NOVEMBER • 1941

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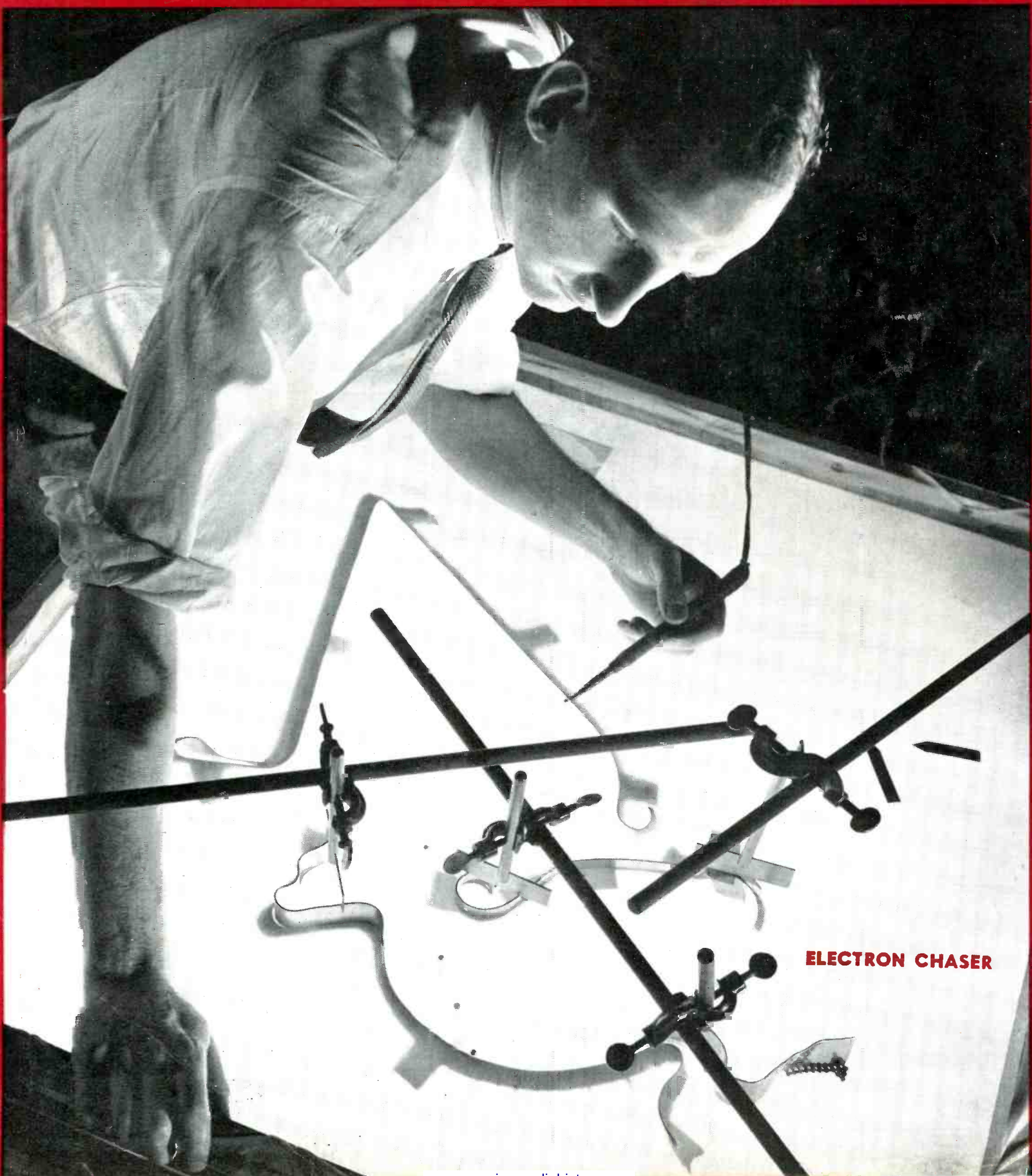

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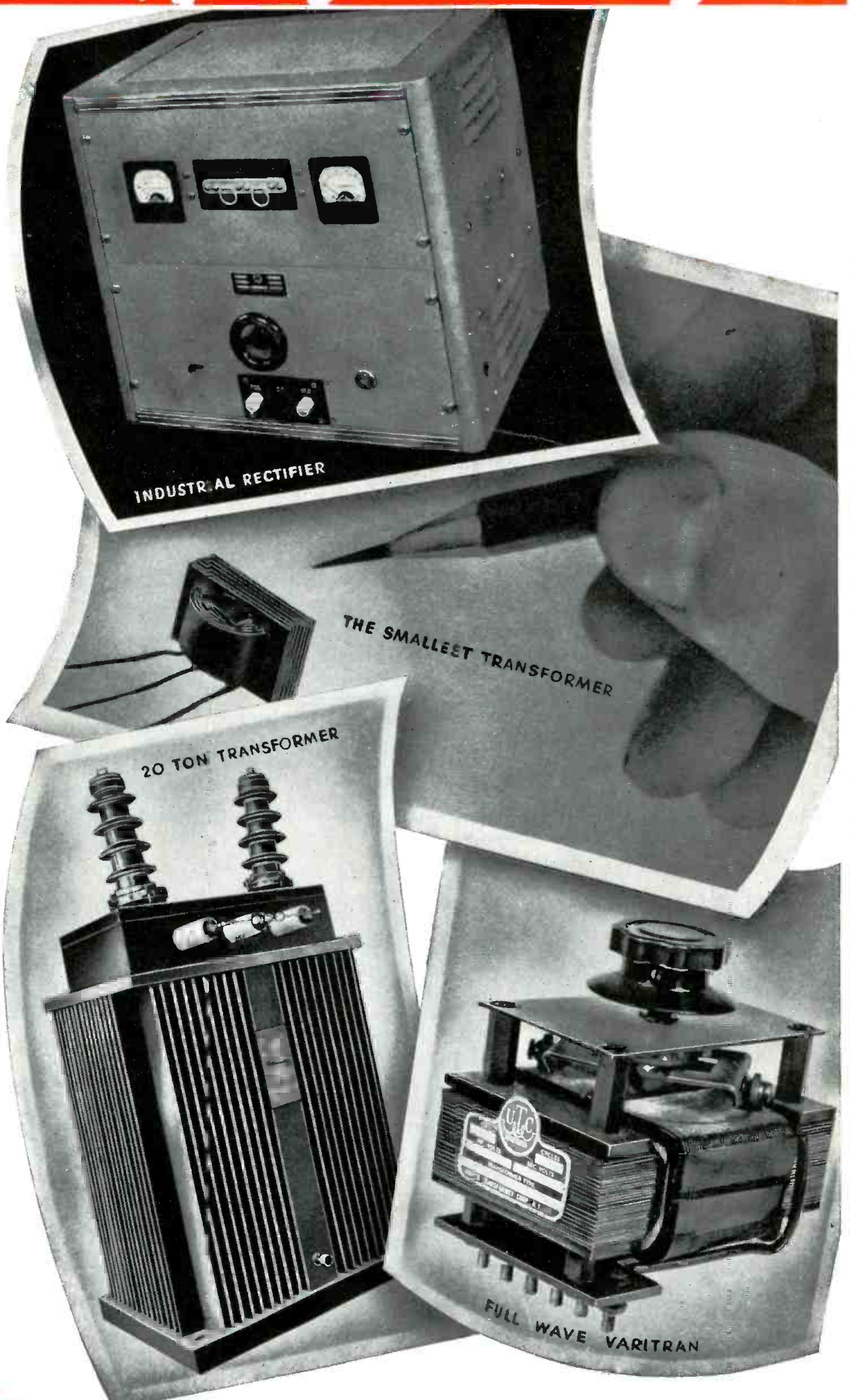

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99-129 North Broadway, Albany, N. Y.
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Editorial and Executive Offices
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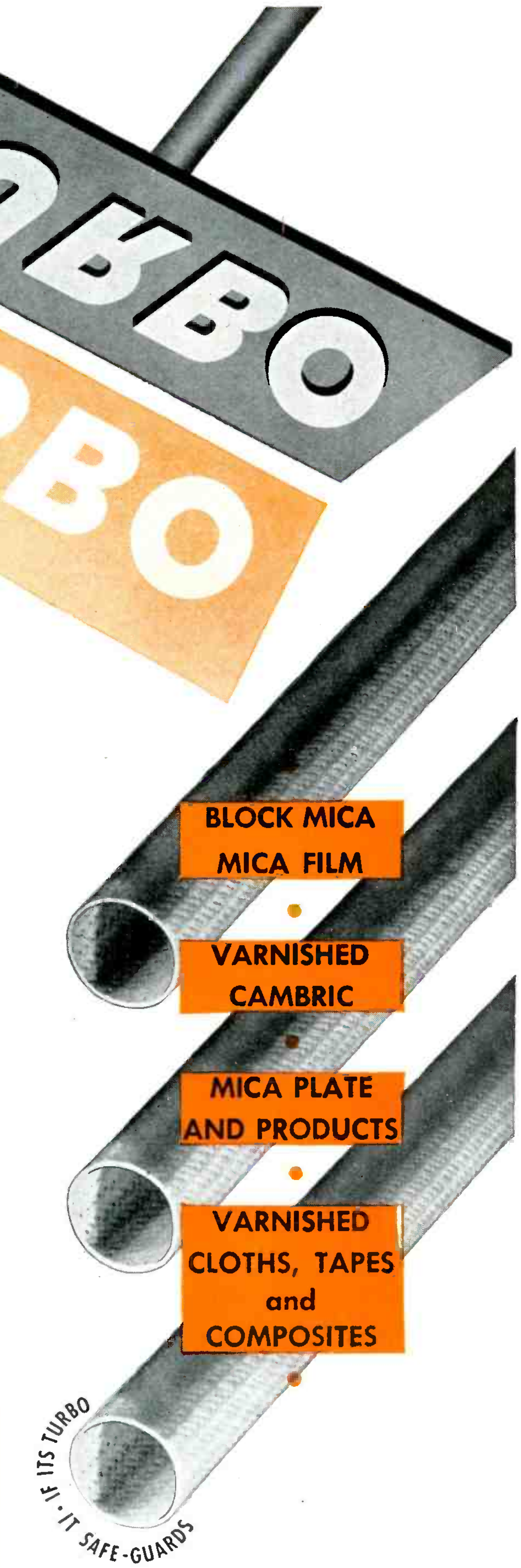
CONTENTS—NOVEMBER, 1941

DEPARTMENTS

ELECTRONICS, November, 1941. Vol. 14, No. 11. Published monthly, price 50c a copy. Allow at least ten days for change of address. All communications about subscriptions should be addressed to the Director of Circulation, 330 West 42nd Street, New York, N. Y.
Subscription rates—United States and possessions, Mexico, Central and South American countries, $5.00 a year, $8.00 for two years, $10.00 for three years. Canada (Canadian funds accepted), $5.50 a year, $9.00 for two years, $11.00 for three years. Great Britain and British possessions 36 shillings for one year, 72 shillings for three years. All other countries, $6.00 for one year, $12.00 for three years. Entered as Second Class matter, August 29, 1936, at Post Office, Albany, New York, under the Act of March 3, 1879. BRANCH OFFICES: 520 North Michigan Avenue, Chicago; 68 Post Street, San Francisco; Aldwych House, Aldwych, London, W.C. 2; Washington; Philadelphia; Cleveland; Detroit; St. Louis; Boston; Atlanta, Ga.



A BRAND... YOU CAN TRUST

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and

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And besides the all-important factor of dependability, constantly present in TURBO electrical insulating materials, the Brand service is geared to the DEFENSE pattern

1. Prompt delivery.
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A culmination of supreme insulation

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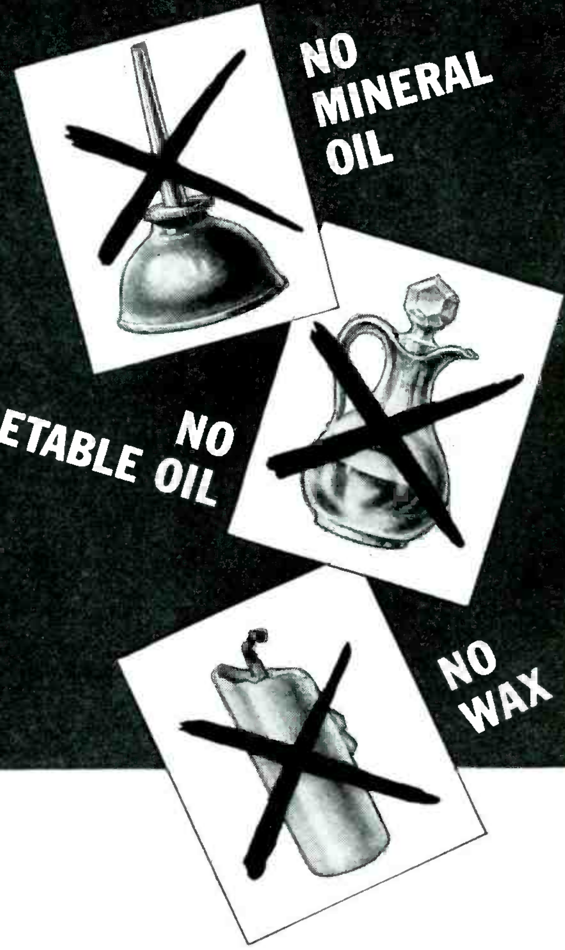

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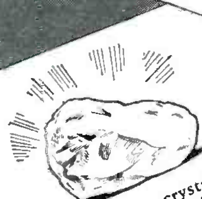

ALBANITE is a crystal-clear synthetic solid, free from oil and wax, physically and chemically inert. Because of this new stabilized transparentizing agent Albanene is unaffected by harsh climates —will not oxidize with age, become brittle or lose transparency.

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A remarkable new transparentizing agent developed in the K & E laboratories—produces this truly permanent tracing paper! ALBANENE is made of 100% long fiber pure white rags—treated with *Albanite*—a new crystal clear synthetic solid, physically and chemically inert. ALBANENE will not oxidize, become brittle or lose transparency with age.

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Make ALBANENE "prove it" on your own drawing board. Ask your K & E dealer or write us for an illustrated brochure and generous working sample.

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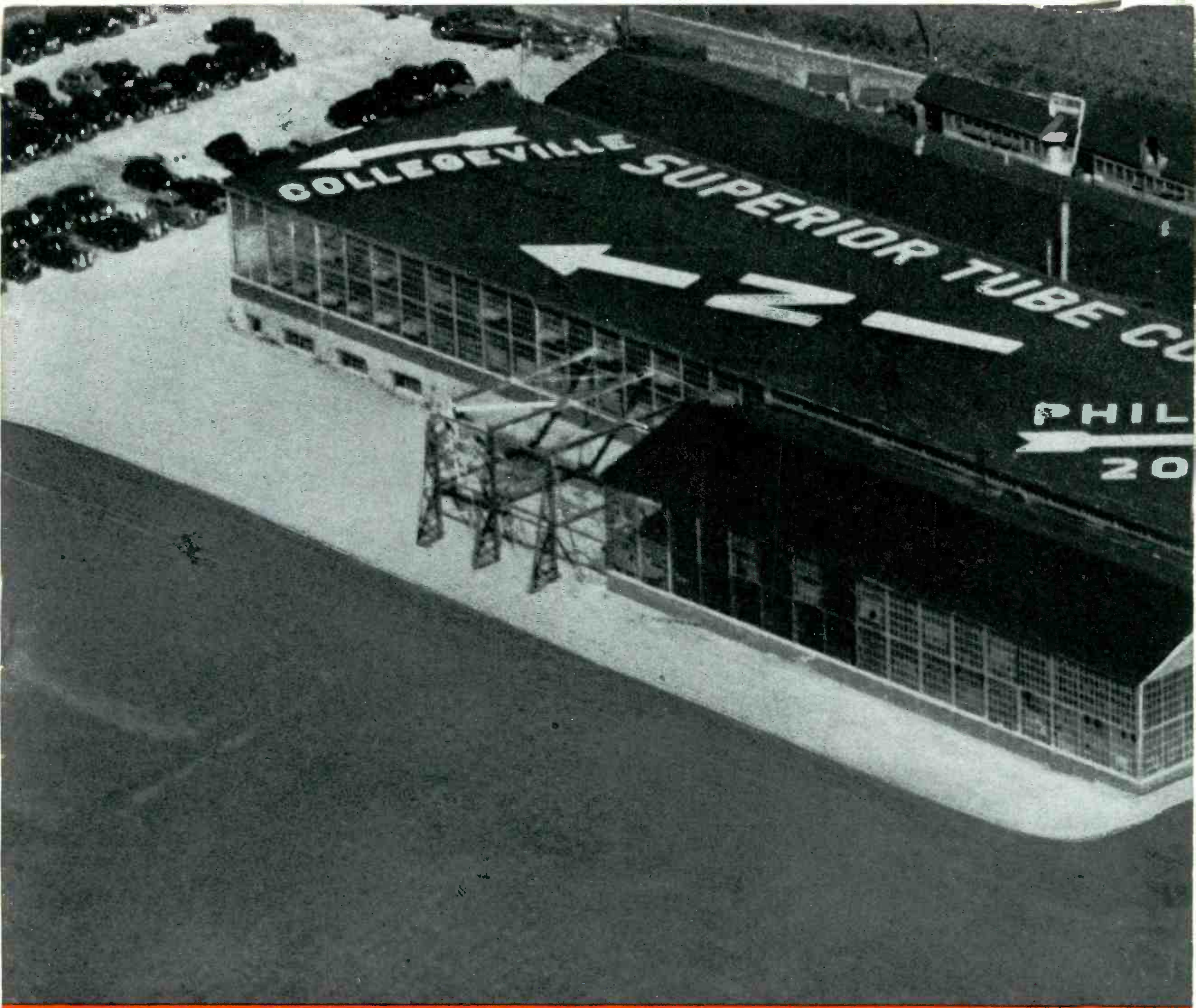
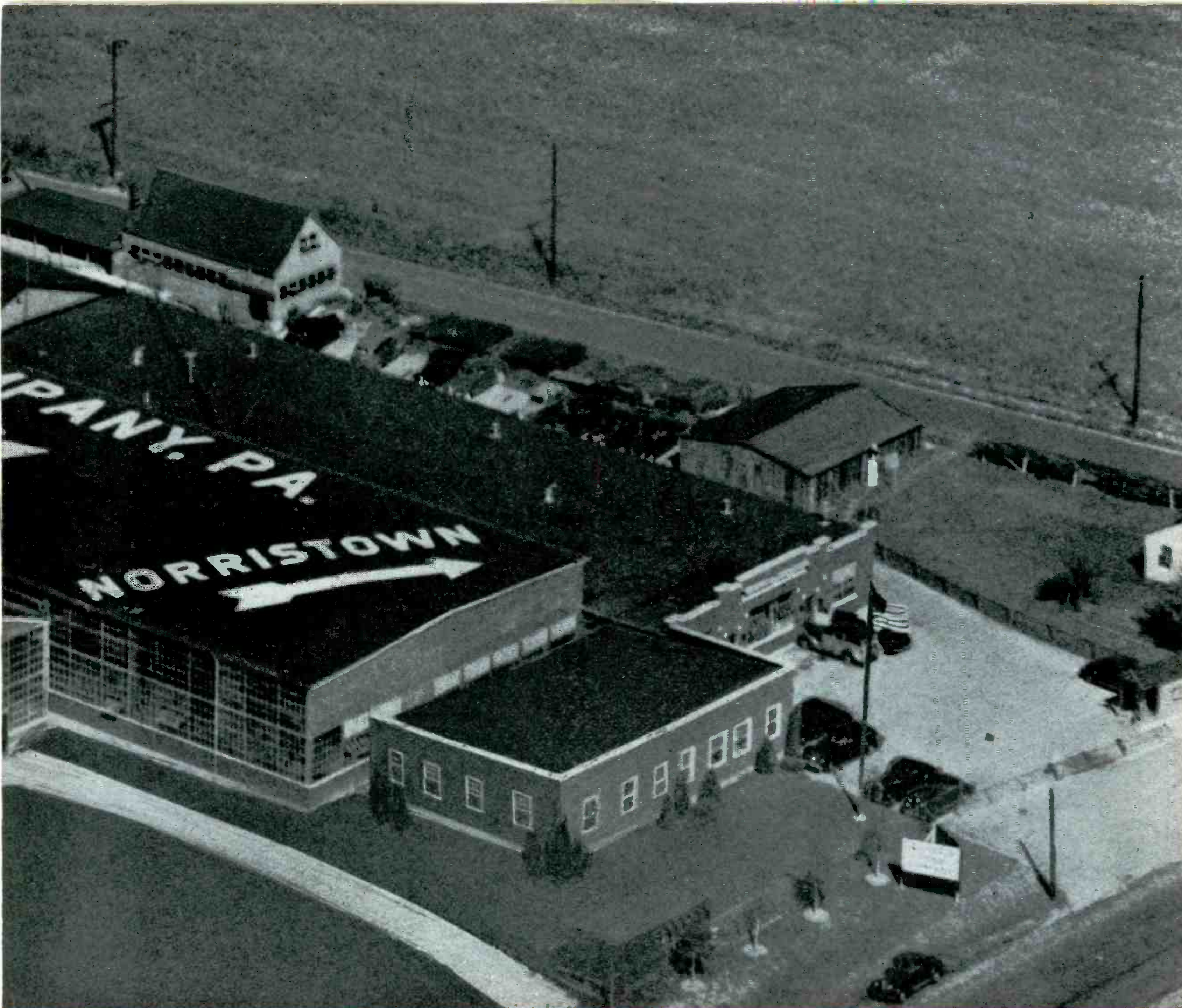


Sure, we're proud of it!

ON our seventh birthday this much we can say. Superior's definite place in the defense program is the culmination of development, planning and expansion since the start of production in 1934. Policies adopted at that time have been faithfully followed to the recent completion of the major building and equipment program shown.



AERIAL PHOTOGRAPH TAKEN SEPTEMBER 12, 1941

"Uniqueness" is as true of Superior now as it was at the start. We are digging in as never before to do a bigger job better, month after month. Our men have the will, plus the equipment, for a real "first line of defense" to produce metal tubing ⅝" O.D. and smaller. SURE, WE'RE PROUD OF THIS PLANT, because we can see a great deal farther over the horizon than before—and to us that is progress.

