COPPER-OXIDE RECTIFIER

Arrows on the copper-oxide rectifying elements indicate directions of current flow.

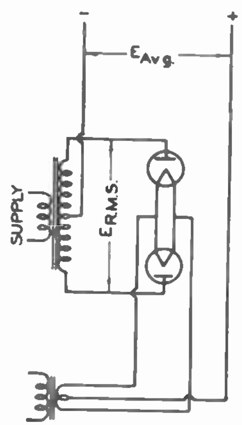
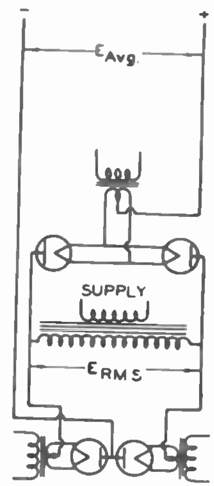
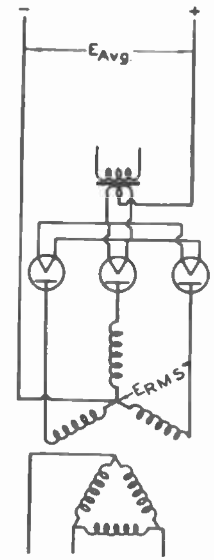
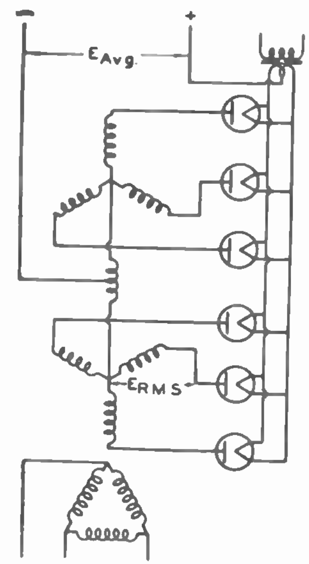
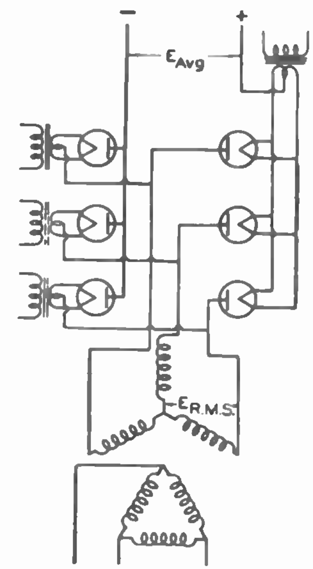
The input transformer is provided with tap switches that allow adjusting the potential on the rectifier elements to required values for charging the load attached to the d-c output.

The retardation coil, or choke coil, smooths the rectified current and reduces the pulsations of voltage and current in the load.

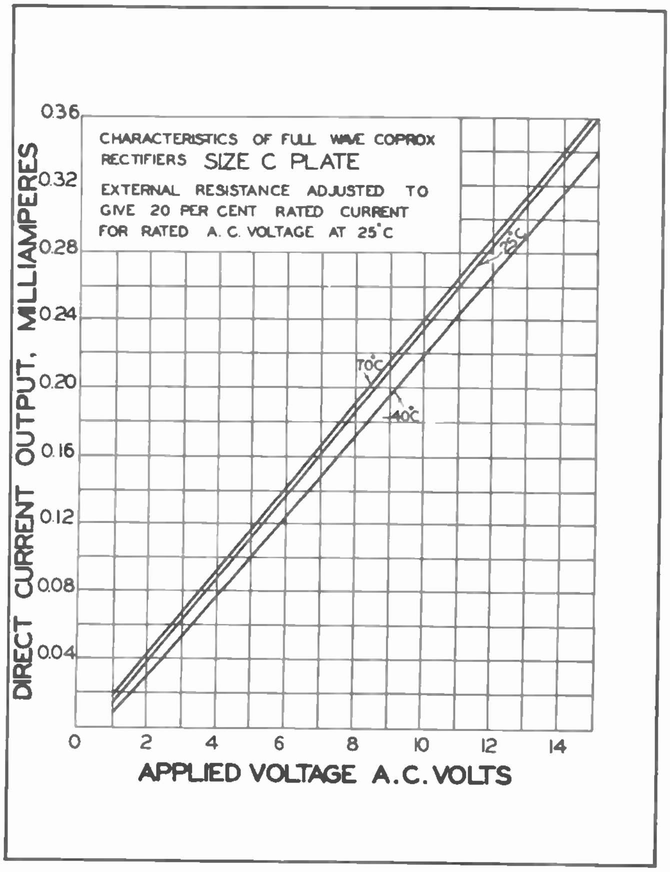


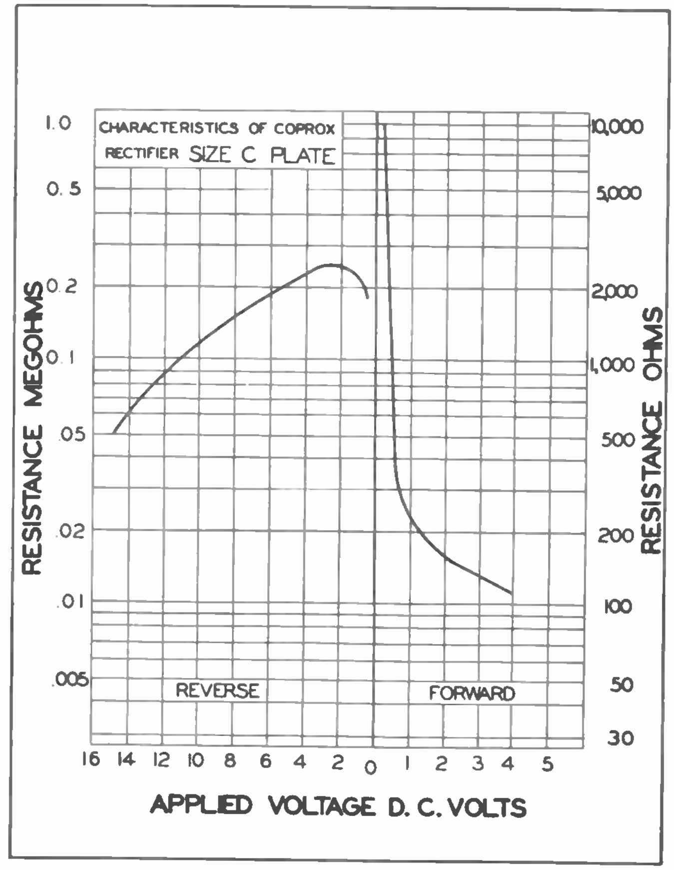
MERCURY ARC RECTIFIER

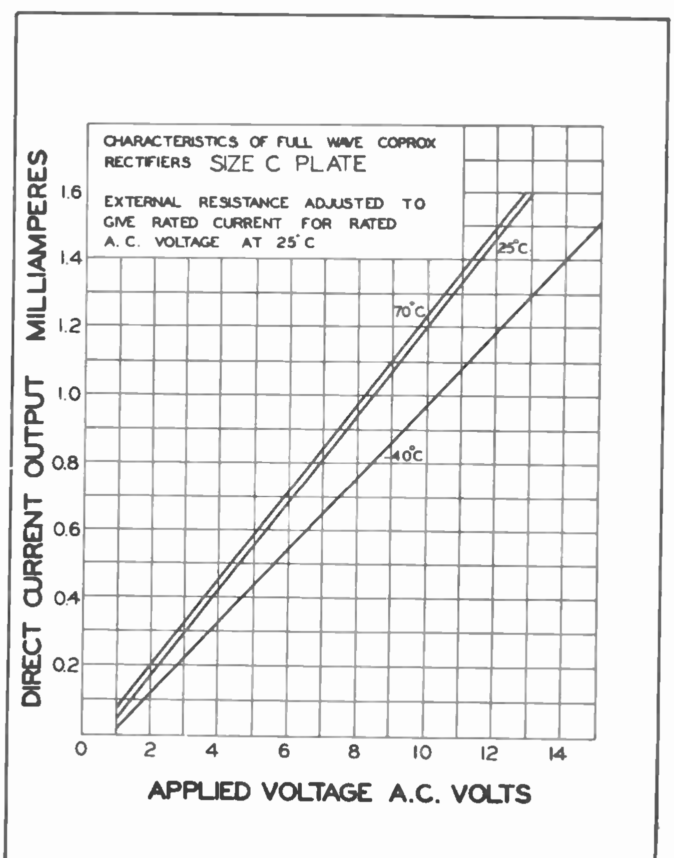
A and B = Terminals connected to alternating-current source shown at the upper left in the diagram.
C and D = Anodes inside the tube.
E = Mercury pool cathode.
F = Short circuiting starter.
G and H = Inductances.
J = Battery (load) being charged.
R = Resistor for limiting current during starting.

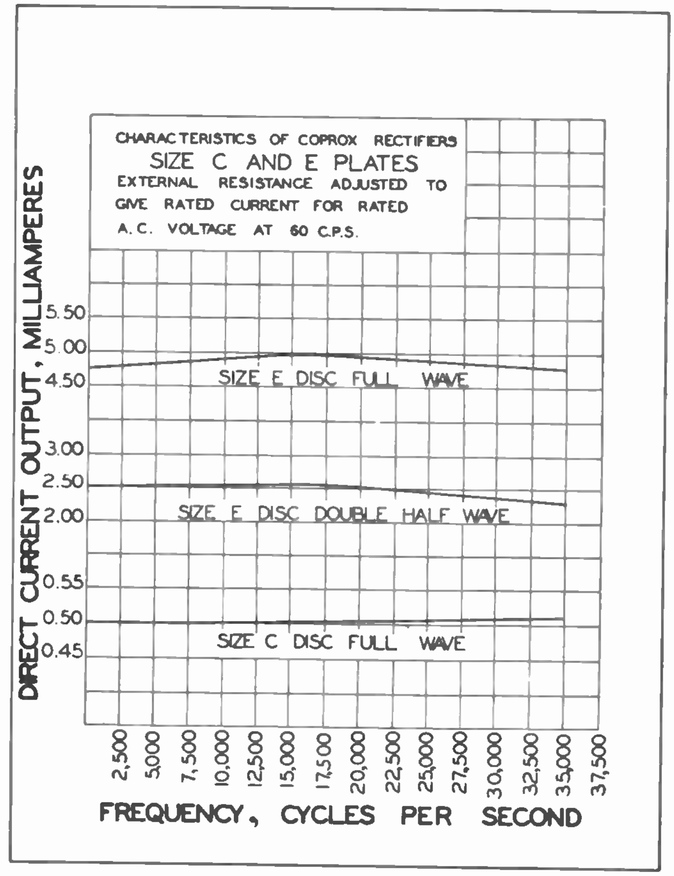
RECTIFIER CIRCUIT	FIG. 1 SINGLE PHASE FULL-WAVE 2 TUBES	FIG. 2 SINGLE PHASE FULL-WAVE 4 TUBES	FIG. 3 THREE PHASE HALF-WAVE	FIG. 4 THREE PHASE DOUBLE—Y	FIG. 5 THREE PHASE FULL-WAVE
Conditions assumed for following relations 1. Sine-Wave Supply 2. Balanced Phase Voltages 3. Zero Tube Drop 4. Pure Resistance Load 5. No Filter Used Note: All rectifier filaments supplied by single phase transformers, with secondaries insulated for voltages greater than the Maximum Peak Inverse Voltage.					
E Average	$.450\ E_{rms}$ $.318\ E_{max}$	$.900\ E_{rms}$ $.636\ E_{max}$	$1.170\ E_{rms}$ $.827\ E_{max}$	$1.170\ E_{rms}$ $.827\ E_{max}$	$2.34\ E_{rms}$ $1.65\ E_{max}$
E Inverse	* $.314\ E_{avg.}$	** $.157\ E_{avg.}$	$2.09\ E_{avg.}$	$2.09\ E_{avg.}$	$1.045\ E_{avg.}$
I Average	$.636\ I_{max}$	$.636\ I_{max}$	$.827\ I_{max}$	$1.91\ I_{max}$	$.955\ I_{max}$
Ripple Frequency	2 X Supply Freq.	2 X Supply Freq.	3 X Supply Freq.	6 X Supply Freq.	6 X Supply Freq.
Ripple Voltage (Rms)	48.3%	48.3%	18.3%	4.2%	4.2%
† Ratio $\frac{\text{Secondary Kva}}{\text{D. C. Output-Kw}}$	1.57	1.11	1.48	1.48	1.05
† Ratio $\frac{\text{Primary Kva}}{\text{D. C. Output-Kw}}$	1.11	1.11	1.21	1.05	1.05

BRADLEY LABORATORIES COPPER-OXIDE RECTIFIERS

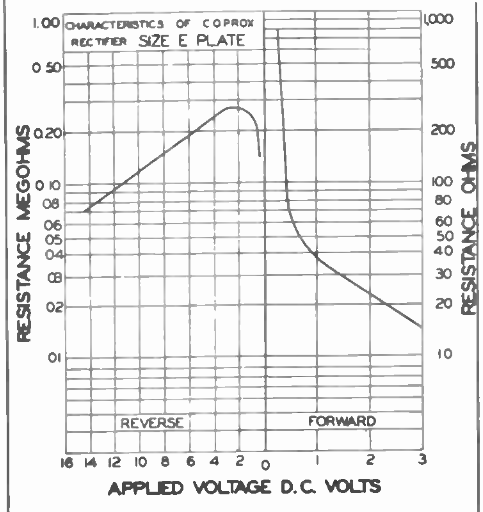


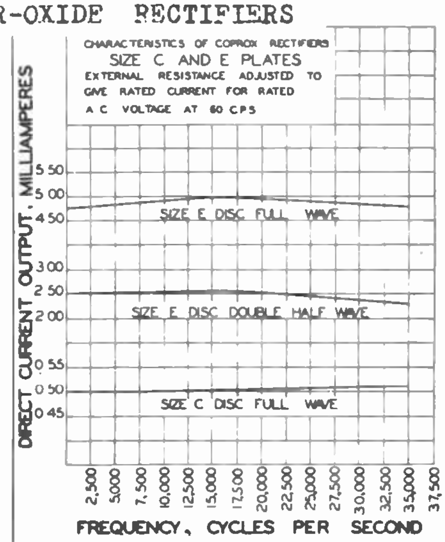


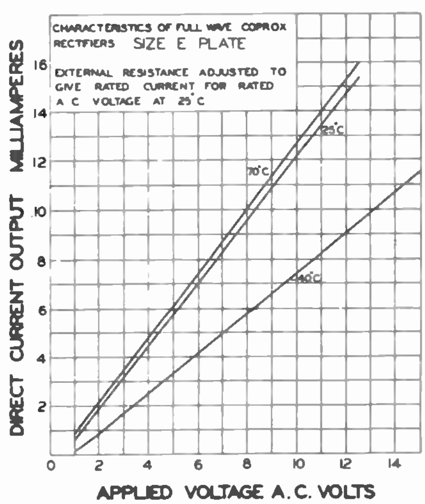


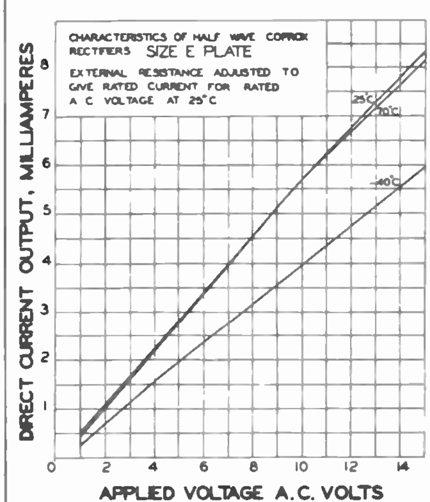


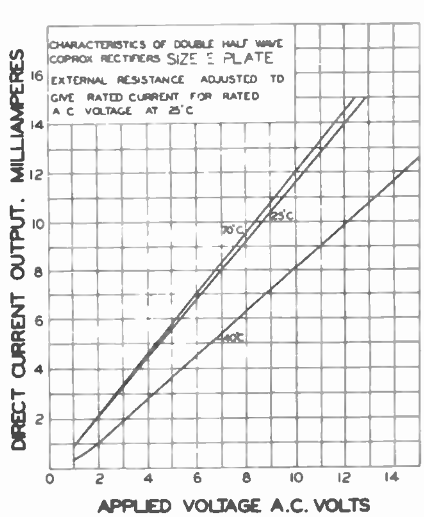
BRADLEY LABORATORIES COPPER-OXIDE RECTIFIERS

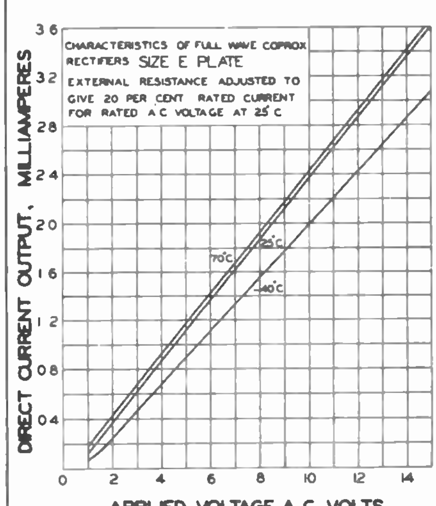




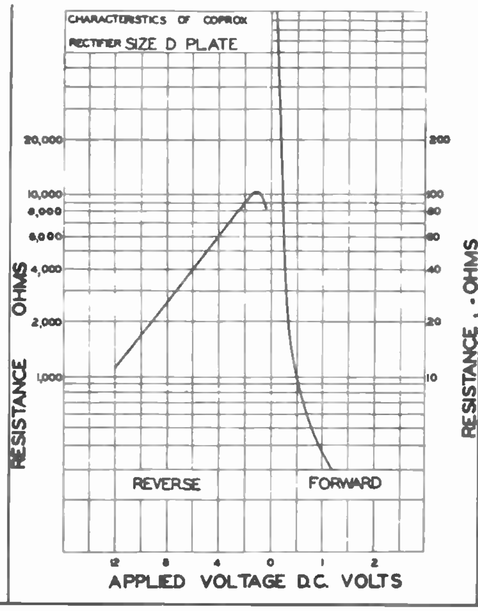


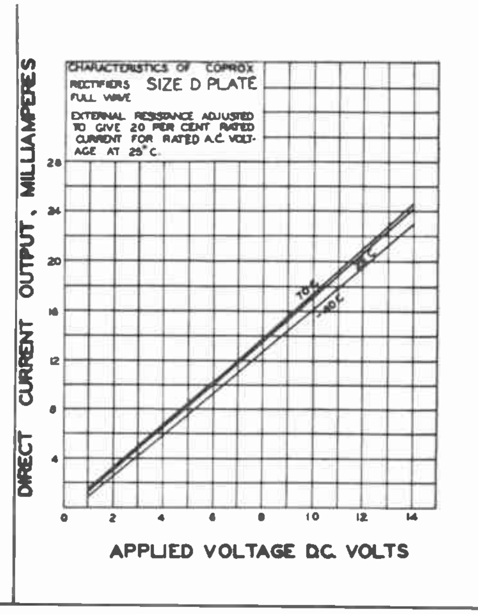


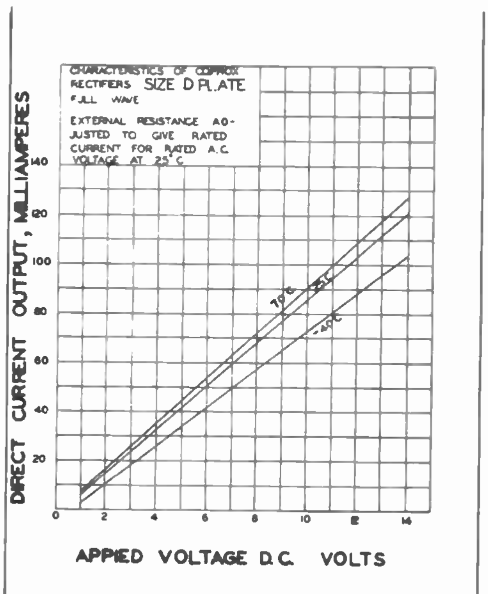


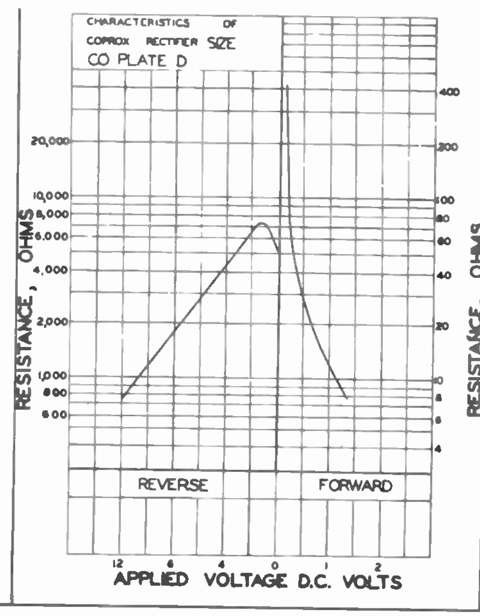


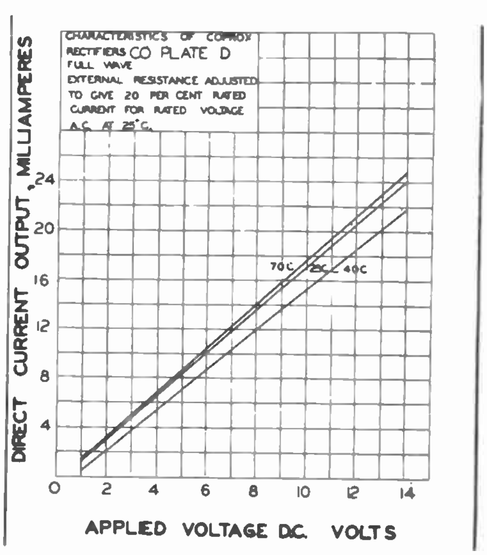
BRADLEY LABORATORIES COPPER-OXIDE RECTIFIERS

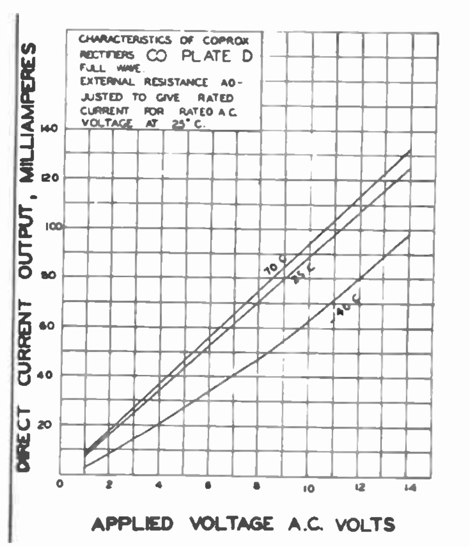




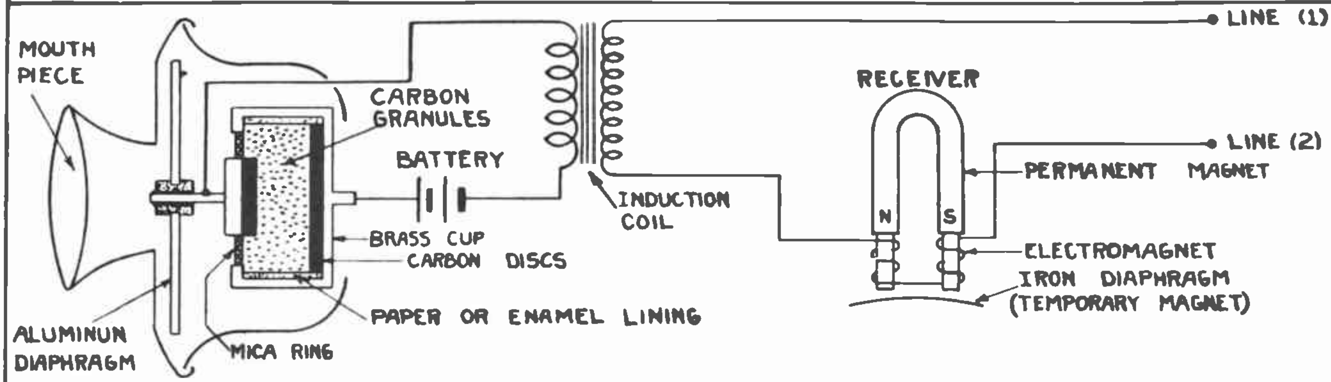








ELEMENTARY DIAGRAM OF THE TELEPHONE

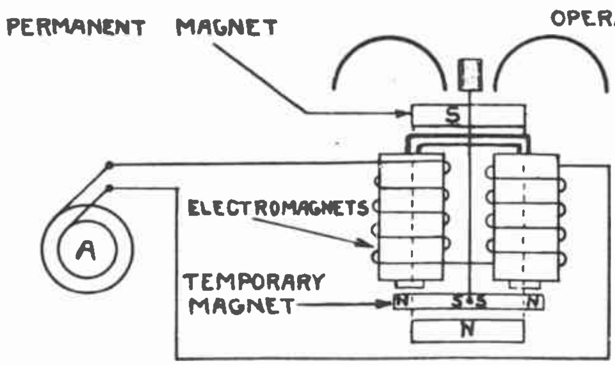


The above diagram shows the equipment and connections for one telephone. Connection can be made to another telephone through points indicated Line "1" and Line "2". The transmitter button is everything enclosed in the brass cup. Sound waves (voice waves), through the mouthpiece, strike the aluminum diaphragm, causing it to vibrate. These vibrations move the front of the transmitter button in and out, which tightens and loosens the carbon granules. This decreases and increases the resistance of the transmitter circuit, thus affecting the value of the current through the primary side of the induction coil. The effect of the change in rate of current in the primary induces an alternating voltage in the secondary, which causes current to flow first one direction then the other through the receiver circuit. A.C. in the electro-magnets, which varies the strength of the permanent magnet and causes the iron diaphragm to vibrate. These vibrations of the receiver diaphragm, which means that the sound waves thus produced by the receiver diaphragm are a reproduction of those impressed on the transmitter diaphragm.

The diagram shows conditions as they exist when the receiver is off the hook. Ordinarily the receiver hook-switch opens the transmitter circuit to prevent drain on the battery, and also opens the receiver circuit. Notice there is nothing magnetic about the operation of the transmitter. Its purpose is purely to convert sound waves to electrical impulses, producing PDC in the transmitter circuit. The receiver operates on the magnetic effect of current. It demonstrates the application of the three artificial magnets - namely - permanent magnet, temporary magnet, and electro-magnet.

POLARIZED BELL

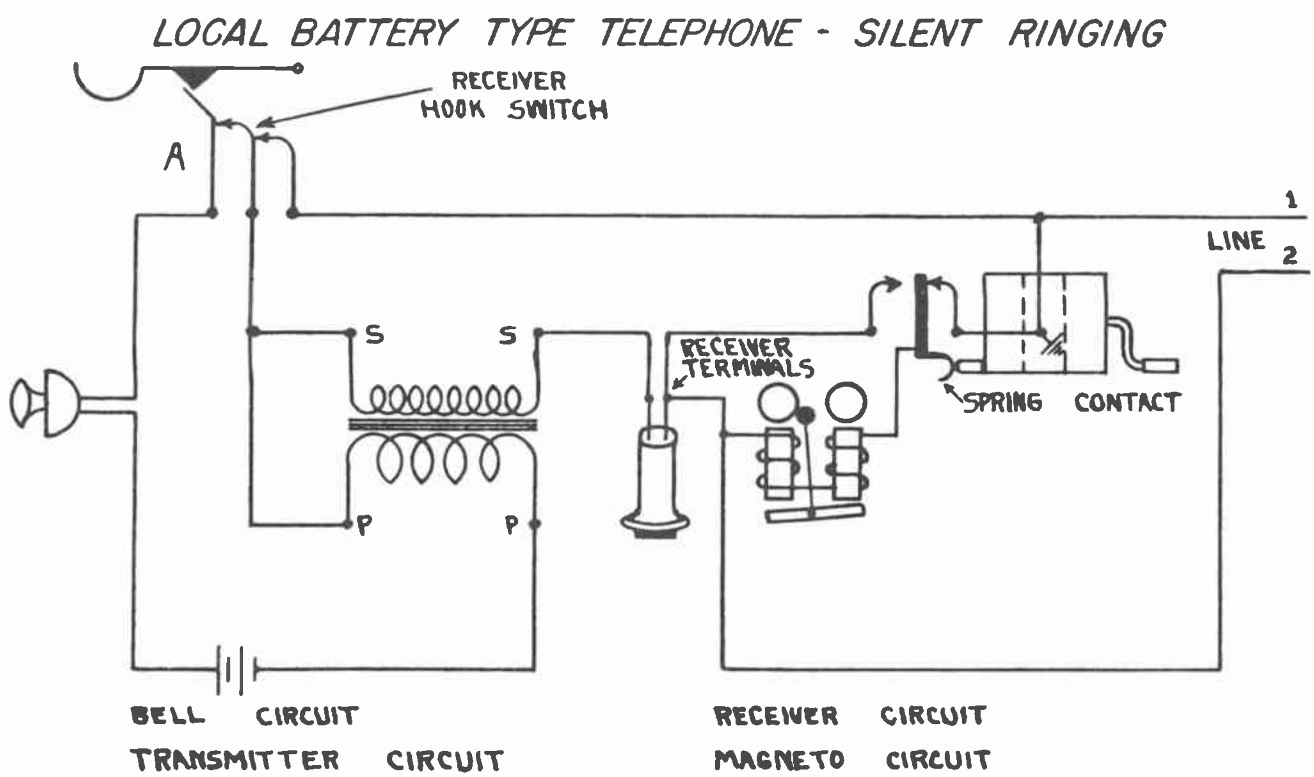
OPERATES ON A.C.



The polarized bell is the device commonly used in connection with the telephone to sound an audible alarm when calling. It requires a source of energy separate from the transmitter circuit and receiver circuit.

The N-pole of the permanent magnet indicates the consequent poles "S" and "S" in the solft iron bar, making the main poles both N-poles. The iron bar is pivoted in the center, which permits its ends to move up and down when attracted or repelled as A.C. changes the polarities of the electro-magnets.

By tracing the circuits for each alternation separately, it will be seen that the "right-hand rule for electro-magnets" applies here; also the "First Law of Magnetism."



Observe that when the receiver is off the hook, as shown in the above diagram, all of the contacts on the hook switch (at "A") are closed, thus completing both the receiver circuit to the line and the transmitter circuit.

Hang the receiver back on the hook. Notice that all of the contacts open, thereby breaking receiver and transmitter circuits. This type of telephone is called silent ringing because, by turning the crank on the magneto to call out, the bell is shunted and does not ring.