SUPERIOR TUBE COMPANY, NORRISTOWN, PENNSYLVANIA

"SMALL TUBING IS OUR ONLY BUSINESS AND WE KNOW IT"


Another "First" for
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To satisfy an ever increasing demand for standardization and interchangeability of parts Centralab introduces the
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NOW . . . when material conservation is so important, this development is doubly significant because it conserves two thirds of the metal formerly needed for shafts.
Manufacturers can take advantage of the standardization in the use of one volume control . . . one tone control . . . one switch . . . one dial drive mechanism which may be used with 54 different shaft lengths.
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A bulletin on the REMOVABLE FLAT SHAFT and its adaptations is in preparation . . . write for it.
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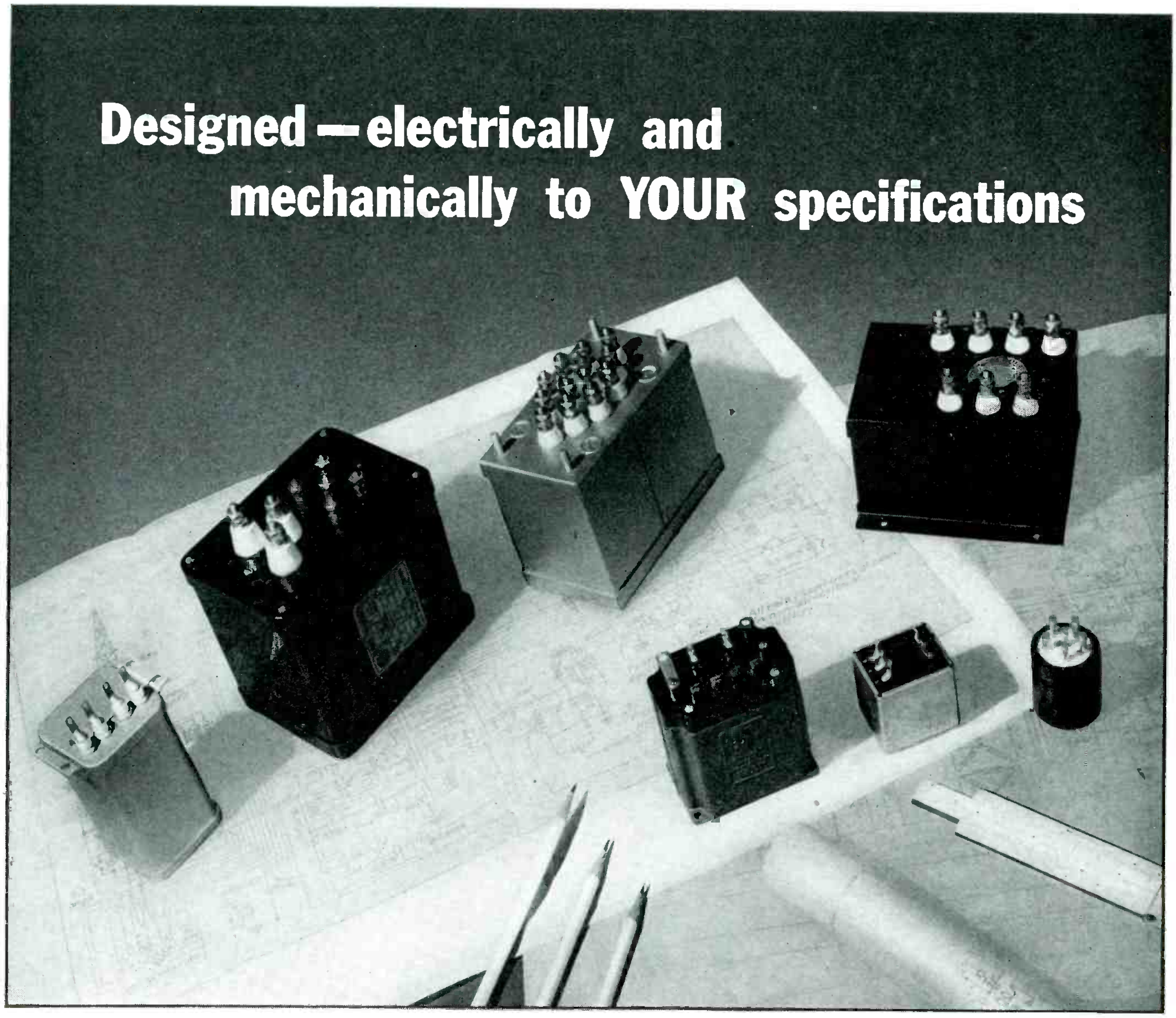

MANUFACTURING transformers for all industrial, electronic and laboratory applications has been our specialized work for 40 years. Today, a very important part of this business is with the electronic industry, and especially with manufacturers who purchase components for refabrication in *their* products. For these customers, AmerTran engineers develop designs to meet exact electrical and mechanical requirements.

While the present needs of National Defense are taxing our expanded engineering and manufacturing facilities, AmerTran quality will not be impaired. The benefits resulting from present experiences will, in the future, place us in a still stronger position to serve our regular and new customers in the commercial field.

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AMER TRAN

Manufacturers since 1901
at Newark, N. J.

AMERTRAN

Iron Horses Talk and Hear

A—Connector plug—sawed, turned, and drilled.
B—Coil form—turned, milled, and threaded.

The speed, numbers and tactics of modern tanks make radio communication necessary for effective action. • Communicating systems represent only one of many defense applications for which the Bakelite-laminated industry produces dependable insulation. The industry is working at capacity producing parts of all kinds for the Defense Program and for essential industry. SYNTHANE CORPORATION, OAKS, PENNA.

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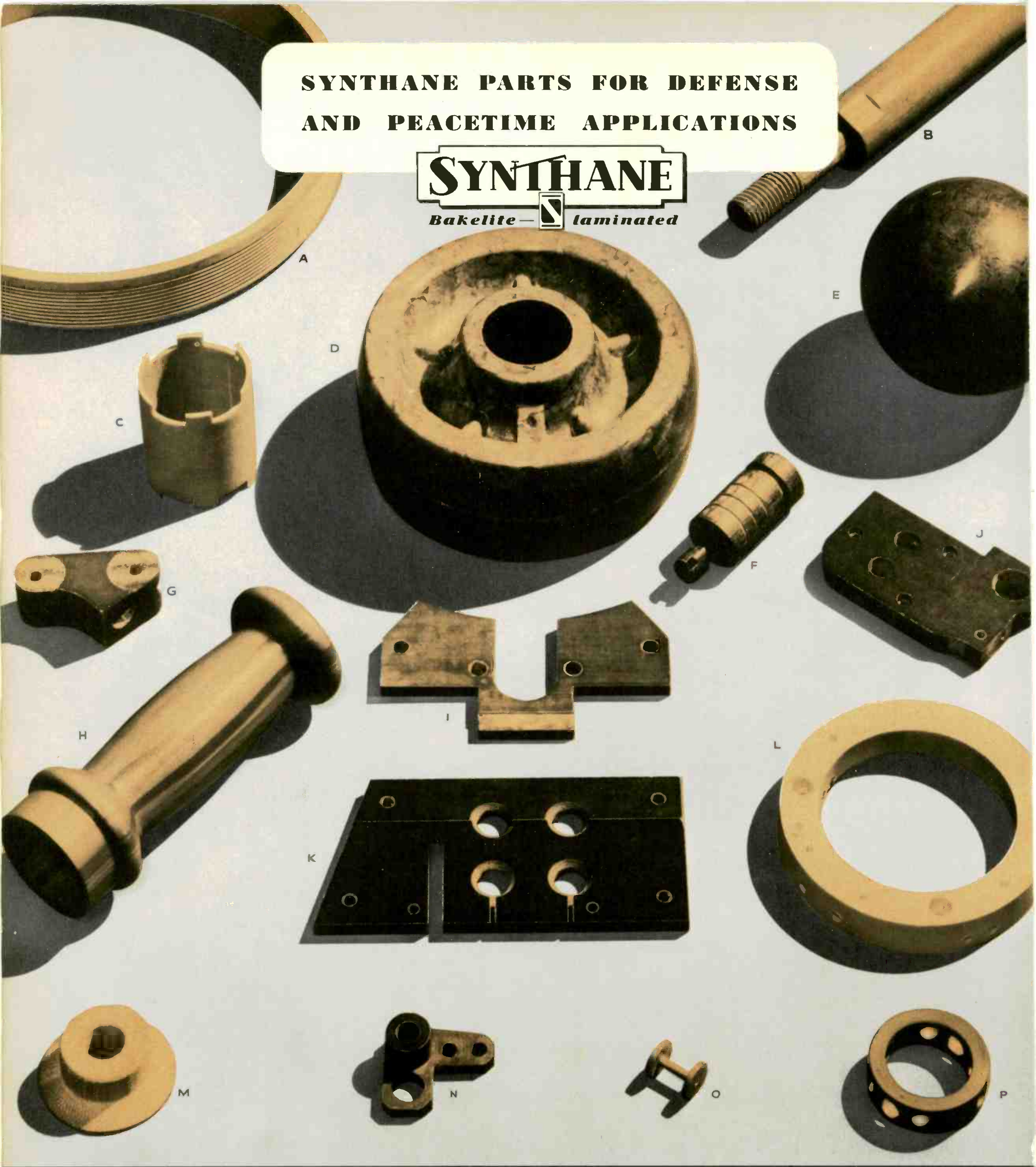


A—Airplane radio loop form
B—Rod for bottle washing machine
C—Variometer stator
D—Molded-macerated truck wheel
E—Molded-macerated valve check ball
F—Airbrake piston
G—Aircraft part
H—Handle for hosiery ironing device
I—Aircraft propeller part
J—Aircraft part
K—Airplane fairlead
L—Brush holder bracket
M—Plug end, rayon industry
N—Aircraft part
O—Radio coil spool
P—Ball bearing retainer

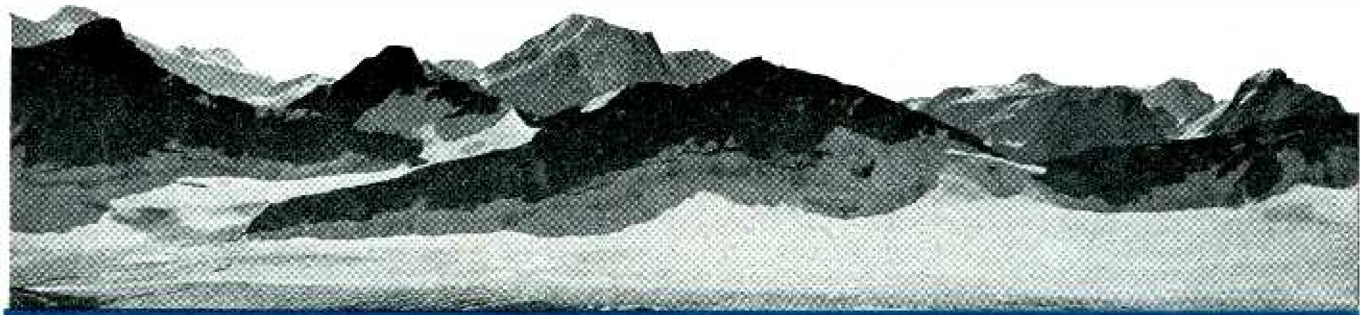
SYNTHANE CORPORATION, OAKS, PA.

The Rockies...

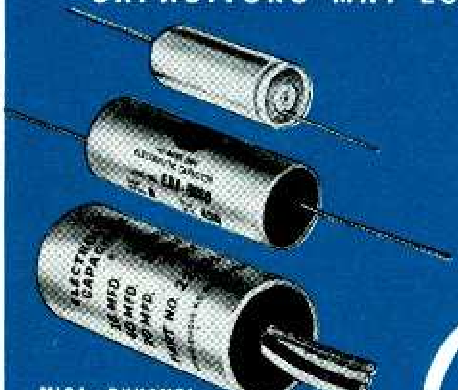
another C-D capacitor "test laboratory"

THERE'S EXTRA DEPENDABILITY IN LONGER LASTING C-D CAPACITORS

It's 450 miles from Vancouver to Lethbridge over the Canadian Rockies. Paving this scenic aerial highway, eight radio ranges help guard the safety of Trans-Canada Air Lines passengers. When so much depends on the flawless performance of radio communications equipment, the components chosen must possess something *extra.* Like so many air lines today, Trans-Canada Air uses Cornell-Dubilier capacitors in its aircraft and ground communications equipment. For Cornell-Dubilier's thirty-two years of specialization in the development, manufacture and application of capacitors gives C-Ds an extra measure of dependability. Why not take advantage of this experienced engineering—it costs nothing *extra.*



CAPACITORS MAY LOOK ALIKE BUT... *There is extra long life, extra uniformity and dependability built into C-Ds. Next time you specify capacitors look for the Cornell-Dubilier seal of experienced engineering. And get the* hidden extras *at no extra cost. Send for Catalog. Cornell-Dubilier Electric Corporation, 1006 Hamilton Blvd., South Plainfield, New Jersey.*



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PAPER - WET & DRY
ELECTROLYTIC
CAPACITORS

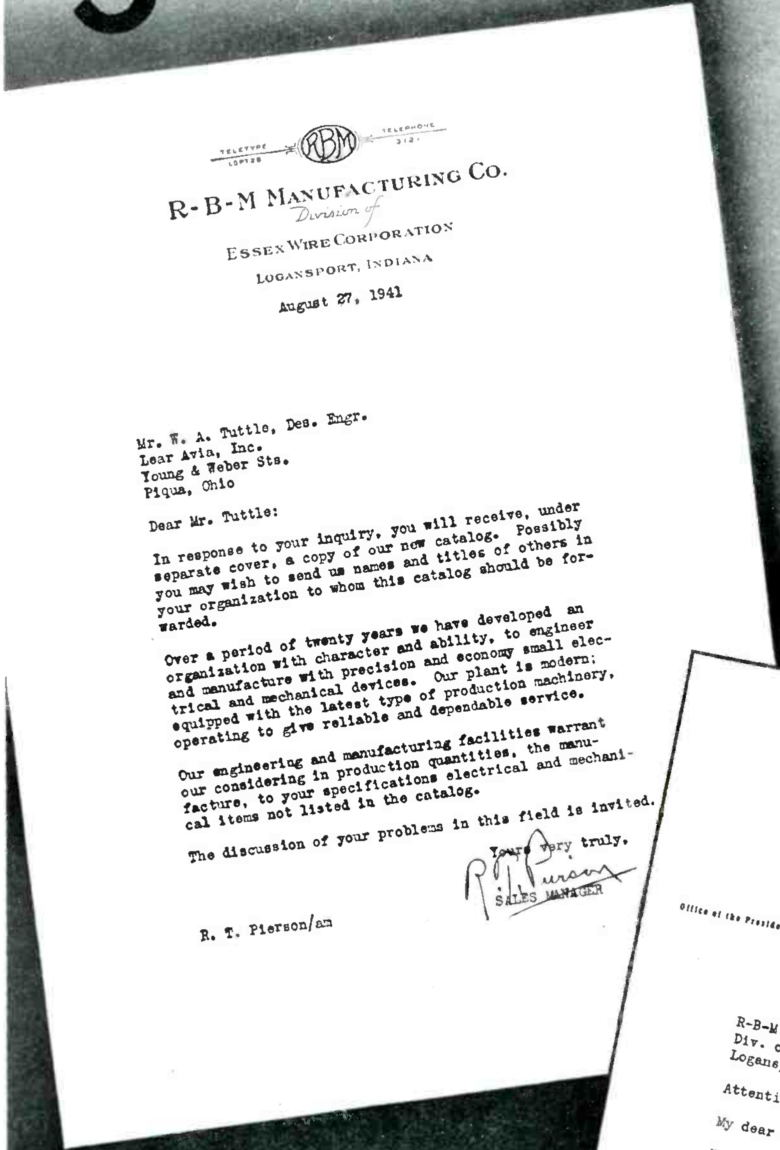
Cornell Dubilier

CORNELL-DUBILIER CD CAPACITORS

SOUTH PLAINFIELD, N. J. NEW BEDFORD, MASS.

... MORE IN USE TODAY THAN ANY OTHER MAKE ...

SUB-CONTRACT


R-B-M MANUFACTURING CO.
Division of
ESSEX WIRE CORPORATION
LOGANSPORT, INDIANA

August 27, 1941

Mr. W. A. Tuttle, Des. Engr.
Lear Avia, Inc.
Young & Weber Sts.
Piqua, Ohio

Dear Mr. Tuttle:

In response to your inquiry, you will receive, under separate cover, a copy of our new catalog. Possibly you may wish to send us names and titles of others in your organization to whom this catalog should be forwarded.

Over a period of twenty years we have developed an organization with character and ability, to engineer and manufacture with precision and economy small electrical and mechanical devices. Our plant is modern; equipped with the latest type of production machinery, operating to give reliable and dependable service.

Our engineering and manufacturing facilities warrant our considering in production quantities, the manufacture, to your specifications electrical and mechanical items not listed in the catalog.

The discussion of your problems in this field is invited.

Yours very truly,

SALES MANAGER

R. T. Pierson/am

your small electrical and mechanical assemblies and, or component parts pertaining to the electronic, remote or automatic control arts. Our engineering and production facilities have been devoted for over 20 years to design and manufacture of RELAYS, SOLENOIDS, SWITCHES and other small electrical and mechanical devices. Write today for our new catalog giving complete information.

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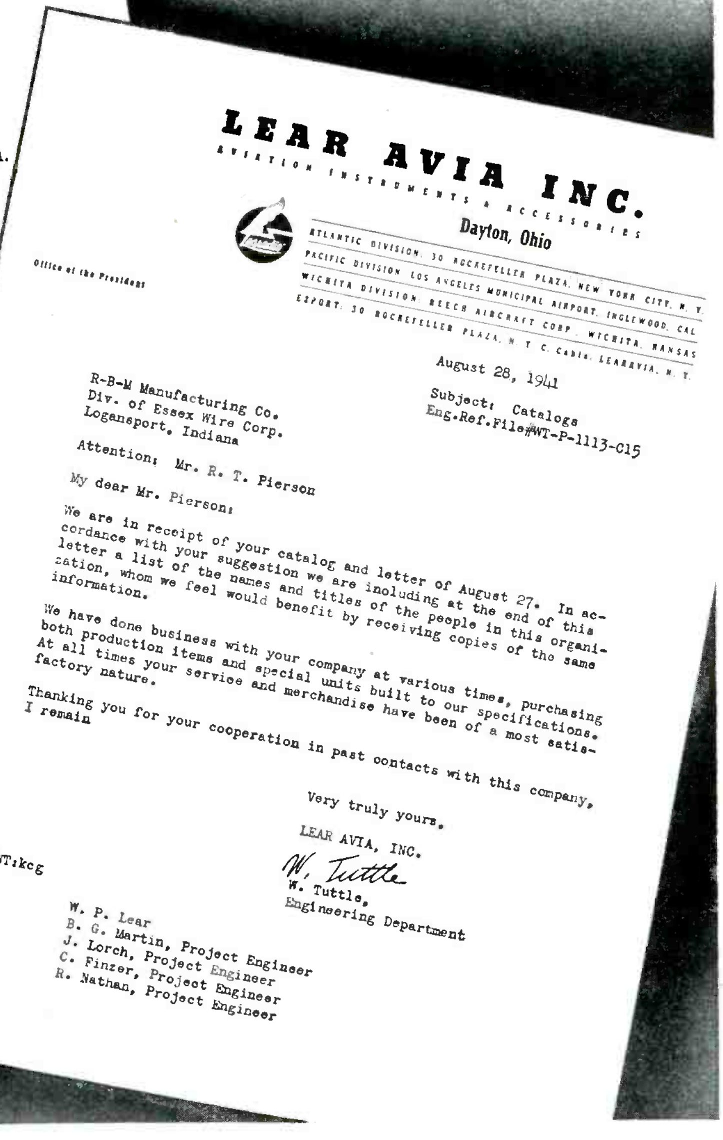
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AVIATION INSTRUMENTS & ACCESSORIES
Dayton, Ohio
ATLANTIC DIVISION: 30 ROCKEFELLER PLAZA, NEW YORK CITY, N. Y.
PACIFIC DIVISION: LOS ANGELES MUNICIPAL AIRPORT, INGLEWOOD, CAL.
WICHITA DIVISION: BEECH AIRCRAFT CORP., WICHITA, KANSAS
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Office of the President

August 28, 1941

R-B-M Manufacturing Co.
Div. of Essex Wire Corp.
Logansport, Indiana

Subject: Catalogs
Eng.Ref.File#WT-P-1113-C15

Attention: Mr. R. T. Pierson

My dear Mr. Pierson:

We are in receipt of your catalog and letter of August 27. In accordance with your suggestion we are including at the end of this letter a list of the names and titles of the people in this organization, whom we feel would benefit by receiving copies of the same information.

We have done business with your company at various times, purchasing both production items and special units built to our specifications. At all times your service and merchandise have been of a most satisfactory nature.

Thanking you for your cooperation in past contacts with this company, I remain

Very truly yours,

LEAR AVIA, INC.

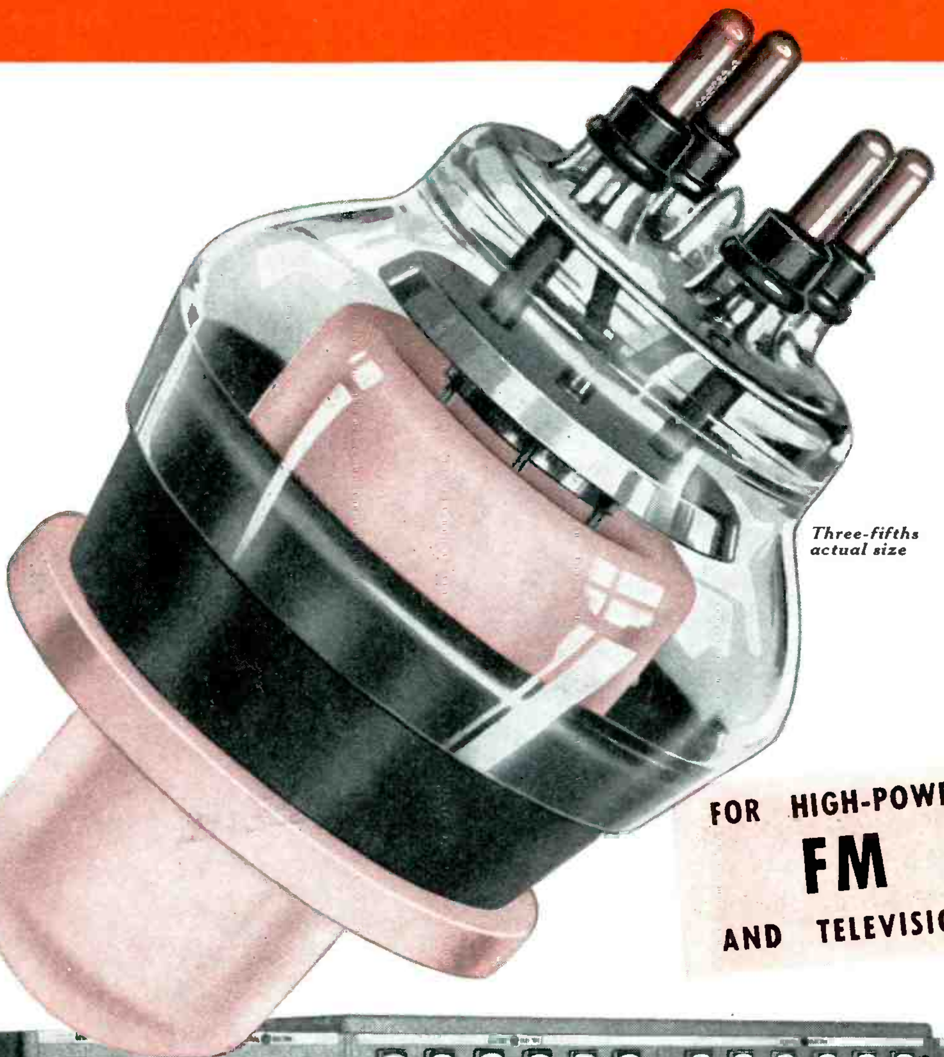
W. Tuttle,
Engineering Department

WT:kcg

W. P. Lear
B. G. Martin, Project Engineer
J. Lorch, Project Engineer
C. Finzer, Project Engineer
R. Nathan, Project Engineer

GL-880

A *MIDGET* IN SIZE—A *GIANT* IN OUTPUT



Three-fifths actual size

FOR HIGH-POWER
FM
AND TELEVISION

To Get the Most from Your Tube Dollar Be Sure to Specify GL-880's

GL-880 is the largest of the G-E developed tubes for high-frequency (FM and television) services. Its background is more than 28 years of G-E tube experience.