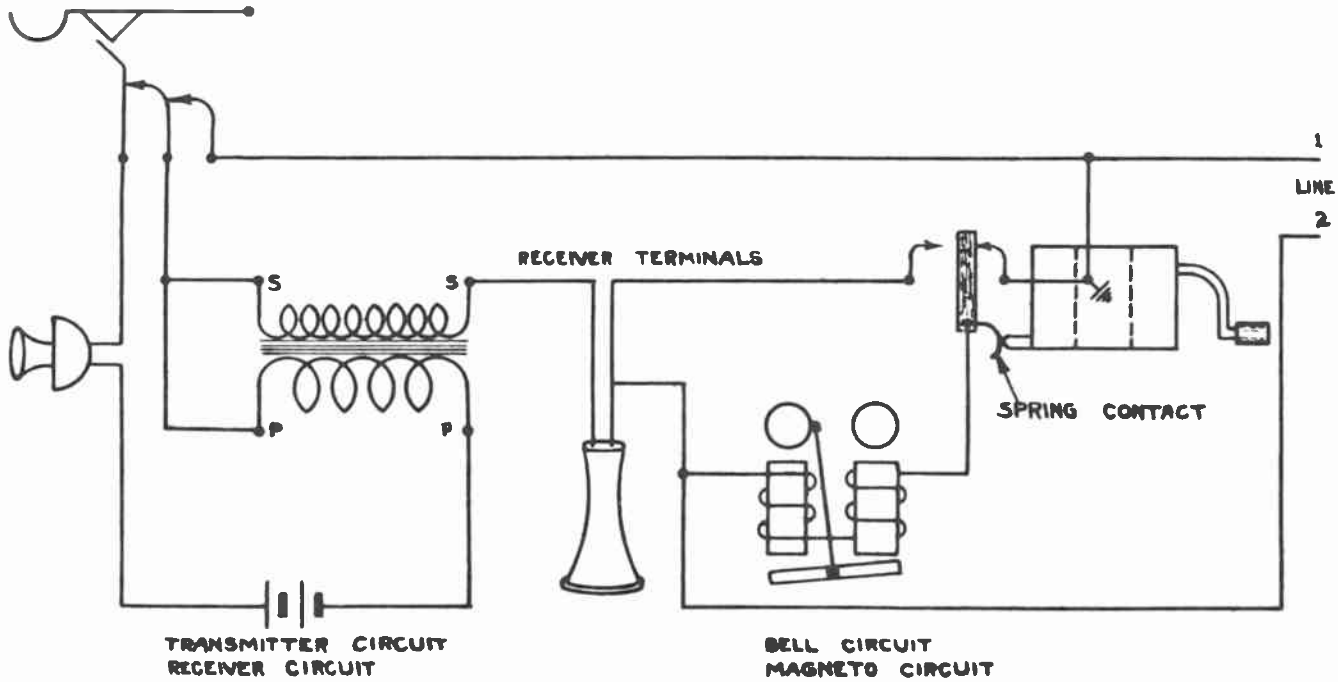
The reason for this can be clearly seen when turning the crank. The mechanical arrangement of the shaft moves the moving contact of the double-circuit switch, on the end of the magneto, away from the closed contact over against the open contact.

This type of telephone can be used on a grounded line by connecting line "2" to the earth and line "1" to a wire extending to the other telephone. It can also be used on metallic line by connecting one wire of the line to line "1" and the other to line "2".

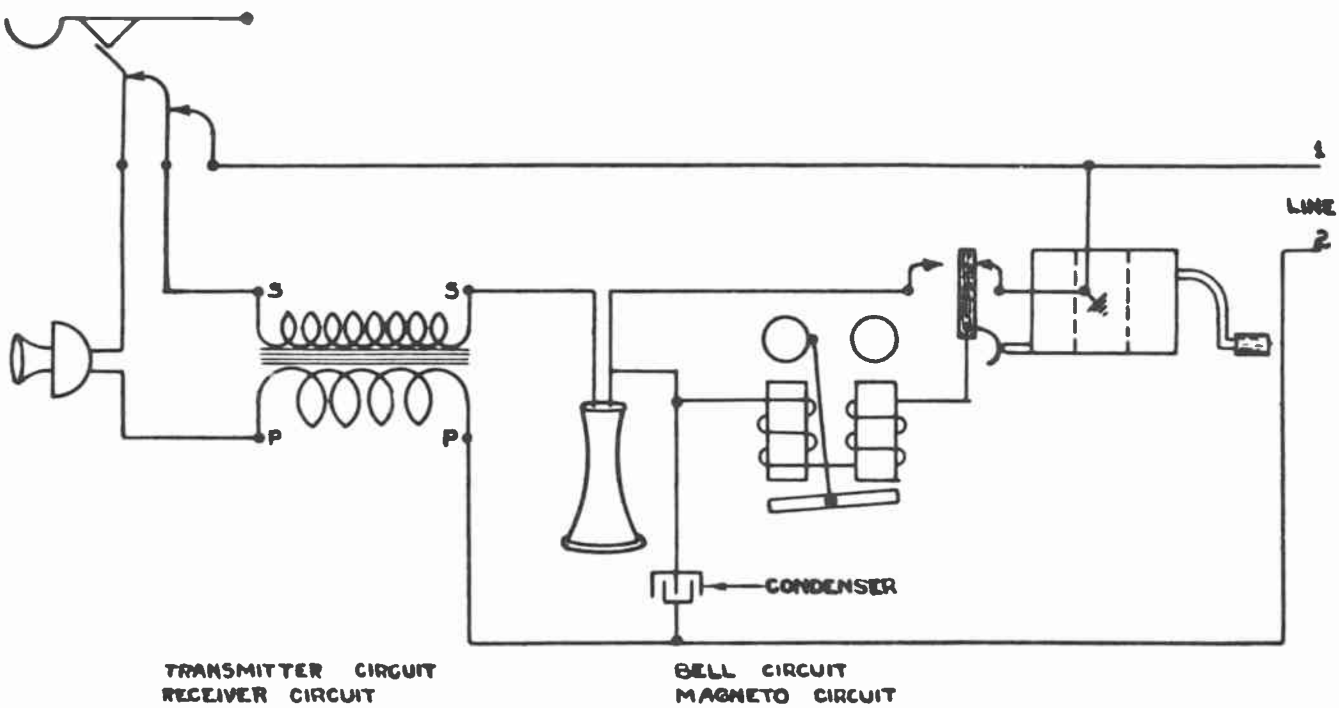
It should be noted that the pulsations in the battery circuit produced by operation of the transmitter result in alternating voltages being induced in the secondary winding of the transformer and that these A.C. voltages force A.C. currents through the line which operate the receiver at the other end.

The magneto shown is also an alternating current device. This explains the need for using a polarized bell on this unit, since positive ringing cannot be satisfactorily obtained on a bell of the ordinary type when it is operated from an alternating current source.

LOCAL BATTERY TYPE TELEPHONE



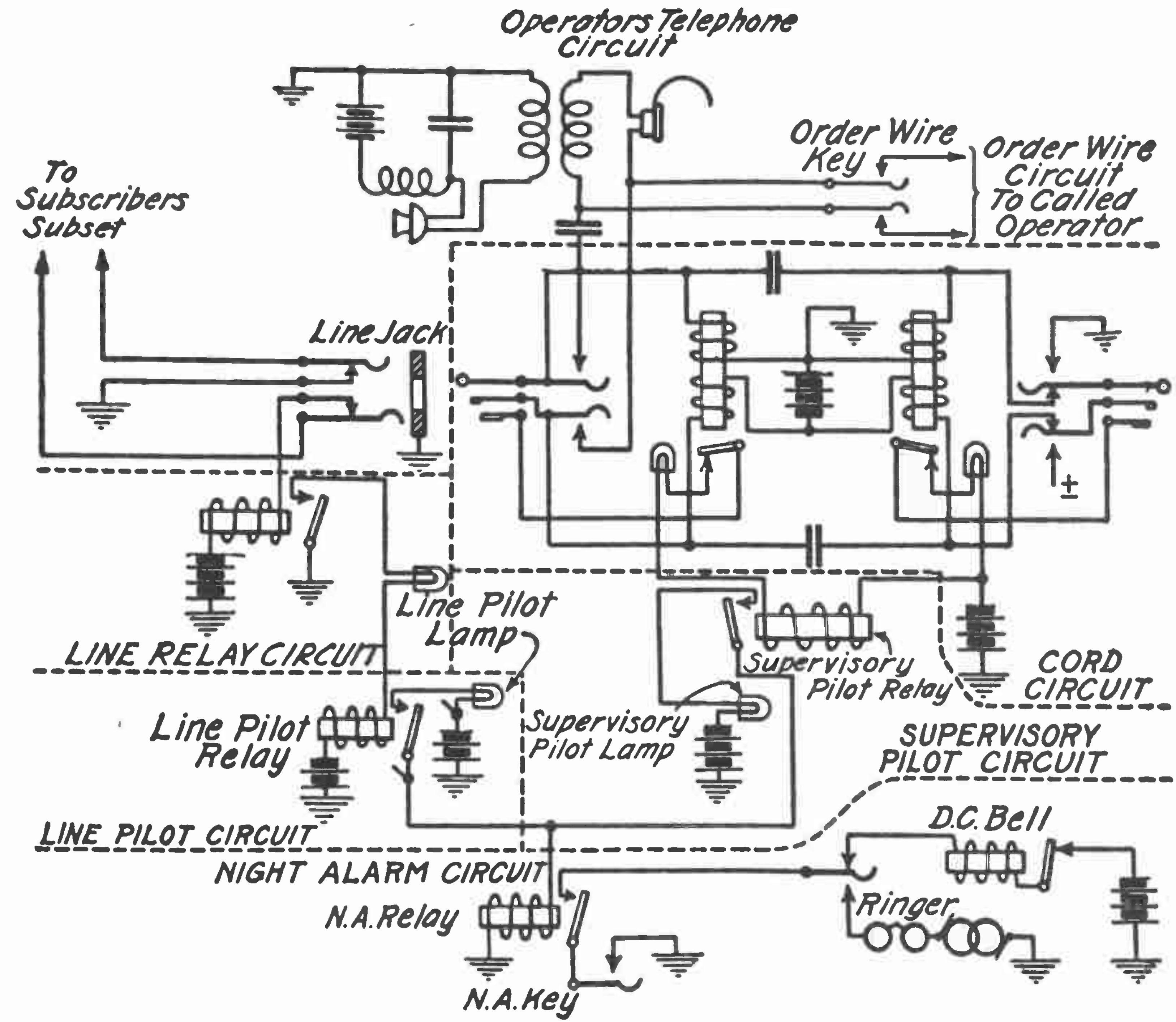
CENTRAL ENERGY TYPE TELEPHONE



This is a comparison of Local Battery Telephone, and the Central Energy Telephone each with a magneto ringer.

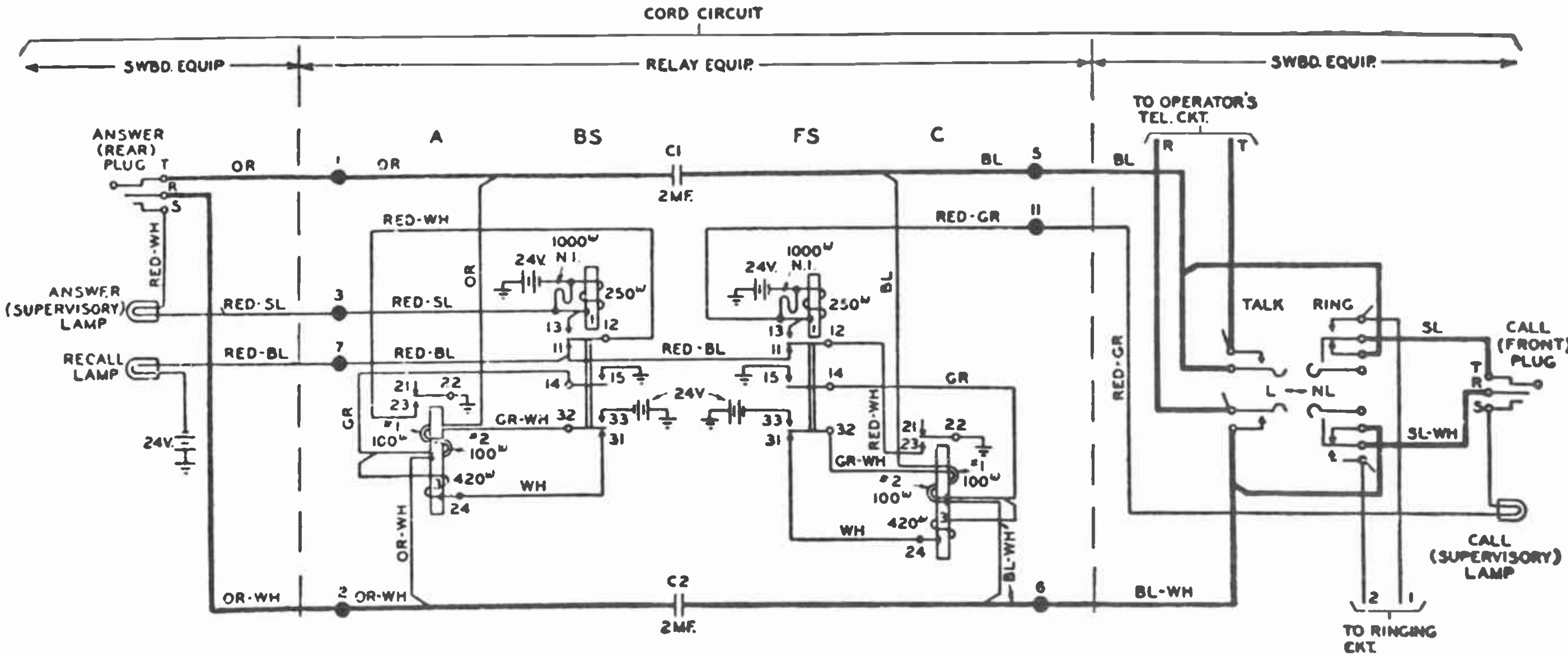
The purpose of the condenser in the Central Energy Telephone is to prevent the D.C. of the transmitter circuit flowing through the receiver circuit, but still permitting the A.C. for ringing and the receiver circuit.

When ringing is done from a central source the magneto will not be necessary. Instead of connecting the polarized bell to the moving contact, connect it direct to line 1 and eliminate the connection from the receiver to the open contact on the magneto.



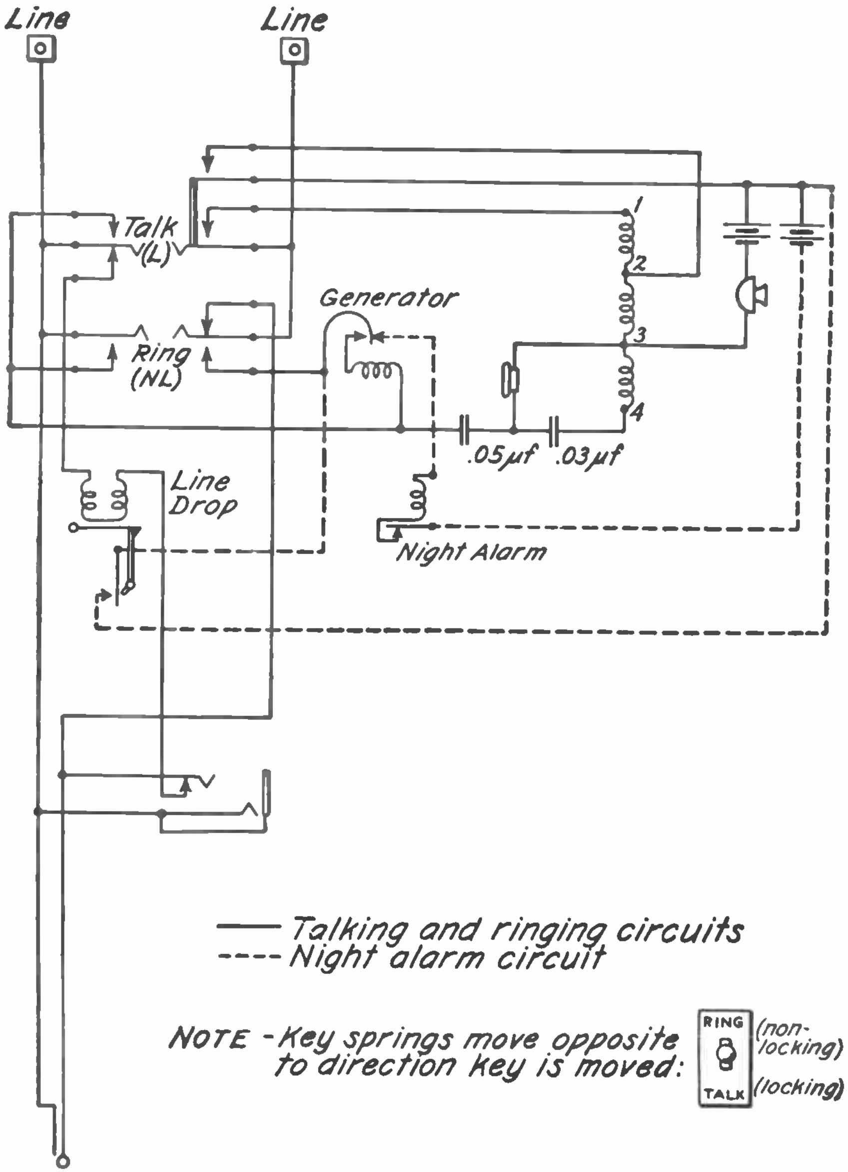
COMMON-BATTERY SWITCHBOARD CIRCUIT

UNIVERSAL CORD CIRCUIT

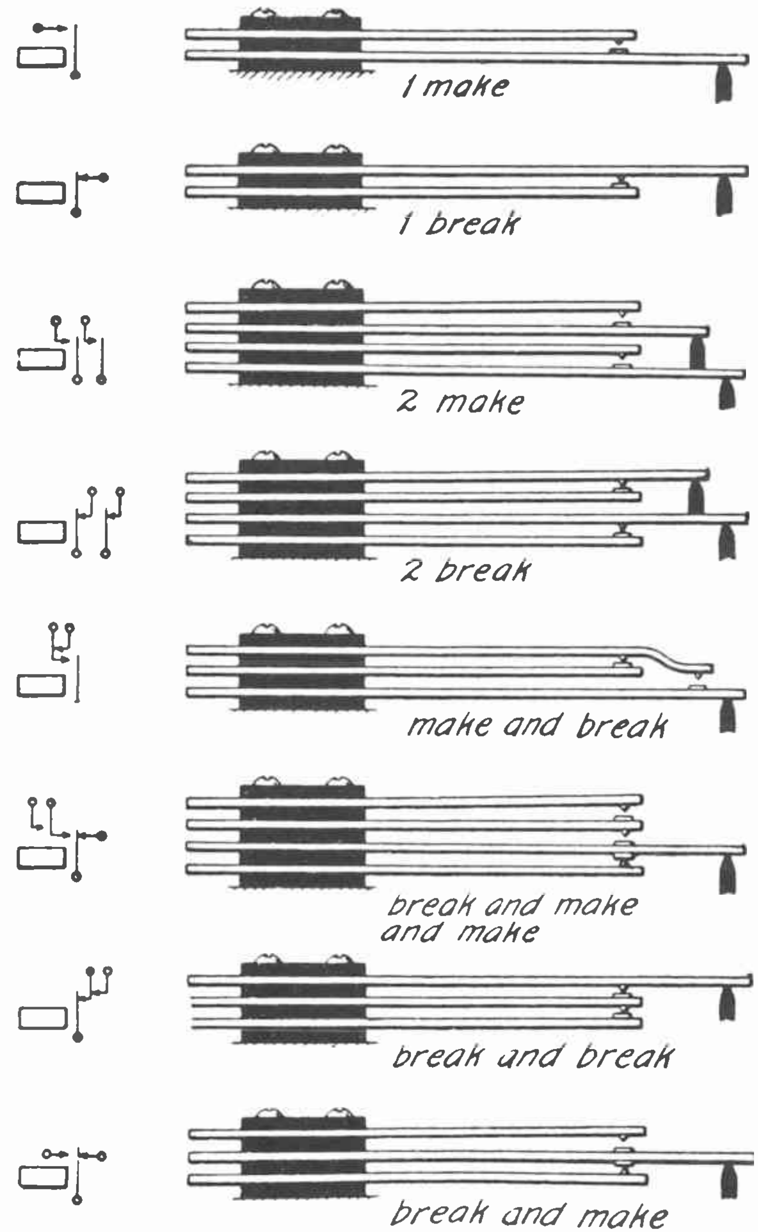


On switchboards having both common-battery and local battery lines it is necessary to have a cord circuit which will supply battery to the common-battery lines and not to the local-battery lines. It must also furnish a talking channel between two subscribers whether either or both lines are common-battery or local-battery. A cord circuit which will do this is called a universal cord circuit. In its usual form a full universal cord circuit uses eight or ten relays in each cord circuit. The above diagram shows a simplified circuit having fewer relays.

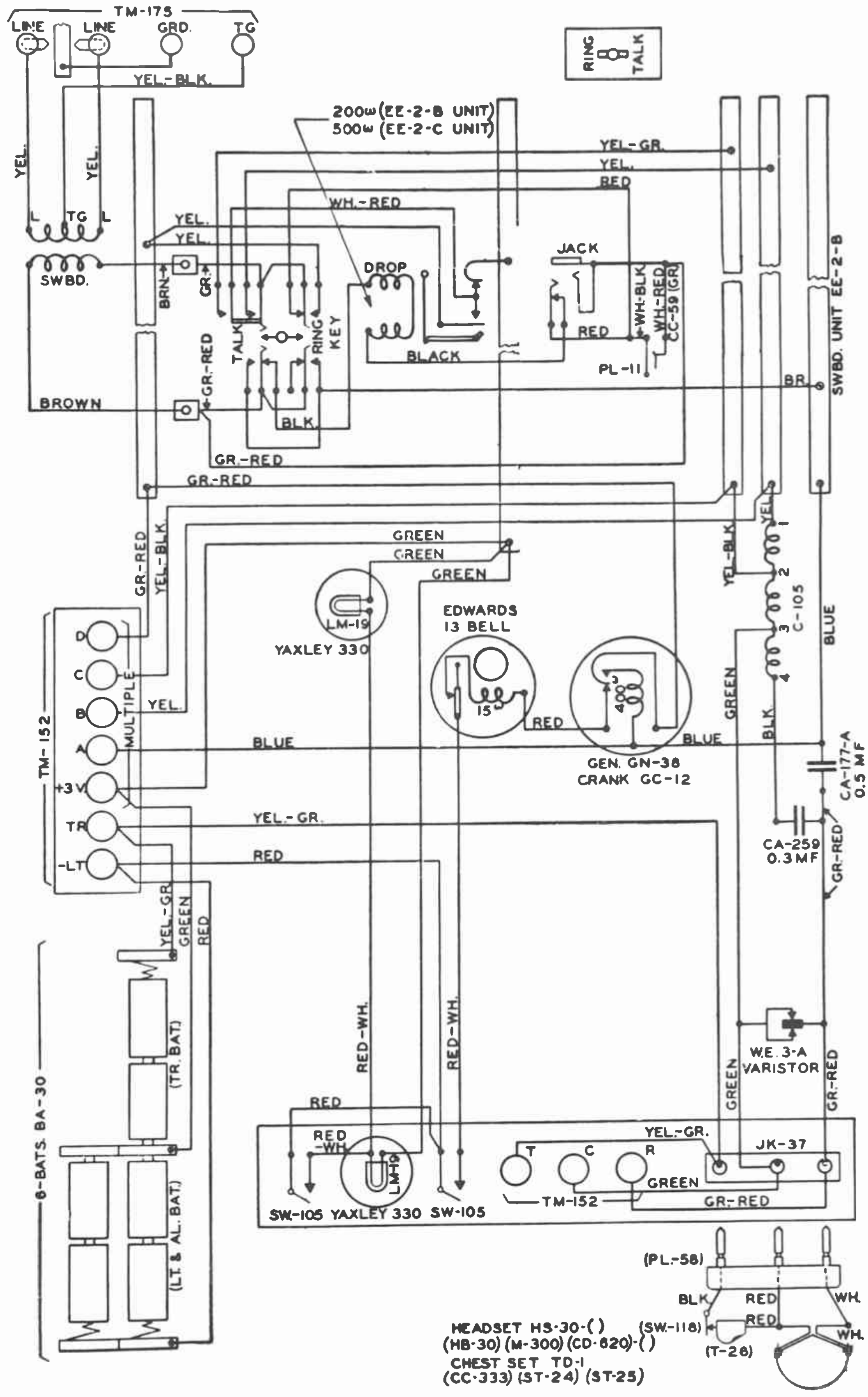
SWITCHBOARD UNIT WITH OPERATOR'S SET AND NIGHT ALARM



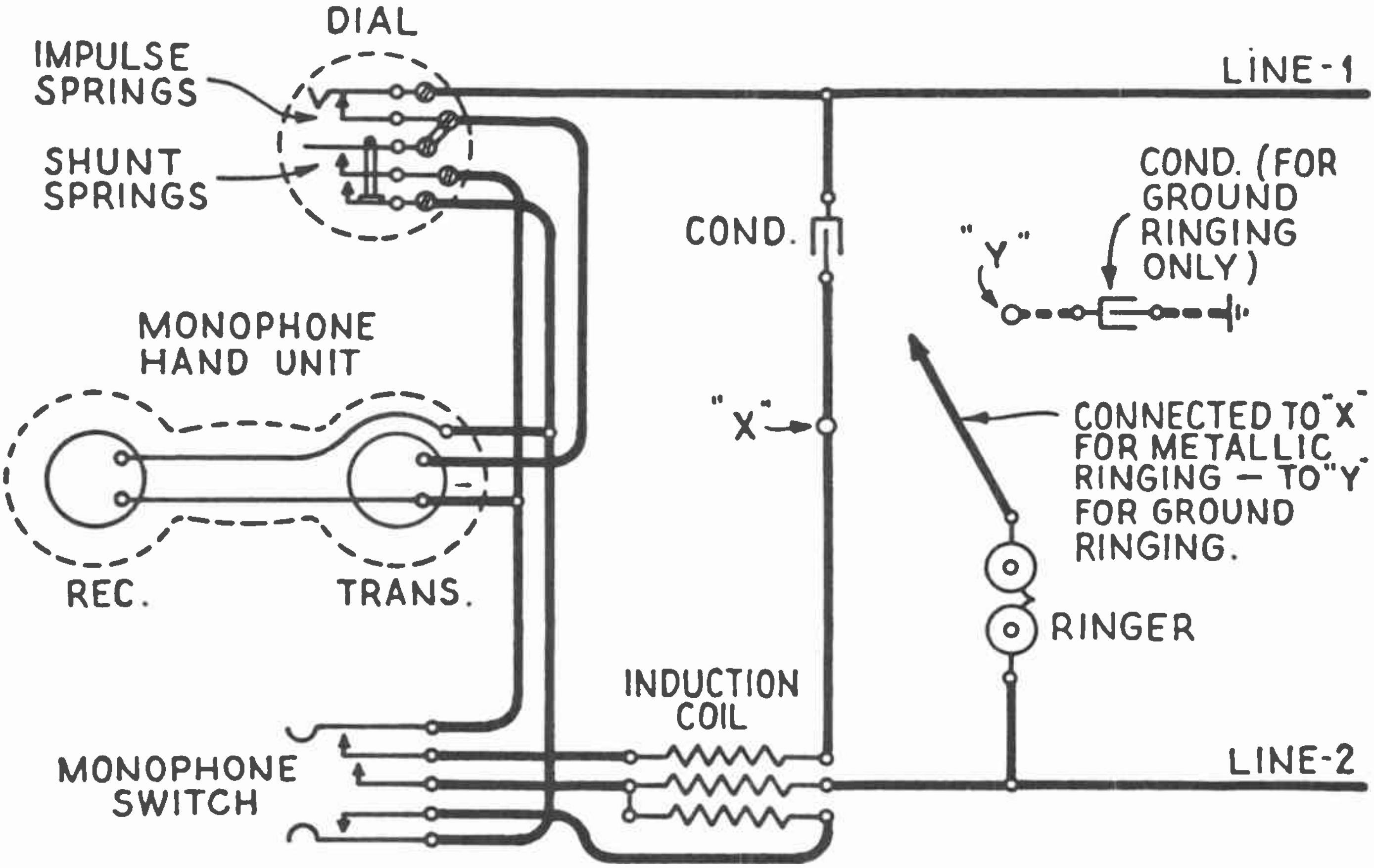
CONTACTS FOR TELEPHONE RELAYS



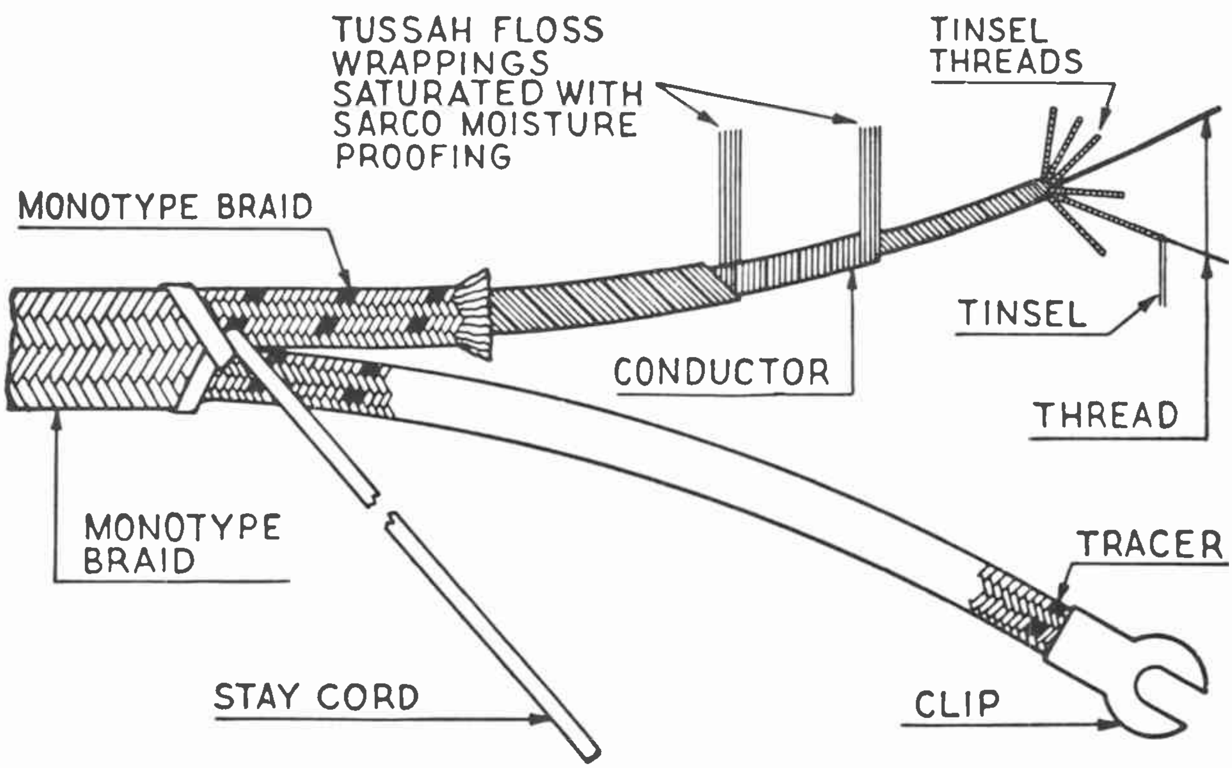
TELEPHONE SWITCHBOARD - PORTABLE MONOCORD MAGNETO TYPE



AUTOMATIC ELECTRIC COMPANY

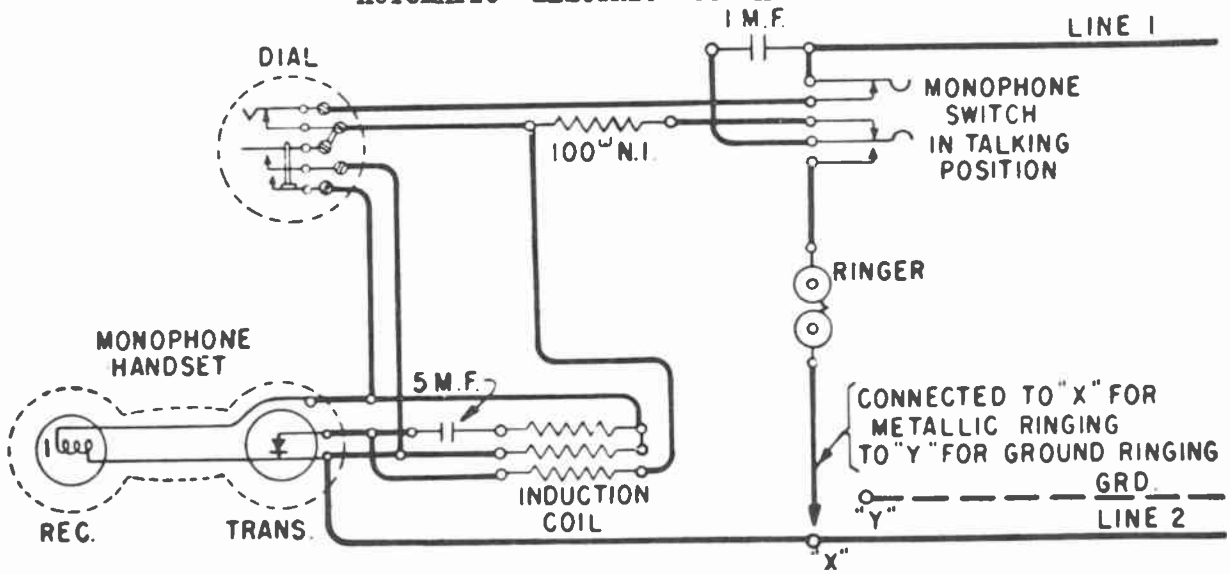


CIRCUIT OF TYPE 1A MONOPHONE AND ASSOCIATED RINGER BOX

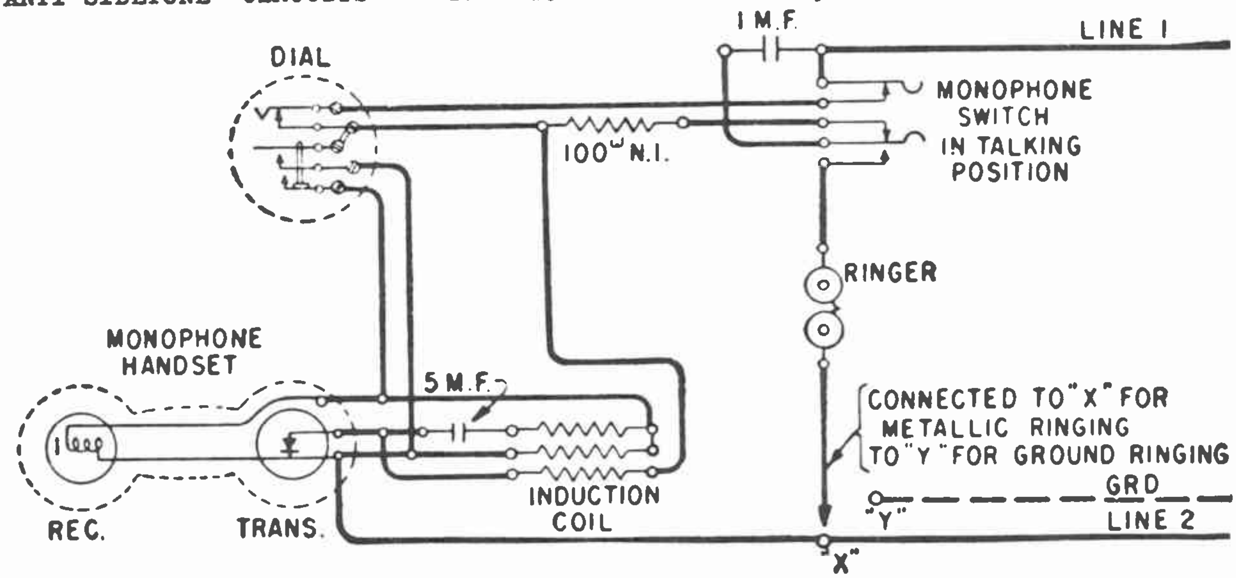


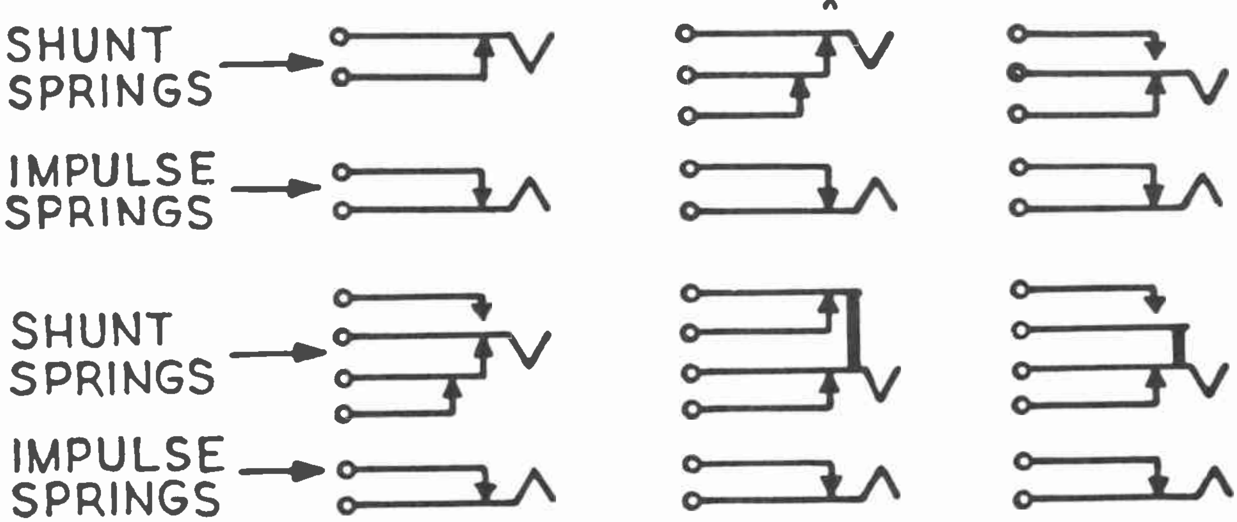
MONOTYPE CORD CONSTRUCTION

AUTOMATIC ELECTRIC COMPANY



ANTI-SIDETONE CIRCUITS - TYPE 40 MONOPHONE ABOVE, TYPE 50 MONOPHONE BELOW

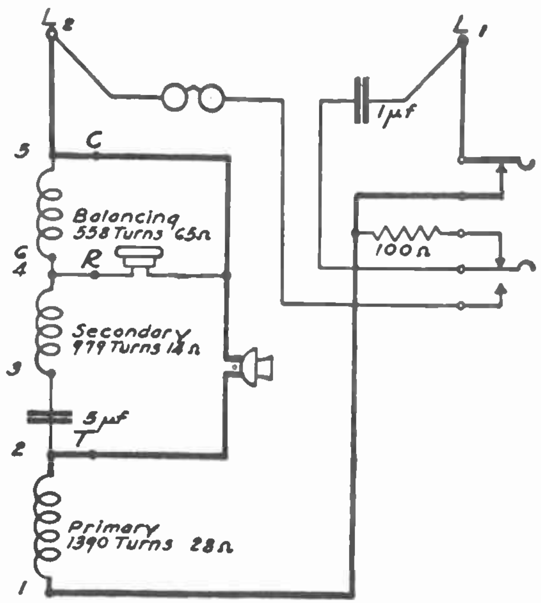


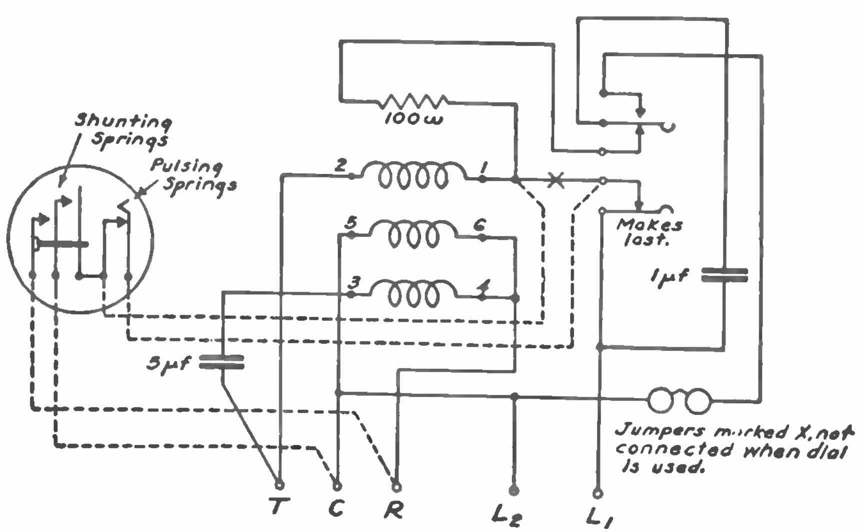


DIAL SPRING ASSEMBLIES

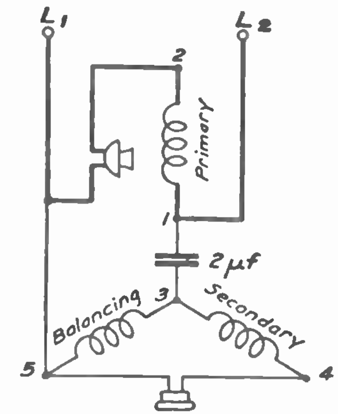
(Shunt springs shown in off-normal position)

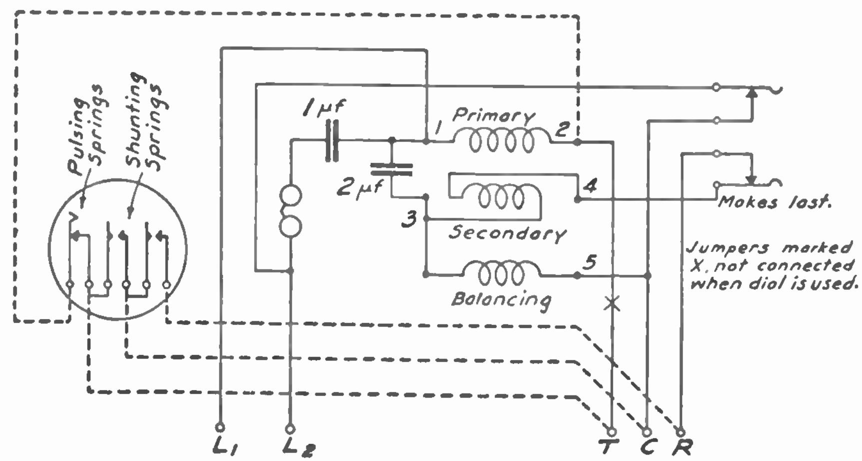
AUTOMATIC ELECTRIC CO. MONOPHONE TYPE 40-AA-52



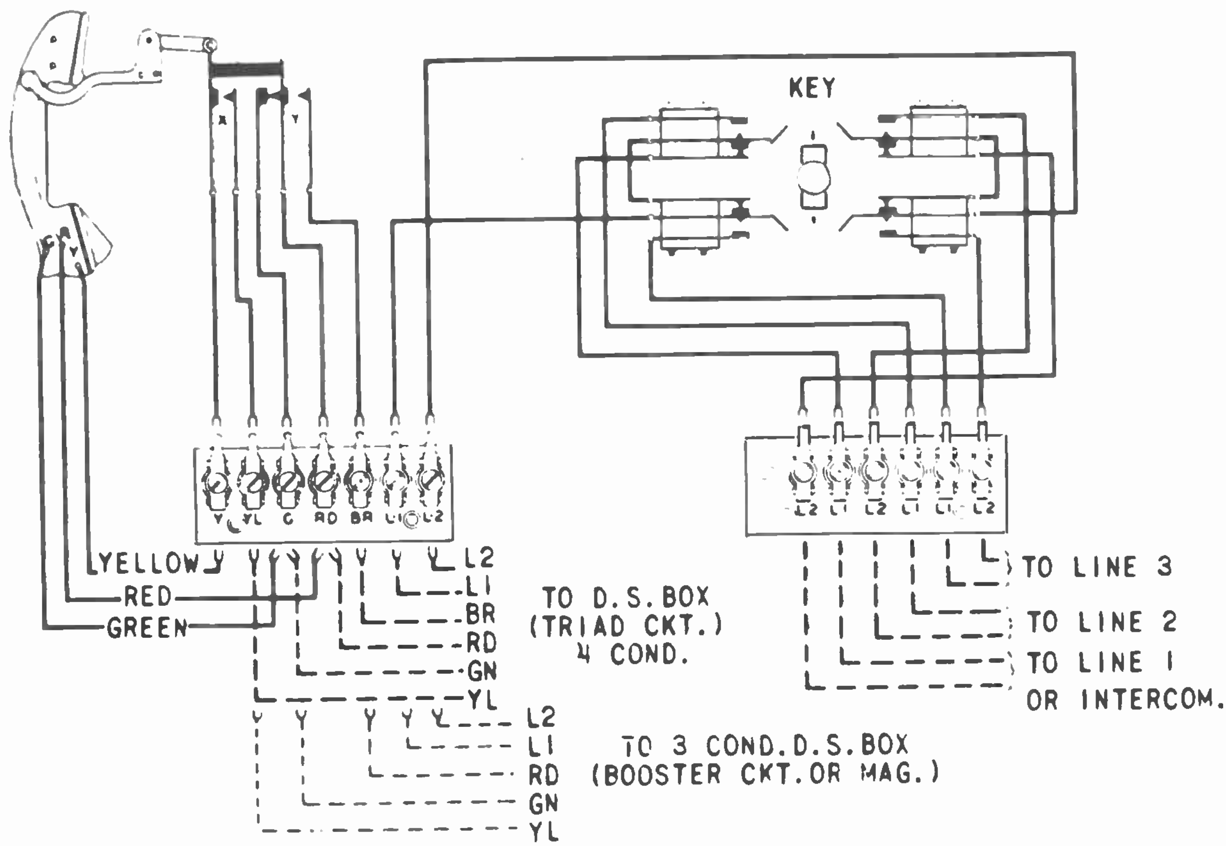


KELLOGG CO. "MASTERPHONE"

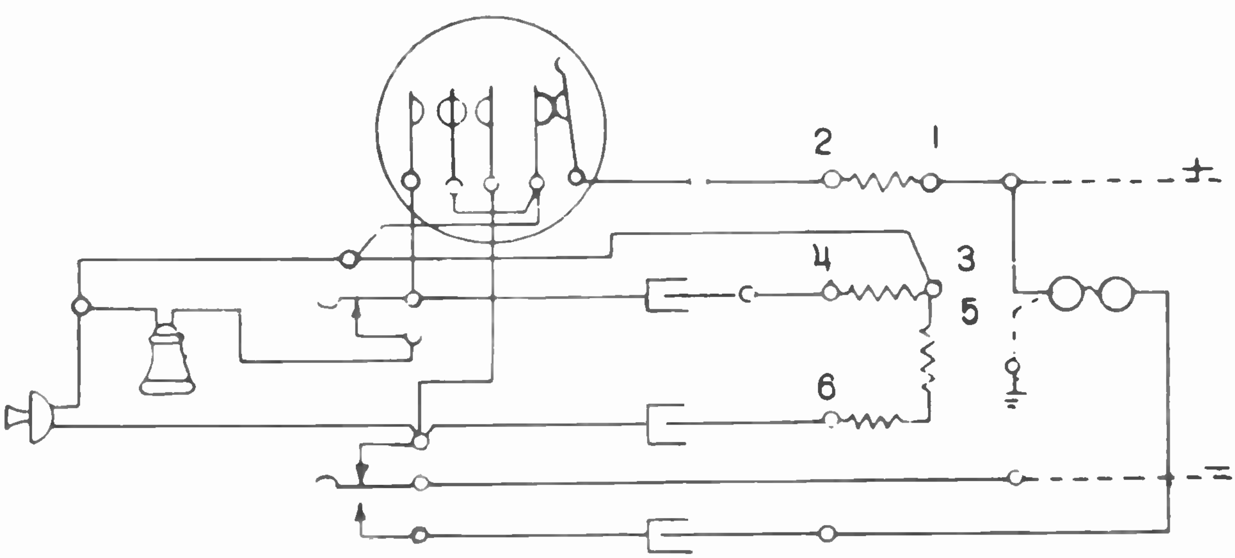




KELLOGG MASTERPHONE

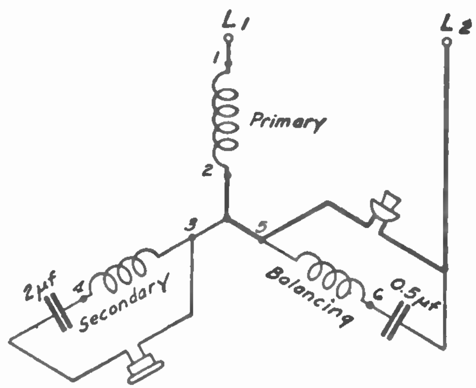


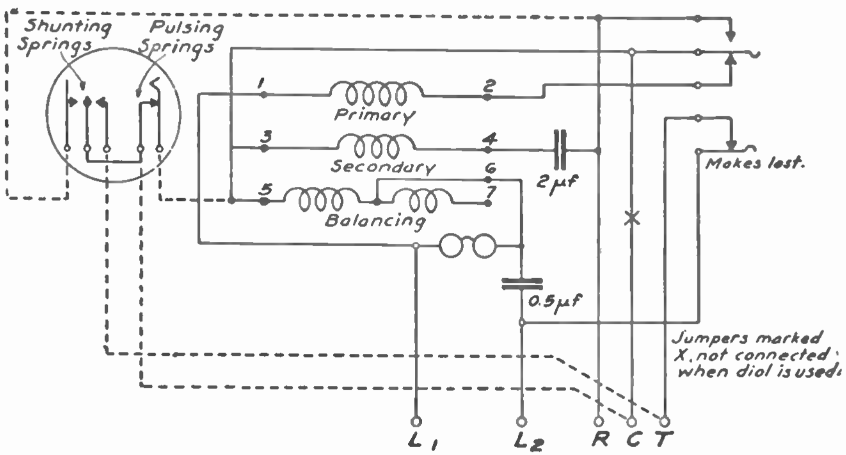
WITH SWITCHING KEY, MANUAL SERVICE - COMMON OR LOCAL BATTERY



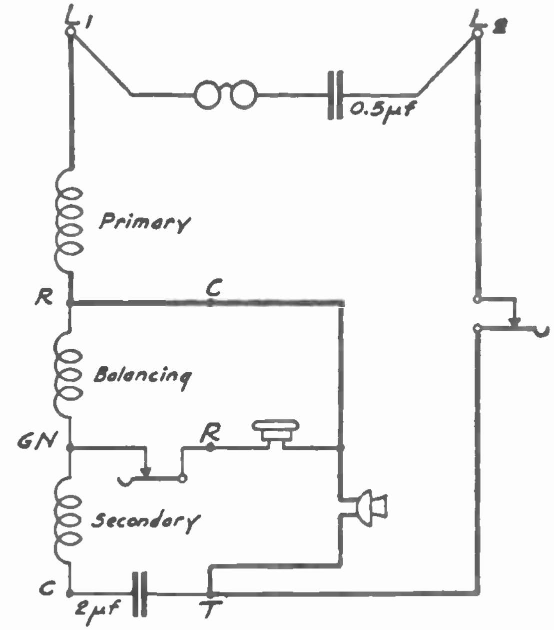
MASTERPHONE CIRCUIT - "X" TYPE - SCHEMATIC DIAGRAM

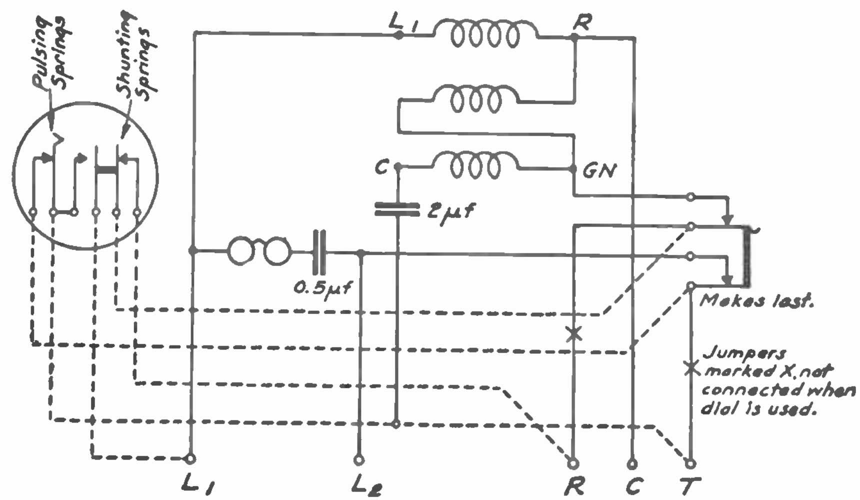
STROMBERG-CARLSON TELEPHONE 1212 ABZ

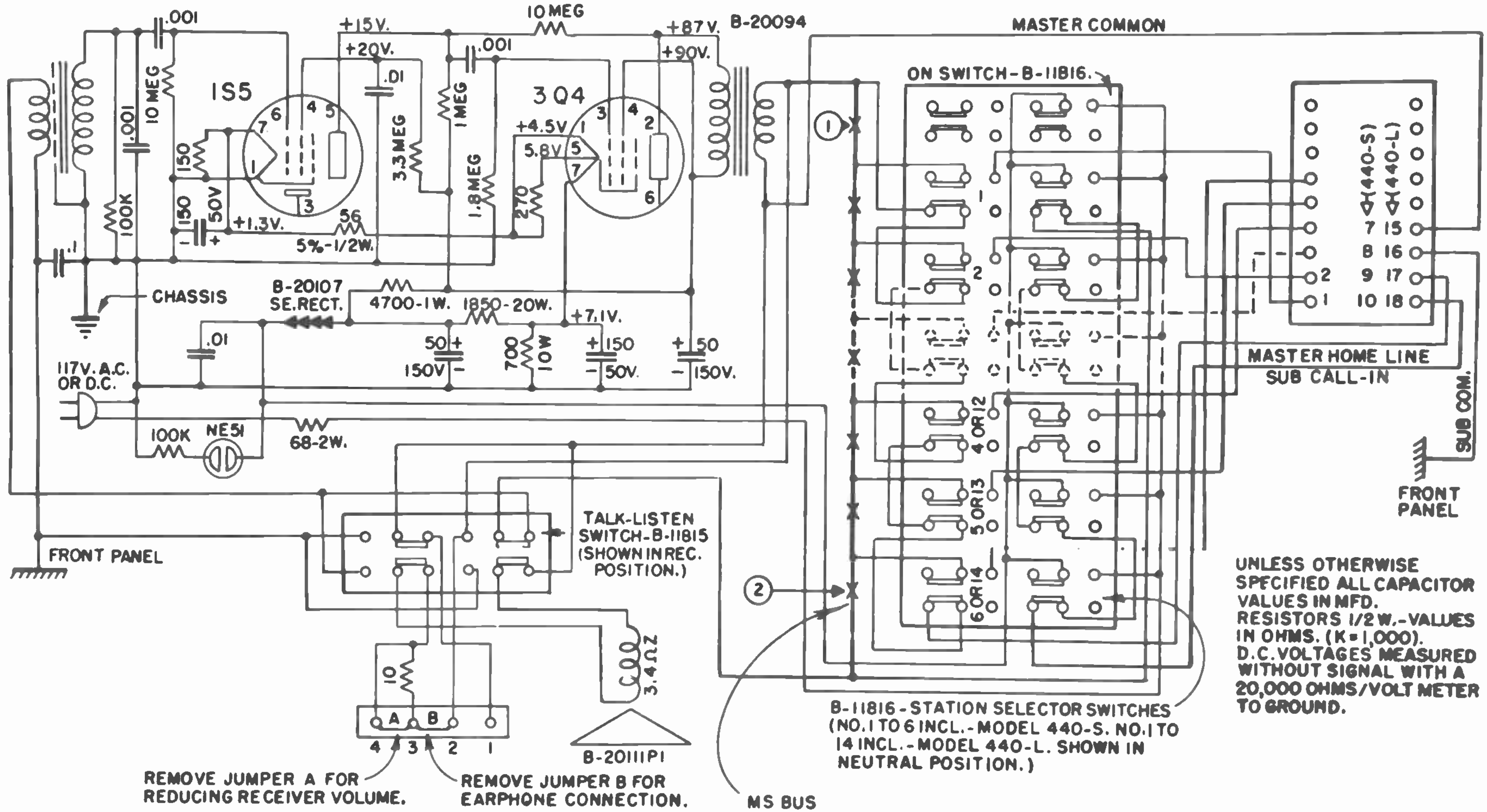




WESTERN ELECTRIC CO. No. 302 SET



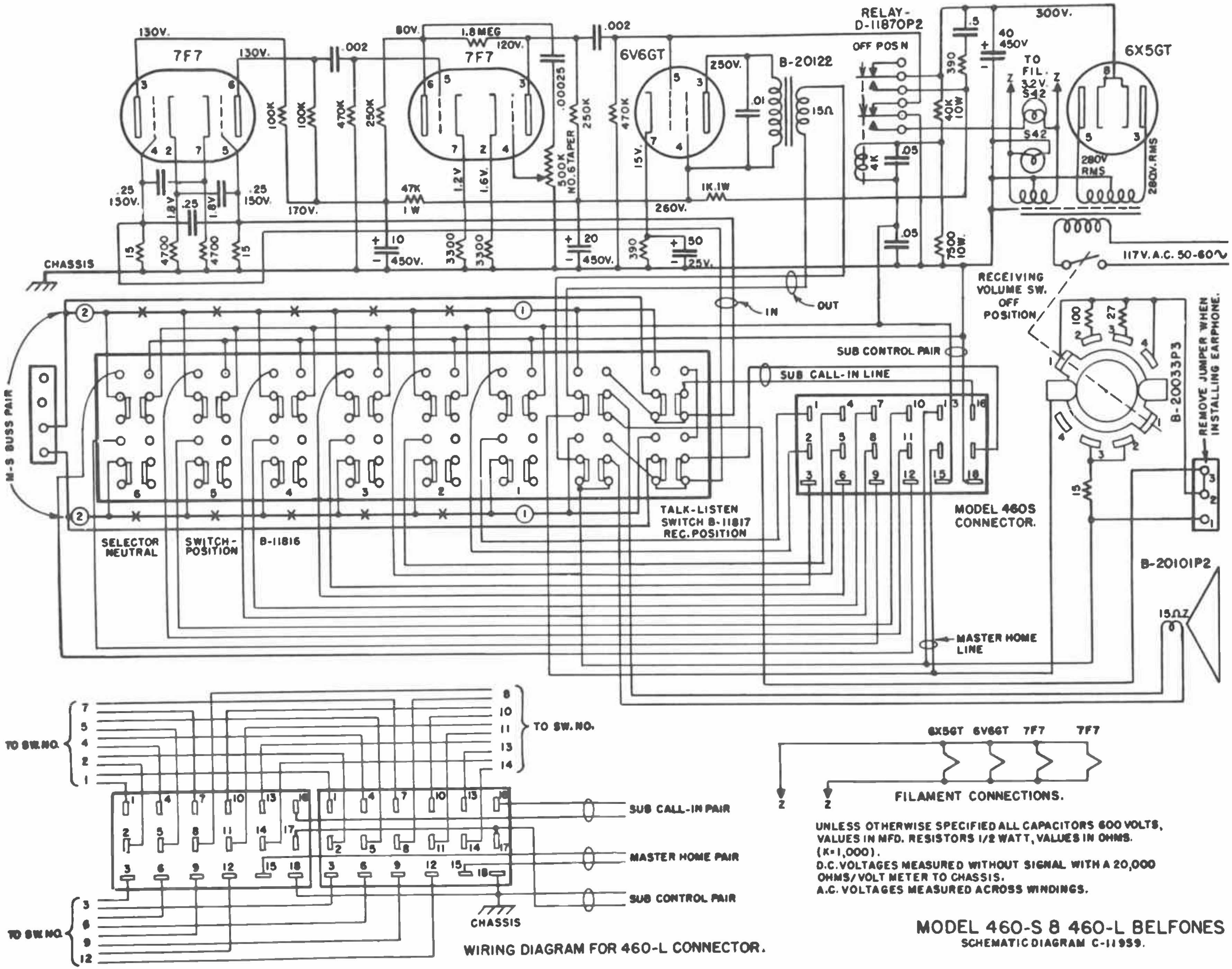




UNLESS OTHERWISE SPECIFIED ALL CAPACITOR VALUES IN MFD.
RESISTORS 1/2 W.-VALUES IN OHMS. (K=1,000).
D.C. VOLTAGES MEASURED WITHOUT SIGNAL WITH A 20,000 OHMS/VOLT METER TO GROUND.

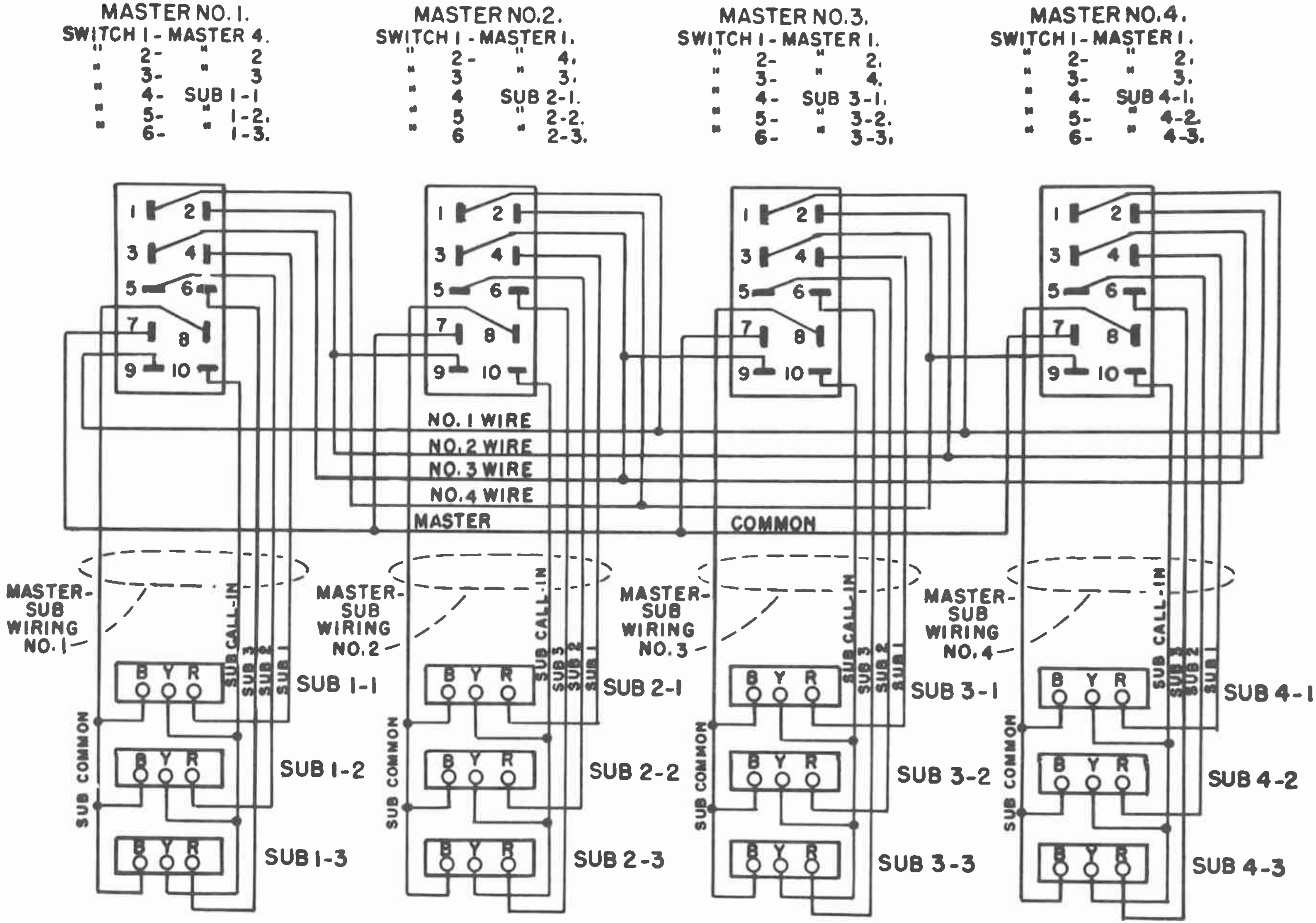
IMPORTANT- MS BUSS MUST BE BROKEN AT ONE OF POINTS MARKED X.
DISCONNECT POWER CORD BEFORE SERVICING. SEE INSTRUCTION MANUAL.