GL-880's ingenious "folded" anode reduces internal lead lengths by 10 inches without sacrificing cooling surface. High efficiency is obtained even at high frequencies.

Dual grid leads for separation of excitation and neutralization minimize neutralizing problems.

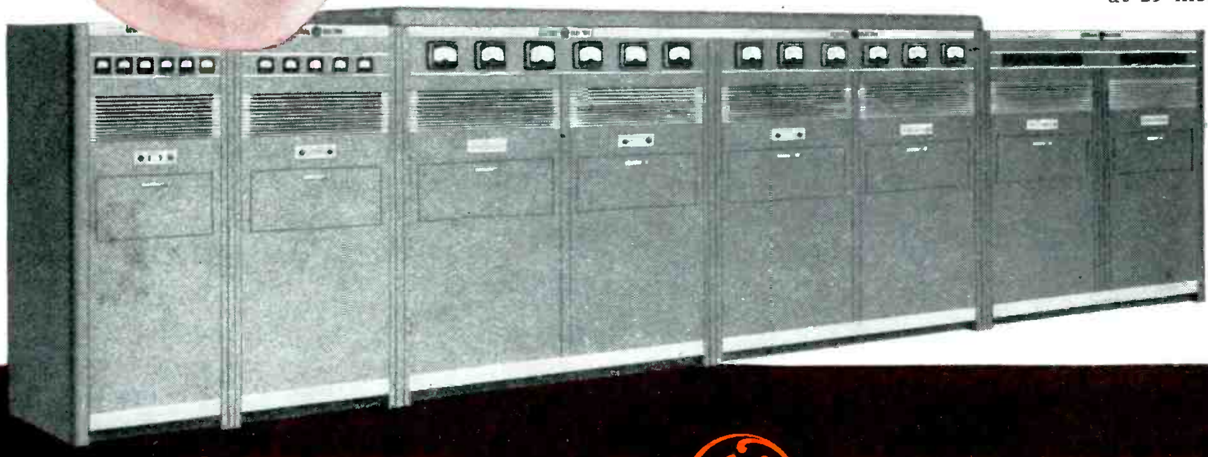
Easy to Drive

With only 1500 watts driving power at the grids, two GL-880's will deliver an easy 50 kw of FM at 50 mc.

Here's Real Versatility

Primarily for FM and Television, yes, but GL-880's have unusual efficiency at international and standard broadcast frequencies, and as modulators. A pair will give a 50-kw plate-modulated carrier at 25 mc!

Be sure to ask your nearby G-E representative for full information on the complete line of G-E transmitting tubes for all services. There are G-E offices in 80 principal cities. General Electric, Schenectady, New York.



G-E 50,000-watt FM broadcast transmitter

GENERAL ELECTRIC

161-18

HOW TO START A STATION

Right!

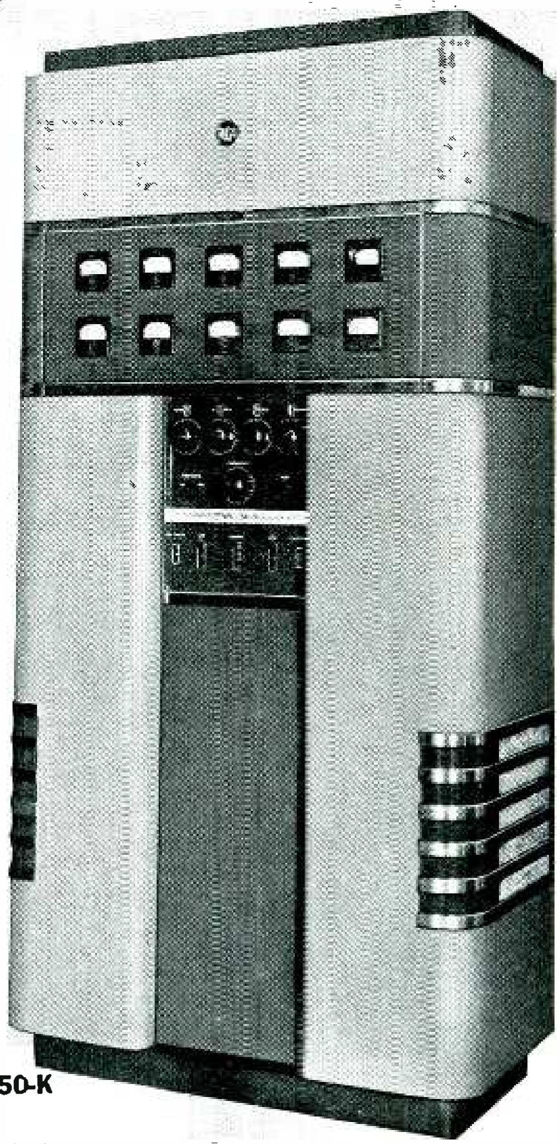
Here's the RCA Transmitter chosen by 84 American Broadcasting Stations!

Starting a *new* station—? Whether your construction permit has already been granted, or your application is still to be filed, choose the transmitter that is America's *first* choice by an impressive margin—the RCA Type 250-K, for efficient, economical, dependable operation at 100/250 watts.

84 stations, built or being built, have purchased this outstanding broadcast transmitter. Foreign purchasers account for nine more. Yet the 250-K has been on the market less than two years!

The *reasons* for such unequalled acceptance are inherent in the 250-K itself. Flat within 1½ db. from 30 to 10,000 cycles, it delivers program-quality difficult to match even at a higher price. High-level Class B Modulation, and efficient RCA-engineered circuits, keep operating costs low. It draws only 1625 watts from your power-line while operating at average program modulation on a 250-watt carrier. Installation is simple and inexpensive; operation is simplicity itself.

And—a thought for the future—the 250-K is easily adapted to 1,000-watt operation at any time, by the simple addition of the RCA amplifier unit, Type MI-7185 and suitable power-supply. Write for complete data today.



RCA 250-WATT TYPE 250-K

American Broadcasting Stations Equipped with the 250-K

including 1,000-watt stations using it as a 250-watt exciter unit

KANA	KBIX	KBWD	KBUR	KFBG	KFIZ	KGLO	KFMB	KFIO	KFPW
KFXM	KHAS	KHON	KLS	KLUF	KRJF	KROD	KSKY	KSRO	KUJ
KVFD	KVOE	KWIL	KWRC	KYCA	KYOS	WAJR	WARM	WATN	WBIR
WBTA	WCED	WBOC	WDAS	WDEF	WCBI	WCRS	WDAK	WFDF	WHKY
WFIG	WGTC	WHBQ	WGOV	WISR	WHUB	WFPG	WINX	WIZE	WHYN
WGAC	WLBJ	WKIP	WKMO	WKWK	WKPA	WLAV	WLOK	WMJM	WMRN
WMOB	WMOG	WOSH	WORD	WSAV	WSGN	WSOO	WSRR	WSLB	WSOC
WTHT	WTMA	WTJS	WWNY						

. . . plus still others to foreign countries, American police installations, and for stations now under construction!

RCA Broadcast Equipment

FOR FINER PERFORMANCE . . . GO RCA ALL THE WAY

Microphones
Speech Input Systems
Associated Equipment
Transmitters

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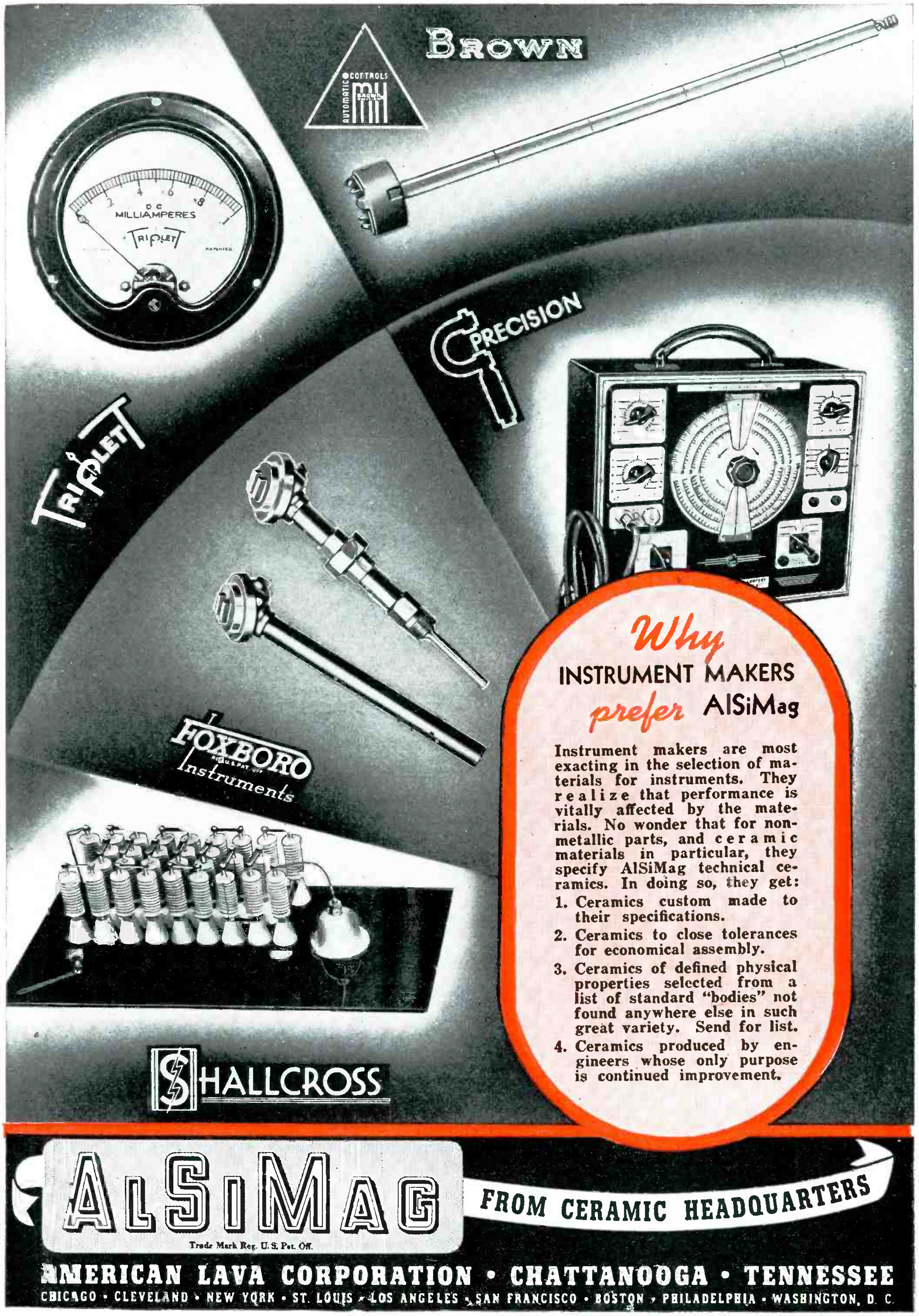
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Instrument makers are most exacting in the selection of materials for instruments. They realize that performance is vitally affected by the materials. No wonder that for non-metallic parts, and ceramic materials in particular, they specify AlSiMag technical ceramics. In doing so, they get:
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Trade Mark Reg. U. S. Pat. Off.
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CHICAGO • CLEVELAND • NEW YORK • ST. LOUIS • LOS ANGELES • SAN FRANCISCO • BOSTON • PHILADELPHIA • WASHINGTON, D. C.

Selenium Rectifier elements are used exclusively in Fansteel—I. T. & T. dry plate rectifiers, manufactured by Fansteel Metallurgical Corporation, North Chicago, Ill.

Fansteel—I. T. & T. Selenium Rectifiers are rapidly gaining favor in railway signal, telephone and telegraph service because of their small compact size, wide temperature range, high efficiency, stable output, electrical stability and low back leak.

Standard Selenium Rectifiers are available in a wide range of styles and capacities for all common signal and communication voltage and current ratings, and are also built to order for interlocking plants, switch machines and other heavy duty purposes.

The small size of Fansteel—I. T. & T. signal and communication selenium rectifiers is especially attractive to railway users because of the saving of space in signal cases, stations and towers. The I. T. & T. Selenium Rectifier is the smallest metallic junction rectifier yet developed, but is meeting all the exacting requirements of railway service.

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Consulting engineering services available for specific requirements.

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International Telephone & Radio Manufacturing Corporation

67 BROAD STREET, NEW YORK, N. Y.

She shall have music WHEREVER she goes

thanks, in part, to

Lustron

Lustron is noted for its beauty—for the limitless range of its clear, true colors and its smooth, lustrous surface.

But it took more than beauty to win this assignment.

The cover of this new Firestone personal radio is molded of Lustron by the Superior Plastics Company of Chicago for two very practical reasons:

1. Since the radio's aerial is coiled inside the cover, Lustron's *dielectric properties* help effectively to reduce static wherever the radio is carried.

2. Lustron's *high dimensional stability* makes it certain that the cover will always fit, however wet or dry, however hot or cold the surroundings.

Other Lustron production-and-sales advantages that may recommend this versatile member of the Monsanto plastics family for a job in *your* products: resistance to acids, alcohol, cleansing alkalis, odorless and tasteless, no moisture absorption, adaptability to low-cost, high-speed injection molding.

For full details and the names of competent molders, inquire: MONSANTO CHEMICAL COMPANY, Plastics Division, Springfield, Mass. District Offices: New York, Chicago, Boston, Detroit, Charlotte, Birmingham, Los Angeles, San Francisco, Montreal.

THE FAMILY OF SIX MONSANTO PLASTICS

(Trade names designate Monsanto's exclusive formulations of these basic plastic materials)

LUSTRON (polystyrene) • OPALON (cast phenolic resin) • NITRON (cellulose nitrate) SAFLEX (vinyl acetal) • FIBESTOS (cellulose acetate) • RESINOX (phenolic compounds)

Sheets • Rods • Tubes • Castings
Molding Compounds
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LET'S GO! U.S.A. • KEEP 'EM FLYING!

MONSANTO PLASTICS

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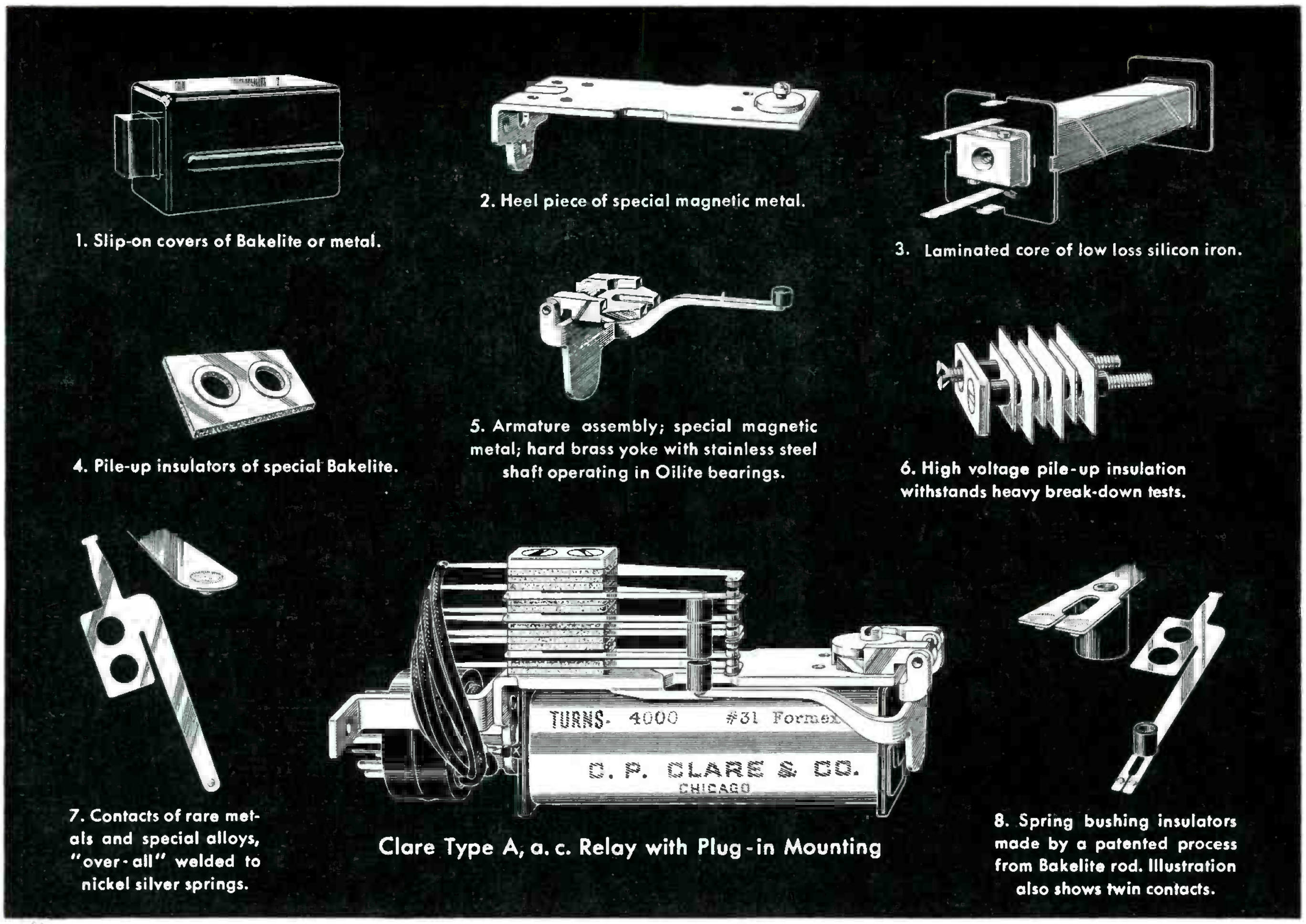
SERVING INDUSTRY . . . WHICH SERVES MANKIND



If You're Fussy About Relays.... READ THIS!

■ Here, illustrated and described, is the Clare Type A, a. c. Relay. It is designed for applications where a highly efficient multiple contact relay is indicated. Its application to the latest model TelAutograph is an example.

By its use ac-dc converters, batteries or d.c. power supplies can be discarded. It is quiet, cool running, constant, efficient and quick acting.

Meticulous attention to design, fine materials and precise manufacturing contribute much to this relay. Analyze these details:

1 Individual slip-on covers of Bakelite or metal make for easy inspection. Group covers are also available.

2 The heel piece is made from special magnetic metal annealed to provide high permeability at required flux densities, low eddy current loss and low hysteresis loss.

3 Coil core laminations are made of low loss silicon iron. Copper shading piece is securely fastened in slotted armature end of coil core. Coils are carefully wound to exact turns on precision machines. Lead out wires are securely soldered; entire coil is impregnated with Glyptol.

4 Spring pile-up insulators of special heat treated Bakelite, provide more favorable characteristics than triple-"X" Bakelite and permits punching without cracks or checks. It has minimum cold flow properties and low moisture absorption content.

5 Armature assembly consists of armature of special magnetic metal; stainless steel shaft operating in Oilite bearings inserted in a hard brass yoke assuring minimum wear with consequent quiet and long-life operation.

6 High voltage pile-up insulation consists of two flat or fillister headed screws of high tensile steel, specially heat treated, enclosed in Bakelite tubes and a combination of two single and one wafer insulator between each spring. Assembly is locked under heavy hydraulic pressure. Projecting wafer insulators provide creepage path of ¼" between contact springs. Assembly withstands very heavy break-down tests.

7 Contacts of rare metals or special alloys are available, in sizes from .062" to .1875" diameter, flat or hemispherical. They are welded to nickel silver springs by a special process, making them an integral part of the spring, thereby reducing contact resistance to the minimum and providing for rapid heat dissipation. Long contact life is assured.

8 Spring bushing insulators are made of Bakelite rod under a patented process. Hard rubber bushings generally employed, while similar in appearance, are inferior in wearing qualities. Strong, hard, long wearing Bakelite bushings are essential where heavy contact pressures are employed, or where vibration exists.

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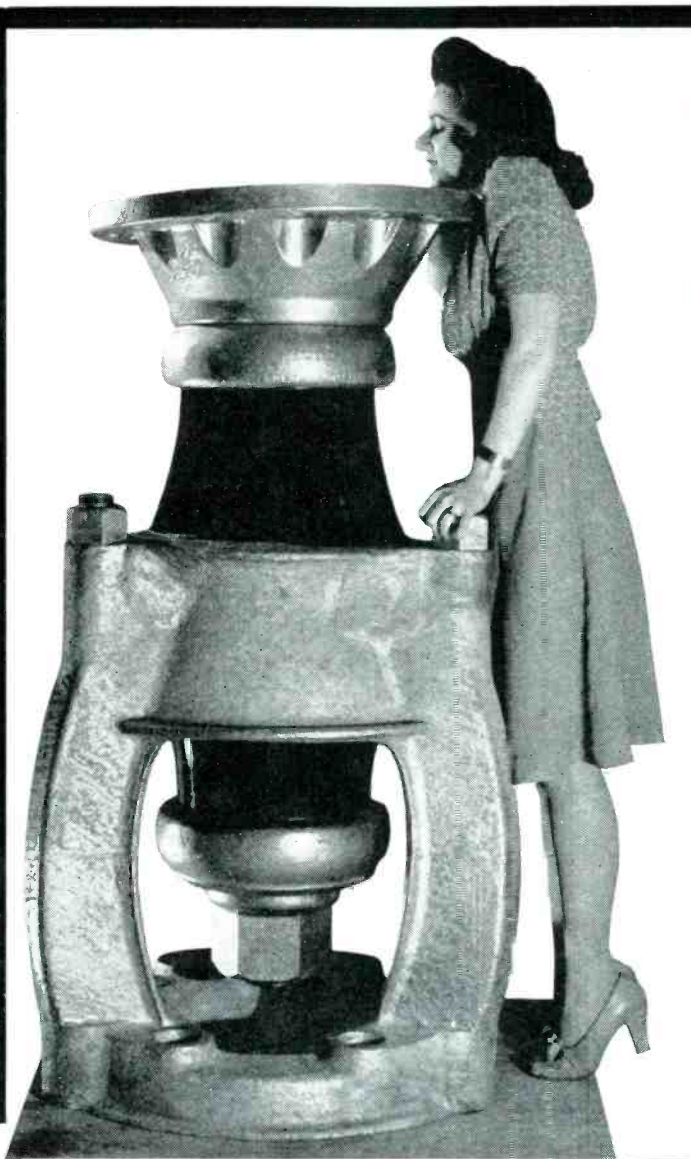

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What is the voltage value at make and break

What is the current value at make and break

What is the frequency of electrical interruptions

What is the opening and closing speed rate

What is the maximum opening distance

What is the arc suppression method

What is the closed contact pressure

What is the actuating method

What is the action of contact . . . butting, wiping or rotary

What severe actions must be planned for...mechanical, gaseous, corrosive

What is the allowable temperature rise

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CROSS TALK

► **MISCELLANY** . . . Much transpires in the course of a month; much that is important; too much if each item got the space here it deserved.