MODEL 440-S & 440-L BELFONES.



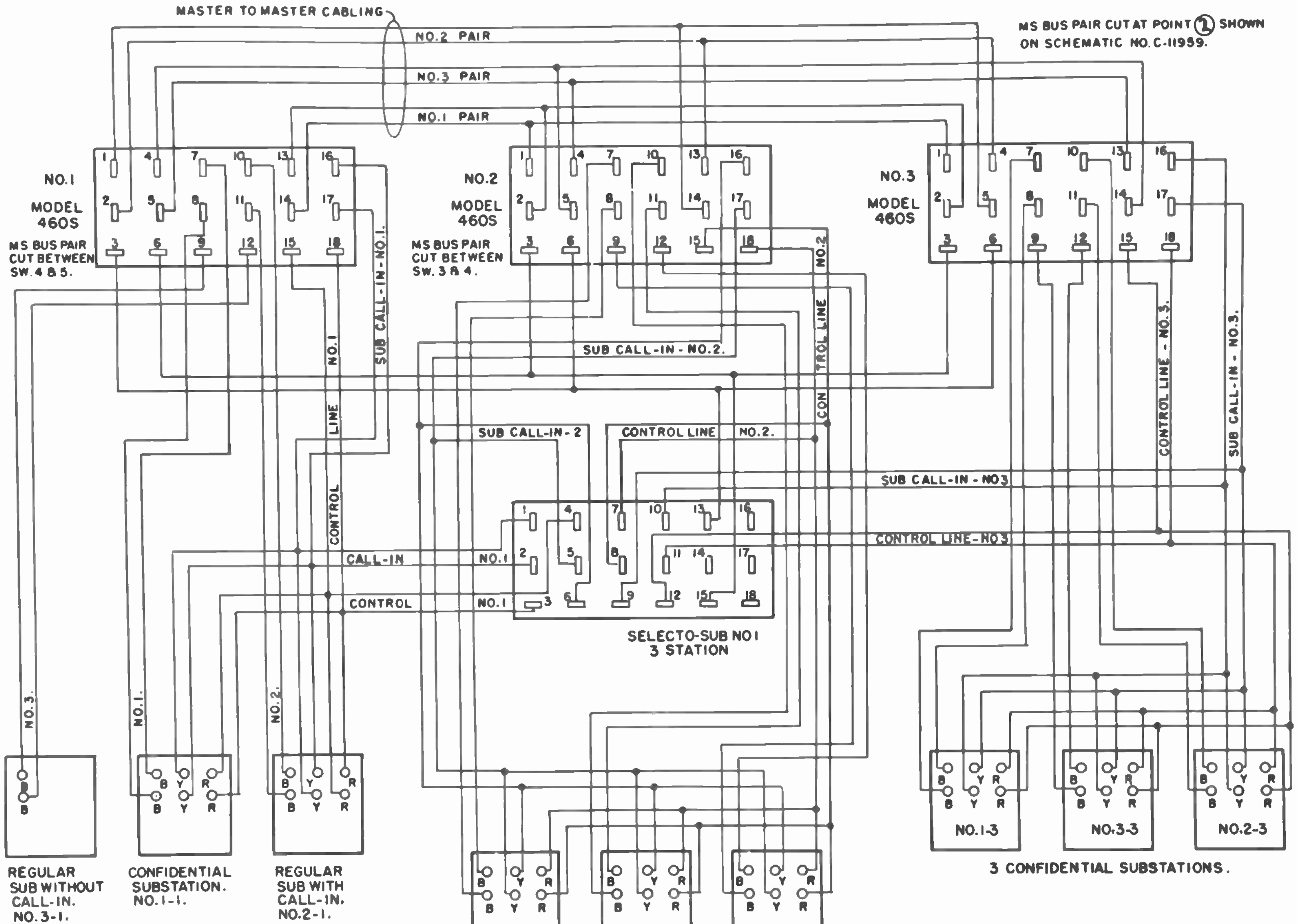
UNLESS OTHERWISE SPECIFIED ALL CAPACITORS 600 VOLTS, VALUES IN MFD. RESISTORS 1/2 WATT, VALUES IN OHMS. (K=1,000).
D.C. VOLTAGES MEASURED WITHOUT SIGNAL WITH A 20,000 OHMS/VOLT METER TO CHASSIS.
A.C. VOLTAGES MEASURED ACROSS WINDINGS.

MODEL 460-S & 460-L BELFONES
SCHEMATIC DIAGRAM C-11959.



MIXED MASTER & SUBSTATION SYSTEM USING 4 MODEL 440-S UNITS, EACH MASTER HAVING COMMUNICATION WITH 3 MASTERS & 3 SUBSTATIONS.

B-BLACK Y-YELLOW R-RED



NO 1 MASTER.

MASTER	SWITCH NO. 1 CALLS STATION 2. SWITCH NO. 2 CALLS STATION 3.
SELECTO SUB	SWITCH NO 3 CALLS SELECTO SUB 1.
CONFIDENTIAL	SWITCH NO 4 CALLS CONFIDENTIAL SUB 1.
REGULAR SUB	SWITCH NO 5 CALLS SUB 2-1. SWITCH NO 6 CALLS SUB 3-1.

NO.2 MASTER.

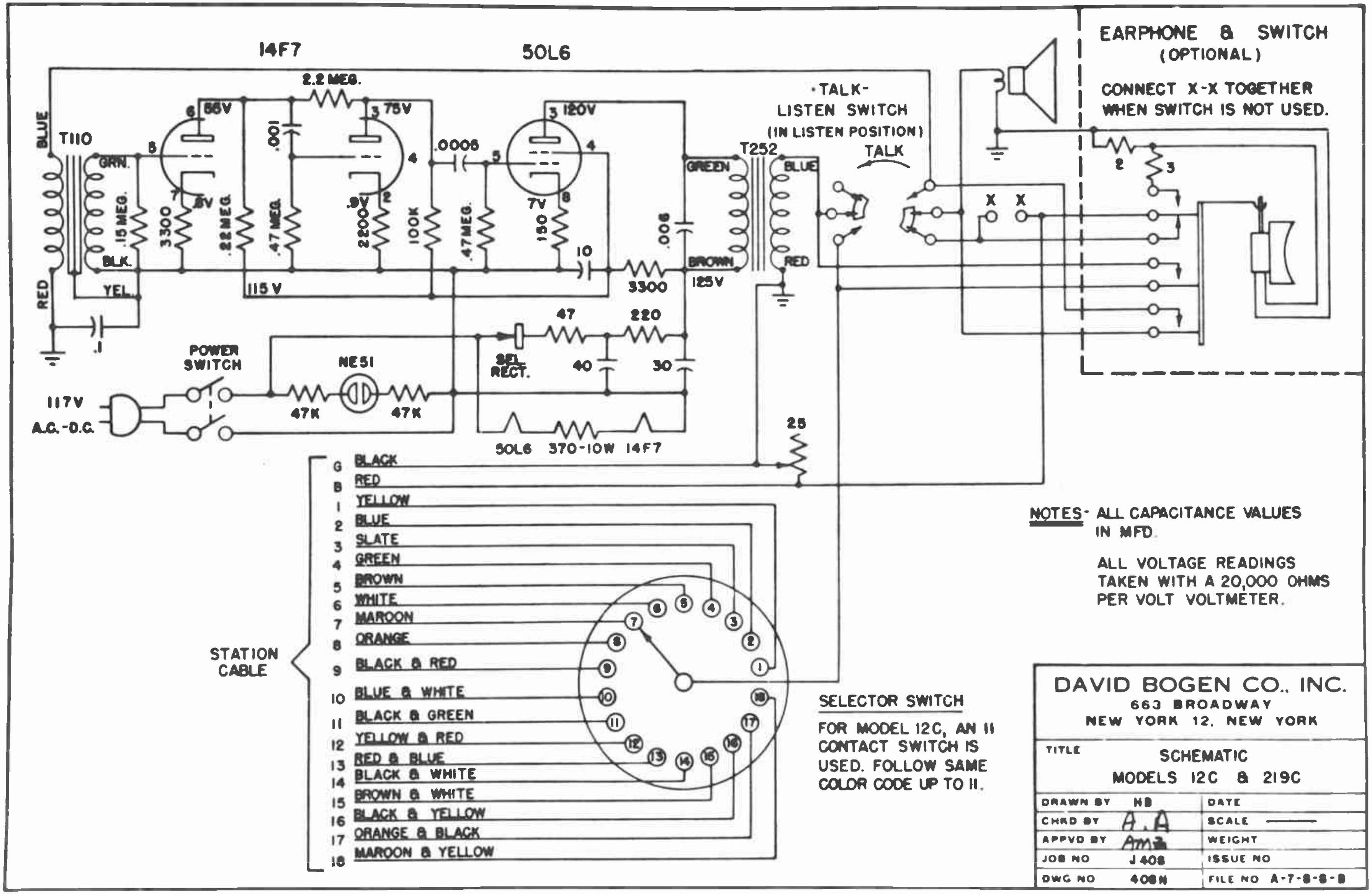
MASTER	SWITCH NO. 1 CALLS STATION 1. SWITCH NO. 2 CALLS STATION 3.
SELECTO SUB	SWITCH NO. 3 CALLS SELECTO SUB 1.
REGULAR SUB	SWITCH NO. 4 CALLS SUB 1-2 SWITCH NO 5 CALLS SUB 2-2 SWITCH NO. 6 CALLS SUB 3-2.

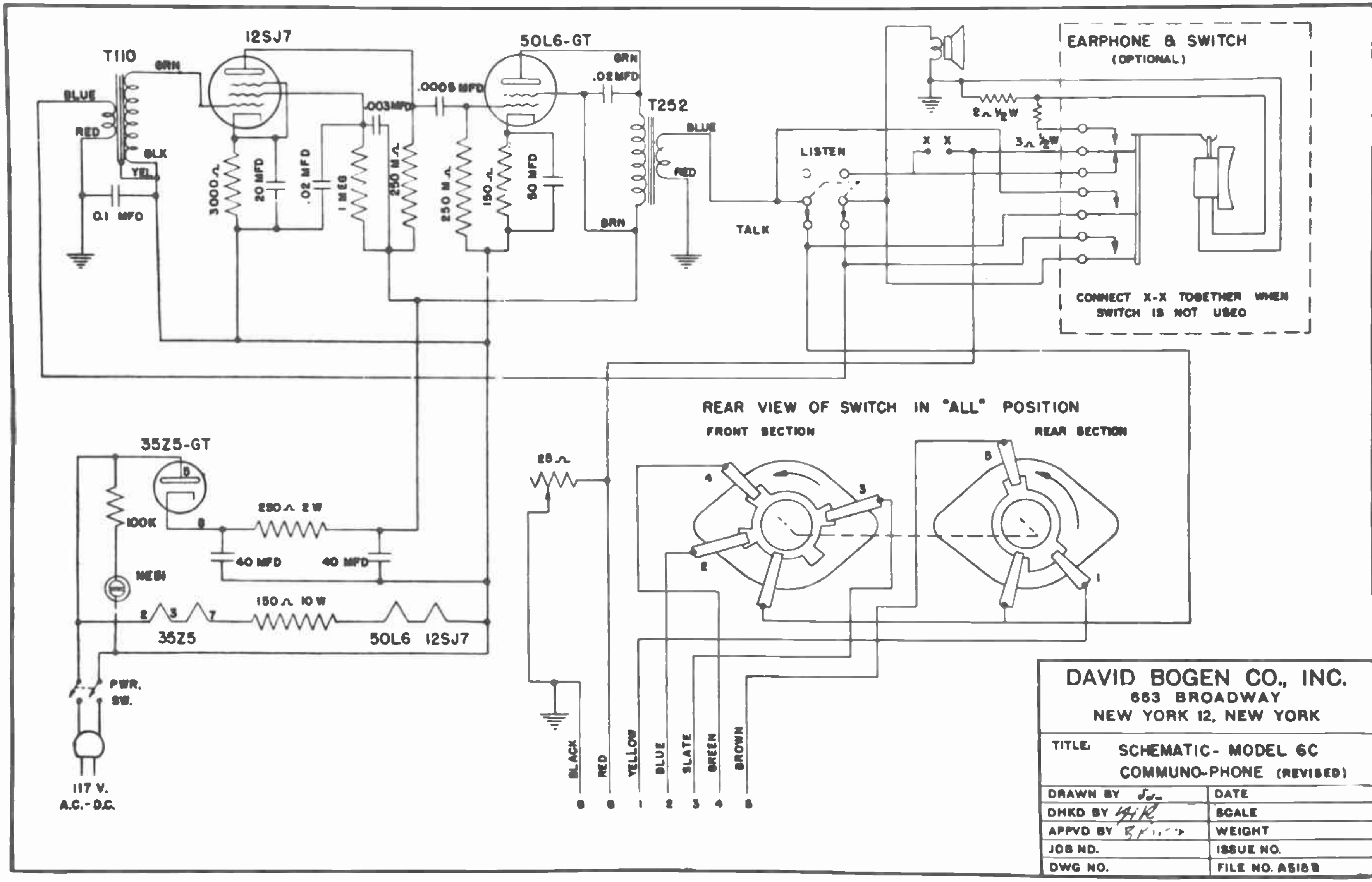
NO.3 MASTER.

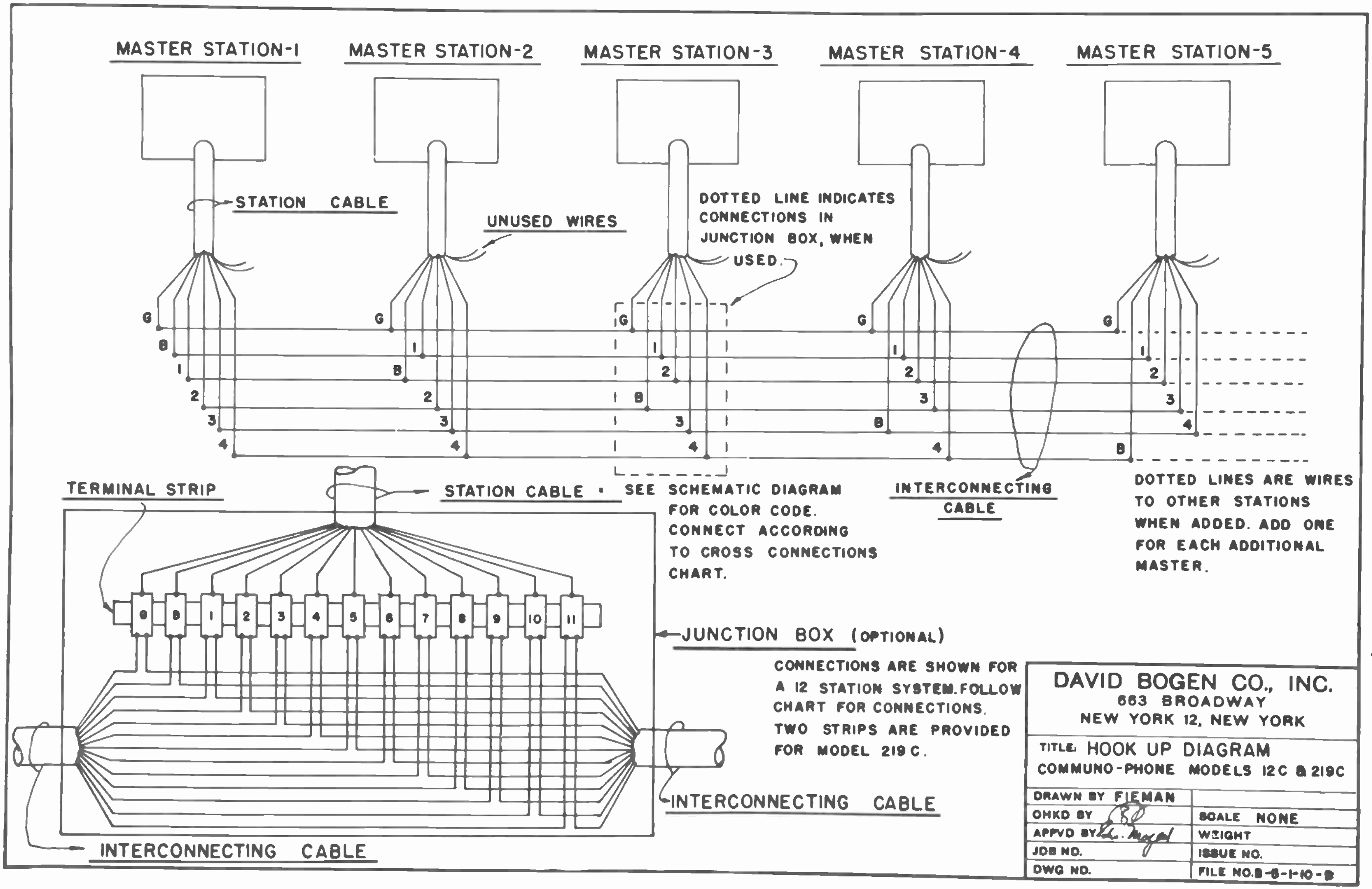
MASTER	SWITCH NO. 1 CALLS STATION 1. SWITCH NO. 2 CALLS STATION 2.
SELECTO SUB	SWITCH NO. 3 CALLS SELECTO SUB 1.
CONFIDENTIAL	SWITCH NO. 4 CALLS CONFIDENTIAL SUB 1-3. SWITCH NO. 5 CALLS CONFIDENTIAL SUB 2-3. SWITCH NO. 6 CALLS CONFIDENTIAL SUB 3-3.

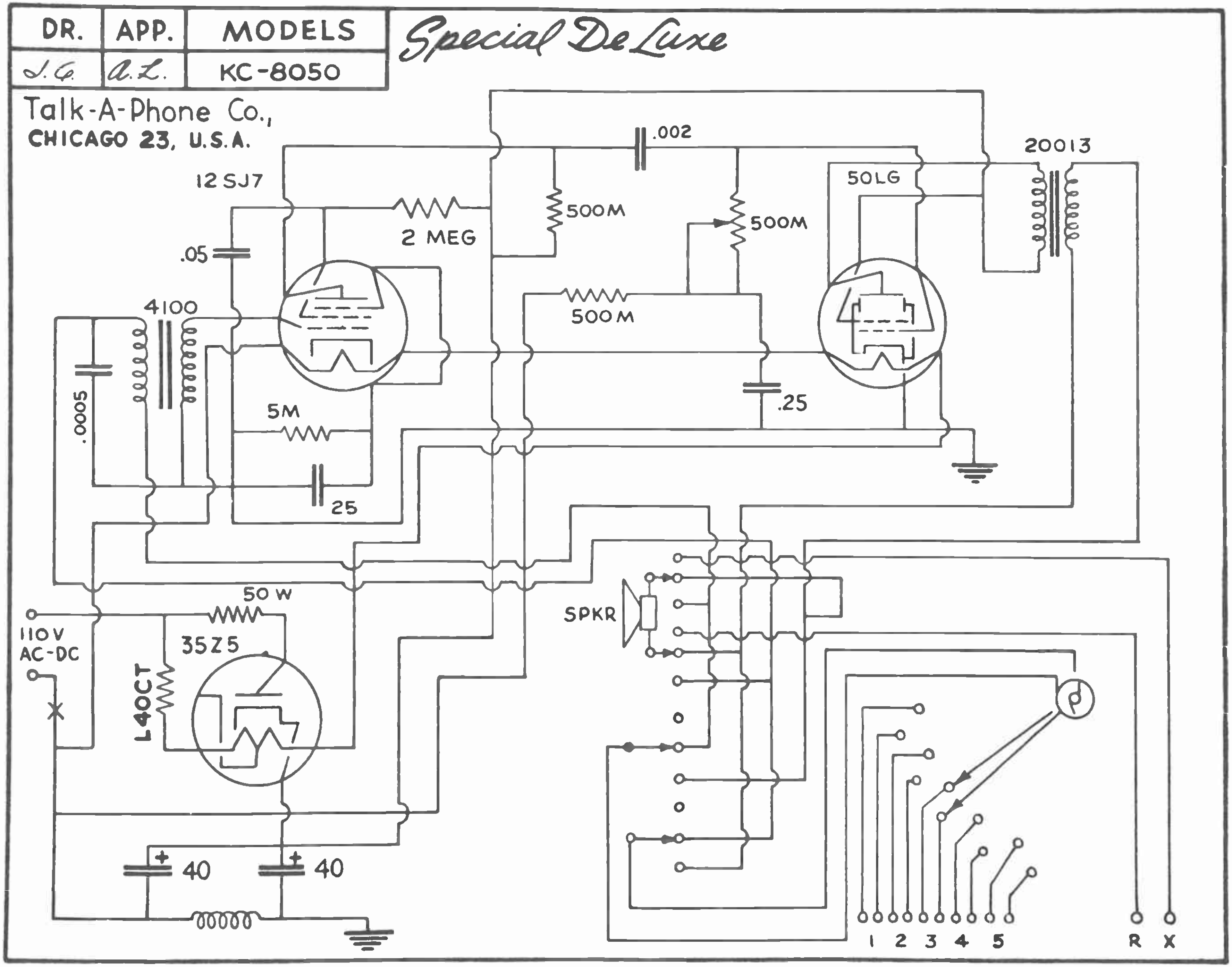
MODELS 460S, 464-3, 465 & 468.

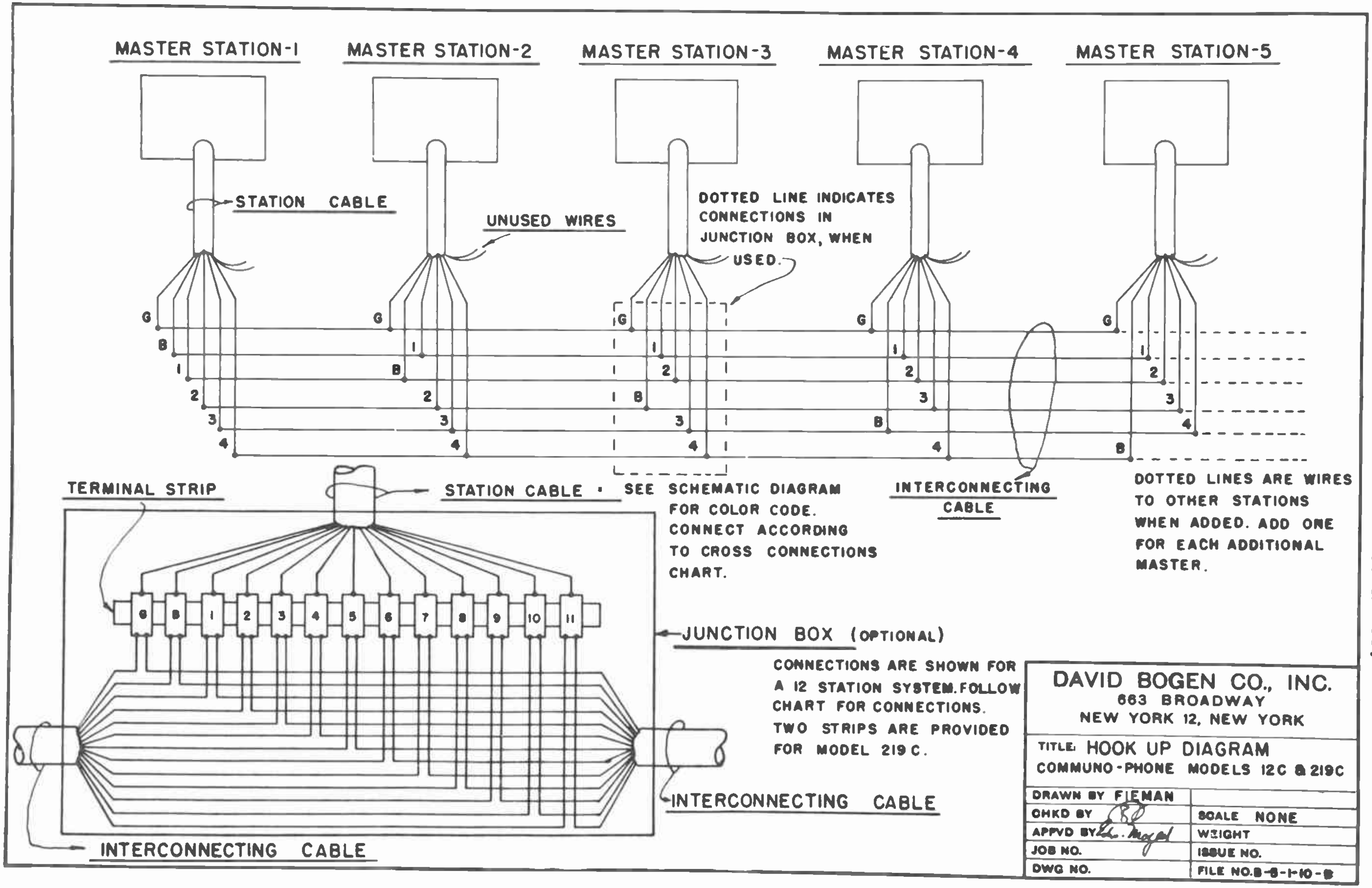
INTERCONNECTION DIAGRAM C-11961.

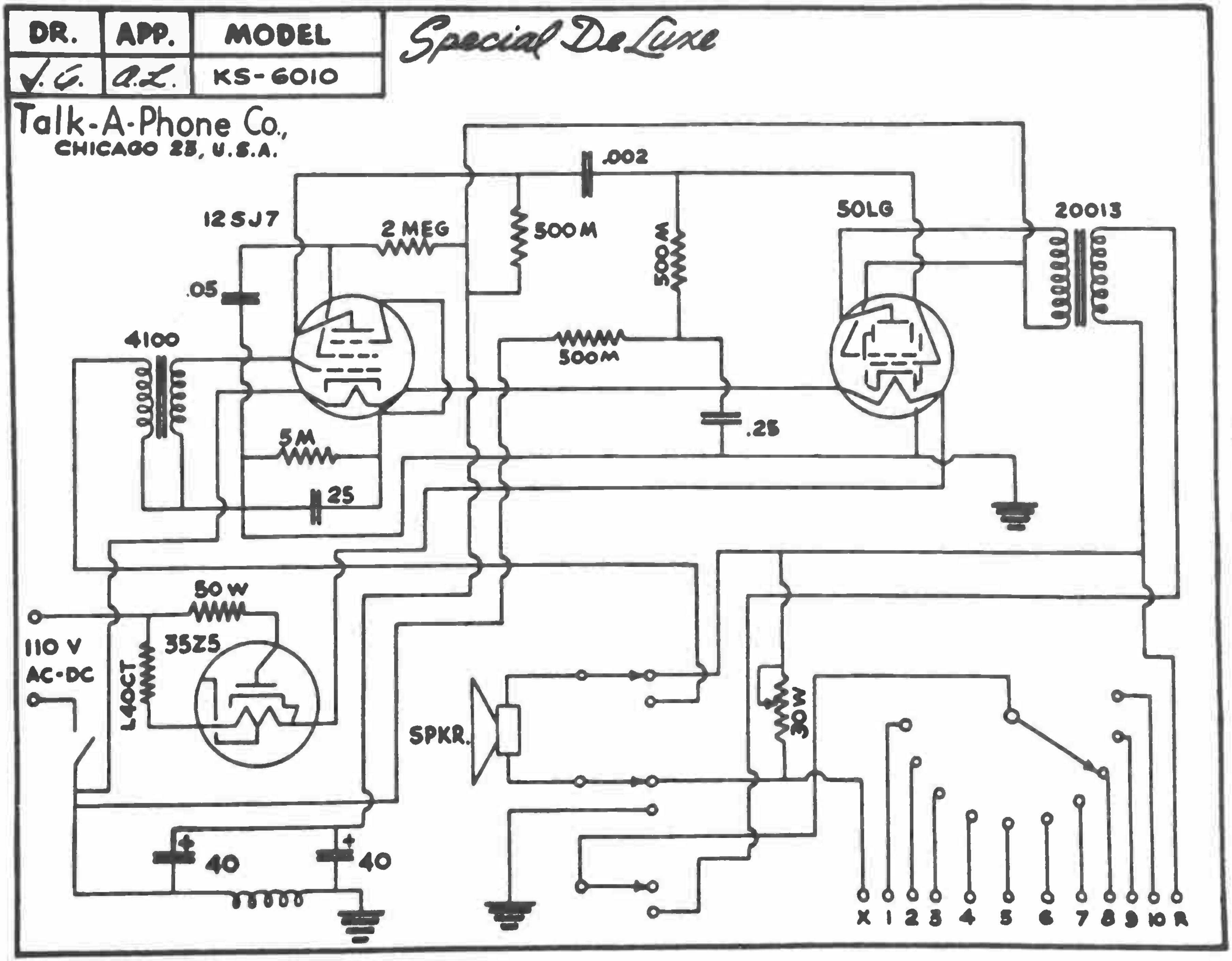

14F7
50L6
2.2 MEG.
.0005
T110
BLUE
RED
GRN.
BLK.
YEL.
.15 MEG.
3300
.22 MEG.
.47 MEG.
2200
100K
150
.006
10
3300
115 V
125V
T252
GREEN
BROWN
BLUE
RED
·TALK-
LISTEN SWITCH
(IN LISTEN POSITION)
TALK
EARPHONE & SWITCH
(OPTIONAL)
CONNECT X-X TOGETHER
WHEN SWITCH IS NOT USED.
X X
47
220
SEL.
RECT.
40
30
POWER
SWITCH
NE51
117V
A.C.-D.C.
47K
47K
50L6 370-10W 14F7
25
STATION
CABLE
G BLACK
B RED
1 YELLOW
2 BLUE
3 SLATE
4 GREEN
5 BROWN
6 WHITE
7 MAROON
8 ORANGE
9 BLACK & RED
10 BLUE & WHITE
11 BLACK & GREEN
12 YELLOW & RED
13 RED & BLUE
14 BLACK & WHITE
15 BROWN & WHITE
16 BLACK & YELLOW
17 ORANGE & BLACK
18 MAROON & YELLOW
SELECTOR SWITCH
FOR MODEL 12C, AN 11
CONTACT SWITCH IS
USED. FOLLOW SAME
COLOR CODE UP TO 11.
NOTES- ALL CAPACITANCE VALUES
IN MFD.
ALL VOLTAGE READINGS
TAKEN WITH A 20,000 OHMS
PER VOLT VOLTMETER.
DAVID BOGEN CO., INC.
663 BROADWAY
NEW YORK 12, NEW YORK
TITLE SCHEMATIC
MODELS 12C & 219C
DRAWN BY HB
CHKD BY A.A
APPVD BY
JOB NO J 408
DWG NO 408N
DATE
SCALE
WEIGHT
ISSUE NO
FILE NO A-7-8-8-B

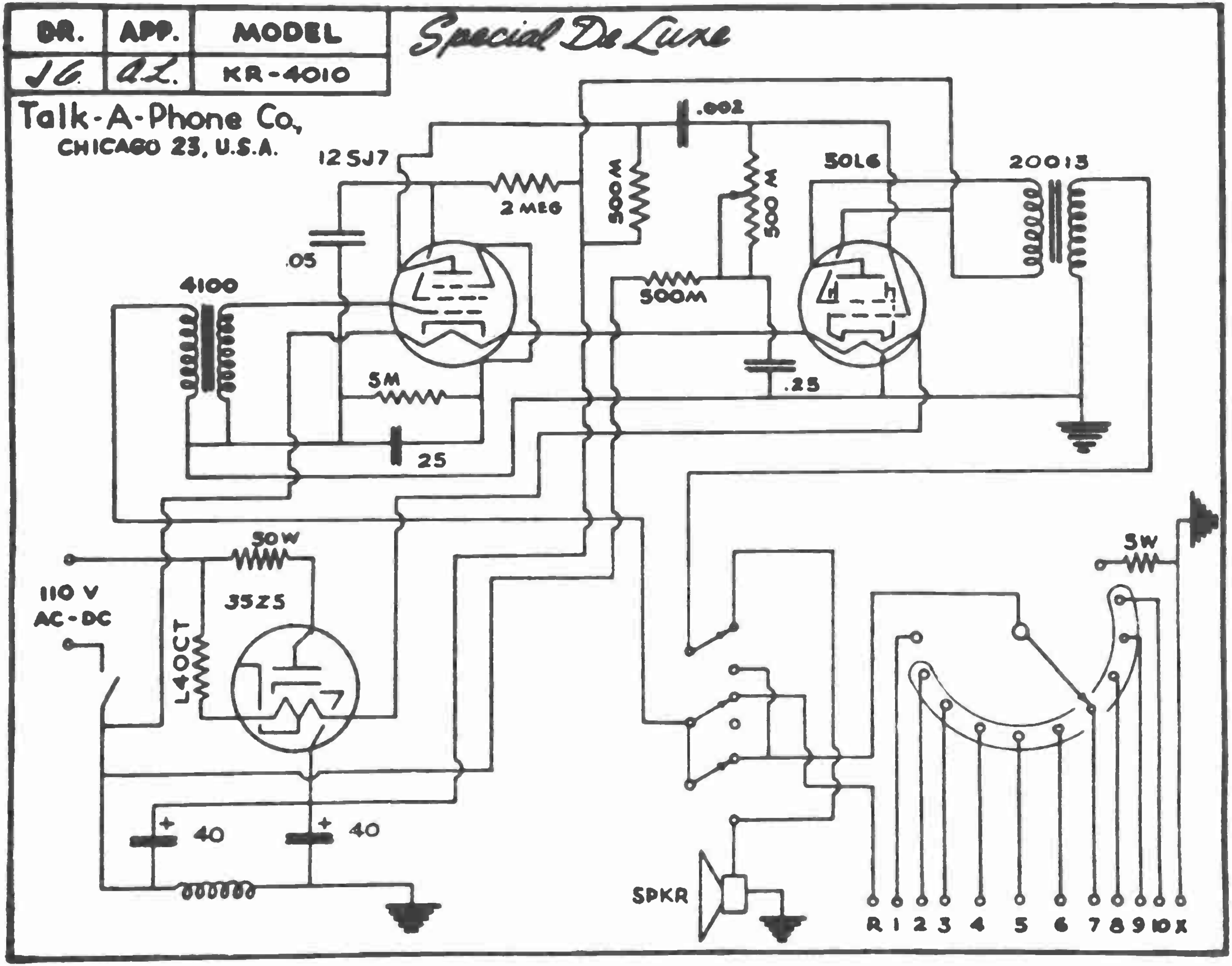

T110
12SJ7
50L6-GT
T252
BLUE
RED
BLK
YEL
GRN
0.1 MFD
3000 Ω
20 MFD
.02 MFD
1 MEG
.003 MFD
250 M Ω
.0005 MFD
250 M Ω
150 Ω
50 MFD
.02 MFD
BRN
EARPHONE & SWITCH
(OPTIONAL)
2 Ω ½ W
3 Ω ½ W
X X
LISTEN
TALK
CONNECT X-X TOGETHER WHEN SWITCH IS NOT USED
35Z5-GT
100K
NE51
250 Ω 2 W
40 MFD
40 MFD
150 Ω 10 W
35Z5
50L6
12SJ7
PWR. SW.
117 V. A.C.-D.C.
REAR VIEW OF SWITCH IN "ALL" POSITION
FRONT SECTION
REAR SECTION
25 Ω
BLACK
RED
YELLOW
BLUE
SLATE
GREEN
BROWN
DAVID BOGEN CO., INC.
663 BROADWAY
NEW YORK 12, NEW YORK
TITLE: SCHEMATIC - MODEL 6C
COMMUNO-PHONE (REVISED)
DRAWN BY
DATE
CHKD BY
SCALE
APPVD BY
WEIGHT
JOB NO.
ISSUE NO.
DWG NO.
FILE NO. A518B

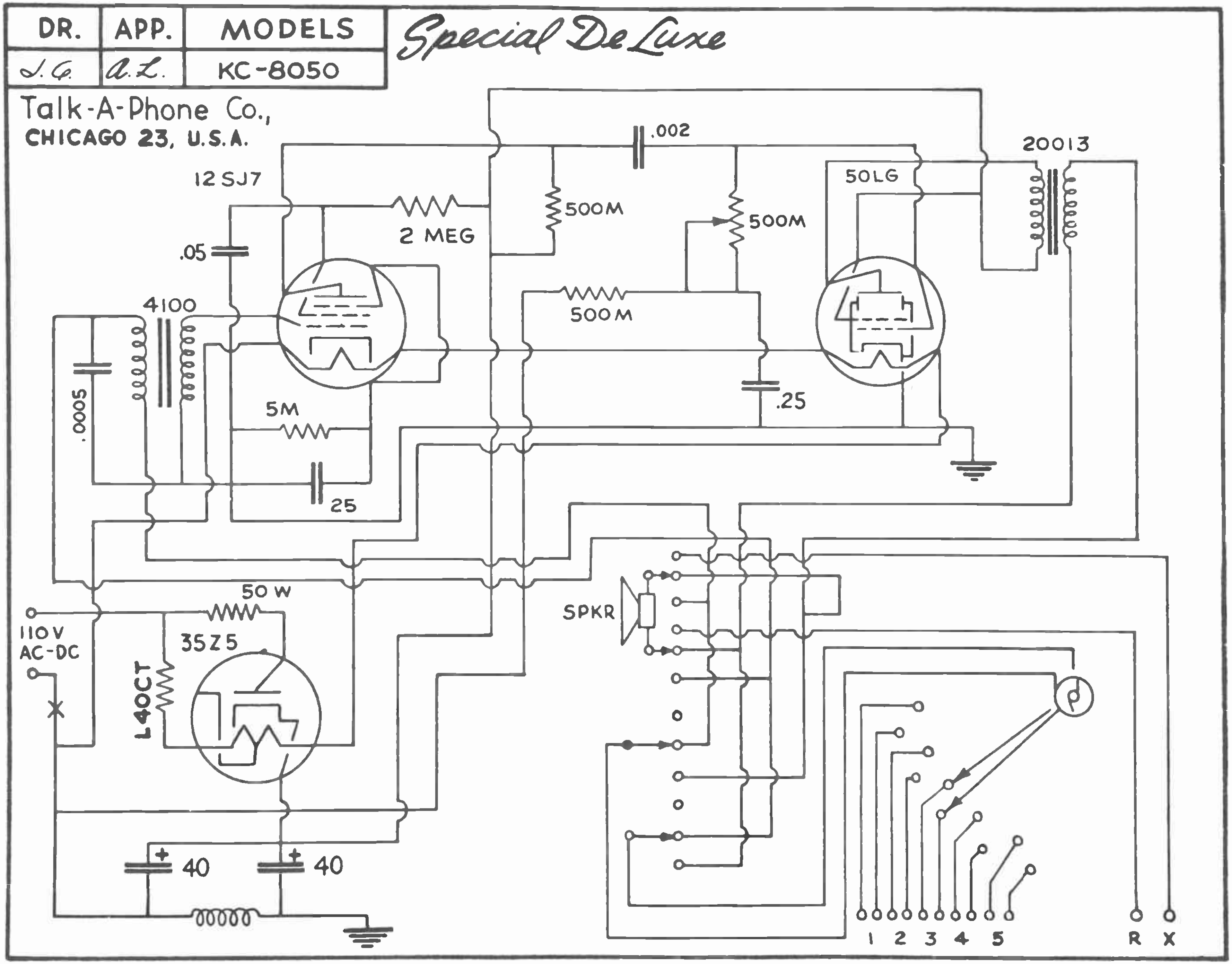

MASTER STATION-1
MASTER STATION-2
MASTER STATION-3
MASTER STATION-4
MASTER STATION-5
STATION CABLE
UNUSED WIRES
DOTTED LINE INDICATES CONNECTIONS IN JUNCTION BOX, WHEN USED.
G
B
1
2
3
4
INTERCONNECTING CABLE
DOTTED LINES ARE WIRES TO OTHER STATIONS WHEN ADDED. ADD ONE FOR EACH ADDITIONAL MASTER.
TERMINAL STRIP
STATION CABLE · SEE SCHEMATIC DIAGRAM FOR COLOR CODE. CONNECT ACCORDING TO CROSS CONNECTIONS CHART.
G B 1 2 3 4 5 6 7 8 9 10 11
JUNCTION BOX (OPTIONAL)
CONNECTIONS ARE SHOWN FOR A 12 STATION SYSTEM. FOLLOW CHART FOR CONNECTIONS. TWO STRIPS ARE PROVIDED FOR MODEL 219 C.
INTERCONNECTING CABLE
INTERCONNECTING CABLE
DAVID BOGEN CO., INC.
663 BROADWAY
NEW YORK 12, NEW YORK
TITLE: HOOK UP DIAGRAM
COMMUNO-PHONE MODELS 12C & 219C
DRAWN BY FIEMAN
CHKD BY
APPVD BY
JOB NO.
DWG NO.
SCALE NONE
WEIGHT
ISSUE NO.
FILE NO. B-6-1-10-B


DR. | APP. | MODELS
KC-8050
Special De Luxe
Talk-A-Phone Co.,
CHICAGO 23, U.S.A.
12SJ7
.002
20013
50LG
2 MEG
500M
500M
500M
.05
4100
.0005
.25
5M
25
50 W
110V
AC-DC
35Z5
L40CT
SPKR
40
40
1 2 3 4 5
R X

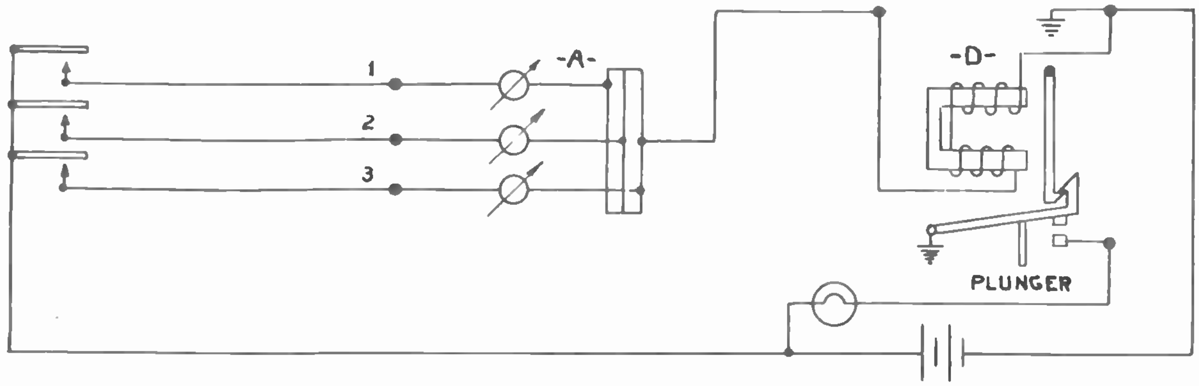

MASTER STATION-1
MASTER STATION-2
MASTER STATION-3
MASTER STATION-4
MASTER STATION-5
STATION CABLE
UNUSED WIRES
DOTTED LINE INDICATES CONNECTIONS IN JUNCTION BOX, WHEN USED.
G
B
1
2
3
4
TERMINAL STRIP
STATION CABLE · SEE SCHEMATIC DIAGRAM FOR COLOR CODE. CONNECT ACCORDING TO CROSS CONNECTIONS CHART.
INTERCONNECTING CABLE
DOTTED LINES ARE WIRES TO OTHER STATIONS WHEN ADDED. ADD ONE FOR EACH ADDITIONAL MASTER.
G B 1 2 3 4 5 6 7 8 9 10 11
JUNCTION BOX (OPTIONAL)
CONNECTIONS ARE SHOWN FOR A 12 STATION SYSTEM. FOLLOW CHART FOR CONNECTIONS. TWO STRIPS ARE PROVIDED FOR MODEL 219 C.
INTERCONNECTING CABLE
INTERCONNECTING CABLE
DAVID BOGEN CO., INC.
663 BROADWAY
NEW YORK 12, NEW YORK
TITLE: HOOK UP DIAGRAM
COMMUNO-PHONE MODELS 12C & 219C
DRAWN BY FIEMAN
CHKD BY
APPVD BY
JOB NO.
DWG NO.
SCALE NONE
WEIGHT
ISSUE NO.
FILE NO. B-8-1-10-B


DR.
APP.
MODEL
J.G.
A.L.
KS-6010
Special De Luxe
Talk-A-Phone Co.,
CHICAGO 23, U.S.A.
.002
12SJ7
2 MEG
500 M
500 M
50LG
20013
.05
4100
500 M
.25
5 M
.25
50 W
110 V
AC-DC
35Z5
L40CT
SPKR.
30 W
40
40
X 1 2 3 4 5 6 7 8 9 10 R


DR.
APP.
MODEL
J.G.
A.L.
KR-4010
Special De Luxe
Talk-A-Phone Co.
CHICAGO 23, U.S.A.
12SJ7
.002
50L6
20013
2 MEG
500M
500 M
.05
500M
4100
5M
.25
25
30W
110 V
AC-DC
35Z5
L40CT
3W
40
40
SPKR
R 1 2 3 4 5 6 7 8 9 10 X


DR.
APP.
MODELS
J. G.
A. L.
KC-8050
Special De Luxe
Talk-A-Phone Co.,
CHICAGO 23, U.S.A.
12SJ7
.002
20013
50LG
2 MEG
500M
500M
500M
.05
4100
.0005
5M
25
.25
50 W
110V
AC-DC
35Z5
L40CT
SPKR
40
40
1 2 3 4 5
R X

ANNUNCIATOR SYSTEMS

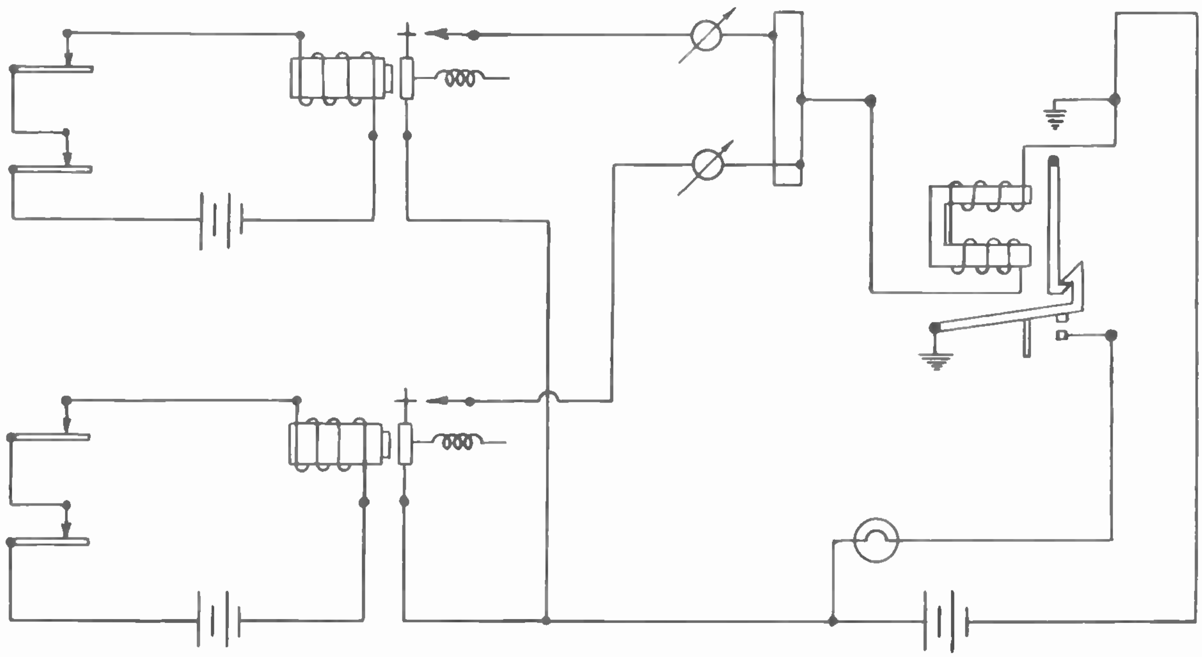


This is an alarm or signal system using an annunciator "A", and a drop relay "D" (drop switch) to provide a continuous alarm until the relay is reset by hand. Apply the following tests to locate terminals on drop relay.

(1) Be sure the drop relay is set. The little plunger must be pushed up as far as it will go, so that the drop contacts are held apart.

(2) Test with test leads until you locate the two terminals which, when connected, will trip the relay. These terminals will be the grounded coil terminal and the insulated coil terminal. The remaining terminal will be the drop contact terminal.

(3) To distinguish between the two coil terminals, connect one lead to the drop contact terminal with the relay tripped and one lead to one of the coil terminals. The insulated coil terminal, when connected, will pull the relay armature over with a click. The other coil terminal will be the grounded coil terminal.



This is a two-section alarm or signal system. Two or more floors, buildings, or departments can be protected in this manner. The annunciator indicates which floor or building the call comes from and the drop relay gives a continuous indication after the system has been disturbed. A bell can be used in place of the lamp if an audible signal is desired.

USEFUL . . . INFORMATION

Solutions for Questions Concerning Larger Installations of Signaling Equipment

AUDIBLE SIGNAL DATA

TYPE OF SIGNAL	AC 12 Volts	AC 24 Volts	DC 12 Volts	DC 24 Volts	AC 12 Volts	AC 24 Volts	DC 12 Volts	DC 24 Volts
	Amperes				Watts			
Small Buzzers	0.5	0.15	0.5	0.3	6.0	3.6	3.5	3.5
Large Buzzers	0.3	0.15	0.5	0.10	6.0	3.6	4.0	4.0
Small Bells 2½"-4" (Special Wound)	0.6	0.2	0.6	0.15	6.0	6.0	3.5	3.5
Large Bells 2½"-4" (Standard Wound)	0.4	0.2	0.5	0.10	5.0	5.0	3.5	3.5
Large Bells 6"-8"	1.0	0.25	0.35	0.11	8.0	8.0	4.5	4.5
Large Bells 10"-12"	1.0	0.25	0.40	0.12	10.0	10.0	5.0	5.0
Polarized Bells 3"-4"	0.35	0.15	....	....	4.0	4.0	....	....
Polarized Bells 6"-8"	0.35	0.15	....	....	5.5	5.5	....	....
Polarized Bells 10"-12"	0.5	0.33	....	....	6.0	8.0	....	....
Small Buzzers Solenoid Type	1.2	0.5	....	....	18	12	....	....
Small Bells, Single Stroke	1.5	0.8	....	....	20	20	....	....
Large Bells, Single Stroke 4"	1.0	1.0	0.5	0.5	24	24	12	12
Large Bells, Single Stroke 6"-8"	1.0	1.0	0.5	0.5	24	24	12	12
Large Bells, Single Stroke 10"-12"	1.0	1.0	0.65	0.65	24	24	16	16
Vibrating Horns	1.6	0.8	1.7	0.7	16	22	20	20
Small Chimes	1.0	1.0	0.5	0.5	15	15	12	12
Large Chimes	1.3	1.3	0.5	0.5	23	23	12	12

GROUPED SINGLE CONDUCTORS

Number of Conductors	No. 18* 1/64" RB	No. 18 1/32" RB	No. 16* 1/64" RB	No. 16 1/32" RB	No. 14 3/64" RB	No. 12 3/64" RB	No. 10 3/64" RB
	Conduit Size—Inch						
5	½	½	½	½	¾	¾	1
10	½	½	½	¾	1	1¼	1¼
11	½	½	¾	¾	1	1¼	1¼
12	½	½	¾	¾	1¼	1¼	1¼
15	½	¾	¾	1	1¼	1¼	1½
16	½	¾	¾	1	1¼	1½	1½
20	¾	¾	¾	1	1½	1½	2
24	¾	1	1	1¼	1½	2	2
25	¾	1	1	1¼	1½	2	2
30	¾	1	1	1¼	2	2	2½
35	1	1	1¼	1¼	2	2½	2½
40	1	1¼	1¼	1¼	2	2½	3
45	1¼	1¼	1¼	1½	2½	2½	3
50	1¼	1¼	1¼	1½	2½	2½	3
55	1¼	1¼	1¼	1½	2½	3	3
60	1¼	1¼	1¼	2	2½	3	3
70	1¼	1½	1¼	2	3	3	....
80	1¼	1½	1½	2	3	....	....
90	1¼	2	1½	2	3	....	....
100	1¼	2	2	2½	3½	....	....

RB—Rubber covered with protective braid.
*Approved by special permission only.

CONDUCTOR SIZE

Length of Circuit (One-way) Feet	Load in Amperes 1	2	4	6	7	8	10
SIZE WIRE ON 12 VOLT SYSTEM—Awg							
50	18	18	16	16	16	14	14
75	18	18	16	14	14	12	12
100	18	18	14	12	12	12	10
150	18	16	12	12	10	10	8
200	18	14	12	10	10	8	8
400	14	12	8	6	6	6	5
600	12	10	6	6	5	4	3
800	12	8	6	4	4	3	2
1000	10	8	5	3	3	2	1
SIZE WIRE ON 24 VOLT SYSTEM—Awg							
50	18	18	18	18	18	18	16
75	18	18	18	18	16	16	14
100	18	18	18	16	16	14	14
150	18	18	16	14	14	14	12
200	18	18	14	12	12	12	10
400	18	14	12	10	10	8	8
600	16	12	10	8	8	6	6
800	14	12	8	6	6	6	5
1000	14	10	8	6	6	5	4

SINGLE TELEPHONE CABLE

Number of Conductors	Braided* Overall Diam.	Braided* Conduit Size	Leaded* Overall Diam.	Leaded* Conduit Size
	Inch	Inch	Inch	Inch
6	0.26	½	0.30	½
11	0.28	½	0.33	½
16	0.31	½	0.36	½
26	0.36	½	0.40	¾
35	0.40	¾	0.45	¾
45	0.44	¾	0.48	¾
55	0.46	¾	0.51	¾
65	0.51	¾	0.55	1
75	0.53	1	0.57	1
85	0.55	1	0.60	1
100	0.60	1	0.64	1

*Number of Single No. 22 & 4 Single No. 18.

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VACUUM ELECTRONIC TUBES

TUBE NAMES	KENOTRON *(Diode)	X-RAY	PLIOTRON *(May be Triode, Tetrode or Pentode)	CATHODE RAY	MAGNETRON	KLYSTRON RHUMBATRON	VACUUM PHOTOTUBE
APPLICATION	Rectifies low values of current (often at high voltage)	Produces X-ray radiation	Amplification and high frequency oscillation	Produces visual indications by controlled electron beam	Ultra high frequency (U.H.F.) oscillation	Used in military radio and detection devices	Used in applications where audio frequency response is important
TYPICAL EXAMPLES	Rectification in radio, X-ray, and electrostatic precipitation	• Medical diagnosis and therapy • Examination of industrial products	• High frequency heating • Carrier current • Control circuits • Radio receivers and transmitters	• Circuit analysis • Television	Short wave radio		Sound movies
TYPE OF CONTROL	None		Electrostatic (Grid)	Electrostatic or Electromagnetic	Electromagnetic field	Resonance chamber	Light variation
TYPE OF CATHODE	Hot						Photoelectric

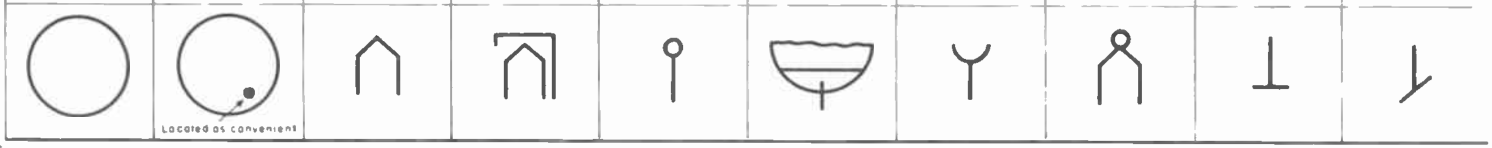
GAS FILLED ELECTRONIC TUBES

TUBE NAMES	RECTIGON • TUNGAR	PHANOTRON (Mercury Vapor Rectifier)	THYRATRON *(May be Gas Triode or Gas Tetrode)	PERMATRON	GLOW TUBE • PROTECTOR TUBES (For special applications)	GRID GLOW TUBE *(Gas Triode)
APPLICATION	Low voltage rectification	Rectification of moderate amounts of current at voltages up to 20,000	Control and controlled rectification of moderate amounts of current at voltages up to 22,000		Illumination, rectification and regulation at low current, low voltage	Controls small amounts of power
TYPICAL EXAMPLES	Battery charging	Radio transmitters and industrial applications	• Welding control • Timing circuits • Motor control • Voltage regulation		• Switchboard indicating lights • Control circuit voltage regulators • Protection of supervisory control circuits	Safety control of furnaces
TYPE OF CONTROL	None		Electrostatic (Grid)	Electromagnetic	None	Electrostatic (Grid)
TYPE OF CATHODE	Hot				Cold	

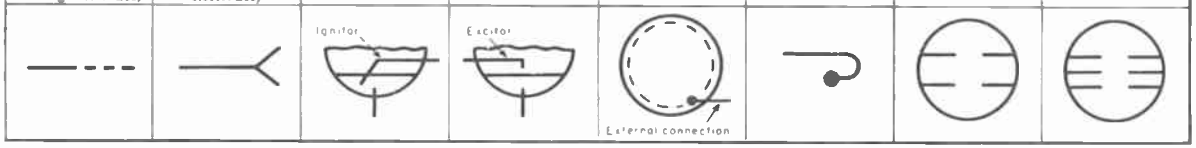
POOL TUBE (Mercury Arc Rectifier)	GRID POOL TUBE • EXCITRON (Mercury Arc Rectifiers)	IGNITRON	GUSETRON	GAS PHOTOTUBE
Rectification, conversion and control of large amounts of power				• Process and quality control • Detection devices
Power for Aluminum, Magnesium, Mining, Electrochemistry, Transportation and Steel. (Ignitrons and Gusetrons are also used in resistance welding control.)				• Sound movies • Pinhole detector • Cutting, winding and printing control
None	Electrostatic (Grid)	Resistance ignition	High potential gradient ignition	Light variation
Pool (usually mercury)				Photoelectric

SYMBOLS FOR TUBE ELEMENTS

ENVELOPES		CATHODES (emitters)						COLLECTORS	
High Vacuum	Gas Filled	Thermionic (hot) Direct Heated	Thermionic (hot) Indirectly Heated	Cold (including Ionic Heated)	Pool	Photo Sensitive	Ionic Heated with Supplementary Heater	Anode (Plate)	Target (X-Ray)



CONTROL ELECTRODES				SHIELD	COUPLING	RESONATORS (Cavity type)	
Electrostatic (Grid) (including beam confining or beam forming electrodes)	Electrostatic (deflecting, reflecting or repelling electrodes)	Resistance Ignitor	Excitor	Internal Envelope	Anode Connected	Single Cavity Envelope	Double Cavity Envelope

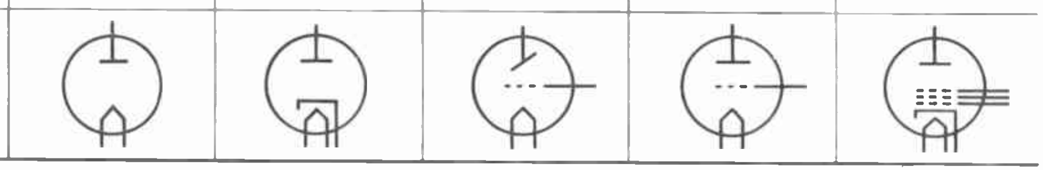


TUBE ELEMENTS

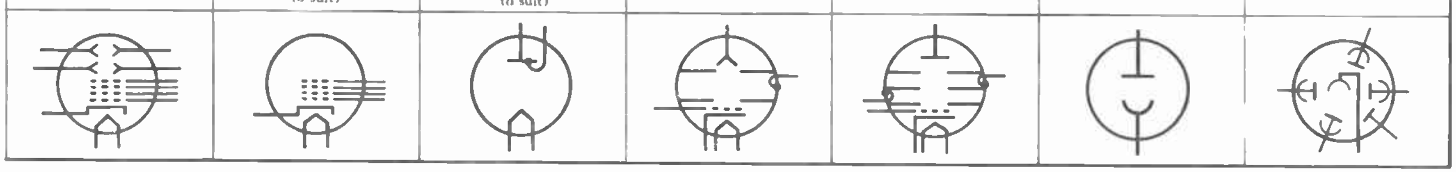
The above symbols represent specific functions of tube elements. When two or more functions are combined in one element (such as a dynode used in multiplier-type phototubes) the symbols are combined like this. All symbols can be used in an unlimited variety of combinations for complete tubes.