For example—Frank Shepard, Jr., (contributor to ELECTRONICS) opened the 1941-1942 season of the Radio Club of America by demonstrating how to get synthetic bass out of small radio sets. He does this by introducing certain forms of distortion which, to the ear, sound like a considerable improvement in the low frequency response. Some time ago Mr. Shepard demonstrated in this office a pocket sized radio which has a really remarkable synthetic bass. . . . During the recent violent sunspot activity, signals got crossed in the circuits feeding WAAT in Jersey City so that listeners within the service range of the station got in on a delightful conversation between a couple of girls on one end of a telephone line being very coy about a date with two men on the other end of the wire. . . . New York City is to have a municipal FM station if the Board of Estimate will kick in with $16,000. A 24-hour service was promised, not only with high fidelity static-less programs but with a facsimile service for the police, fire and sanitation departments. At the present time station WNYC shares time with WCCO in the Middle West, being forced off the air at sundown at the latter station. The FM station would suffer from no such privation.

Speaking of FM, as of October 1 the total national ownership of receivers amounted to 70,000, production was running at about 1000 sets a day (Armstrong licensed), and during August the total number of sets in use increased by almost one third. Philco says this improvement in sales is "undoubtedly due to the fact that the first low-priced radio sets capable of receiving FM" were recently put on the market. Philco also has a lot to say about low-priced FM sets, and in effect states that anyone is foolish to pay much more than $60 for such receivers. There is much about anti-static but not one word about high fidelity. What do *you* want FM for?

If there were enough FM stations to broadcast a sufficiently wide range of program service we would never listen to another AM program. This is approaching the case in New York City, but in New Hampshire where the Mt. Washington station is visible on good days (some 35 miles away) we get good service, also from Paxton, but there is only one program to listen to and that is not enough. There isn't much of the la-di-da stuff that we can take without an emetic and so the FM rig stays off the air except for occasional attempts to find something to listen to. Two New England FM stations, however, can supply as good coverage as all the AM transmitters combined.

► **MORE MISCELLANY** . . . A school of electronics in Minneapolis, was charged in a complaint by the Federal Trade Commission with trying to get students through exaggerated claims about the physical equipment of the school, and otherwise putting up a story that was somewhat on the optimistic side. This department gets many inquiries from prospective students about the merits of certain schools, offering courses in radio, television, facsimile, FM, electronics, etc., and in only cases where the school is well and widely known can we offer any aid. There are individuals who have worked up mimeographed sheets (as home-study courses) which will get you through an FCC exam, there are real schools, however small in enrollment and in teaching staff, and of course there are come-ons of all types. Which reminds us of the fellow who got sore when he answered an advertisement which would teach him a sure way to raise beets if he sent in ten cents. The required method was to "catch hold of the tops and pull." Prospective students can tell quite a lot from the tenor of the blurbs that attempt to get him to take the course. . . . In Louisana maneuvers of the army recently, a secret aircraft detector was used, so the papers claimed. Although a closely guarded secret the device consisted of portable radio receivers which picked up engine noise of approaching planes, automatically integrated vital facts concerning their strength and direction of flight, automatically transmitted the data to headquarters by teletype. . . . Radiosondes are to be made of plastic, thus releasing 6 tons of aluminum for defense purposes.

Down in Washington there is someone who reads the U. S. Patent Office Gazette regularly and breaks into the newspapers with some of the screwyist ideas that get patented. He always writes as though the patented idea was ready for the market and gets us, and a lot of other people probably, all excited. Then we learn that it is just a patent and we say pfui, or worse.

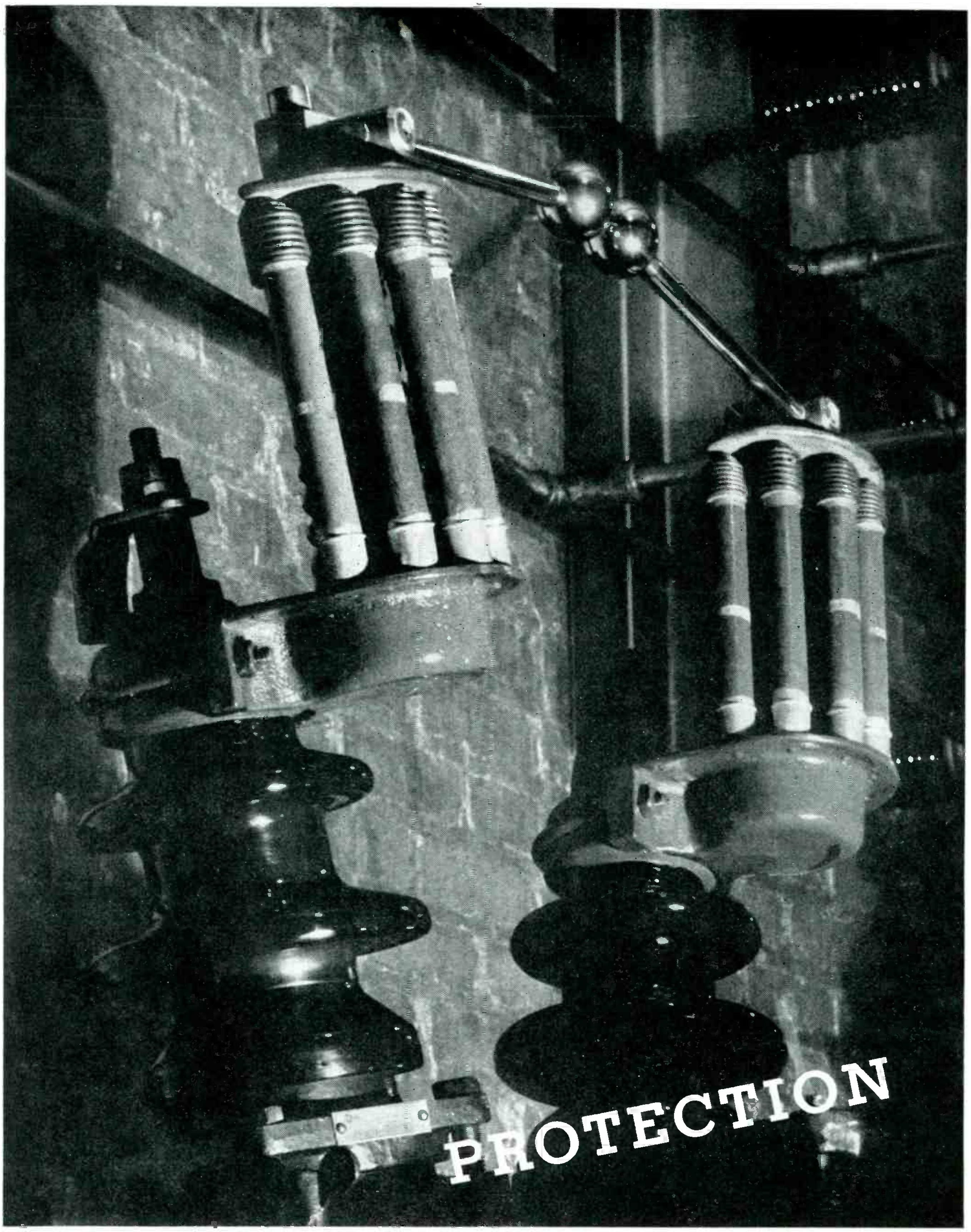


Photo by OTTO F. HESS, New York

Arc-over gap on one of the high voltage transformers at WOR

SENSITIVE D-C AMPLIFIER WITH A-C OPERATION

High sensitivity and stability, negligible zero drift, low noise level, and flat frequency response up to at least 12 kc are features of this a-c operated d-c amplifier. Cathode control amplifier eliminates drift, while gaseous discharge coupling tubes enable cascade stages to be operated from a comparatively low voltage regulated power supply

By STEWART E. MILLER

Jackson Heights, New York

DIRECT-current amplifiers are commonly used in a wide variety of applications. In many of these applications the signal input to the amplifier is of the order of one-tenth or one volt, and the important frequency components of the signal are no higher than a few cps. The problem of designing an amplifier to operate satisfactorily under these conditions is not difficult, and such an amplifier is commercially available.

However, in other applications the maximum input signal may be of the order of one to ten millivolts, and the signal may contain frequency components well into the audio range as well as the d-c component, Signals of this type are encountered in connection with strain measurements. In biology the increasing interest in electric currents associated with body activity makes it necessary to amplify signals in which there is a small but important d-c component. The writer knows of no commercial d-c amplifier which is designed for operation under these conditions, although a number of laboratory amplifiers (usually requiring a skilled operator) have been reported. [1, 2]

The amplifier described in this article has been designed to meet the needs outlined in the above paragraphs. Its operation is so simple that even a non-technical person can obtain satisfactory results when using it. Trick balancing schemes and designs which are critically dependent upon tube characteristics and resistance values have been avoided on the assumption that such methods would not give the best results in a device which must meet commercial requirements. Because of the bulk and inconvenience of batteries and because they are unreliable in an instrument which may be used intermittently, it was decided to make the instrument completely a-c operated.

The completed instrument may be considered as a specially designed d-c amplifier with regulated voltage supply. However, the special requirements of the instrument required many new circuit improvements and modifications of new design, some of which are believed to be sufficiently fundamental as to represent new techniques, and making a thorough review of tube and amplifier operation imperative. Among the more important features which have been incorporated in this amplifier, and which contribute to its stability may be listed the following: (1) cathode control circuit for overcoming the difficulties of slow drift in the operation of the amplifier, most of which are caused by ambient temperature changes, (2) the development of voltage-regulated power supply in which the a-c component in the output is 0.5 millivolt for a 250 volt supply, and in which variations of input voltage from 95 to 125 volts produce changes in the output of less than 0.4 millivolt, (3) interstage coupling device enabling several cascaded stages having a gain, without feedback, of about one million, to be operated from a single 250-volt supply.

The characteristics of the completed amplifier (see Figs. 1 and 2) may be summarized as follows:

(1) Input Circuit. Both terminals are normally at low potential, one terminal grounded. Input resistance may be any value from zero to several megohms.

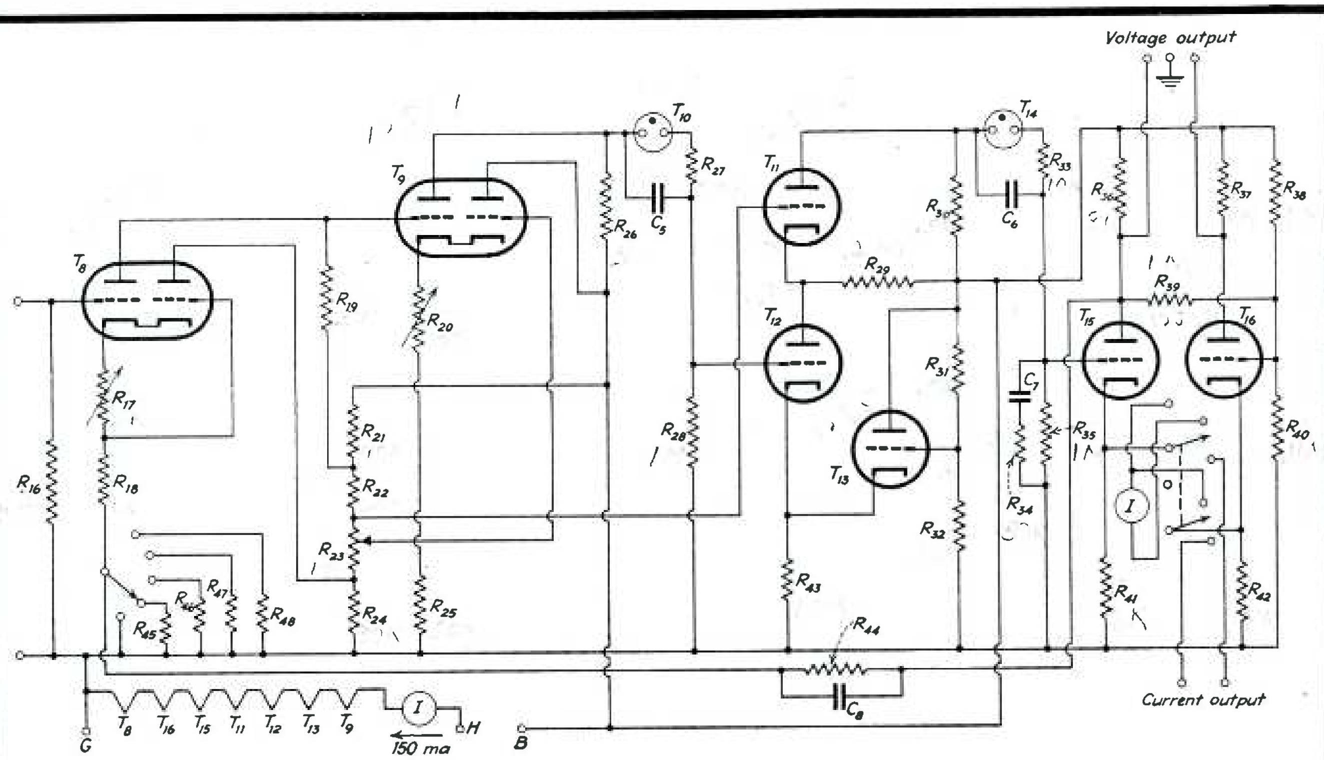
(2) Output Circuit. Both voltage and current output terminals are available simultaneously. Current output is ±5 milliamperes, and voltage output is ±80 volts peak from a balanced output circuit. Thus an Esterline-Angus 5 milliampere recorder may be used, or a 4-inch pattern may be produced on a cathode-ray tube having a deflection sensitivity of 40 volts per inch.

(3) Sensitivity. Full-rated output is obtained for input of 0.35 to 10 millivolts.

(4) Amplifier Gain. Transconductance is variable from 14 mhos to 0.50 mho. Voltage gain is variable from 72 db to 102 db. The overall voltage feedback is varied from 15 to 45 db.

(5) Frequency Response. Uniform response is obtained from direct current to 12,000 cps or 20,000 cps (depending upon the sensitivity setting) from a low-impedance source. Stray input capacitance limits its frequency response for high-impedance sources, as shown in Fig. 3.

6. Noise Level. Noise level is 4 microvolts peak or roughly 1 micro-



Metallized Resistances
R_{26} = 0.5 megohm
R_{27} = 50,000 ohms
R_{28} = 1.0 megohm
R_{29} = 0.2 megohm
R_{30} = 0.5 megohm
R_{31} = 0.5 megohm
R_{32} = 0.1 megohm
R_{33} = 10,000 ohms
R_{34} = 50,000 ohms
R_{35} = 1.0 megohm
R_{38} = 1.0 megohm
R_{39} = 1.0 megohm
R_{40} = 0.11 megohm
R_{36} = 8,000 ohms
R_{37} = 8,000 ohms
R_{41} = 8,000 ohms
R_{42} = 8,000 ohms
R_{43} = 15,000 ohms
R_{44} = 151,000 ohms

Nichrome Wire-Wound Resistances
R_{16} = 0.47 megohm
R_{25} = 50,000 ohms

Advance-Wire Resistances
R_{18} = 1,000 ohms
R_{19} = 0.5 megohm
R_{21} = 40,000 ohms
R_{22} = 20,000 ohms
R_{24} = 30,000 ohms
R_{45} = 1.04 ohms
R_{46} = 3.62 ohms
R_{47} = 11.0 ohms
R_{48} = 37.4 ohms

Wire-Wound Variable Resistances
R_{17} = 2,000 ohms
R_{20} = 10,000 ohms
R_{23} = 10,000 ohms

Condensers
C_5 = 0.03 μf mica
C_6 = 0.01 μf mica
C_7 = 0.0001 μf mica
C_8 = 0.00003 μf mica

List of Tube Types
T_8, T_9 = 12SC7
T_{10}, T_{14} = VR-150-30
T_{11} = 12SF5
T_{12}, T_{13}, T_{15}, T_{16} = 12J5GT

Fig. 1—Schematic wiring diagram of the complete d-c amplifier

volt rms (referred to the input) with the input shorted, or 16 microvolts peak (11 microvolts rms) with input resistance equal to 0.5 megohm. This noise is of the impulse type and has a nearly uniform frequency distribution.

(7) Distortion. On 10-millivolt sensitivity setting, distortion is negligible and less than 1 percent on 1-millivolt sensitivity setting (measured at 80 percent maximum output).

(8) A-C Operation. Amplifier and power supply are independent of line voltages greater than 94 volts.

(9) Long-Term Drift. A typical zero-drift recording is shown in Fig. 4.

The wiring diagram of the amplifier is shown in Fig. 1, while that of the voltage regulated power supply is shown in Fig. 2. The problems involved in the design of these two units are sufficiently involved that the amplifier and voltage supply will be discussed separately in considerable detail.

Amplifier Design—Cathode-Control Amplifier

There are several important problems which are encountered in designing a d-c amplifier whose instabilities (long-term drift and instantaneous fluctuation of the output corresponding to zero input) must be small compared to 1 millivolt when referred to the input. One of these problems is that of overcoming what is sometimes known as grid drift, but which might better be called cathode drift. Cathode drift is an undesired change in plate current due to uncontrolled conditions in the grid-cathode circuit, and there are several factors which contribute to it. First, changes in cathode temperature due either to ambient-temperature changes or to heater-voltage fluctuations are reflected directly in changes of plate current, even though the grid bias of the tube remains constant. It is sometimes suggested that the work-functions of the cathode and grid surfaces change during the operation of the tube, yielding a change in contact potential between the grid and cathode, in turn causing a change in plate current. Consequently, the plate current of the conventional amplifier is a function of these cathode-grid effects, and in a d-c amplifier the result is zero-drift, i.e., a drift of the output corresponding to zero input.

As a remedy for cathode drift a number of designers have attempted to maintain constant heater current in the low-level amplifier tubes. One commercial amplifier, for instance, is equipped with a constant-current transformer and a ballast lamp to regulate the heater current. This would appear to overcome changes in cathode temperature due to line-voltage fluctuations.

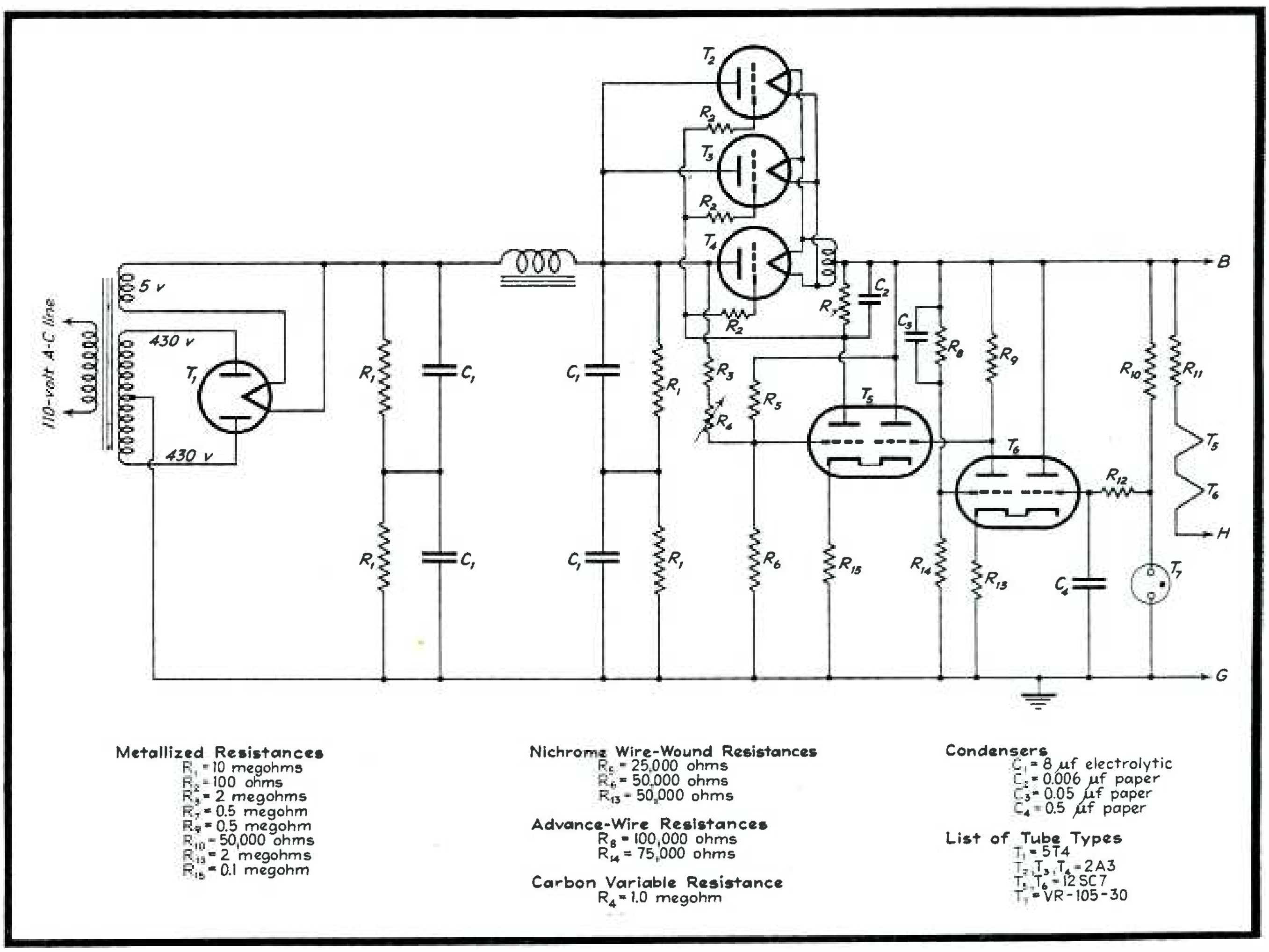
However, the severity of the problem is not fully realized until one sees quantitatively the amount of zero drift caused by heater-voltage fluctuations. In Fig. 5 we see plotted the equivalent input to a single-stage conventional d-c amplifier as a function of the heater voltage. The ordinate represents that voltage which, if applied to the input of the amplifier, would cause the same change in plate current as that actually caused by a change in heater voltage. We see that for the conventional amplifier a linear relation holds, and what is more important, a 10 percent change of heater voltage produces the same effect as an equivalent input of 0.1 volt. When it is remembered that we are trying to amplify a signal of a few millivolts, it is obvious that this is an important problem.

Attempts have been made to use a balanced or push-pull amplifier to eliminate the effects of changes in cathode temperature. This scheme is not successful because the rate of heating for two different cathodes is not the same. Thus the equivalent input voltage due to cathode-temperature fluctuations will be different in the two tubes of the balanced amplifier, and the output will not be independent of the heater voltage.

A common error in connection with this problem is the assumption that feedback will aid in reducing cathode drift. Suffice it to say that cathode drift is a form of tube noise, and tube noise is not reduced by means of negative feedback.

As a partial solution to the problem the writer has developed what he calls the cathode-control amplifier. The reasoning behind its development may be given with reference to Fig. 6. Assume that the heater voltage E_h is made variable, and the other voltages are held constant. Then it will be found that the plate current is a function of the heater voltage, and if the changes in plate current are referred to the input, a plot may be made showing the equivalent input to the amplifier as a function of the change in heater voltage. This has been done in Fig. 5. It is commonly accepted in elementary theory that the voltage which a tube will amplify is that existing between the grid and the cathode. The problem now is to determine that point in the cathode-grid circuit for which the equivalent input voltage represents the effect of the change in heater voltage. Since the effect is one which is related to the tube and not to the external grid-cathode circuit there are only two choices—at the grid or at the cathode. There is no reason to believe that a fluctuation in heater voltage should change the conditions at the grid, but there is an effect at the cathode due to the change

Fig. 2—Wiring diagram of the voltage-regulated power supply



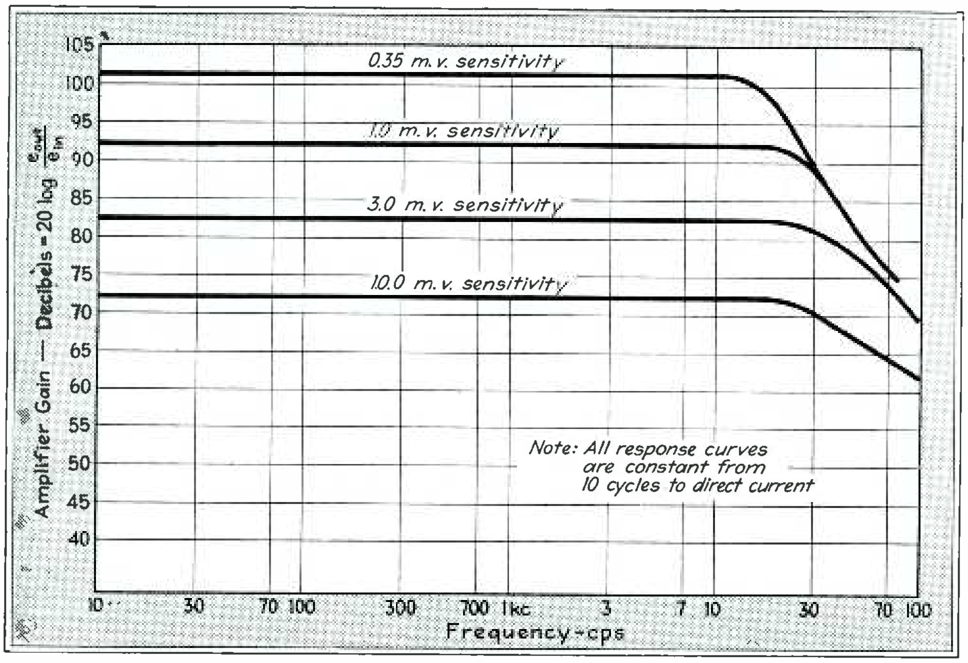


Fig. 3—Frequency response characteristics of the d-c amplifier for various settings of the gain control

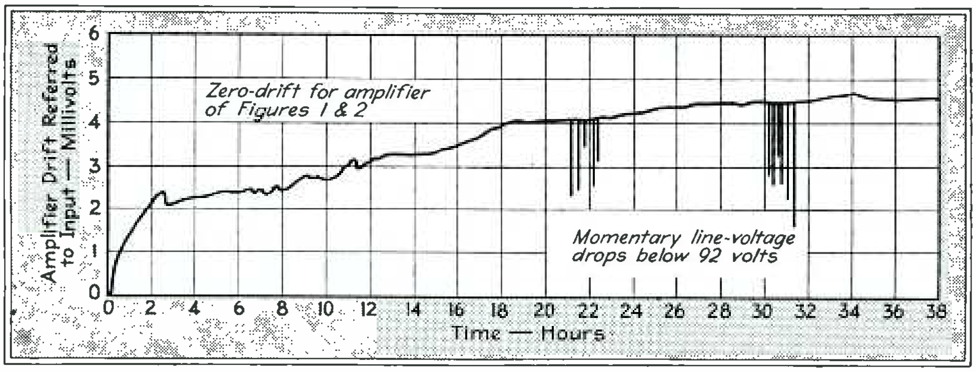


Fig. 4—Stability of zero-drift curves for the d-c amplifier, covering an operating period of more than a day and a half of continuous operation

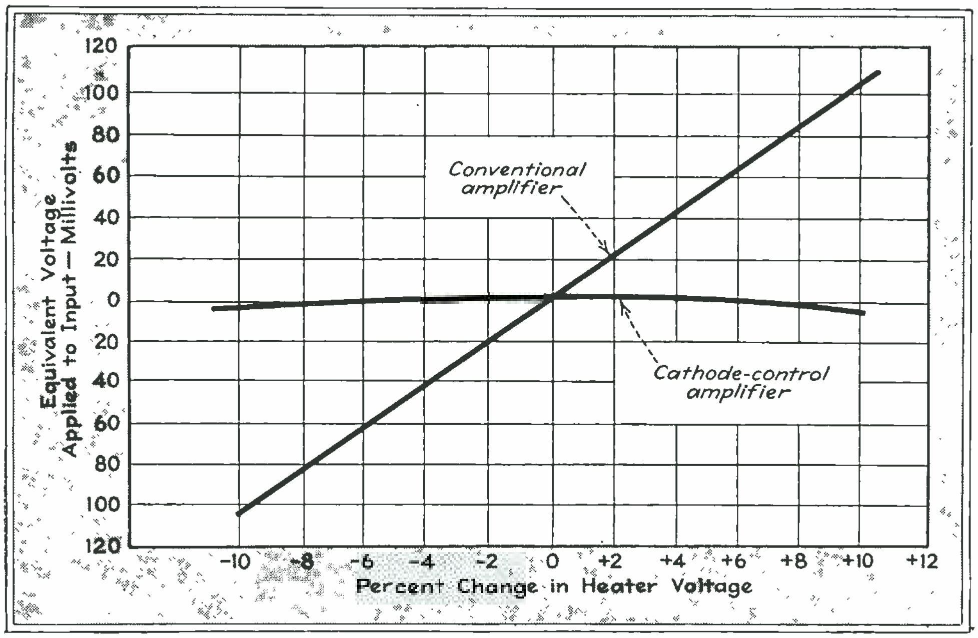


Fig. 5—Manner in which changes in heater voltage affect the equivalent input voltage applied to a conventional amplifier and to the cathode control amplifier described in this article

in heater voltage, namely, a change in the initial velocity of the emitted electrons. Hence the equivalent input voltage which represents the effect of a change in heater voltage may be placed in series with the cathode lead inside the tube, as shown in Fig. 6. It is to be emphasized that this voltage source is purely fictitious and cannot be measured directly in the laboratory. However, laboratory measurements do check the assumption that the change in heater voltage can be represented by the fictitious source V. Once this has been established, the solution to the problem is straightforward. By choosing a tube having two sections arranged around a common cathode and by connecting these sections in the proper manner the cathode-drift may be eliminated from one section.

With reference to Fig. 7, the section P_1, G_1, K functions as an amplifier, and the section P_2, G_2, K functions as a control section. The effect of variations at the cathode is represented by the fictitious source, V. Then, for R_3 large compared to the internal plate resistances it may be shown that e will be zero for R_2 equal to $1/g_2$, where g_2 is the transconductance of the section P_2, G_2, K. The result is that the amplifier employing section P_1, G_1, K will be nearly independent of heater-voltage fluctuations over a wide range, as shown in Fig. 5. This type of circuit has been used in the first stage of the amplifier.

The discussion so far has pointed out that the cathode-control amplifier helps overcome the effects of heater-voltage variations; it is readily seen that the cathode-control circuit will be equally effective in overcoming the effects of ambient temperature variations and other variations which are common to both portions of the common cathode. Likewise, the discussion so far has assumed that the undesired cathode variations will be identical in both portions of the common cathode; this condition has been observed in many tubes, but it is not essential. If the fictitious source V is proportional in the two sections, that is if,

$$V_{amp} = kV_{control} \qquad (1)$$

then e will be zero if

$$R_2 = k/g_2 \qquad (2)$$

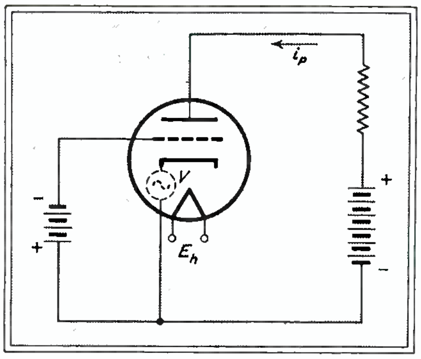


Fig. 6—Equivalent circuit of vacuum tube showing fictitious interval voltage, V, representing equivalent input voltage having the same effect as that produced by change in heater voltage

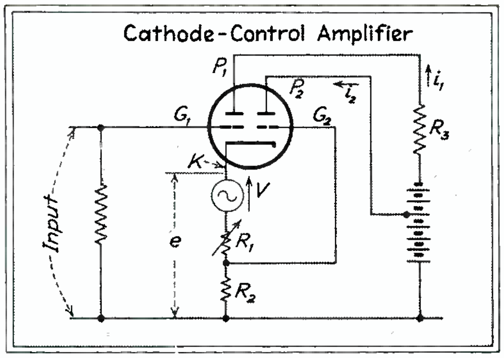
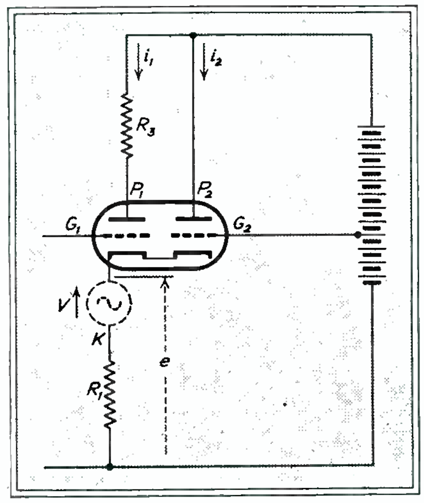


Fig. 7—Fundamental circuit of cathode control amplifier

Fig. 8—Another arrangement of the cathode control amplifier which has merits under certain conditions



In certain applications it is sufficient to make e very small but not quite zero, in which case the circuit of Fig. 8 has proved useful. This degenerative cathode-control circuit makes use of the same ideas as the balance cathode-control circuit of Fig. 7, except that R_2 is made zero (making $e = 0$ impossible) and the grid G_2 is brought part way up the plate battery to make the resistor R_1 large. If we neglect the presence of the amplifier section momentarily, it may be shown that

$$e/V = 1/(1 + g_2 R_1) \quad (3)$$

where g_2 is the transconductance of section P_2, G_2, K. The degenerative action of R_1 in the amplifier circuit employing section P_1, G_1, K makes the ratio e/V even smaller than given by Eq. (3), but the exact equations are too complicated to be given here. In practice, e/V may be made 1/20 to 1/75.

Regulated Power Supply

It is of course possible to derive expressions giving the voltage gains of the circuits of Fig. 7 and 8; the results of such derivations are given by the following approximate equations: For Fig. 7, the amplification is given by

$$G = \frac{\mu_1 R_3}{R_3 + r_1 + r_2} \quad (4)$$

when $g_2 R_2 = 1$. For Fig. 8,

$$G = \frac{\mu_1 R_3}{R_3 + r_1 + \mu_1/g_2} \quad (5)$$

where r_1, μ_1, and r_2, g_2 are the constants of the first and second tube sections, respectively. These voltage gains may be made 30 to 45 in practice.

The degenerative type of cathode-control circuit is employed in the amplifier and regulator stages involving tubes T_5, T_6, and T_9 of Figs. 1 and 2.

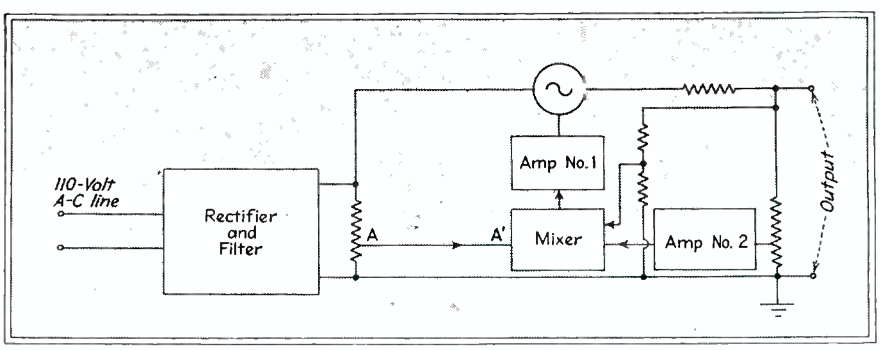
As a further means of overcoming cathode-drift it was decided to regulate the heater voltage. Ballast lamps were tried in this application, but were found objectionable because of a heating transient which occurs each time the source voltage is changed. Since it was also necessary to regulate the plate-voltage supply, it was considered good economy to use the same regulator for plate and heater currents. The 12-volt 150-milliampere series of tubes was used, the heaters being placed in series.

In the amplifier design, no attempt was made to balance out the effect of plate voltage variations. This meant that a very constant plate-supply must be available. In particular, we may assume for purposes of estimation that a variation in plate battery at the first amplifier stage will be reduced by a factor of 100 when referring it to the amplifier input. If we aim at maintaining input instabilities less than 10 microvolts, we find that the plate battery may not vary by more than 1 millivolt. Assuming a line variation of ±10 percent, our 250-volt plate-supply voltage must be constant within 4 parts in a million, and a stabilization ratio of 25,000 to 1 is required in the regulator. The stabilization ratio is the factor by which the regulator reduces line variations.

The regulator which was designed to meet the above specifications has been redrawn in functional form in Fig. 9. It is common practice in regulators of this type to feed back a portion of the output voltage, compare it with a constant voltage reference, amplify the difference and impress the amplified difference on the grid of an amplifier tube in such a phase as to maintain the output voltage constant. With such a regulator (illustrated by the diagram of Fig. 9 if the connection AA' were omitted) it is impossible to get

(*Continued on page* 105)

Fig. 9—Block diagram illustrating the fundamentals of the regulated power supply unit used with the amplifier



POWER AMPLIFIER

By
ARVID
B. NEWHOUSE

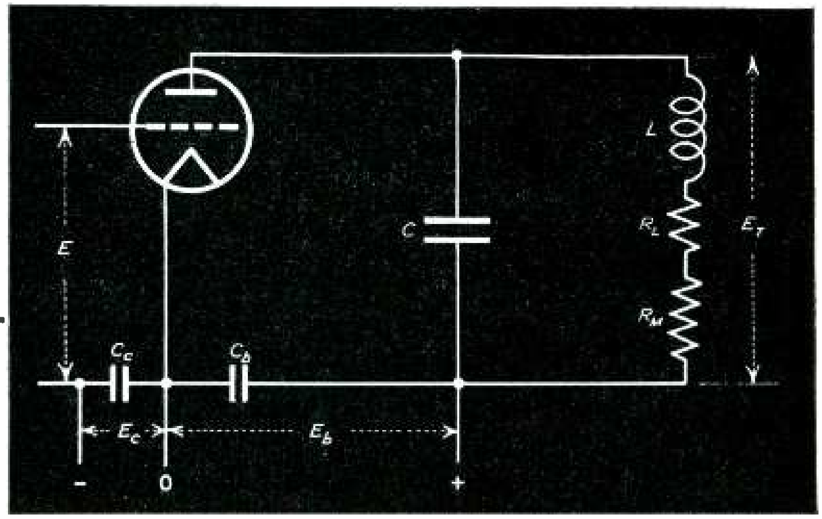


Fig. 1—Simplified circuit diagram of a triode radio frequency power amplifier

TIME spent on calculations of tank circuits of radio frequency power amplifiers can be considerably reduced by an analysis of the circuit conditions and the use of certain equations. This paper discusses some aspects of the design of power amplifier plate tank circuits, particularly amplitude modulated amplifiers for broadcasting service. Equations are derived for calculating pertinent tank circuit quantities, and methods of calculating values of inductors and capacitors to satisfy power and selectivity requirements are given. For a study of Class B and C amplifier tank circuits the reader is referred to a paper by P. H. Osborn.[1]

Energy Storage

The radio frequency amplifier which will be studied is represented by the simplified circuit shown in Fig. 1. Although a series-fed, unbalanced circuit is illustrated the analysis will apply to other arrangements. It is assumed that the impedance of C_b is so low that substantially the full voltage developed across the tank circuit appears at the plate of the tube, and also that the excitation voltage E, the grid bias E_c, and the d-c plate voltage E_b are such as to deliver the required power with a known minimum of distortion. The inductor resistance is represented by R_L; whereas R_M represents the resistance reflected into the tank circuit from the load (succeeding amplifier, transmission line, or antenna) by the coupling system. It is assumed that only resistance is reflected into the tank circuit by the coupling system.

It is understood, of course, that the tube has been selected for this amplifier, and that it will deliver the expected output with the specified plate voltage, grid bias, and excitation.

The relations between plate current and plate and grid voltages during a radio frequency cycle are shown in Fig. 2. The instantaneous grid voltage e_g is equal to the bias voltage E_c plus the exciting voltage which has the maximum value E. Likewise, the instantaneous plate voltage e_p is the sum of the direct current plate voltage E_b and the superimposed voltage across the tank circuit, the latter reaching E_T as its maximum value. The plate current i_p flows during approximately one-half cycle in Class B amplifiers, and for a shorter period in Class C amplifiers. Both i_p and E_T vary in magnitude when the carrier is amplitude modulated, E_T attaining twice its carrier value when 100 percent modulation peaks are reached.

Let P_t = the power output of the tube, delivered to the tank circuit.

$R = R_L + R_M$, the total series resistance in the tank circuit.

$V = E_T/\sqrt{2}$, the root-mean-square voltage across the tank circuit.

$I = 2\pi fCV$, the root-mean-square current flowing in C.

f = the carrier frequency.

Although strictly true only for the case of an ideal parallel resonant circuit, it is sufficiently accurate for this discussion to assume that $X_L = 2\pi fL$ is equal to $X_c = 1/2\pi fC$. Also, with respect to the tank current, it will be assumed that R^2 is small compared with X_L^2 in the expression $I_L = V/\sqrt{X_L^2 + R^2}$, so that I_L is substantially equal to V/X_L. Then I_L is equal to $I = 2\pi fCV = V/X_c$, and I may be used as the root-mean-square value of the tank current. The error introduced by these approximations is about one percent. The ratio X_L/R and X_C/R will be designated Q_T, the figure of merit of the tank circuit, as distinguished from $Q_L = X_L/R_L$, the figure of merit of the inductor. In this discussion the capacitor is assumed to have no resistance.

When tuned to resonance (unity power factor) the tank circuit will appear to the plate of the tube as a

PLATE TANK CIRCUITS

resistor having the value $R_T = V^2/P_t$ ohms. But R_T may also be expressed in any of the following forms.[2, 3]

$$R_T = \frac{X_C^2}{R} = \frac{X_L^2}{R} = Q_T X_C = Q_T X_L$$

$$= \frac{X_C X_L}{R} = \frac{2\pi f L}{2\pi f C R} = \frac{L}{CR} \qquad (1)$$

Energy is received from the tube in pulses, a pulse each time plate current flows, and is delivered to the coupled load in a continuous flow. This means, of course, that the inductor and capacitor must act as a flywheel or tank for the storage of energy to maintain the flow. Let us postulate steady state conditions. Then just sufficient energy is received by the tank circuit to maintain the oscillations at constant amplitude. Now at the instant the circulating current is zero, the voltage across the tank circuit is at its maximum and all the energy is stored in the capacitor. The amount of this energy is $\frac{1}{2}CE_T^2$ or CV^2 joules.

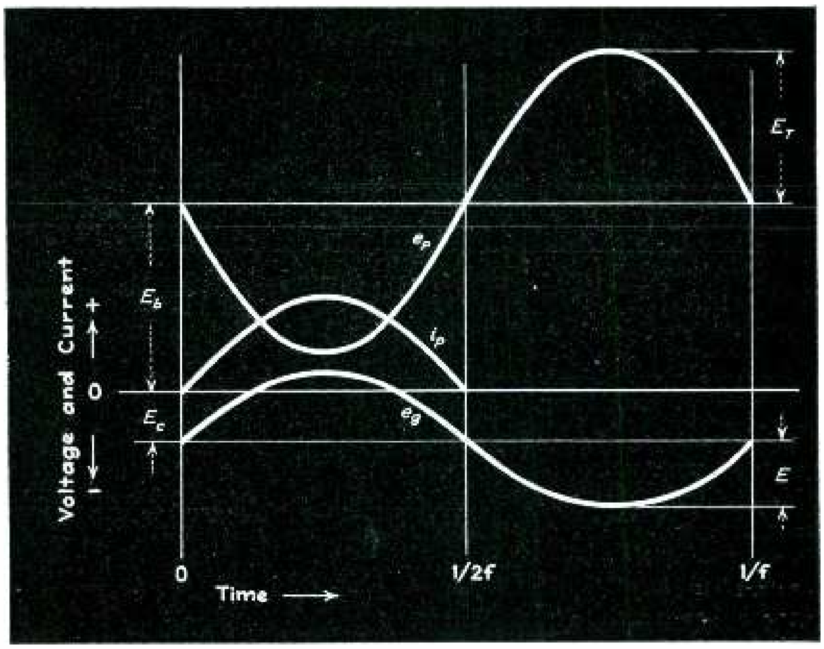


Fig. 2—Voltage and current relations in a triode power amplifier

The energy expended as heat in the tank circuit and that passed on to the load each cycle is equal to that delivered by the tube each cycle or P_t/f joules. The ratio of the stored energy to the energy lost each cycle is fCV^2/P_t. Multiplying numerator and denominator by 2π, we have $VI/2\pi P_t$.

Prince and Vogdes'[4] work with self-controlled oscillators yielded results showing that, for stability and for minimizing harmonics, twice as much energy must be stored in the tuned circuit as is dissipated each cycle. The ratio $VI/2\pi P_t$ is then about 2. However, this requirement is relaxed in the case of amplifiers, especially if they are followed by coupling systems or filters which discriminate against harmonics. In such applications, because of the external control of frequency and the reduction of harmonics passed on to the radiating system, a storage of energy equal to about 150 percent of the loss appears ample. The ratio of circulating volt-amperes to output power may then be about 3π, and the constants commonly used in design computations are 9 or 10.

Then number and amplitude of the harmonics emitted by the radiating system depend upon a number of elements other than the power amplifier plate load circuit. Generation of harmonics is reduced by carefully selecting the operating parameters for the tubes, and the harmonics generated may be prevented from reaching the output device by employing coupling systems and filter networks which discriminate against them. The relation between the amount of tank current and the second harmonic magnitude has been measured and calculated by Osborn,[1] and the adjustment of the tank current to minimize harmonics has been treated by Dietsch.[5] Both Osborn and Dietsch show the rapid increase of the second harmonic as the tank volt-amperes is reduced below 4π times the power output. However, the practice now prevailing of using push-pull power amplifiers minimizes the amount of second and other even harmonics in the output. In a push-pull amplifier the tank circuit must furnish the flywheel effect for only one-half cycle which permits the use of lower values of the ratio VI/P_t.

The choice of transmitter equipment to be used in any case depends upon the service requirements and the economic considerations involved. The plate voltage and the excitation may be varied, within limits, independently of these considerations, but the addition of suppressor networks or the elaboration of circuits adds to the initial and maintenance costs as well as to the equipment failure possibilities. In the case of tank circuits the relative costs of capacitors and inductors for a given power output are factors which determine the selection of these components. The usual result is that the volt-amperes of circulating tank current are not far in excess of actual energy storage requirements.