TYPICAL SYMBOLS FOR HIGH VACUUM ELECTRONIC TUBES

Tube Names	KENOTRON		X-RAY	PLIOTRON	
	Direct Heated Cathode	Indirectly Heated Cathode		Triode with Direct Heated Cathode	Pentode Indirectly Heated Cathode
Symbol					

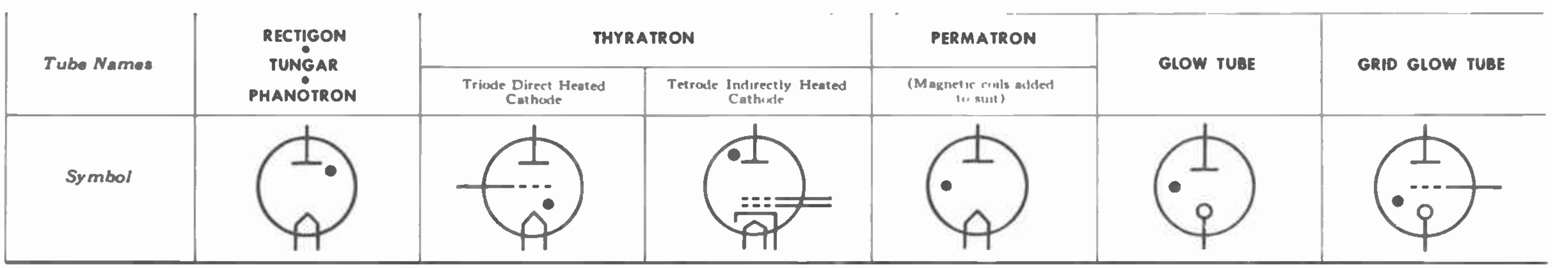


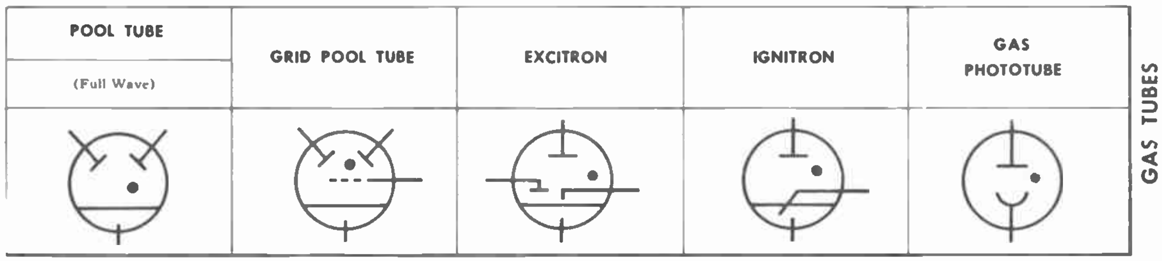
CATHODE RAY		MAGNETRON	KLYSTRON		VACUUM PHOTOTUBE	
Electrostatic Control	Electromagnetic Control (magnetic coils added to suit)	Resonant Type (magnetic coils added to suit)	(Single Cavity)	(Double Cavity)		Multiplier Type



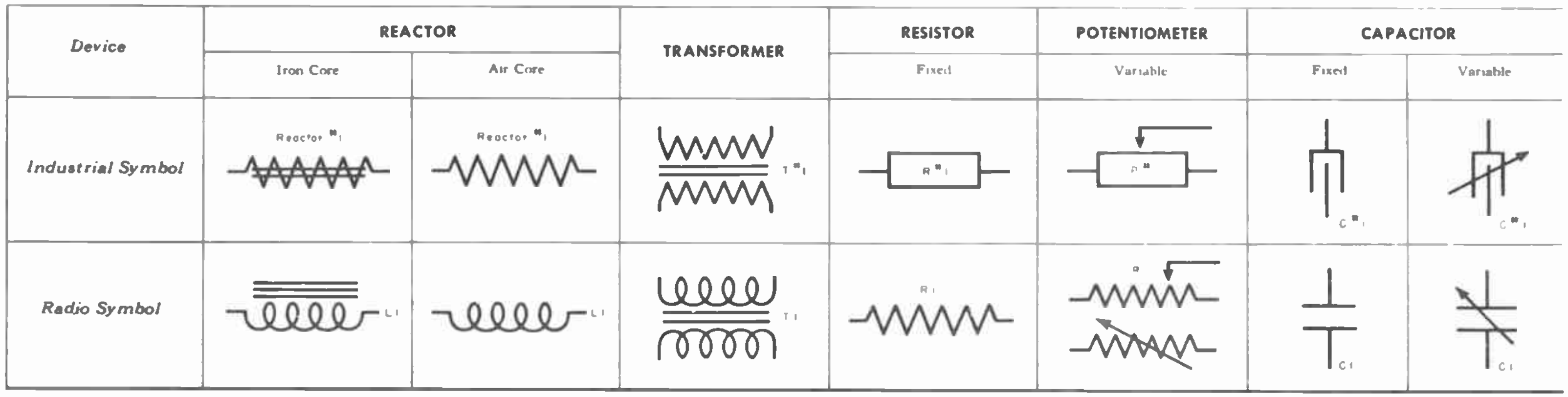
VACUUM TUBES

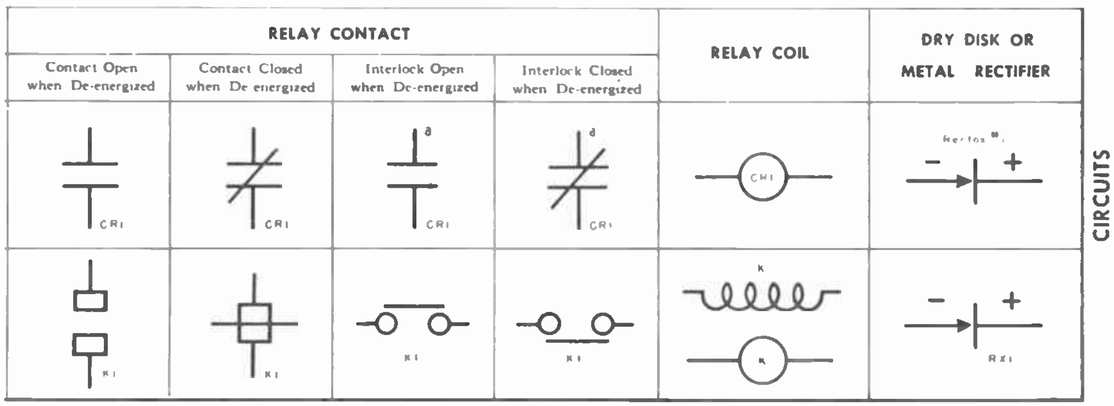
TYPICAL SYMBOLS FOR GAS FILLED ELECTRONIC TUBES



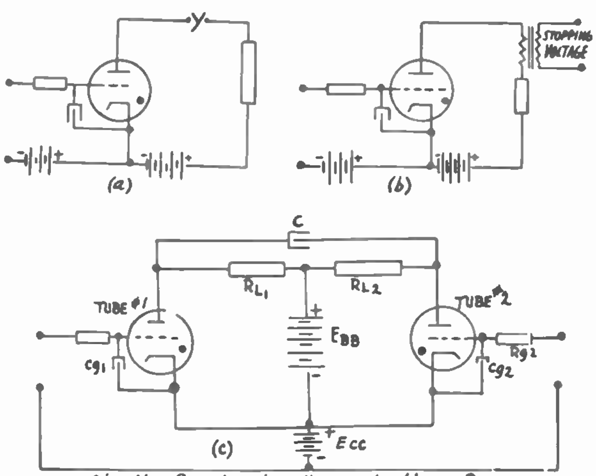


TYPICAL CIRCUIT SYMBOLS

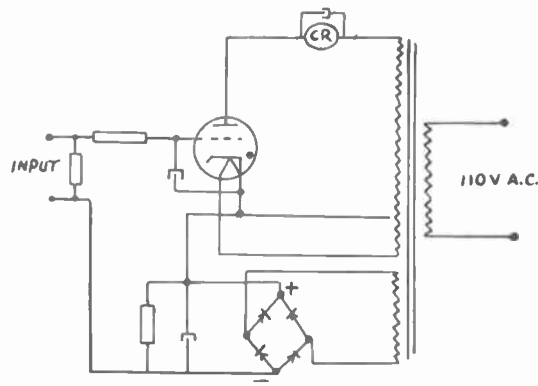




THYRATRON AND IGNITRON CONTROL PRINCIPLES



Circuits for stopping the conduction of thyratrons operating on D.C.



Circuit showing a thyratron operating a relay, a grid resistor, a shock-over capacitor and a rectox bias supply are used

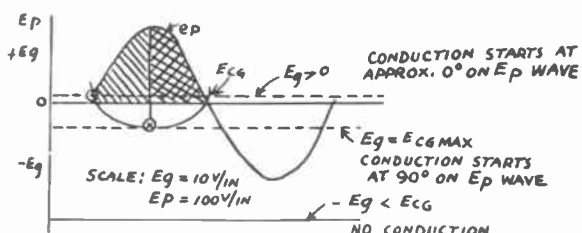
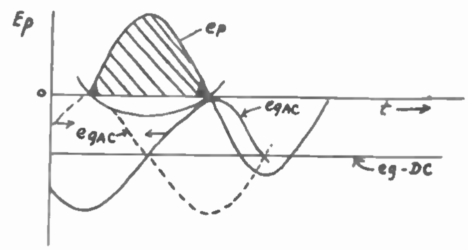
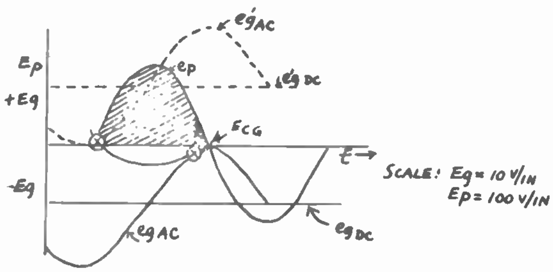


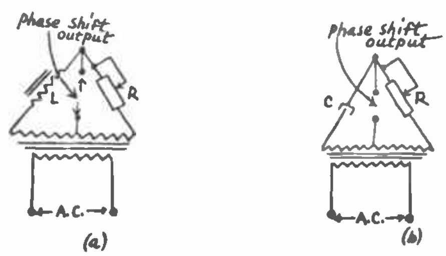
Diagram showing control of a thyratron by varying the amplitude of the D.C. voltage on its grid.



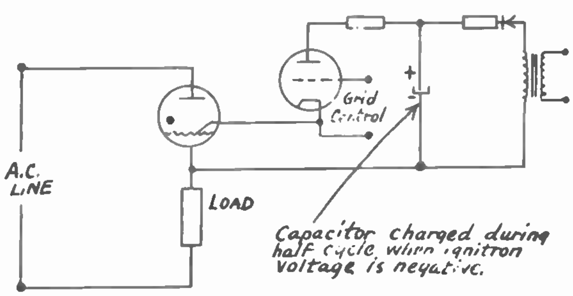
Control of a thyratron by phase shifting the A.C. grid voltage

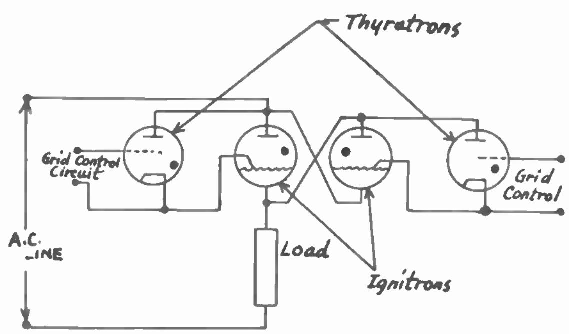


CONTROL OF A THYRATRON BY VARYING THE AMPLITUDE OF THE D.C. GRID VOLTAGE UPON WHICH IS SUPERIMPOSED A PHASE-SHIFTED A.C.



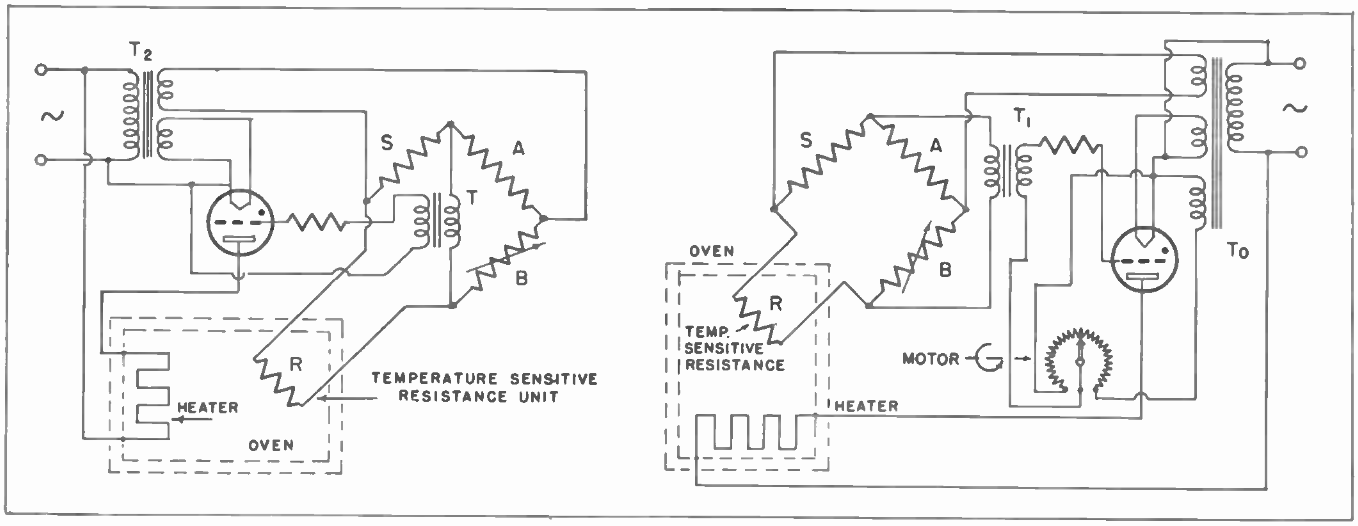
Circuits for phase-shifting an A.C. Voltage



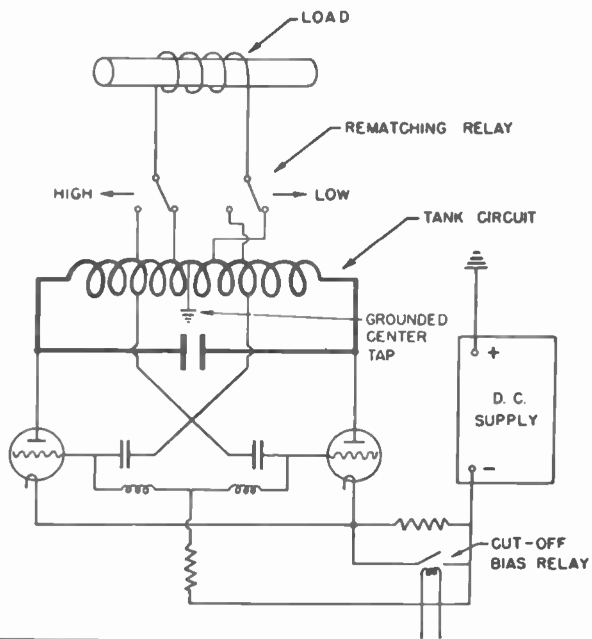


(From Westinghouse electronic engineering notes)

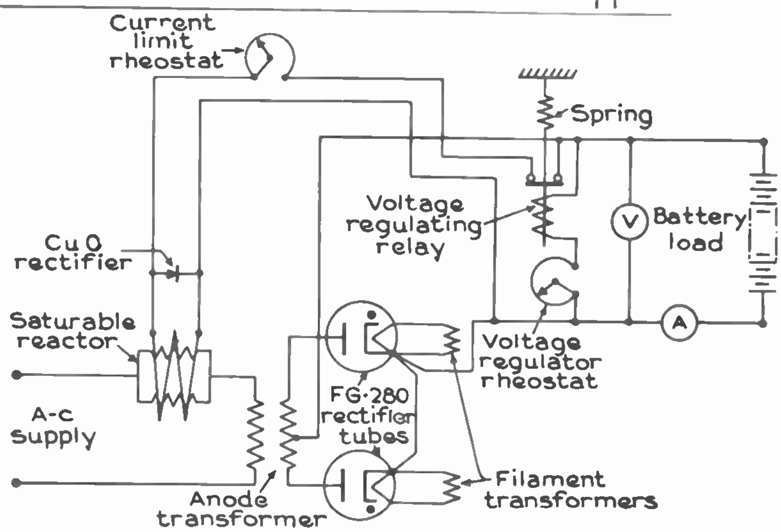
INDUSTRIAL ELECTRONIC APPLICATIONS



Oven heat control using thyratron tube. At left above the unbalanced bridge has arm R exposed to heat, and arm B adjustable for temperature. Lower temperatures cause bridge transformer to apply grid voltage for breakdown, and conduction through heater. At right, motor driven voltage divider controls pulses of heating. Drawings are from "Electronic Industries" magazine.

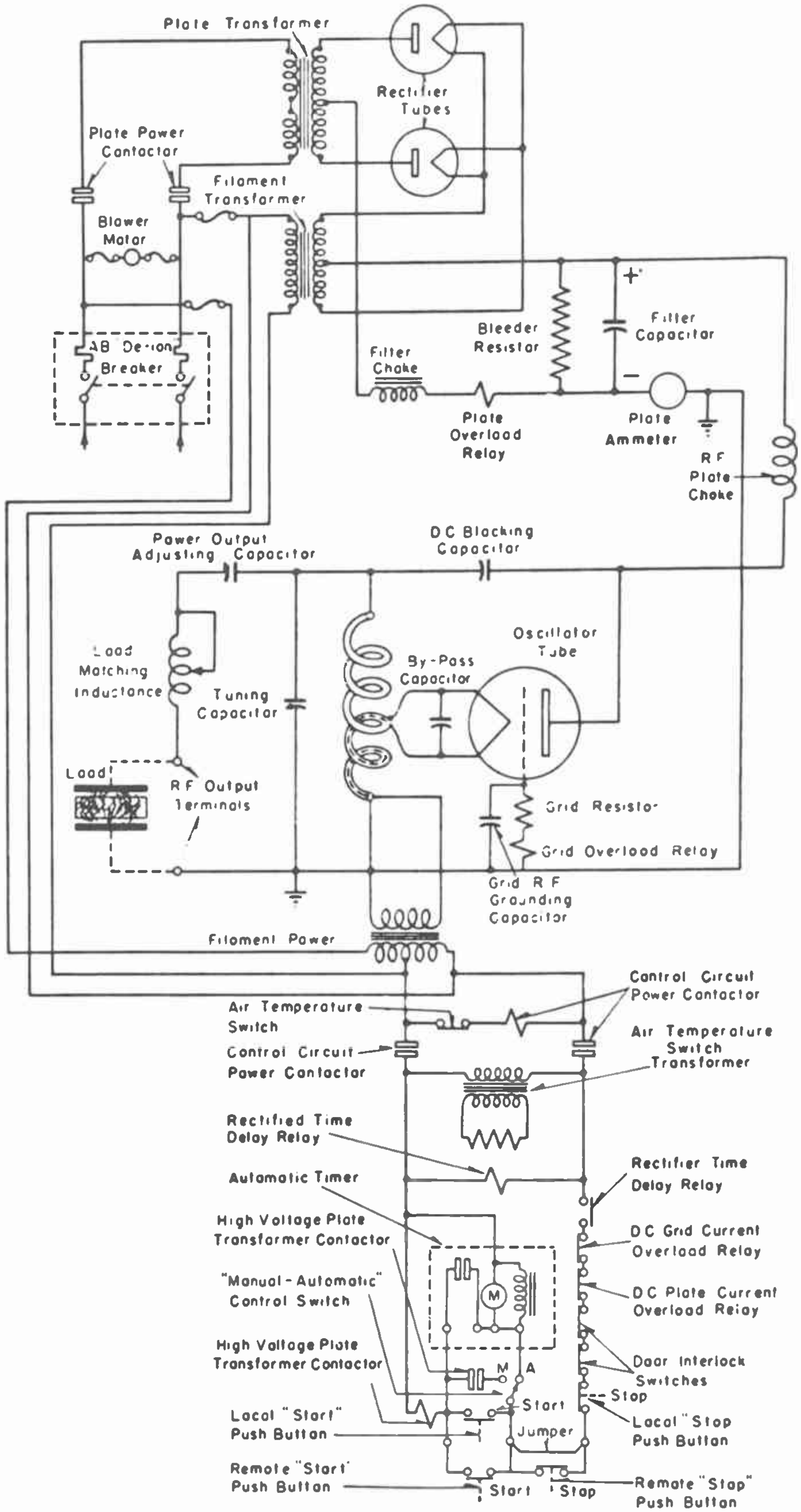


Illitron high-frequency induction heating with re-matching of general and load impedances above temperature at which metal loses its magnetic properties. Circuit is push-pull modified Hartley operating at frequency of approximately 2 megacycles. Heater coil is tapped into only a portion of the tank circuit, with tapping automatically changed during heating cycle to effect re-matching.

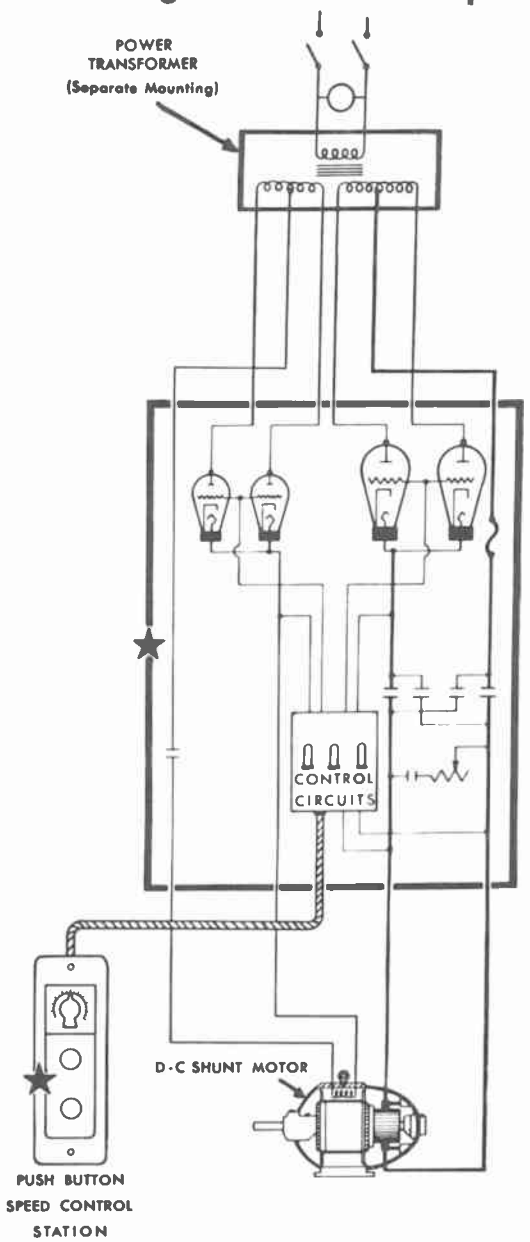


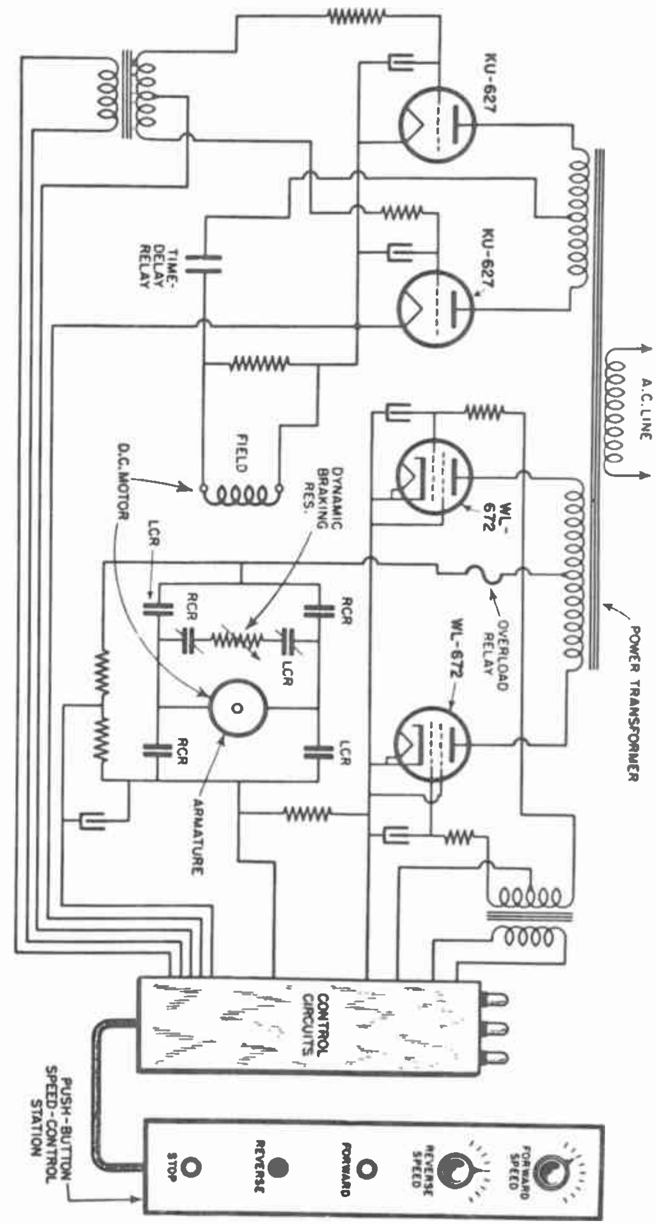
General Electric battery charger using phanotron rectifier tubes, for batteries operating at 120 volts or higher. Voltage regulating relay has feedback circuit through saturable reactor. Relay coil is connected across d-c output, opening and closing the relay contacts with changes in battery voltage. Current limit rheostat determines voltage at which relay opens and closes its contacts. With contacts closed, d-c current flows through reactor to increase voltage on transformer primary and increase current furnished by rectifiers.

WESTINGHOUSE RADIO-FREQUENCY GENERATOR FOR INDUCTION HEATING AND DIELECTRIC HEATING



WESTINGHOUSE MOT-O-TROL method of securing stepless wide-range d-c motor speeds from an alternating current source.

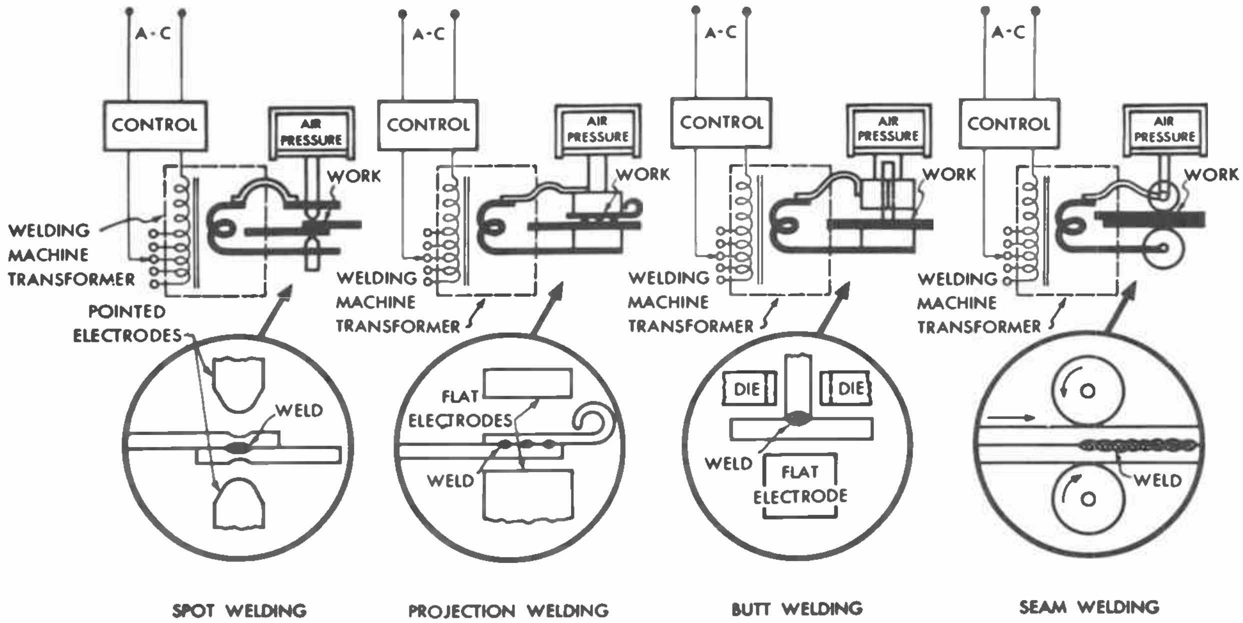




The incoming a-c power is converted to direct current by thyratron tubes. These supply the direct current to armature and field circuits of the d-c driving motor. A potentiometer in the control station varies the voltage of the rectified direct current supplied to both armature and field circuits by shifting the phase of the grid control voltage of the thyratrons. Both armature and field circuits (which control the entire speed range possible) are controlled by the one dial on the control station. Some stations provide two dials, for forward and reverse

The left-hand diagram shows the elementary principle. The right-hand diagram is a schematic of the power circuit. Power from the a-c line is rectified by two 672 tubes and supplied to the motor armature through a reversing contactor. Two 627 thyratrons supply rectified voltage to the field of the motor.

WESTINGHOUSE RESISTANCE WELDING



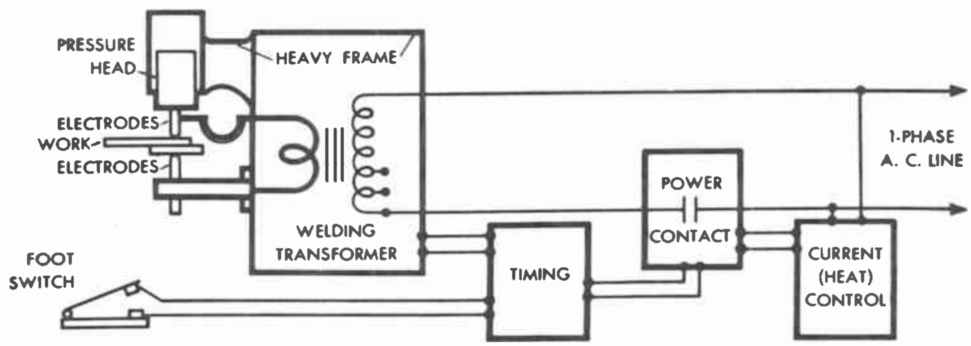
Various types of resistance welding machines with the forms of their welding electrodes and cross sections of typical welds.

Spot welding is performed using stud-type electrodes with small area tips which concentrate both pressure and current for welding metal sheet or other semi-flat structures.

Projection welding is essentially a form of spot welding utilizing a similar machine but having flat or die-type electrodes. Parts to be welded have small projections already formed on surfaces to be joined. Heat is concentrated at these projection points, making a series of individual spot welds simultaneously.

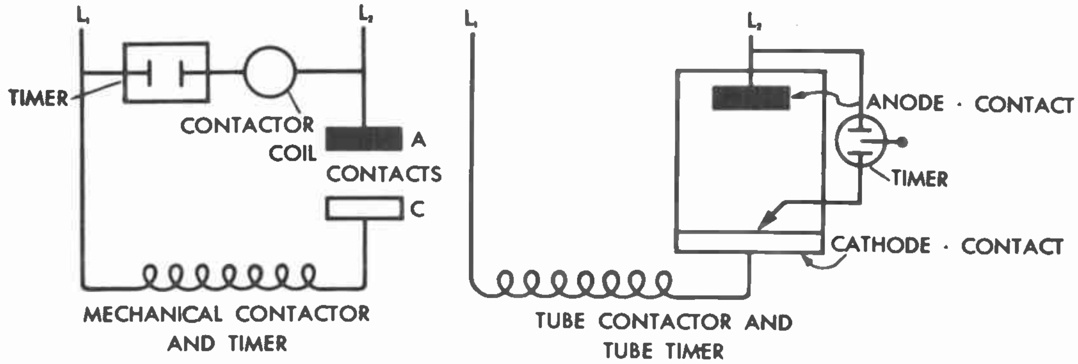
Butt welding is similar to projection welding except that no projection is raised on either part. Die-type electrodes are used to hold the work which is pressed together and welds at the point of contact. Butt welding is used for rods, lengths of pipe, handles on pans, and similar work.

Seam welding sometimes is called stitch or roller welding because it consists of a long series of spot welds made in rapid succession with wheel-type electrodes. It is of particular value in joining parts where a continuous tight seam is required.

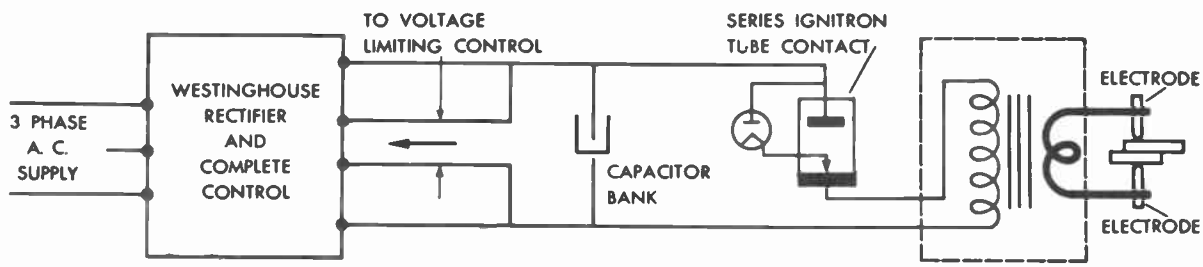


Principal parts of resistance welding machine.

WESTINGHOUSE RESISTANCE WELDING

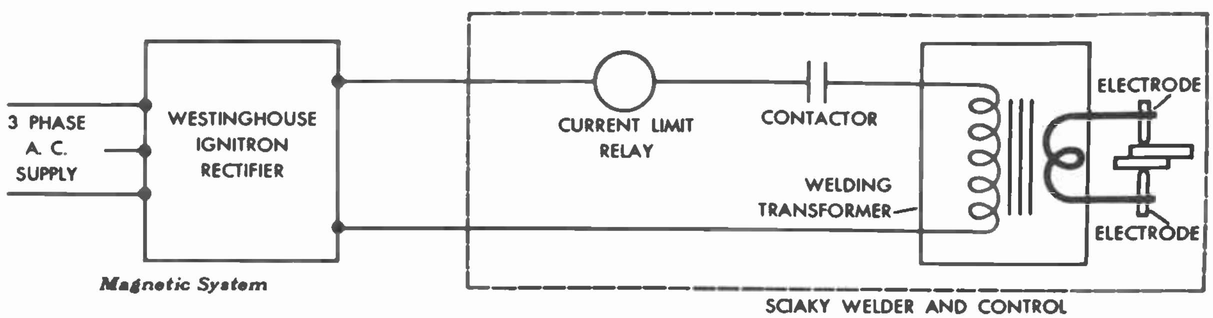


Left-hand diagram shows mechanical contactor and timer as used for resistance welding without electronic control. At the right is the equivalent electronic control in which the ignitron takes the place of the large contactor and the thyratron circuit replaces the timing relay.