Obviously, the power wasted as heat in the tank inductor varies directly with the high frequency resistance, while the power passed on to the load is I^2R_M. It follows that the tank circuit efficiency factor is

$R_M/(R_L + R_M)$. In order to make the circuit efficiency as high as possible it is necessary that the inductor be designed for a minimum radio frequency resistance at the frequency contemplated. Because of the change in the current distribution and density in the conductor, the radio frequency resistance varies with frequency in such a manner that the Q_L of any inductor is virtually constant over a wide frequency range. This figure of merit is used for comparing different inductors. The equivalent criterion for capacitors is $D=R_C\omega C$, where R_C is the radio frequency resistance of the capacitor. This factor is not often considered in transmitter design because in most capacitors D is rather small, and because for a given frequency, mode of operation, and cost the choice of capacitors is limited. Ordinarily, there is some latitude in inductor design. This subject has been treated in a number of books and periodicals.

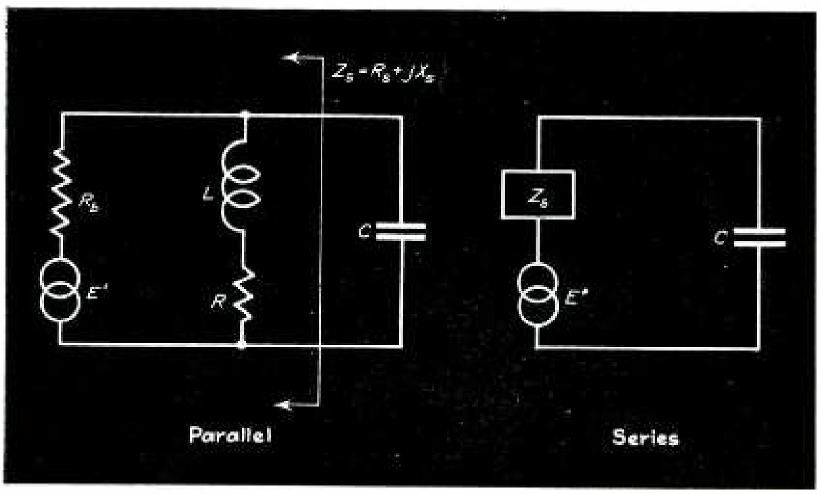


Fig. 3.—Parallel-to-series transformation of a triode amplifier output circuit network

With respect to the figure of merit of the tank circuit, $Q_T=X_L/R$, where $R=R_L + R_M$, the following relations are assembled for reference.

$$R_T = V^2/P_t = X_L^2/R = Q_T X_L$$

and $X_L = V/I$, approximately.

$$Q_T = \frac{R_T}{X_L} = \frac{V^2}{P_t} \times \frac{I}{V} = \frac{VI}{P_t} \qquad (2)$$

That is, Q_T is also the ratio of the tank current volt-amperes to the tube power output, and therefore indicates the energy storage capability of the tank circuit.

In his paper Osborn[1] described how too high a ratio of tank circuit volt-amperes to output power caused the tank circuit to discriminate against the higher side band frequencies. He also derived a formula for calculating the distortion at any modulating frequency for a given ratio of VI to P_t.

When it is desired to obtain a measure of the amplifier output channel width, a relationship similar to $f/(f_2-f_1)=Q$, which holds for the series circuit, might be convenient. Here f is the carrier frequency and $f_2-f=f-f_1$ are the two side bands so related to f that the output power at f_1 and f_2 is one-half that at f for the same voltage V. Under these conditions Q is then the ratio of the total inductive (or capacitative) reactance to the total resistance, including that in the generator. Hence for a given carrier frequency f and a given value for Q the channel width between the half-power (or 3 decibels down) frequencies can be readily computed.

However, to make use of this concept in power amplifier plate tank circuit design it is necessary to take into account the equivalent series resistance in the plate circuit due to the tube resistance shunting the tank circuit. The relation of this internal resistance to the tank circuit is shown in Fig. 3, in which the tube output circuit is redrawn to place all the resistance in adjacent branches of the network. L and C are the tank inductance and capacitance, $R=R_L + R_M$, and R_b is the apparent internal resistance of the tube plate circuit path viewed as an alternating current generator. Then by the use of Thevenin's equivalent series circuit theorem we obtain the series impedance, $Z_s=R_s + jX_s$.

$$Z_s = \frac{R_b(R + jX_L)}{R_b + R + jX_L}$$

$$= \frac{(R_bR + jX_LR_b)\,[(R_b + R) - jX_L]}{(R_b + R)^2 + X_L^2}$$

$$= \frac{R_bR(R_b + R) + R_bX_L^2}{(R_b + R)^2 + X_L^2}$$

$$+ j\,\frac{(R_b + R)R_bX_L - R_bRX_L}{(R_b + R)^2 + X_L^2}$$

The Q of the output circuit will be designated Q_o and is equal to the reactance divided by the resistance, or X_s/R_s.

$$Q_o = \frac{(R_b + R)R_bX_L - RR_bX_L}{R_bR(R_b + R) + R_bX_L^2}$$

$$= \frac{R_b^2\, X_L}{R_bR(R_b + R) + R_bX_L^2}$$

Since R is small compared to R_b, $R_b + R=R_b$, very nearly. Then

$$Q_o = \frac{R_b^2X_L}{R_b^2 + R_bX_L^2} \qquad (3)$$

The ratio of the channel width (between the half-power frequencies) to the carrier frequency is $(f_2-f_1)/f=1/Q_o$.

$$\frac{1}{Q_o} = \frac{R_bR + X_L^2}{R_bX_L} = \frac{R_bR}{R_bX_L} + \frac{X_L^2}{R_bX_L}$$

$$= \frac{1}{Q_T} + \frac{X_L}{R_B}$$

Equation (3) indicates the relation which exists between R, X_L, R_T, and R_b for the assumed 3 decibel distortion limit. That is, for a certain desired value of (f_2-f_1) at a carrier frequency f, the value for Q_o determined by Eq. (3) may not be exceeded. Since R_T and R_b are fixed when the power output and the tube operating parameters are set, the limitation falls on Q_T, X_L, and R, and determines an inferior limit for the tank reactance and the coupling to the load.

Equation (3) serves as a guide for the power amplifier output channel width. To apply the equation it is necessary to find the value of R_b, the apparent internal resistance of the amplifier tube plate circuit. This may be done as follows. In Fig. 4

is shown the relation of R_b to the tank circuit, the latter indicated by R_T. In this diagram $I_a^2R_T = P_t$, the tube output power; and $I_a^2R_b = P_b$, the power loss in the tube.

$$\frac{P_b}{P_t} = \frac{I_a^2R_b}{I_a^2R_T} = \frac{R_b}{R_T}$$

$$\text{Hence, } R_b = \frac{P_b}{P_t} \times R_T \qquad (4)$$

It will be noted that R_b is not the alternating current plate resistance, r_p, included in the tube data by manufacturers or calculated from static characteristics. The tube plate resistance has a finite value only when plate current is flowing, and increases without limit during non-conducting intervals. Further, plate current flows only during periods when the instantaneous plate voltage is low, as may be seen in Fig. 2.

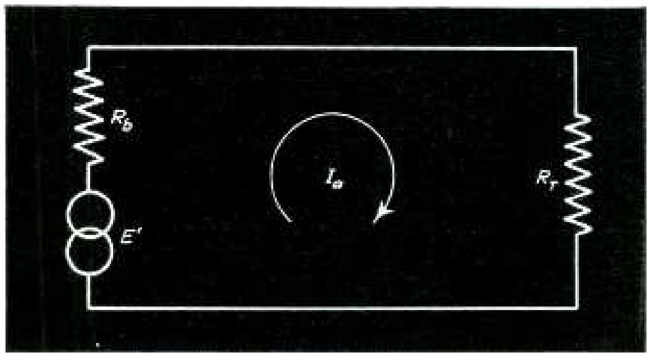


Fig. 4—Triode amplifier output circuit viewed as a generator with a resistive load

If R_b, the apparent resistance, is large so that X_L/R_b is small compared to $1/Q_T$, Q_o will approach Q_T as a limit and the selectivity of the entire output circuit will approach that of the tank circuit alone. Usually X_L/R_b is comparatively large, making Q_o much less than Q_T.

In amplitude modulated amplifiers conditions at 100 percent modulation should be investigated in the event that changes in bias and operating angles affect impedances and distortion.

Conclusion

In this discussion two limits have been found for the ratio of power amplifier tank current to output powers, a minimum value determined by energy storage requirements, and a maximum which is determined by the tube constants and output distortion limitations. It was also noted that this ratio is Q_T, which is equal to the quotient of load resistance R_T divided by the reactance, X_L or X_C, and to the quotient of the reactance divided by the total series resistance in the tank circuit.

Appendix

To justify the approximations preceding Eq. (1) the following developments are appended.

Let the impedance which the tank circuit presents to the plate of the tube in Fig. 1 be $Z_T = R_T + jX_T$. Also, for simplicity, let $R = R_L + R_M$.

$$Z_T = \frac{-jX_C(R + jX_L)}{R + j(X_L - X_C)}$$

$$= \frac{(X_LX_C - jRX_C)[R - j(X_L - X_C)]}{R^2 + (X_L - X_C)^2}$$

$$= \frac{RX_LX_C - RX_C(X_L - X_C)}{R^2 + (X_L - X_C)^2}$$

$$+j\frac{-R^2X_C - X_LX_C(X_L - X_C)}{R^2 + (X_L - X_C)^2}$$

$$= \frac{RX_C^2}{R^2 + (X_L - X_C)^2}$$

$$+j\frac{X_LX_C(X_C - X_L) - R^2X_C}{R^2 + (X_L - X_C)^2}$$

For parallel resonance (unity power factor) $X_T = 0$, and the numerator of the second term in the equation above must equal zero.

$$X_LX_C(X_C - X_L)\, R^2X_C = 0$$

$$X_L(X_C - X_L) = R^2$$

$$X_LX_C - X_L^2 = R^2$$

$$X_C = \frac{R^2 + X_L^2}{X_L} = X_L + \frac{R^2}{X_L}$$

A hypothetical tank circuit may have an R_T of 1000 ohms and a Q_T of 10. Then X_L will be 100 ohms, and R will be made 10 ohms by adjustment of the coupling to the load.

$$X_C = 100 + \frac{10^2}{100} = 100 + 1 = 101 \text{ ohms}$$

Hence, equating X_C to X_L in this case introduces an error of only one percent. When Q_T is greater than 10, X_C will approach closer to X_L in size, and would coincide, of course, if R could be made zero. However, it is apparent that the error introduced by this approximation will be of the order of one percent in most practical circuits.

To compare the current in the L and C branches, let I_L be the root-mean-square current in the inductor and I_C the root-mean-square current in the capacitor. The root-mean-square voltage across the tank circuit is V. The current flowing in each branch is equal to the voltage across the tank circuit divided by the impedance of the branch.

$$I_C = \frac{V}{X_C} \text{ and } I_L = \frac{V}{\sqrt{X_L^2 + R^2}}$$

$$\frac{I_C}{I_L} = \frac{V}{X_C} \times \frac{\sqrt{X_L^2 + R^2}}{V} = \frac{\sqrt{X_L^2 + R^2}}{X_C}$$

Inserting the previously assumed values for X_L, R, and X_C,

$$\frac{I_C}{I_L} = \frac{\sqrt{100^2 + 10^2}}{101} = \frac{10\sqrt{100 + 1}}{101}$$

$$= \frac{10\sqrt{101}}{101}$$

$$\frac{I_C}{I_L} = \frac{10 \times 10.05}{101} = \frac{100.5}{101}$$

Equating I_C *to* I_L involves an error of only about 0.5 percent in a circuit with a Q_T of 10, and this error becomes less for higher values of Q_T. The errors introduced by setting X_L equal to X_C and I_L equal to I_C are small compared to the inaccuracies in most of the data from which power amplifier plate tank circuits are designed.

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NEW RADIOGRAPHIC UNIT AIDS INDUSTRY

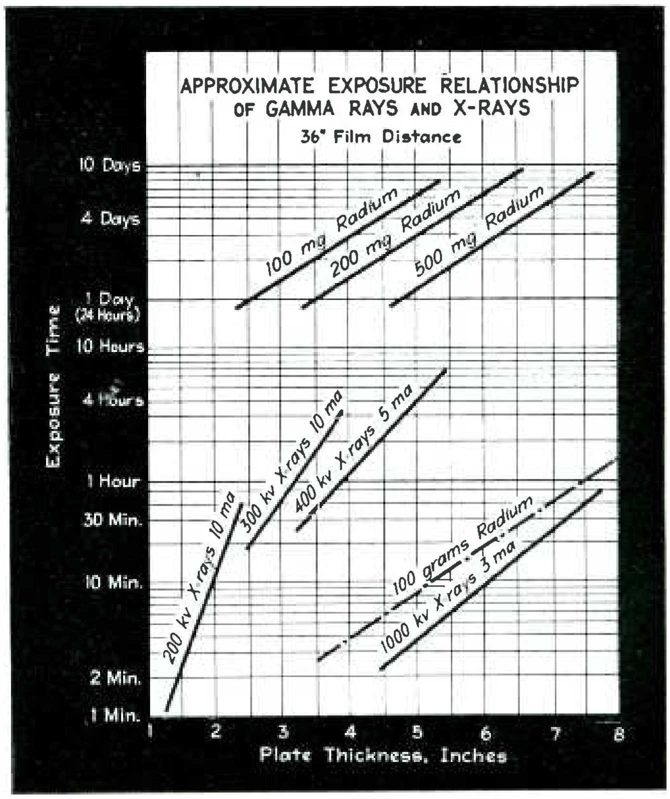
Another example of the manner in which electronic engineering is aiding industry is given by the new million volt industrial x-ray unit developed by GE engineers. Use of Freon gas for insulation, resonance transformer for obtaining high voltages, and hot cathode multisection tube with focusing coil are among major contributions

ELECTRONIC engineering chalked up another milestone in its contributions to science, technology, and industry recently with the perfection by General Electric engineers of the newly designed million volt x-ray unit for industrial radiography. The design and construction of this new device have been in progress for about four years, and some half dozen units have been in operation for a year or so during which time they have undergone a thorough "shake-down" test to demonstrate conclusively, their practical utility. Therefore, in a certain sense, the million volt equipment is not entirely new. Still, the symposium of scientific and industrial workers, held in Schenectady on October 7, in which the new equipment and its applications were discussed by those who have been in intimate touch with the development and industrial application of such units, brought forth and displayed publicly for the first time, those many modifications and improvements of past practice which makes the present equipment outstanding.

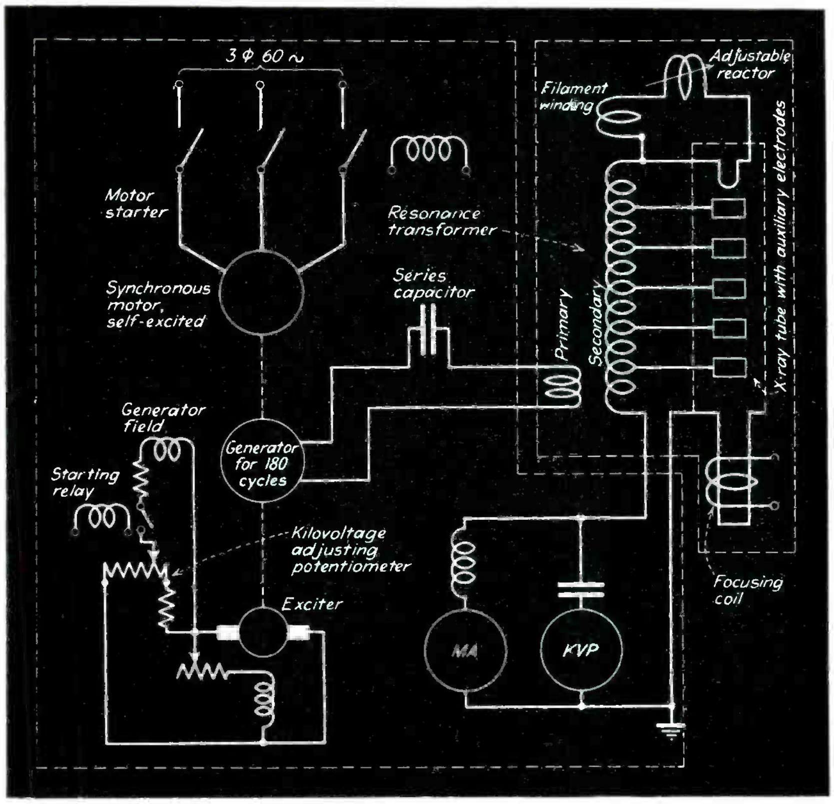
Principal feature of the new radiographic unit is, of course, the fact that at one million volts it operates at two and one-half times the voltage of previously available units.

Increased voltage is not the complete story, and, indeed, this step could not have been made without the accompaniment of other improvements all of which aided in the production of a completely new and fully integrated unit. The development of a hot cathode, multisection tube permitted the production of a copious and consistent source of electrons by which x-rays could be produced in a tube in which the voltage gradients could be restricted to safe limits. The use of this tube in a self-rectifying circuit arrangement eliminated the rambling, space

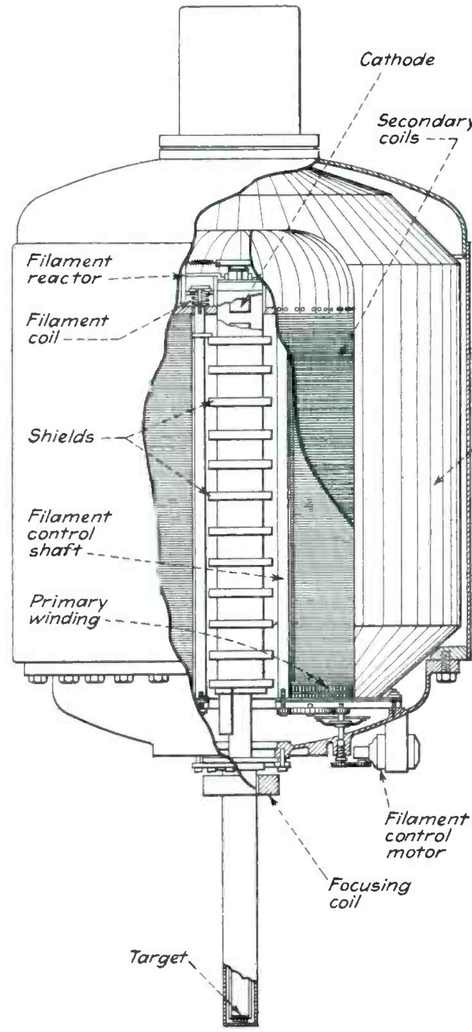
Approximate exposure relations for various radiographic units and different amounts of radium. Note that the million volt tube makes possible the examination of very thick castings in less than an hour while several hours or even days would be required for lower voltage units



The hot cathode, multisection x-ray tube with filament at upper end and target at bottom is the key to the new radiographic unit

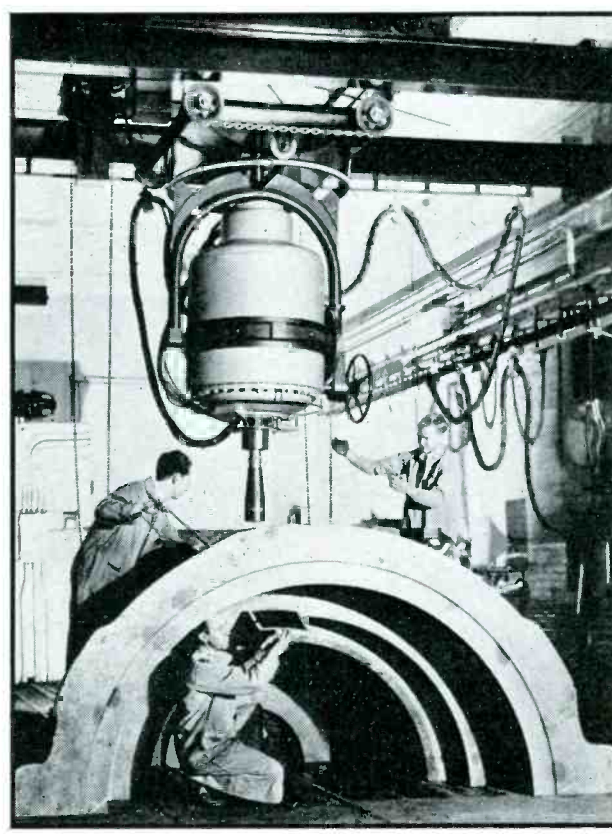


Simplified wiring diagram of connections for the x-ray unit. The section in upper right corner is contained in the tank, while rest of equipment is relay rack mounted control system



Sectional drawing of the multisection x-ray tube concentrically mounted within the high voltage resonance transformer. The unit has a diameter of 3 feet and a total length of 6 feet

The x-ray tube in position for examining a section of a thick casting. The x-ray film, in light protected envelope, will be affixed to the casting below the target of the x-ray tube



consuming rectifiers of former installations. The development of a 180 cps resonance transformer made possible the generation of the high voltage utilized by the tube, while at the same time provided an unusually compact and fool-proof housing which automatically affords the necessary protection from high voltages even without the outer shell casing, by permitting the tube to be inserted within the transformer itself. The complete removal of air and moisture from the transformer and tube housing, and its replacement with Freon, a gas of unusually high insulating properties, has permitted great reductions in the physical size of the complete unit for a given operating voltage. Finally, provision for focusing the beam of x-rays not only permits the attainment of more sharply defined radiographs, but speeds up the taking of test and routine radiographs by making unnecessary the use of lead blocks for the reduction of scattered radiation through appropriate shielding.

The complete million volt industrial x-ray unit is housed in a tank 4 feet in length and 3 feet in diameter, but the projections of the concentrically mounted x-ray tube and other parts increase the overall length to about 6 feet. The unit weighs 1500 pounds and is sufficiently light and flexible as to be readily moved about by means of a crane for the examination of industrial welds and castings which may weigh as much as 60 to 90 tons. Lest the reader gain the impression that three-quarters of a ton hardly represents a portable unit, it is well to point out that this represents the complete x-ray unit, except for the appropriate relay-rack type of control panel, and to point out further, that only a few years ago a multistory building was required to house an 800,000 volt medical radiographic unit; that an 800-kv multisection tube operated in air was 14 feet long and 1 foot in diameter, while the million volt tube operated in an atmosphere of Freon, has an insulating envelope 30 inches long and 3½ inches in diameter.

(Continued on page 110)

DIELECTRIC IGNITERS for

A study of the igniting conditions in mercury pool tubes indicates that conduction can be initiated by a dielectric igniter. Use is made of the ability of glass to withstand increased potential gradients as its thickness is decreased. This article gives the fundamentals of successful tube operation, and indicated good agreement between the theory and experiment.

By HANS KLEMPERER

Raytheon Mfg. Co., Waltham, Mass.

ABOUT thirty years ago Peter Cooper Hewitt started an arc on a mercury pool cathode by applying high voltage between the cathode and a metal band placed around the tube at the mercury level. Because of its simplicity this method for starting has been used to some extent since,[1] mainly for arc lamps. However, it is not very reliable because of the formation of neutralizing charges along the glass wall and also because of the danger of electrical breakdown of the tube walls.

An improved dielectric starter was devised several years ago[2] by relieving the dielectric layer of its former duty as a wall of the tube. It thus became possible to make the layer very thin and to take advantage of the singular property of glass to withstand an increased voltage gradient for very thin layers.[3]

A typical dielectric starter consists of one or several wires of tungsten coated with glass and floating on or dipping into the mercury pool. Typical dimensions, as given in Fig. 1, are: radius of the core wire r = 0.325 mm (25 mil wire) and thickness of the glass layer d = 0.075 mm (3 mil). So long as the mercury pool is free from impurities and resulting chemical deterioration, a meniscus depression exists at the edge of the starter forming a curved, wedgelike approach from mercury to glass.

To present a possible theory of the dielectric starting mechanism, a magnified section of Fig. 1 is shown in Fig. 2. No particular significance need be applied to the exact geometry of the meniscus with a quiescent pool because in ordinary operation surface ripples always exist which continuously change the form of the meniscus. It is therefore as well to consider a meniscus bounded by plane surfaces. Calculations of the electrostatic forces involved and deforming the meniscus are given in the appendix.

The lines of force of the electric field pass from starter core wire, W through the glass dielectric (dielectric constant $\xi = 5$) to the mercury. Others also pass through the meniscus depression ($\xi = 1$) into the cathode pool (Hg). The voltage applied to the starter is E, and E_1 and d are voltage drop and width along a line of force across the layer, while E_2 and δ are correspondingly voltage drop and length of field line across the vacuum gap that is formed by

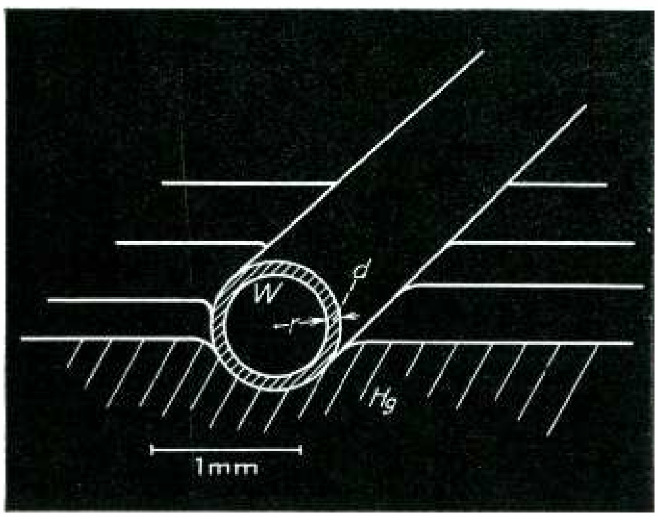


Fig. 1—Cross section of igniter element in mercury pool, showing the meniscus which is formed at the edge of the starter electrode

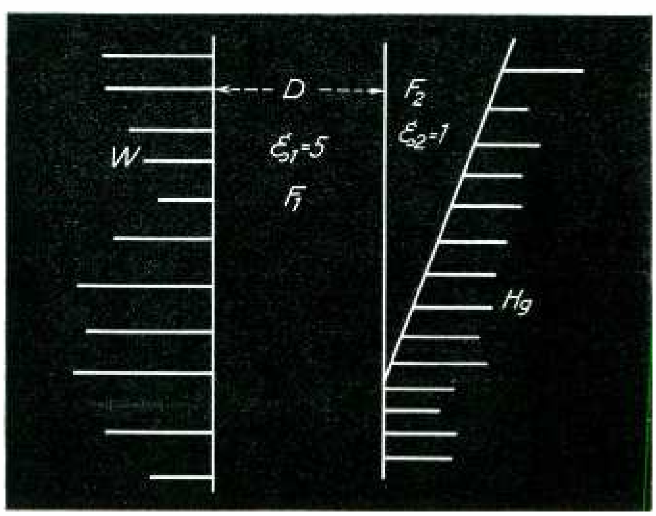


Fig. 2—Field configurations of the starter element upon which the principles of this article are based

Mercury Pool Cathode Tubes

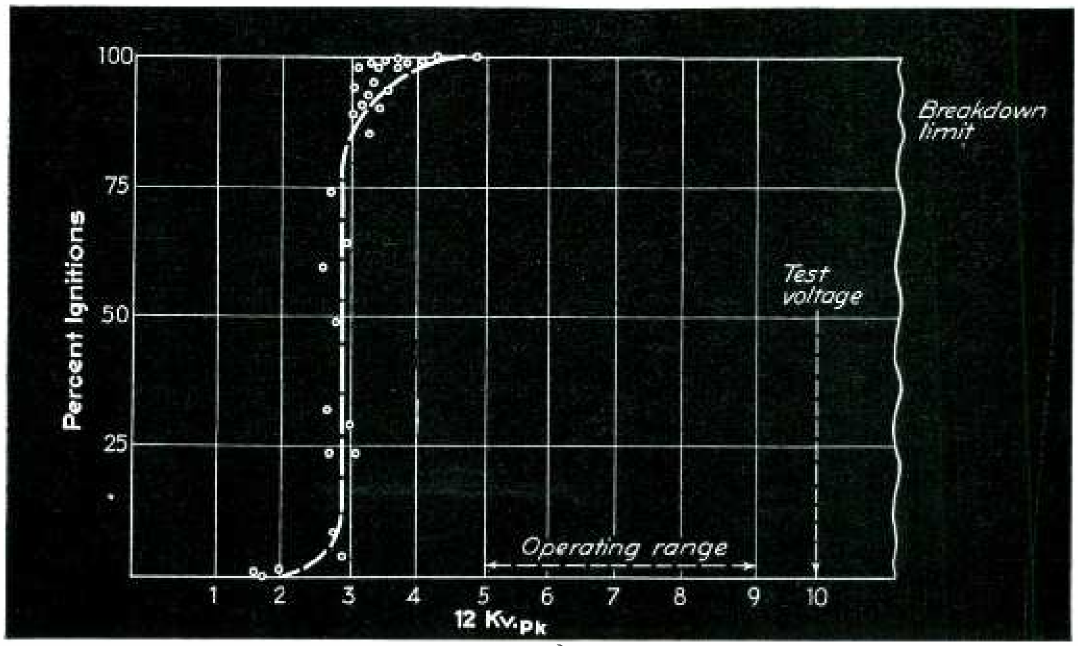


Fig. 3—Ignition characteristics of the dip-in starter electrode. Ignition occurs for voltages above 3,000 or 4,000 volts

the meniscus. The field in the dielectric layer is F_1 and F_2 is the field in the gap.

Now $E_1 + E_2 = E$
and $F_2 = \xi F_1$
or $E_2/\delta = \xi\, E_1/d$

Therefore

$$E_1 = E_2\, d/\xi\, \delta$$

and $$E = E_2\left(1 + \frac{d}{\xi\,\delta}\right)$$

Hence, $$E_2 = \frac{E}{1 + \dfrac{d}{\xi\,\delta}} \quad \text{and} \quad F_2 = \frac{E}{\delta + \dfrac{d}{\xi}}$$

and for $\delta \ll d$ we have approximately $F_2 \cong \xi\, E/d$.

Therefore, applying 5 kv to the above starter (E = 5000 volts) the field at the bottom of the gap may build up to

$$F_2 \cong 5 \times 5000/0.0075 = 3300 \text{ kv per cm}$$

while the strain on the insulating layer is not larger than

$$F_2 \cong 660 \text{ kv per cm}$$

Thus, without undue strain on the dielectric layer, an exceedingly high field is built up on the edge of the mercury pool. Since cold emission starts at around 1000 kv per cm[4] it appears that under favorable circumstances a starter of the described dielectric type may initiate a discharge from a pool at as little as 1500 to 2000 volts. This is indeed the lower voltage limit at which occasional discharges are observed around the starter.

If the mercury in such a tube develops an oxide film or if, due to other chemical impurity (copper or barium amalgam, for instance) it gets sticky, the meniscus depression disappears and the mercury starts to wet the surfaces. Such tubes get insensitive, for although the starter may be satisfactory in every other respect, it cannot raise the critical field strength to the cold emission limit. It seems to be a fact strengthening the above theory that at the same degree to which the meniscus depression disappears (due to gradually developing stickiness) starting sensitivity is reduced.

Under favorable conditions cold emission adjacent to the starter is followed by formation of a self-supporting gas discharge and a cathode spot on the mercury pool. Such favorable conditions are a gas or vapor pressure sufficiently high to cause ionization of the emitted electrons at such a distance that the ions will strike back on the original point of emission without too much dispersion. For these reasons, starting below freezing temperatures is difficult unless some inert gas is added to the mercury vapor in the tube.

The time of buildup of the dielectrically ignited discharge has not been accurately measured experimentally, but from theoretical deduction it can be assumed to take place within a few tenths of a microsecond (see appendix) which is also approximately the pickup time of thyratron and ignitron tubes.

No appreciable heat appears to be involved either in dielectric ignition or in support of the mercury pool cathode spot. A field strength of the order of 100 kv per cm enables the free conduction electrons within the atomic structure of a metal to overcome the barrier of the surface forces and to leap the surrounding space. In contrast to thermionic emission this so-called cold emission is not affected by temperature, at least in the range between room temperature and incandescence,[5] but it is mainly a function of voltage.[6] Similarly, as shown by L. Tonks and others, the cathode spot on a mercury pool consists of a high ionic charge in so close proximity to the pool surface that electrons continuously are liberated. The luminosity of the cathode spot is not a temperature radiation but it is due to excitation and recombination of ions. Therefore, although the arc develops in the immediate proximity of the thin, vulnerable starter coating, no evidence of heating of that glass layer has been encountered even with currents rising in a few milliseconds to thousands of amperes, as happens in some welding applications.

It has often been suggested and it probably will be the future trend to use dielectric starter materials with a higher dielectric constant. Pyrex glasses have a dielectric constant of about 4 to 5; there are glasses with $\xi = 16$; there are ceramics containing Rutil (TiO_2) with $\xi = 100$ and with certain crystals much higher dielectric values have been observed. With such high dielectric material, sufficient field strength at the mercury-dielectric point of contact could be obtained using a much thicker dielectric layer and therefore possibly be cut into such thick layers to further increase the area available for the formation of meniscus depressions at the contact edge to the mercury pool.

Experience shows that the ignition voltage limits, below which the dielectric starter will fail to ignite and above which it will operate reliably, are not sharply defined. A great number of independent factors influence ignition potentials, as, for instance, the erratic shape of the meniscus depression, cleanliness of the mercury, the possible effect of free charges on the glass, etc. Therefore, the prediction of ignition of a dielectric starter from a probability (random) law is as impractical as the prediction of backfires in a high voltage tube. Test results are shown in Fig. 3 for a mercury pool tube with a single dip-in starter of the type described above. The curve gives average values and is arranged to cover as many measured points as practicable. These points were measured using an ignition counter and a response counter while the tube was excited from a 60 cps peaker transformer with an impulse voltage 30 deg in width at base of wave. Using sine-wave excitation the distribution of points is more erratic and average starting values are between 10 percent and 20 percent higher. The measurements were made with mercury condensing at room temperature.

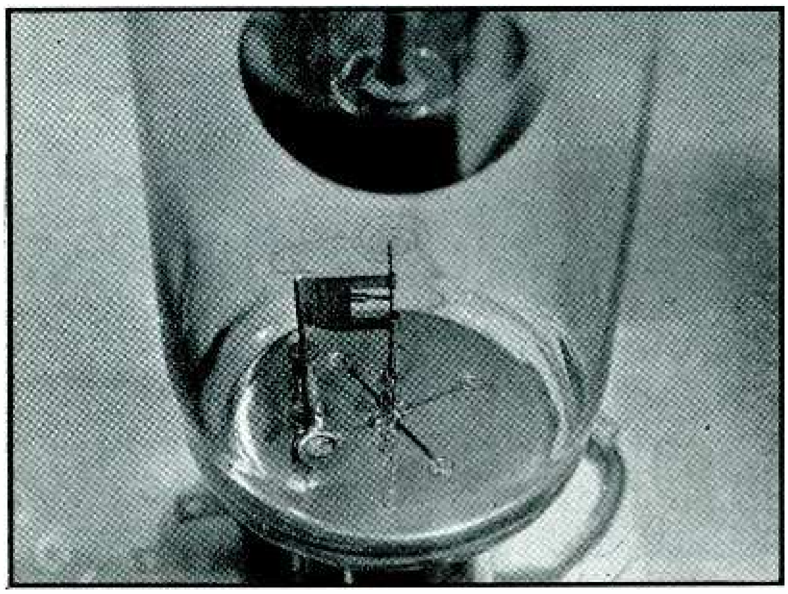


Fig. 4—View of pool cathode with floating starter assembly

The influence of age on the starting characteristic is not yet sufficiently explored to allow giving definite information in connection with surface deterioration and insensitivity as may influence life. Such effects, however, may be caused by impurities which however do not necessarily follow with extended use of the tube. In contrast, only a slight initial decrease in sensitivity and a remarkable stability thereafter have been observed with properly processed tubes during about one year of operation on welding duty.

Vibrations upset measurements of the starting characteristic by causing frequent ignitions at exceptionally low voltages. Sudden variations of the meniscus shape and perhaps also friction phenomena are believed to be the reason. Very similar to the influence of mechanical vibrations is the effect of steep wave fronts on the starting voltage. Here, too, the meniscus is suddenly agitated and may be ruptured in some cases by the rapidness of appearance of the electrostatic force. (See appendix for calculations.)

Above the zone of erratic behavior, and below the breakdown limit of the glass, a relatively wide range for reliable practical operation exists. This practical range (from 5 to 9 kv) is sufficiently wide and stable to grant the practical applicability of the dielectric starter types in their described present state of development.

In tubes containing mercury vapor alone, most favorable starting conditions fortunately prevail at normal operating temperatures. At low temperatures, around 0 deg C, operation stops in tubes of the usual construction. The starter produces tiny sparks at the edge of the mercury, but the ensuing discharge is not concentrated enough to produce the high local ion density necessary to build up the luminous cathode spot. Towards higher temperatures, on the other hand, the limit of operation is reached beyond 80 deg C. At this temperature the mercury pressure is so high that a glow forms around the starter lead inside the tube. This glow drains the ignition voltage source and reduces the starter potential below the value required for ignition.

The capacity of a single starter element which dips 1 cm into mercury is about 15 $\mu\mu$f. Such single starters are not practical; present day tubes contain several starter elements connected inside of the tube to their common supply lead through fusible links. If one starter element should contain an overlooked manufacturing flaw, or, due to accidental overvoltage should become punctured and make connection to the pool, the fusible link is blown, and the rest of the starter assembly is kept operating as before. Such assembly starters have capacities between 30 and 150 $\mu\mu f$, the lower values corresponding to the dipping type used for smaller tubes and the larger values to the floating type in bigger and more expensive tubes. (See Figs. 4 and 5). At 3 kv rms such starters draw a charging current of 30 to 150 microamperes at sinusoidal 60 cps excitation, or consume about 150 to 750 milliwatts. Resistors of the order of 10 to 100 megohms are allowable in the ignition circuit. To pass the increased amount of instantaneous charging current these values must be reduced by the factors 10 or 100 (depending on steepness) if peaked starting impulses are used.

Several outstanding features of the mercury pool tube with a dielectric starter appear from the foregoing description. It combines the peak current carrying ability, inherent to mercury pool cathodes, with a very low starting power requirement; the dielectric starter does not overheat from excitation at high frequencies, and no rectifying means **are necessary in the** starter circuit. Though present experience is too limited to review the practical applications of the new tube, it can be stated that its life and reliability seem amply sufficient to grant it a place of its own amongst the related members of the tube family.

Appendix

A typical starter has the following dimensions:

Radius of conducting core r = 0.325 mm

Thickness of insulating layer d = 0.075 mm

Dielectric constant of layer $\xi = 5$

Voltage applied between core and mercury pool E = 5 kv peak

1. The highest dielectric stress in the layer, at its inside bordering the core wire:

$$F_W = \frac{E}{r \ln\left(\frac{r+d}{r}\right)} = 740 \text{ kv per cm}$$

At breakdown voltage E_B = 12 kv the field across the layer becomes 1780 kc per cm.

2. The electrostatic force deforming the meniscus gap and pressing the mercury on the layer:

$$P = \frac{1}{2}\,\xi\,\xi_o F_{Hg}^2\,;$$

$$F_{Hg} = \frac{E}{(r+d)\ln\left(\frac{r+d}{r}\right)}\,;$$

$$\xi_o = 0.886 \times 10^{-13}\,\frac{\text{amp sec}}{\text{volt cm}}$$

$$= 0.08\,\frac{WaHsec}{\text{cm}^3} \text{ or } 0.82\ Kg/\text{cm}^2$$

or about 11 pound/square inch**

At 60-cps excitation this force varies 120 times per second between zero and full value and is responsible for a visible stirring of the pool surface and for a variation of starter capacity and pickup voltage.

3. The capacity of a single dip in starter of the above dimensions, dipping about l = 10 mm into the mercury pool, in farads, is

$$C = \frac{2\pi\,\xi\,\xi_o l}{\ln\left(\frac{r+d}{r}\right)} = 13.3 \times 10^{-12}$$

Experimental values are about 15 $\mu\mu f$.

4. On the capacitive current of the starter there is superimposed an ohmic leakage current of the same amount of a few microamperes. Resistance measurements with a dip in the starter showed almost the same value of 3×10^9 ohms at room temperatures with d-c and 60-cps excitation for voltages between 3 kv and 5 kv. From this, the resistivity of the glass layer is found to be 10^{11} ohms per cm.

5. The pick-up time of the dielectrically started discharge may be calculated as follows:

Let i_o be the cold emission current, having a value of 1 ma,
i_t be the anode current after establishment of the discharge, and having a value of 10 amperes,
t be the time required to establish the discharge,
t_ξ be the electron transit time from cathode to anode, determined from the equation, $t_\xi = (2md^2/eE)^{1/2}$
Z be the number of ions formed by one electron during one transit, and having a value of approximately 0.15 for 1 micron pressure and 50 volts average electron velocity,
d be the distance between cathode and anode, equal to 5 cm,
E be the anode voltage, (100 volts), and
e/m be the ratio of charge to mass of an electron, and equal to 1.77×10^8 absolute electromagnetic units per gram

Then,

$$i_t = i_o + (Z/t_\xi)\int_o^{i_t} i\,dt$$

$$\left. di_t = (Z/t_\xi)\, i\, dt \right]_{t = o;\ i = i_o}$$

$$i_t = i_o \exp\,(Zt/t_\xi)$$

$$t = (t_\xi/Z)\ln\,(i_t/i_o) = 9.7 \times 10^{-8} \text{ sec.}$$

A more exact calculation should take into account the increase of t due to ionizing collisions and would lead to a somewhat greater value of t.

** At breakdown voltage the electrostatic force across the layer rises to almost 2 atmospheres.

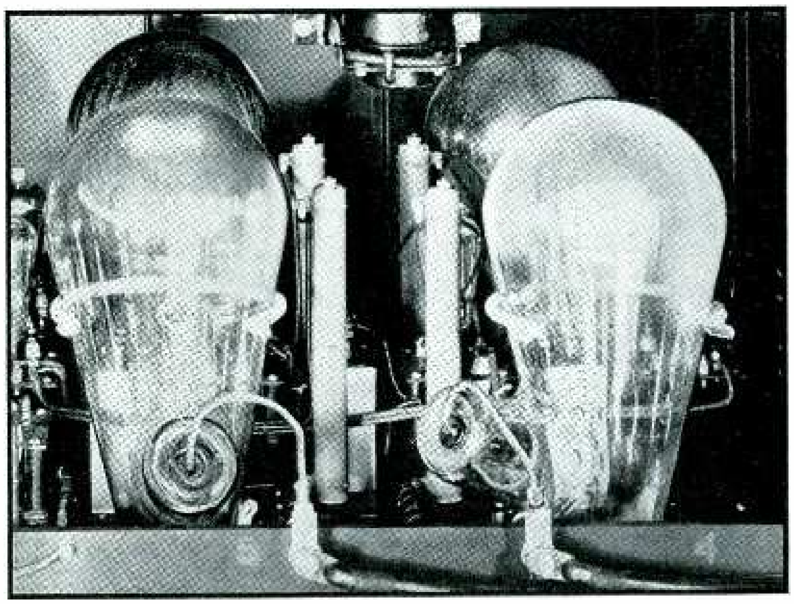


Fig. 5—Assembly of tubes with dielectric igniter, as used in industrial equipment

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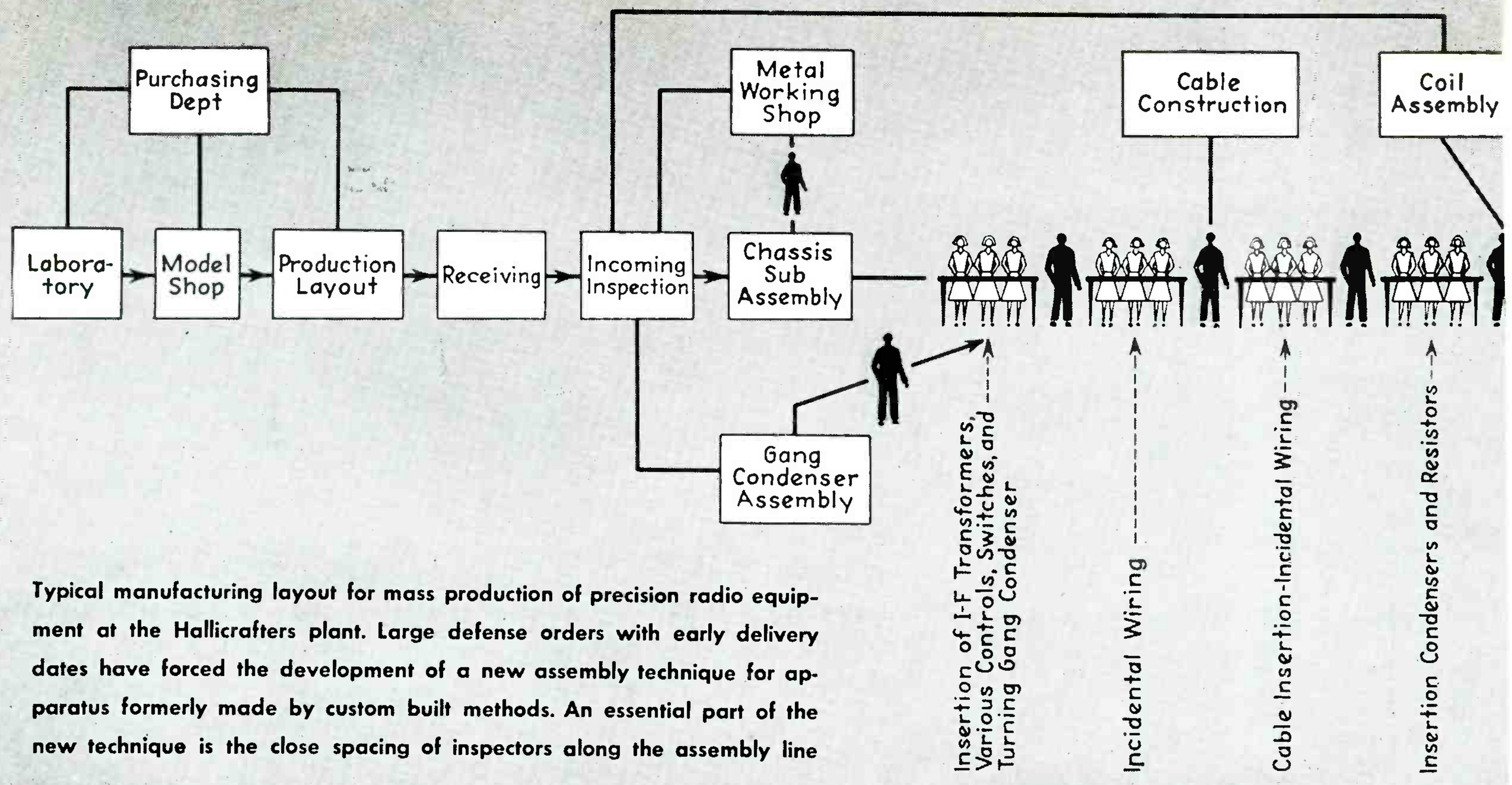