Capacitor System

Capacitor energy-storage system. Energy from 3-phase a-c line is rectified to charge the large capacitor bank. An electronic voltage limiting device stops the rectifier charging when a predetermined voltage setting is reached. This charge is kept in the capacitor bank until operator closes the initiating switch to make a weld. This fires the series ignitron to discharge the capacitor through the welding transformer.



Magnetic System

Magnetic energy-storage system. D-c power for welding machine is furnished by the ignitron rectifier. Electrodes are closed and apply pressure to the work, and the contactor is closed. Current builds up in primary of welding transformer to value for which limit relay is set. Contactor then is opened and rapid decay of current in transformer primary causes high inductive current in secondary to make the weld.

WESTINGHOUSE RESISTANCE WELDING

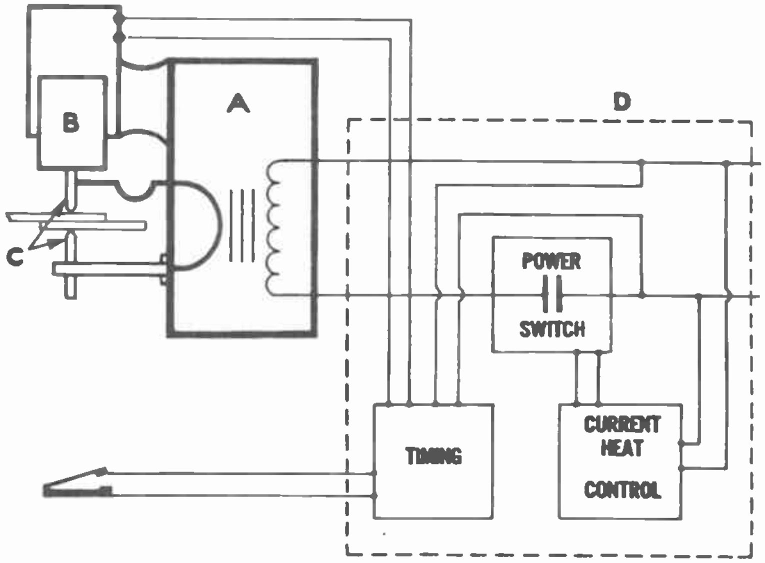
Principal elements of a resistance spot welder.

A, frame supporting high-current transformer.

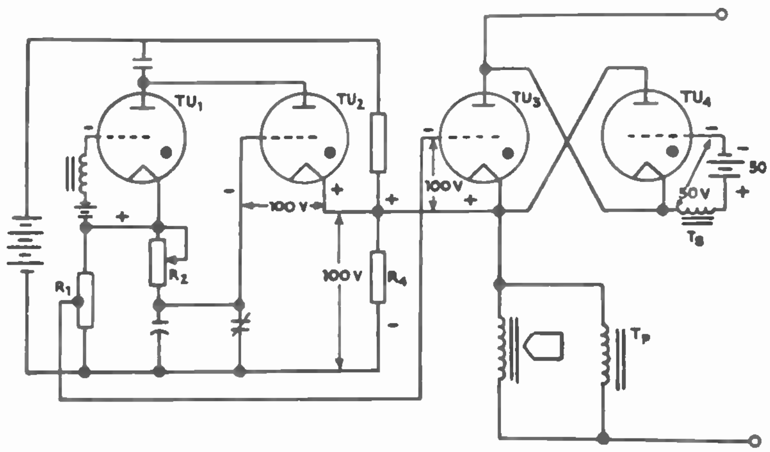
B, pressure head for electrodes. The pressure in some cases is rapidly varied between two values, allowing a squeeze pressure before welding and a forge pressure after welding.

C, electrodes of copper or copper alloys, usually water cooled.

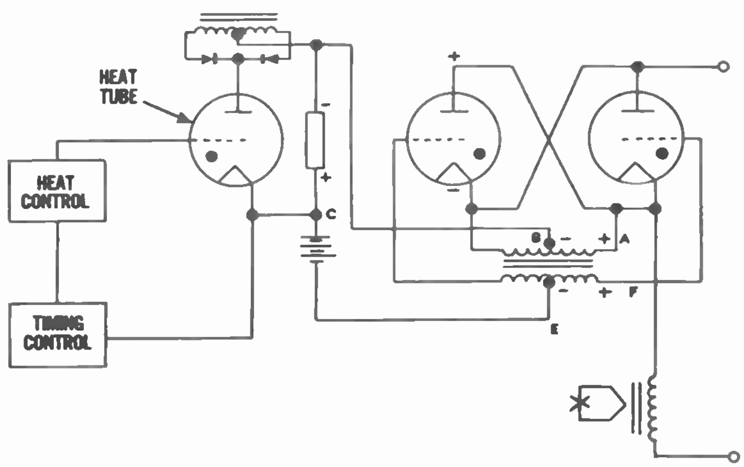
D, controls for various steps of the welding process.



Synchronous weld timer. Ignitrons omitted from diagram for simplicity and two thyratrons in series with primary of welding transformer are considered to carry welding current. Conditions just before operation, with no tubes conducting. Anode circuits are open on tubes TU1 and TU2. Grid of TU3 is negative by amount of voltage across R4. TU4 has negative grid bias. Peaking transformer is in series with grid of TU1.

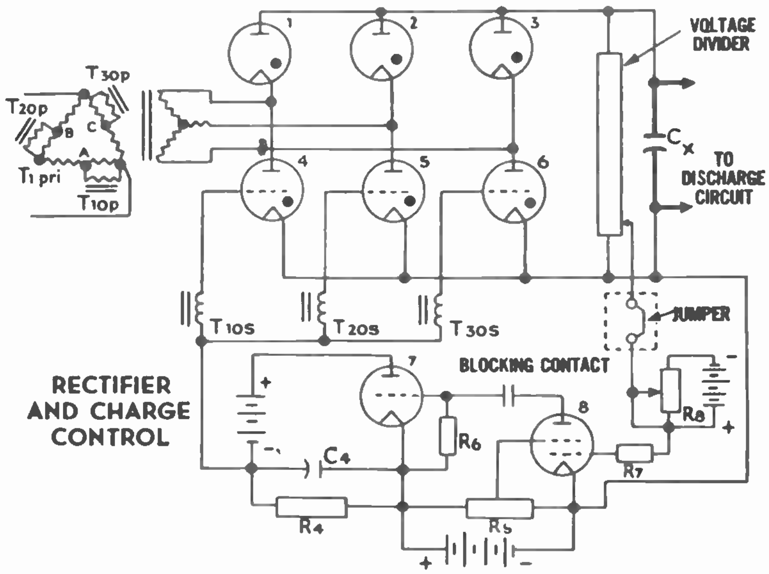


Synchronous weld timer with heat control. Ignitrons omitted for simplicity. Intermediate heat tube controls firing thyratrons which, in turn, control ignitrons. Heat control regulates magnitude of current in welding transformer

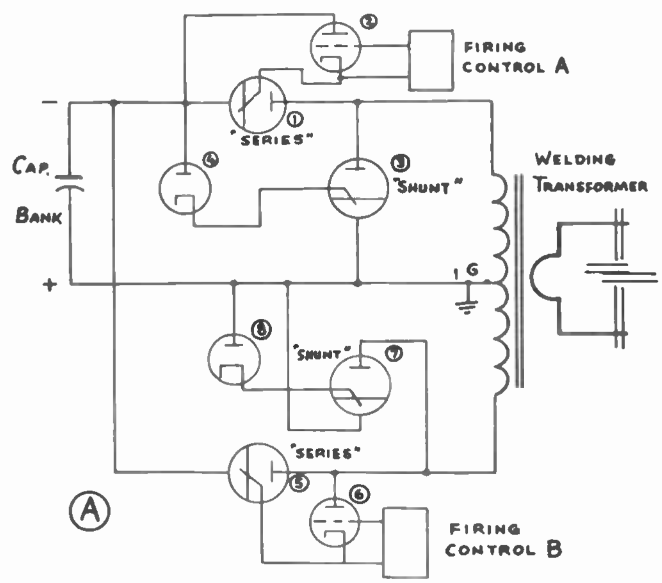


WESTINGHOUSE RESISTANCE WELDING

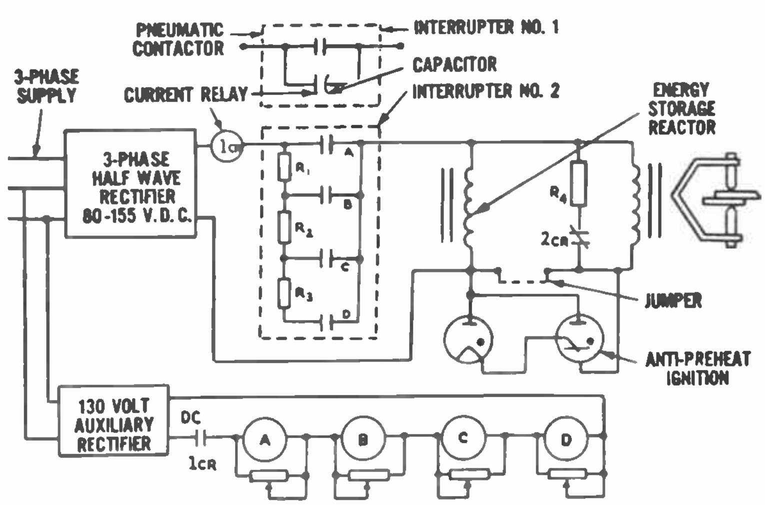
Capacitor discharge energy storage system of resistance welding. This diagram shows transformer connections between a three-phase supply line and the three-phase rectifier furnishing high voltage for charging the capacitor Cx, and shows also the circuits which control the rectifier output. Tubes 1, 2 and 3 conduct in series with tubes 4, 5 and 6 respectively. Tubes 4, 5 and 6 are controlled by a-c voltage from transformers T10, T20 and T30 applied in the grid circuits. This a-c grid voltage is in series with d-c voltage from amplifier circuit containing tubes 7 and 8.



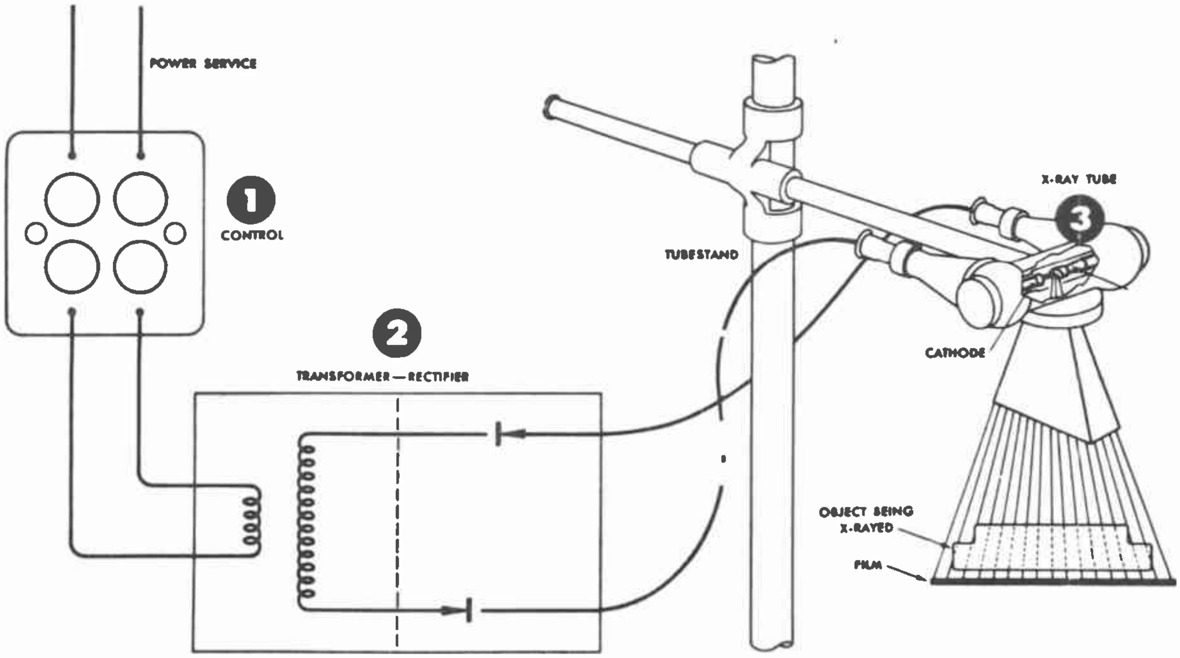
Discharge circuit of capacitor energy storage system. There are two sets of "series" and "shunt" ignitron tubes and thyratron firing tubes. Controls in the sequence timer discharge the capacitor bank alternately through series tube 1 and series tube 5 to reverse the polarity of discharge current on successive welds.



Magnetic energy-storage resistance welding system



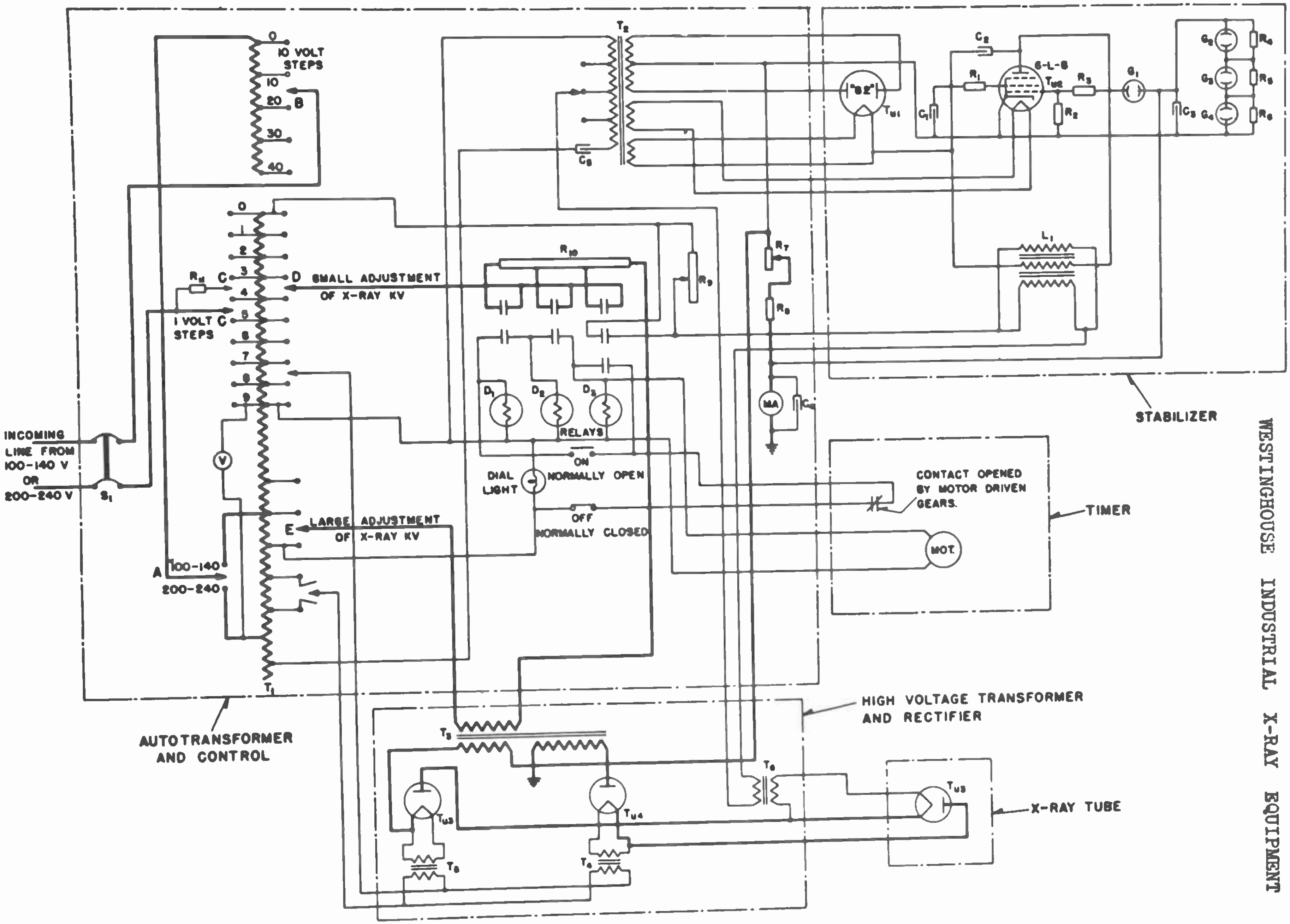
WESTINGHOUSE INDUSTRIAL X-RAY EQUIPMENT



The following notes apply to the diagram of Westinghouse X-ray apparatus shown on the adjacent page.

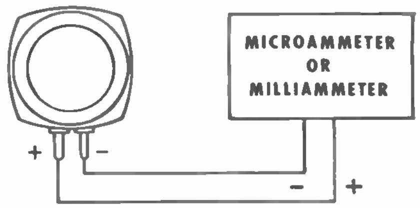
The anode of the X-ray tube is connected to the positive side of a half-wave rectifier consisting of tubes TU3 and TU4 connected in series with each other and the anode-cathode path in the X-ray tube. In series with this circuit is the milliammeter MA for indicating the anode-cathode current. One side of the X-ray tube cathode is connected to the negative side of the rectifier system.

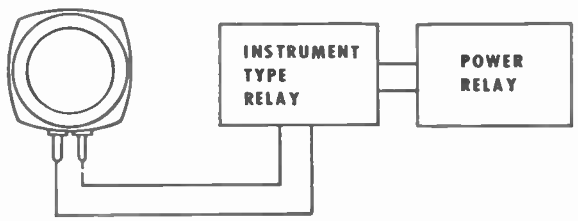
Voltages and currents suitable for the various circuits are furnished from the auto-transformer which is connected to the incoming line. One of these circuits goes to the primary of the high-voltage transformer T3 whose secondaries are in the rectifier circuit. The high-voltage primary circuit is completed through the step resistor R10. To begin an exposure the motor-driven timer is placed in operation to actuate the relays which close the primary circuit first through the entire resistor and then successively cut out the sections within a fraction of a second. This applies anode-cathode voltage to the X-ray tube from the rectifier system. At the end of the time for which the timer has been set the relays are dropped out to cut off the high voltage and end the exposure. In the primary circuit of the transformer whose secondary heats the filament-cathode of the X-ray tube is the stabilizer which regulates filament temperature. The stabilizer is controlled by voltage in the anode-cathode circuit and acts to compensate for voltage variations by simultaneously varying the filament-cathode current and electron emission in the X-ray tube.

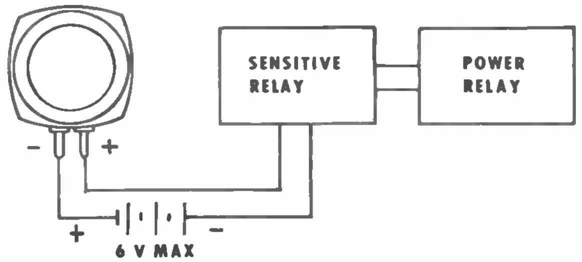


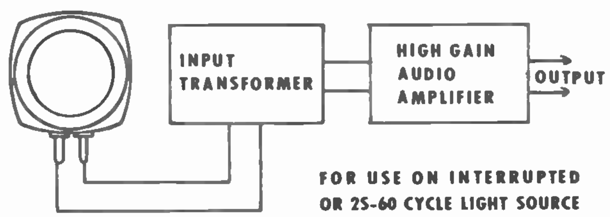
WESTINGHOUSE INDUSTRIAL X-RAY EQUIPMENT

BRADLEY "LUXTRON" PHOTO-ELECTRIC CELLS







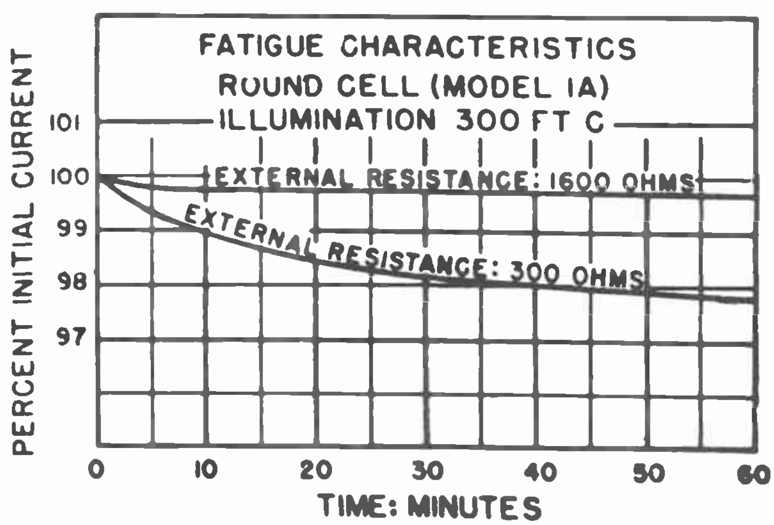


FOR USE ON INTERRUPTED
OR 25-60 CYCLE LIGHT SOURCE

POTENTIAL-ILLUMINATION CHARACTERISTICS
This graph shows the open-circuit voltage, which is independent of the active area of the cell and which varies with the intensity of illumination.

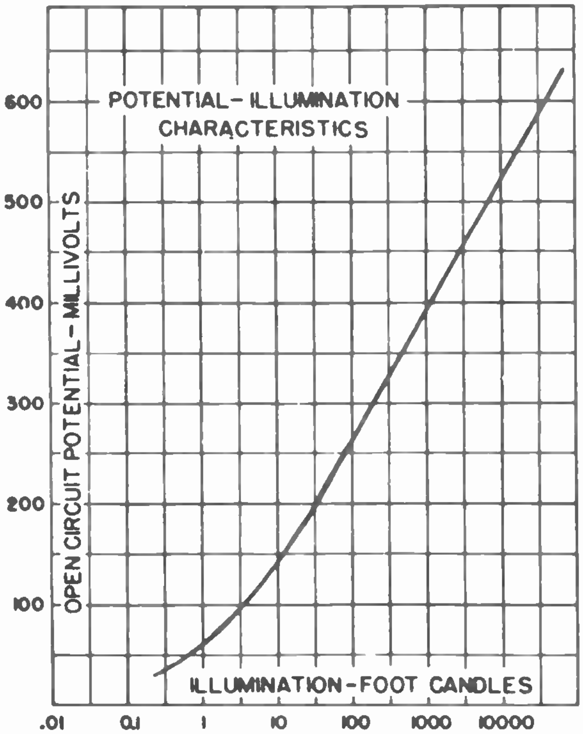
RELATIVE SPECTRAL RESPONSE
This graph compares the response of the photo-electric cell with that of the average human eye to visible light and, for the cell, shows response in the near ultra-violet wave lengths.

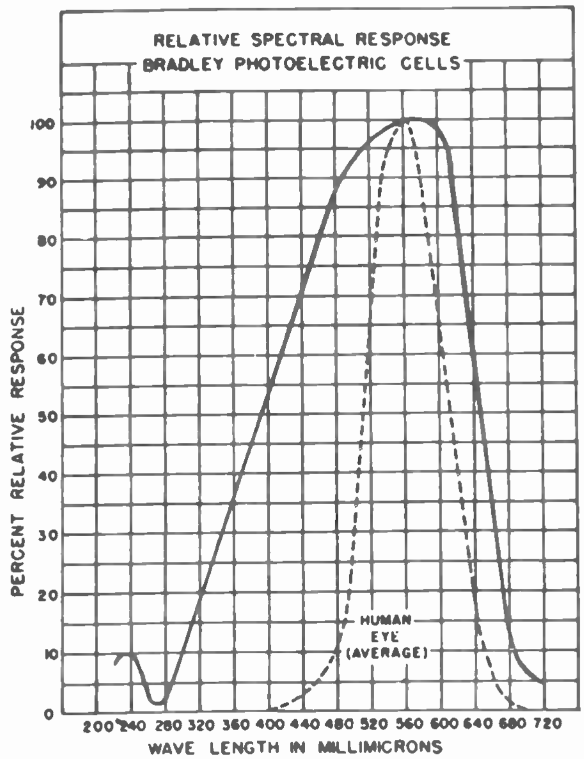
PHOTOCURRENT CHARACTERISTICS
One graph applies to a round cell having active area of 1.75 sq. in. and the other spplies to a rectangular cell having active area of 0.70 sq. in. When light falls on a photo-electric cell a current is generated. The magnitude of this current depends on the external circuit resistance or resistance of the measuring instrument, on the intensity of illumination, and on the active area of the cell.

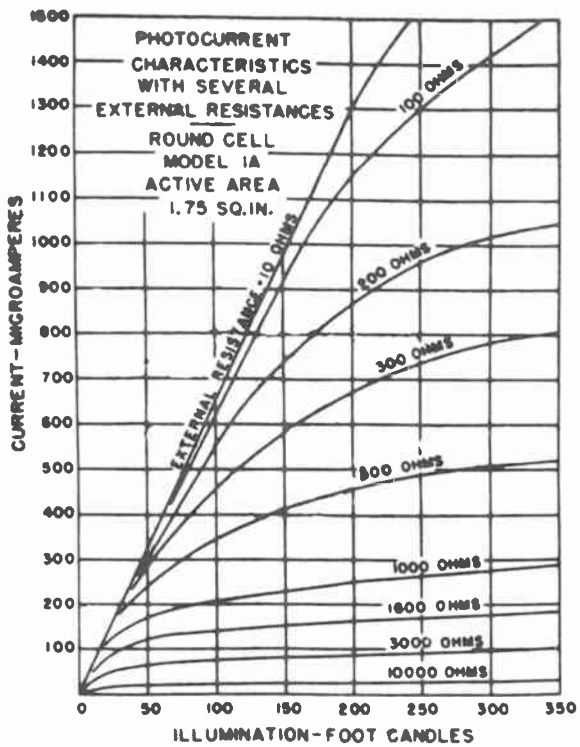


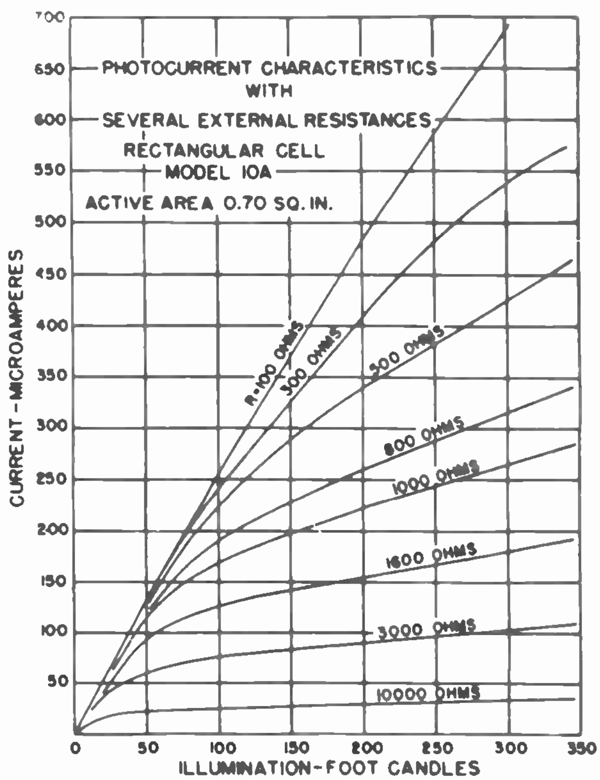
FATIGUE CHARACTERISTICS
The term fatigue refers to an initial inherent drift in the current output of photo-electric cells when they are exposed to light. When illumination is removed the cell regains its original characteristics after a short period of recovery. There is no permanent fatigue. There is some variation in the fatigue characteristics of cells of the same type.

BRADLEY "LUXTRON" PHOTO-ELECTRIC CELLS









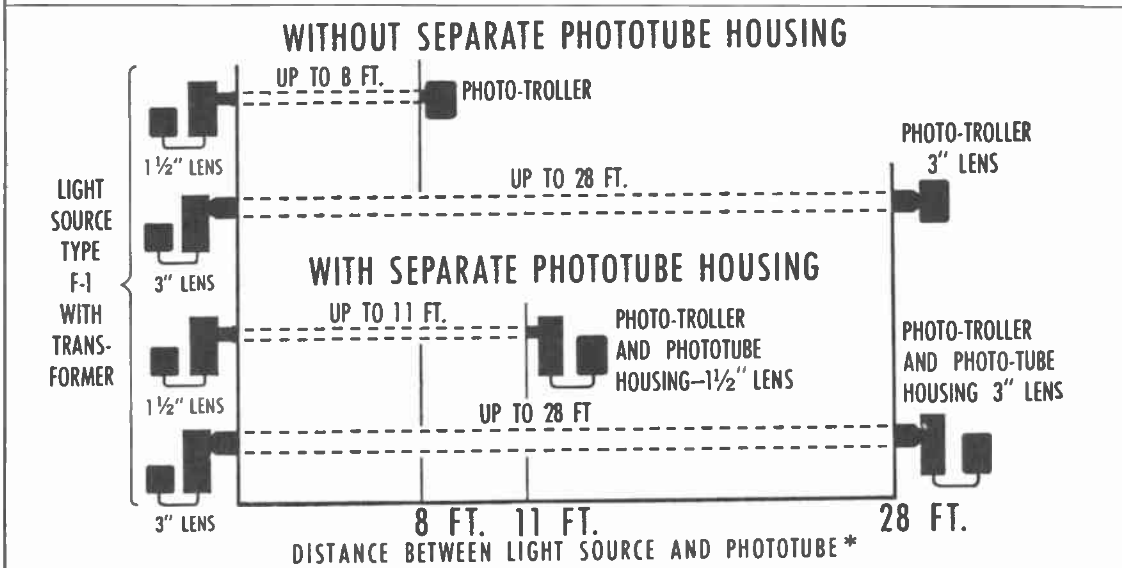
PROCEDURE FOR SELECTING COMPLETE PHOTO-TROLLER EQUIPMENT

1. Measure the distance between Photo-Troller and light source on your proposed installation.
2. Refer to charts below or on page 7 and select Photo-Troller type based on distance between light source and phototube; also on service required.
3. Check the specification of the type chosen (pages 4 to 11) to determine if it is suitable for the following variables.
   A. Sufficient interruption of light beam necessary for maximum operating distance as explained in paragraph under Contactor or Load Relay. Ratings are based on complete interruption of a visible light beam under ideal conditions.
   B. Speed of operation. See paragraphs under Speed of Response and Operations per Minute.
   C. Operating conditions such as temperature, dust and weather conditions. See general description.
   D. Space for mounting the light source, phototube housing and/or Photo-Troller.

TYPE RQ—FOR INDOOR USE ONLY

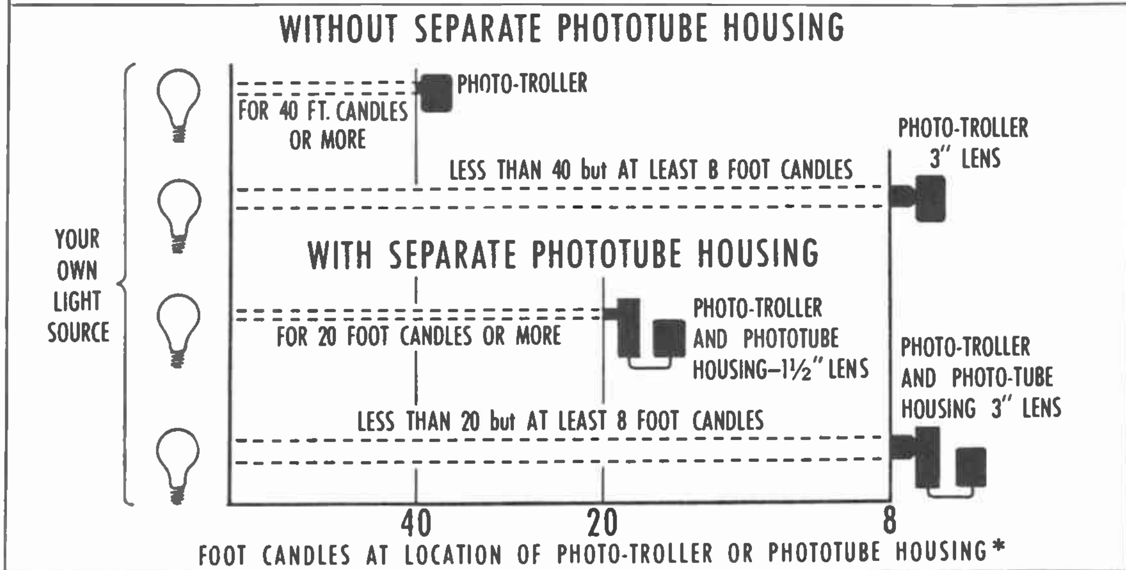
Style Numbers Include All Components Shown in Chart

INCLUDING LIGHT SOURCE—Measure Distance and Select Control Here



STYLE NUMBER
1183 191
1183 192
1183 193
1183 194

USING YOUR OWN LIGHT SOURCE—Measure Light Intensity at Phototube Location



STYLE NUMBER
1183 188
1183 196
1183 189
1183 190

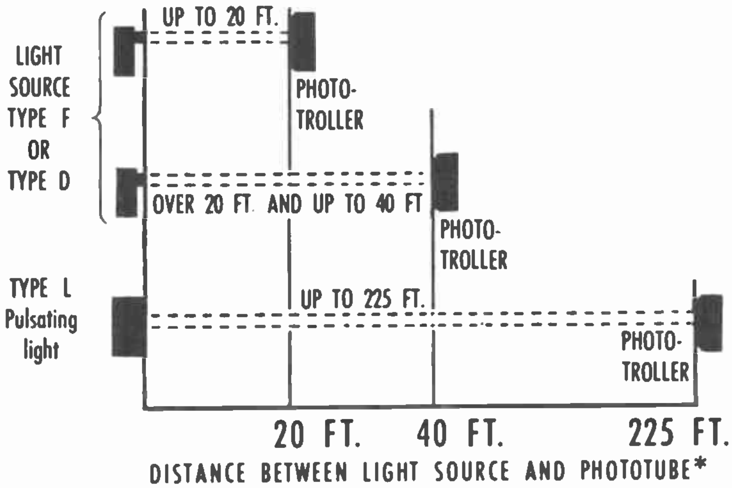
* The maximum operating distance is reduced to one-third of above distances when a 10% transmission light filter is used.

TYPE RX SERIES FOR INDOOR AND OUTDOOR USE AND RR-5

All Types Require a Light Source

FOR INDOOR USE

WITHOUT SEPARATE PHOTOTUBE HOUSING



TYPE

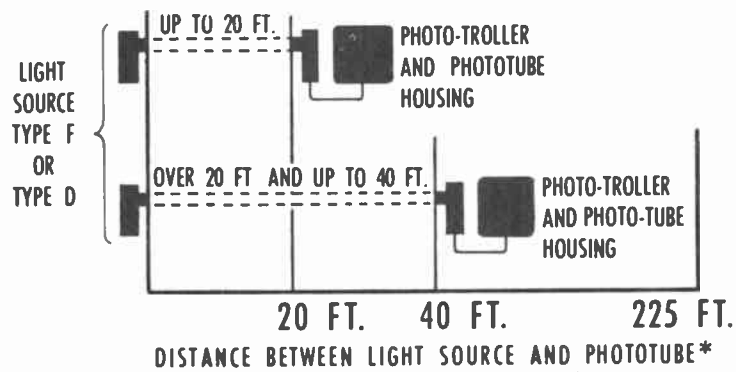
TYPE RX for instantaneous operation
or
TYPE RX-T for TIME DELAY before operation

TYPE RX-1 for instantaneous operation
or
TYPE RX-1A for instantaneous operation when light change is abrupt

TYPE RX-2 for long range applications or where unit might be affected by extraneous steady state light

Type J Light Source and Type D Phototube Housing may be used for applications where distance between light source and phototube housing is 2 inches or less.

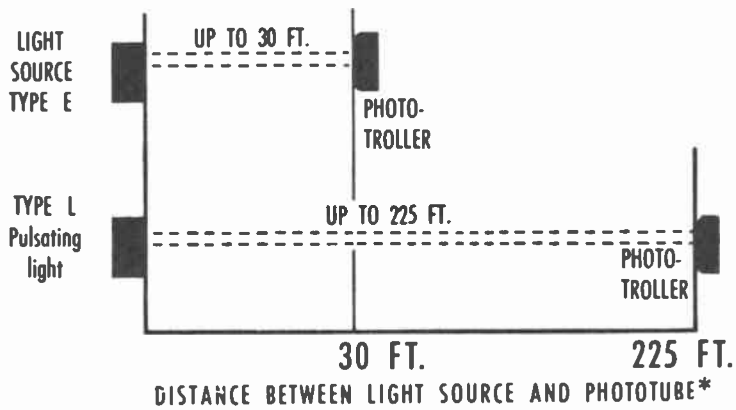
WITH SEPARATE PHOTOTUBE HOUSING



TYPE RX for instantaneous operation
or
TYPE RX-T for TIME DELAY before operation
Phototube housing Type A or B

TYPE RX-1 for instantaneous operation
or
TYPE RX-1A for instantaneous operation when light change is abrupt
or
TYPE RR-5 for HI-SPEED LOCK-IN operation
Phototube Housing Type A or B

FOR OUTDOOR USE—OR ADVERSE INDOOR CONDITIONS



TYPE RX-3 for instantaneous operation

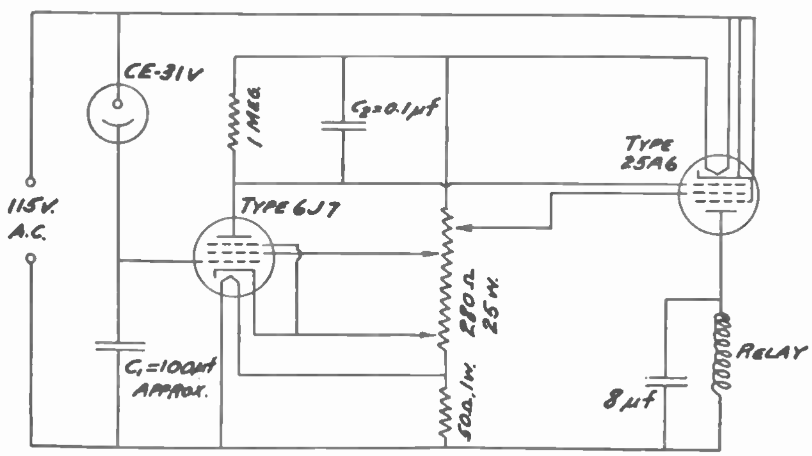
TYPE RX-2 for long range applications
or
where unit might be affected by extraneous steady state light.

Type J Light Source and Type D Phototube Housing may be used for applications where distance between light source and phototube housing is 2 inches or less.

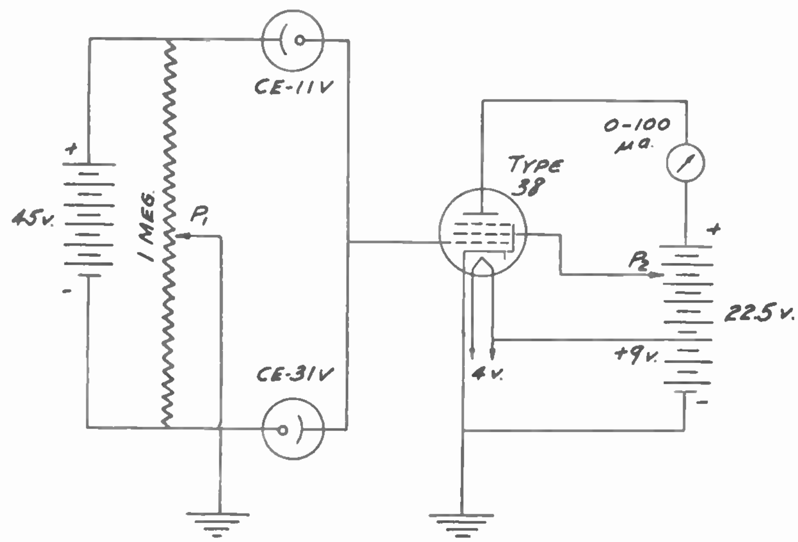
* The maximum operating distance is reduced to one-third of the above distances when a 10% transmission light filter is used.

CETRON PHOTOTUBE CIRCUITS

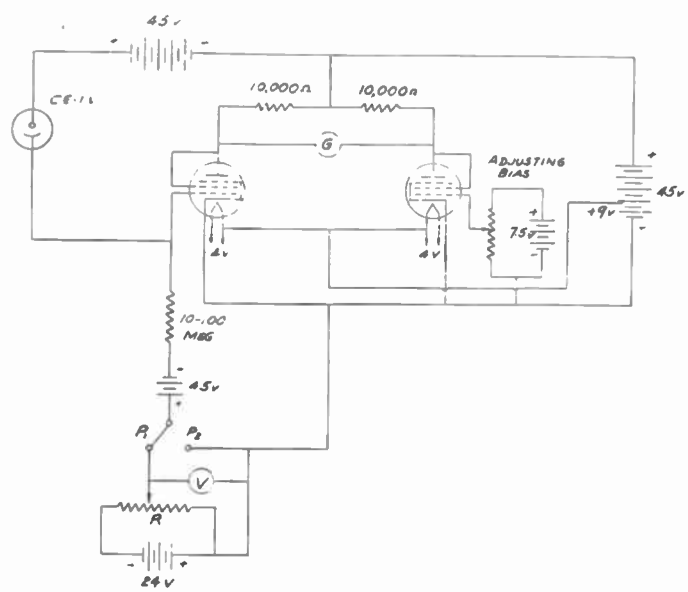
A-c operated two-stage phototube relay. Capacitor C1 is load for phototube, being charged during half-cycle in which anode of phototube is negative, and discharging through phototube during opposite half-cycle. Amount of discharge determined by light and controls grid voltage on 6J7 tube. High sensitivity of circuit makes it necessary to guard against leakage current on phototube.

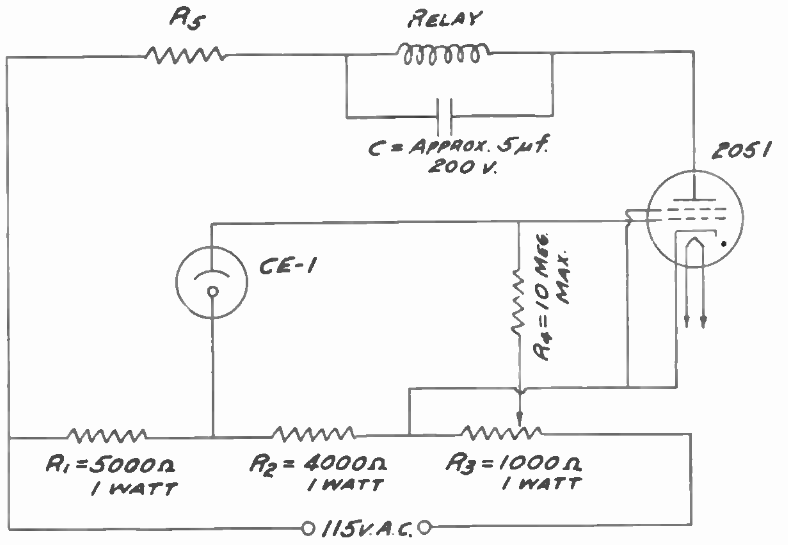


Circuit for matching of colors, candlepower, turbidity, etc. Phototube CE-31V is load for tube CE-11V in series. If either receives more light than other its resistance decreases and changes the voltage distribution. First short the pentode grid to its cathode and adjust P2 so microammeter less than full scale. Remove short and adjust P1 with phototubes dark to make meter read midscale. Expose one phototube to known illumination and adjust illumination on other until meter again reads midscale.

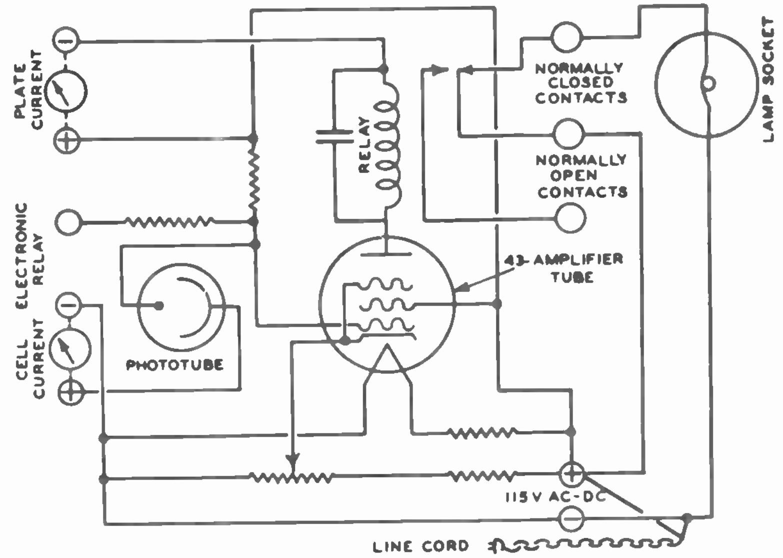


Photometry (light measurement) circuit, using null method. Adjust bias of right-hand pentode until galvanometer reads zero with phototube dark and switch at P2. This compensates for possible phototube leakage. Set switch at P1 and expose phototube to the test lamp. Adjust pointer of potentiometer R until galvanometer again reads zero. Reading on voltmeter is a direct measurement of light flux from test lamp. Voltmeter can be calibrated to read lumens or candlepower. Galvanometer may be replaced with electronic voltmeter for greater sensitivity.

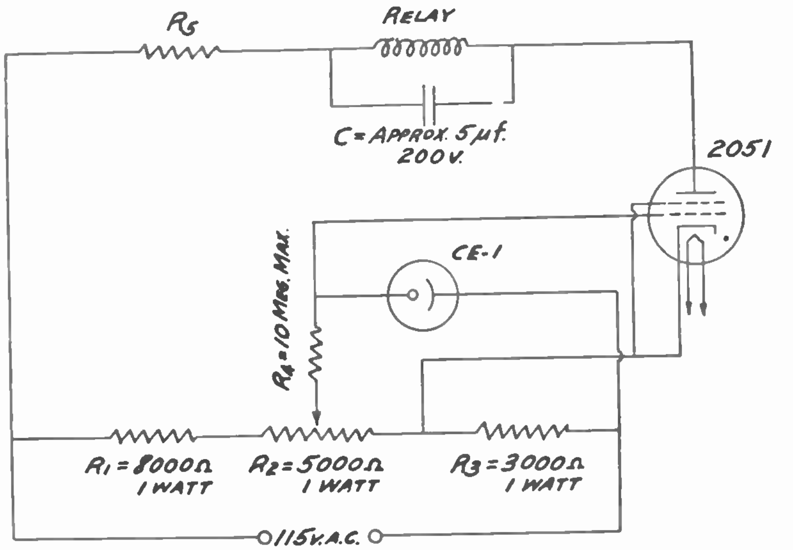




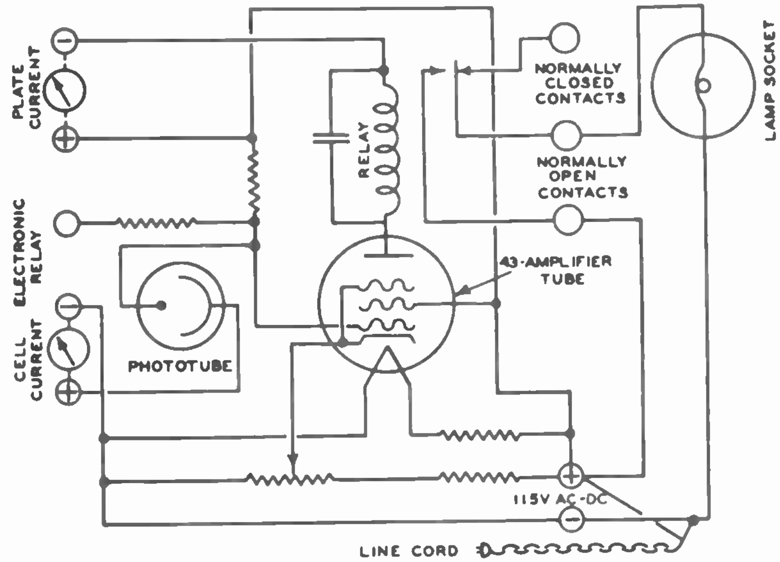
A-c operated photo-relay. Relay current increased by increase of illumination. R5 selected to limit current through relay. Cetron phototube.



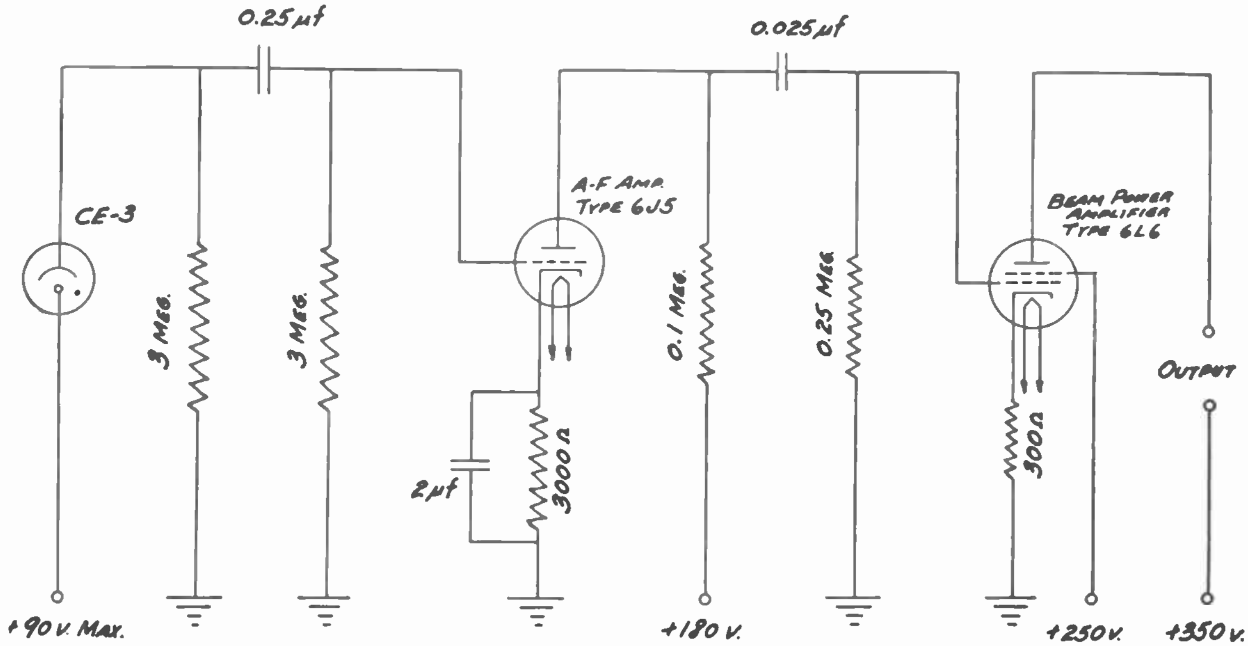
Phototube control of lamp. Lamp lights as illumination increases. G-M phototube. A-c operation.



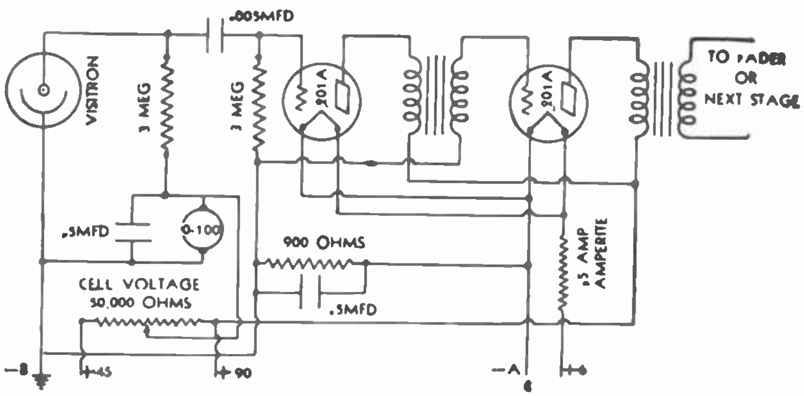
A-c operated photo-relay. Relay current increased by decrease of illumination. Cetron phototube.



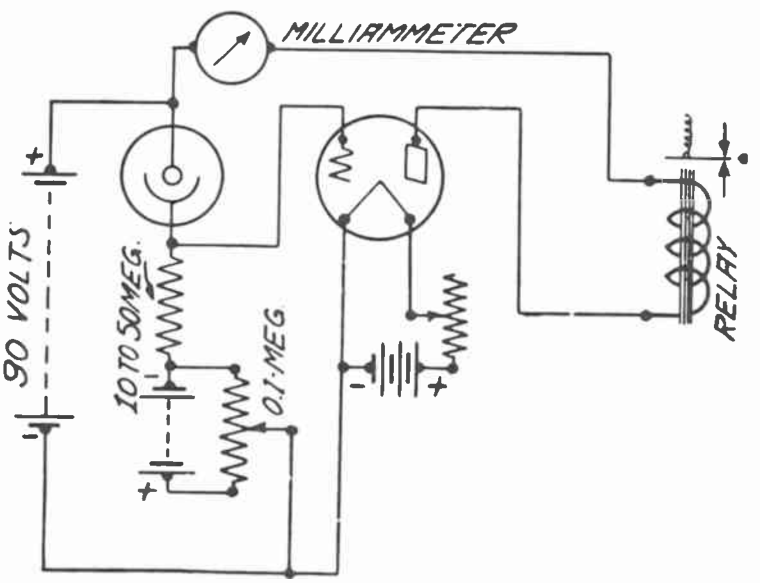
Phototube control of lamp. Lamp lights as illumination decreases. G-M phototube. A-c operation.



Simple circuit for sound-frequency reproduction. Approximate values for resistances and capacitances. Cetron phototube.



Battery operated preamplifier for sound frequencies. Visitron phototube.



Battery operated single-stage photo-relay with relay current increasing with increase of illumination. Visitron phototube.

WESTINGHOUSE ACROSS THE LINE STARTER WITH PHOTO CELL CONTROL

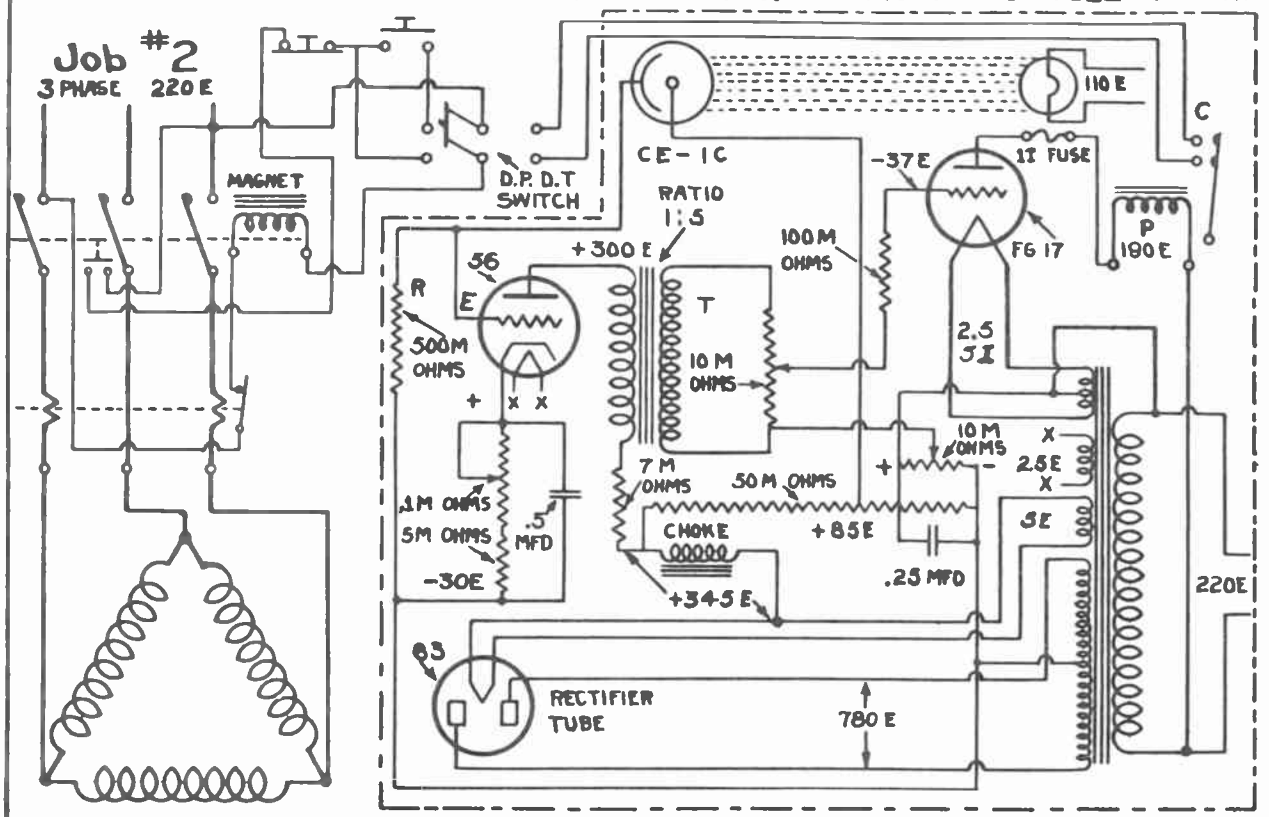


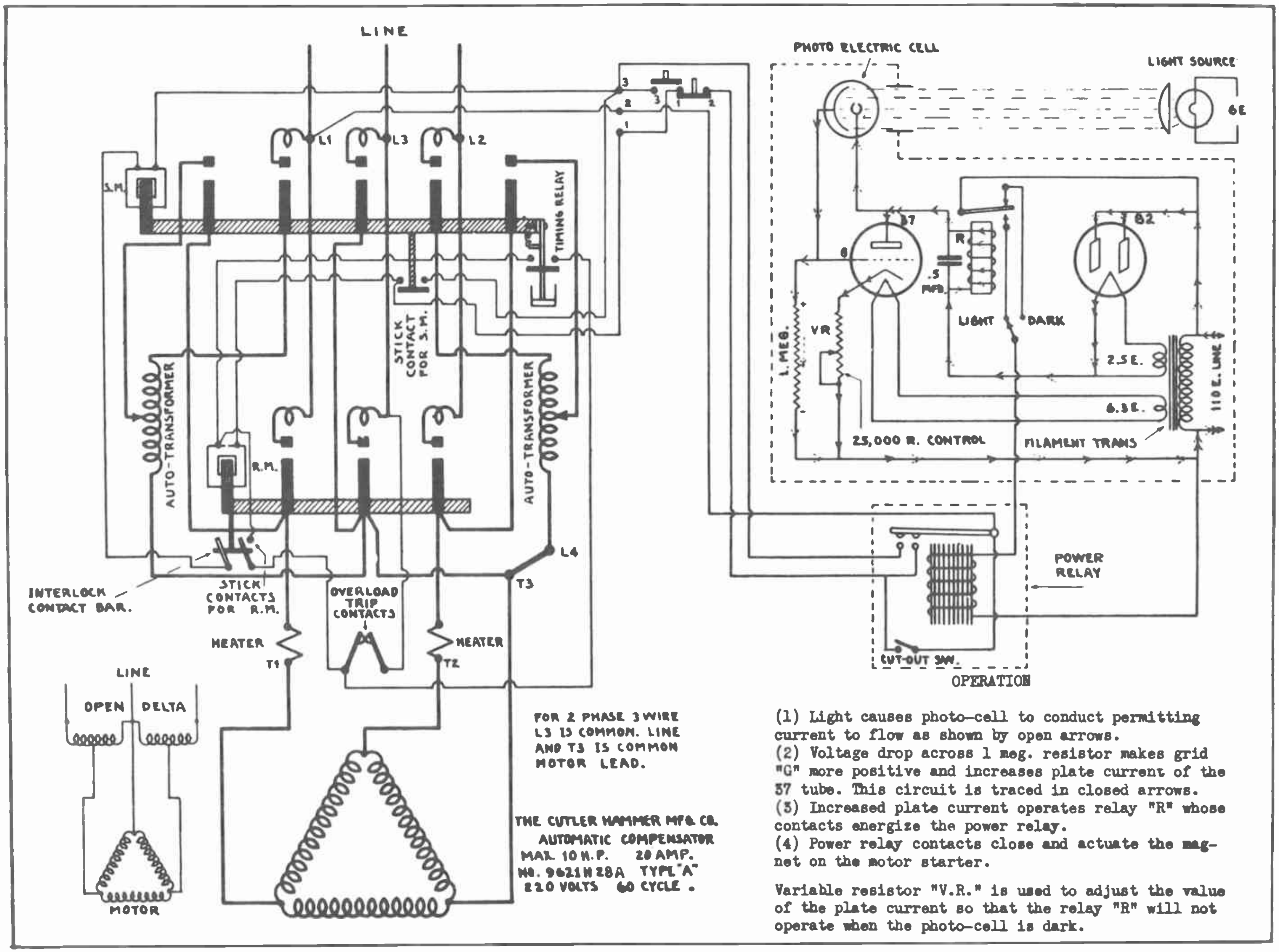
PHOTO-CELL CONTROL

In the operation of electrical equipment there are many situations where direct electrical connections between the operating apparatus and the point of control is undesirable, it is under such circumstances that photo-cell controls are frequently used, and this job demonstrates such an application. When considering the operation of such controls, it will aid the understanding to think of the photo-cell merely as a light-operated switch - as a switch which completes a circuit whenever a sufficient quantity of light falls upon it.

The control shown above employs a Type 83 tube as a full-wave rectifier to supply the necessary D.C. voltages, a Type CE-1C Cetron photo-cell tube as the light-operated switch, a Type 56 tube to amplify the minute current carried by the photo-cell, and an FG-17 Thyratron tube to complete or interrupt the circuit for the power relay "P". The Thyratron is a mercury-vapor, grid-controlledtube of relatively high current carrying capacity. The photo-cell is equipped with a centrally-located anode, and a caesium oxide-coated cathode which has the characteristic of emitting electrons wherever light falls upon it - these electrons constitute the photo-cell current

When a beam of light falls on the photo-cell cathode, the positively charged anode (85 volts D.C.) attracts the emitted electrons and the tube conducts a current of about 100 micro-amperes which, flowing through resistor "R", raises the potential of grid of the 56 tube, causing its plate current to increase, and the increase in current induces a voltage in the secondary winding of coupling transformer "T" which drives the grid of the Thryatron more positive, with the result that it conducts and allows current to flow through relay "P". The relay contacts close and complete the circuit for magnet "M" which operates the controller.

When the light beam is interrupted, current ceases to flow through the photo-cell and resistance "R", with the result that the potential of point "E" falls, there by reducing the plate current of the 56 tube. This reduction in current induces a voltage in the secondary winding of the coupling transformer of a polarity opposite to that produced before, and by lowering the negative potential on the grid, enables the tube to regain control and de-energize "P". Contacts "C" open the main controller contacts drop out to stop the motor.



OPERATION

(1) Light causes photo-cell to conduct permitting current to flow as shown by open arrows.
(2) Voltage drop across 1 meg. resistor makes grid "G" more positive and increases plate current of the 37 tube. This circuit is traced in closed arrows.
(3) Increased plate current operates relay "R" whose contacts energize the power relay.
(4) Power relay contacts close and actuate the magnet on the motor starter.

Variable resistor "V.R." is used to adjust the value of the plate current so that the relay "R" will not operate when the photo-cell is dark.

MASTER INDEX

The Master Index is furnished for your convenience in locating the Shop Prints and trouble shooting information you want. Subjects are arranged alphabetically like a classified telephone directory. It has been cross-referenced wherever possible to further simplify and speed up the location of technical material. Use this Index often--it saves time for you.