Typical manufacturing layout for mass production of precision radio equipment at the Hallicrafters plant. Large defense orders with early delivery dates have forced the development of a new assembly technique for apparatus formerly made by custom built methods. An essential part of the new technique is the close spacing of inspectors along the assembly line

MASS PRODUCTION for

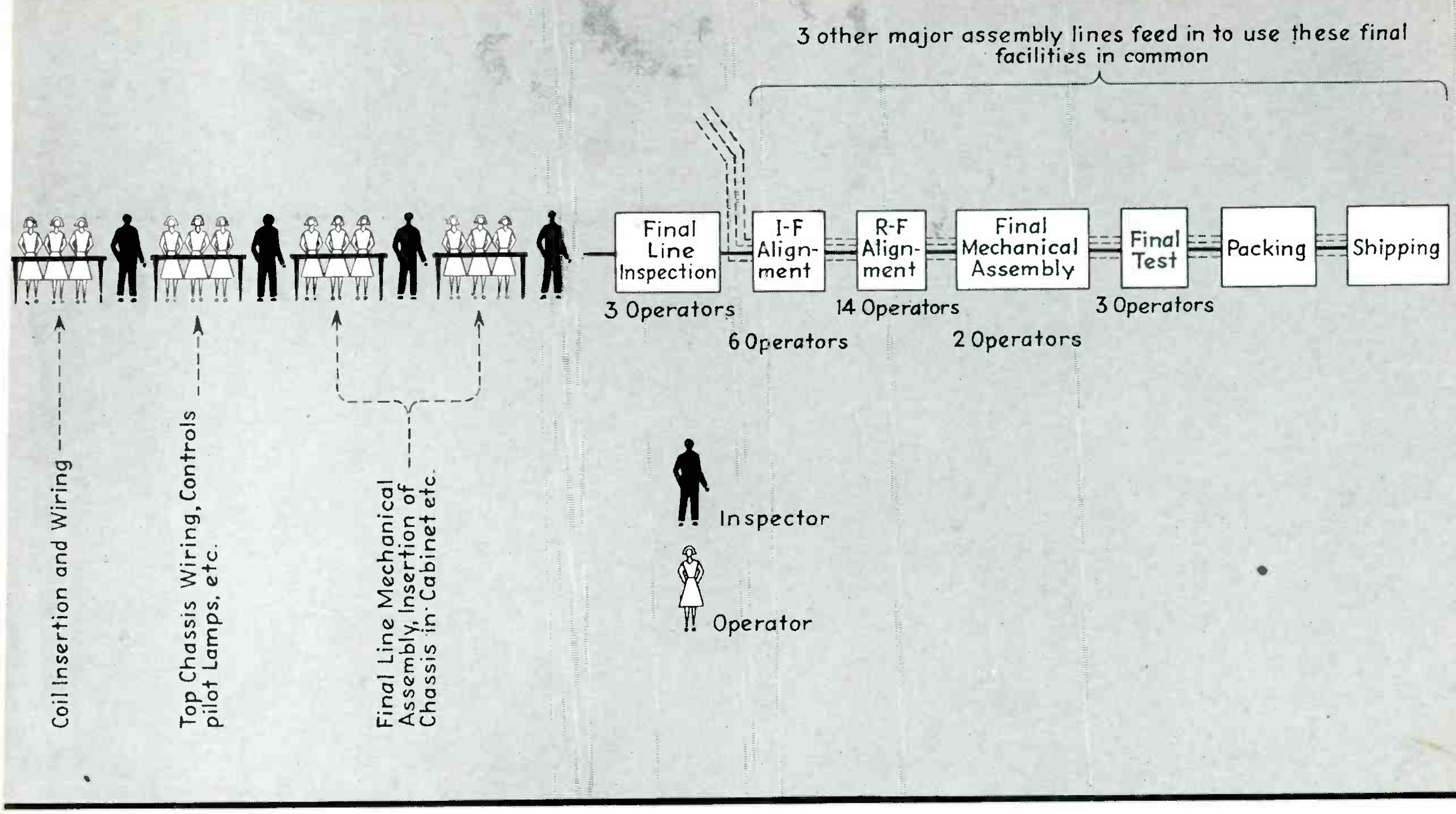
By HOWARD J. EMERSON

STIMULATED by the greatly increased demand of recent months for their products, manufacturers of precision radio equipment, including receivers and transmitters, have adopted mass production methods to replace the formerly used "custom built" methods. It has been necessary to maintain the accuracy and quality of workmanship achieved by a few skilled workers building a complete unit from the ground up. A few organizations have made this transition successfully, and others are still working to adjust their factory technique to get the most out of the heavy influx of new orders.

As an example of how straight-line production can be made to produce precision electronic equipment in large quantities without sacrificing quality, ELECTRONICS offers a study of the production line at The Hallicrafters Co., Chicago. One of the leaders in the manufacturing of communication receivers and low-powered transmitters, Hallicrafters has stepped up production to an estimated 35,000 units for 1941 through the development of this new technique. Their engineers have worked out a form of straight-line production which is a modification of the factory plan used by most manufacturers of home receivers, except that the assembly line is interspersed with inspectors at frequent intervals to keep each operation at a high quality level.

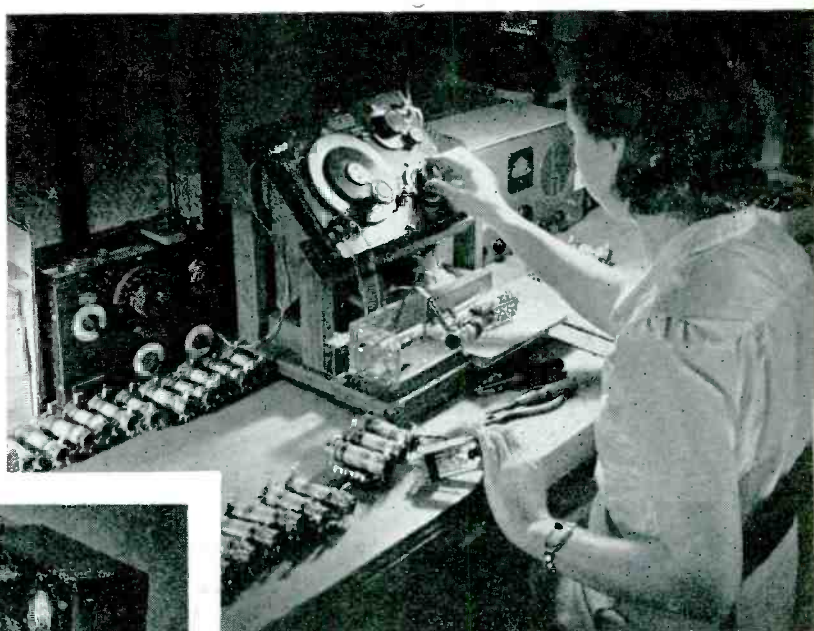
It is a very easy matter to say that this type of apparatus should be produced in a high speed assembly line, but it is quite different to design such an assembly line to do the job. Different concepts of how various operations should be performed are necessary. Methods which are entirely satisfactory for home receivers may or may not be adequate for the precision equipment under discussion. Time and motion studies must be made and the new personnel trained. In addition to the usual difficulties of setting up a production schedule, there are the difficulties of an organization which is used to thinking in terms of a very small number of units per day, week or month, suddenly swinging over to manufacturing large numbers of units in the shortest possible time.

In the Hallicrafters plant, the chassis of a receiver or a transmitter travels directly along the assembly line from the time it is stamped out until the completed unit is placed in a cabinet and checked against laboratory standards or government specifications. As the chassis is passed along the line the various parts and sub-assemblies are inserted and connected in much the same manner as it is done in standard mass production lines for home receivers. Probably the greatest difference between the Hallicrafters "precision" production line and the standard production

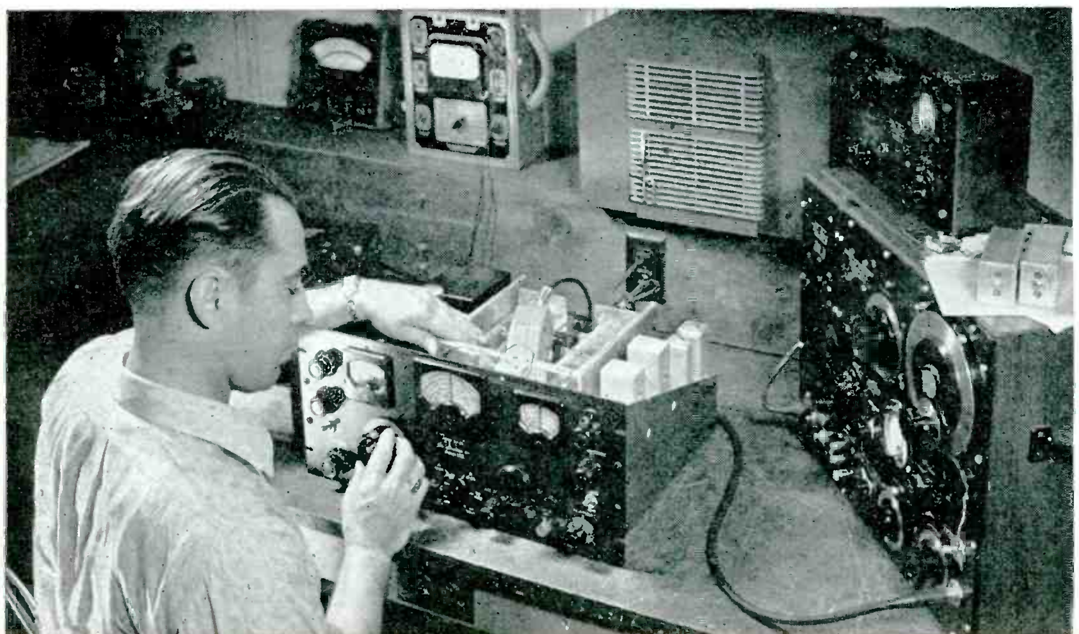


PRECISION EQUIPMENT

line is in the method of inspecting the partially assembled units. Here, inspectors are placed after every third operator to catch defects as soon as possible after they occur. In addition to physical tests, the circuits are also given electrical tests to insure that they operate properly as soon as they are completed. At a given inspection station, all the work of previous operators is reinspected so that by the time a receiver or transmitter is completed, some of the work may be inspected as much as half a dozen times. It is this rigid inspection plus a large number of simple assembly operations performed by relatively unskilled workers that permits the high quality of custom built apparatus to be maintained in the face



2 On arrival at the factory, all components are inspected and checked against the laboratory specifications



1 Finished engineering model of a Hallicrafter's Super Skyrider receives final checking before engineers plan a flow-sheet for its mass production

PHASE SHIFTING UP to 360 DEGREES

IT is well known that in a circuit composed of resistive and reactive elements in series the voltage drop appearing across the various elements may be either in phase with the current or leading or lagging it by any angle up to, but not exceeding 90 degrees, depending upon the circuit proportions. It is a patent fact that the great bulk of the phase shifters in use today utilize this principle in its simplest form. There appears in the literature little specific information on phase shifting bridges and circuits, with the result that many phase-shifting jobs are done in a makeshift manner, and no doubt many are not done at all. It is the purpose of this paper to survey the general types of phase shifters available, and to describe a continuously adjustable 0-360 degree phase shifter for operation over a wide range of frequencies.

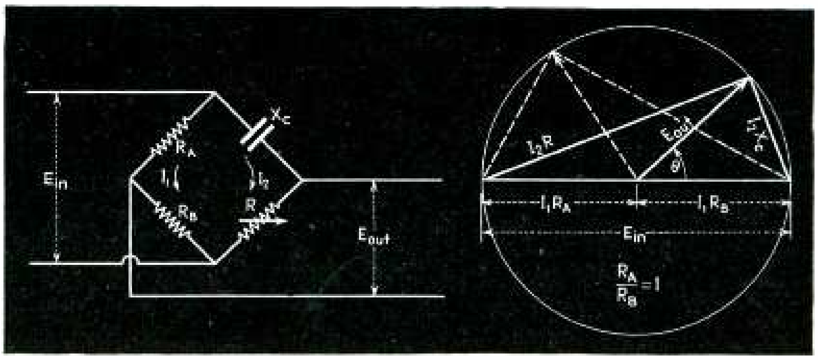


Fig. 1—The single reactance bridge phase shifter and its vector diagram. The output voltage is constant for varying phase angles when $R_A = R_B$

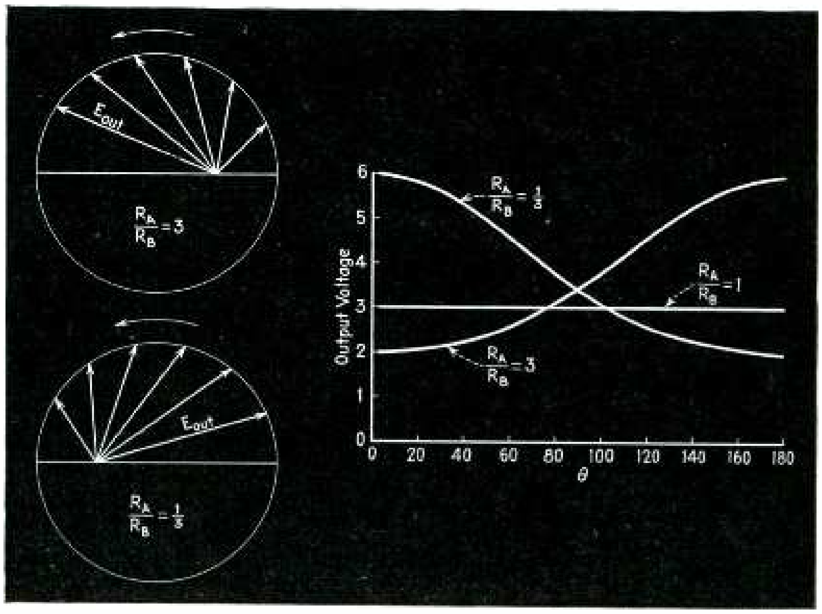


Fig. 2—Diagrams showing how the circuit of Fig. 1 can be made to produce varying output voltages for varying phase angles

Single-Reactance Bridge Phase Shifter

A bridge involving a single reactive element capable of a phase shift from zero to almost 180 degrees is shown in Fig. 1. A capacitance is shown, although an inductance would work practically as well. In general, capacitive reactance elements are preferred over the inductive because of the higher Q readily attainable and because of economy, and freedom from extraneous fields. The principle of operation is demonstrated in the vector diagram of Fig. 1. The current I_2 flowing through X_c and R gives rise to voltage drops I_2X_c and I_2R which are mutually perpendicular. The output voltage is that vector voltage appearing between the junction of I_2R and I_2X_c and the junction of I_1R_A and I_1R_B.

If R_A is equal to R_B, the output voltage will be equal to half the input voltage and will remain constant as long as the input voltage is constant. Figure 2 shows the effect of an inequality between R_A and R_B. If it is desirable to have an output voltage that varies in a specified manner with the phase angle variations, this feature may prove useful. The output voltage can be made to increase, decrease, or remain constant with phase angle merely by adjusting the ratio of R_A to R_B. The resistance ($R_A + R_B$) could be a potentiometer with the output voltage connected to the slider for ease in adjusting this ratio.

The impedance offered to the source and to the load depends upon the setting of R. For instance, when $R = 0$, the input impedance is R_A and R_B in series shunted by X_c, and when R is a maximum (which is very high compared to X_c), the input impedance is very closely R_A and R_B in series shunted by R. Buffer amplifiers or impedance-matching

A review of the general subject of bridge phase shifters plus a description of a continuously variable 0-360 degree phase shifter which is independent of frequency over a wide range. A pair of ganged potentiometers having continuous resistance elements are used

By F. ALTON EVEREST *Oregon State College*

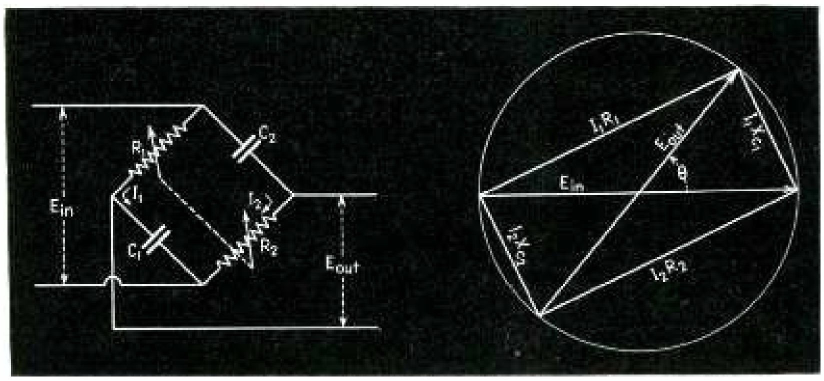


Fig. 3—Double-reactance bridge phase shifter and its vector diagram. Note that the output voltage is equal to the input voltage

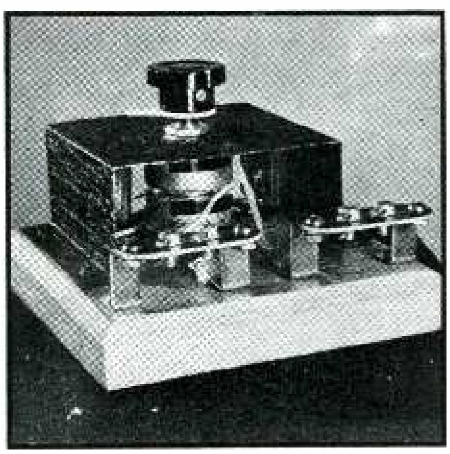


Fig. 4—Laboratory model of the circuit of Fig. 3. At 1000 cps a phase shift of about 174 degrees can be obtained

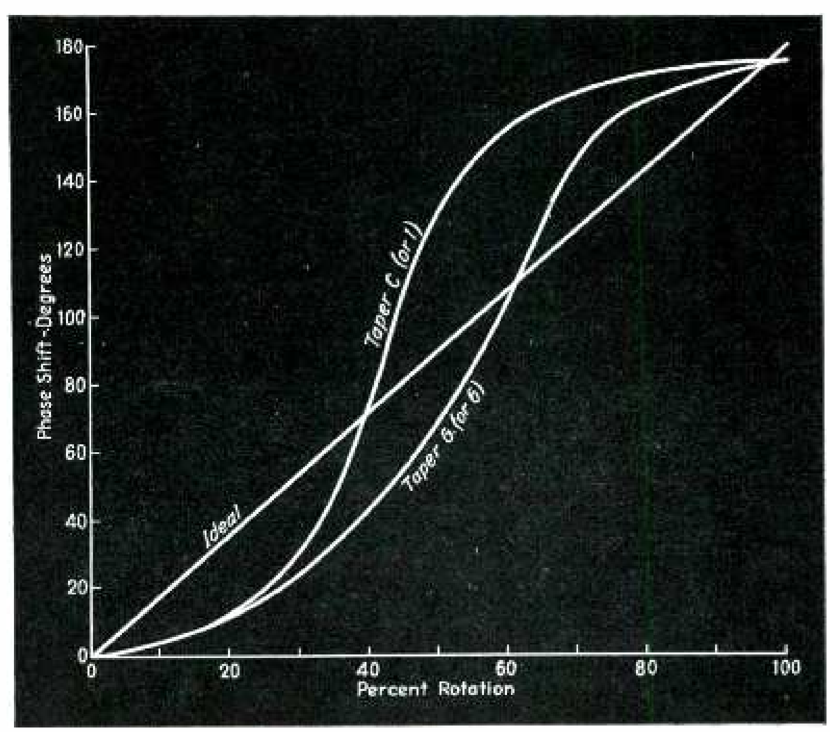


Fig. 5—Suitable resistance tapers for bridge phase shifters. The variation of phase shift with rotation of the resistance shaft depends upon this taper

transformers may be used to minimize the effects of this variable impedance. A tapped transformer winding may be used in place of R_A and R_B if desired.

Double-Reactance Bridge Phase Shifter

A phase shifter similar in many ways to the shifter described above is the double-reactance phase shifter illustrated in Fig. 3. An examination of the vector diagram will reveal that it is built up of two halves, each similar to that of Fig. 1. Instead of terminating one end of the output voltage vector at the fixed junction of R_A and R_B as in the single-reactance bridge of Fig. 1, it is terminated at the junction of R_1 and C_1 which point moves with changes in R_1–R_2 setting, always being diametrically opposed to the opposite junction point if $R_1 = R_2$ and $C_1 = C_2$.

One of the big advantages of this bridge circuit is that the input and output voltages are always equal as long as the resistance arms are equal and the reactance arms are equal. A 180-degree shift is available if the resistance of R_1 and R_2 is made infinitely large compared to the reactance of C_1 and C_2. The expression for the phase angle is:

$$\theta = 180 - 2 \text{ arc tan } \frac{X_c}{R}$$

The impedance of this type of shifter also varies with the setting of the adjustable arms. The input impedance varies approximately from a reactance of half that of one reactive arm to a resistance whose magnitude is half that of one resistive arm. The output impedance varies in a similar manner.

An inexpensive double-reactance bridge of this phase shifter is shown in Fig. 4 built up in a form convenient for laboratory purposes. It utilizes 0.01 microfarad condensers for the reactance arms and a dual 250,000-ohm potentiometer for the resistance arms. At 1,000 cps this bridge will give a phase shift up to about 174 degrees. The taper of the resistance elements determines how the phase shift varies with rotation. For the shifter described above, taper *G* (or taper 6) was selected, which is readily obtained (in dual form) on special order. Taper *C* (or taper 1) spreads the calibration out fairly well. (See Fig. 5.) The ideal arrangement would be a tap switch with the resistance of each point adjusted accurately for, say, 5-degree steps. The calibration of these bridge units, and in fact any of the simple phase shifters, will hold for only a single frequency. The constancy of the output voltage of the shifter of Fig. 4 is shown by the oscillogram of Fig. 6. The input voltage was applied to one pair of cathode-ray tube deflection plates, the output voltage to the other pair (through matching transformers to work into the single-ended oscilloscope), and the exposure was made while the knob was rotated.

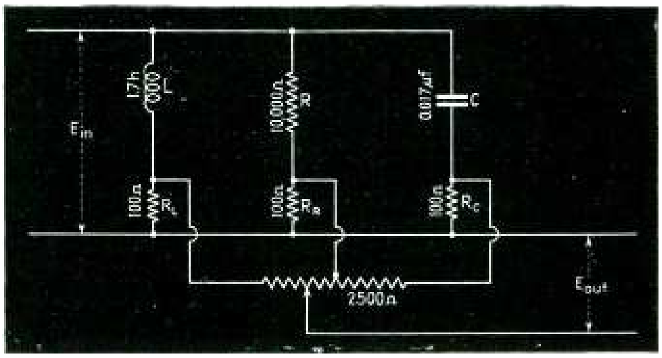
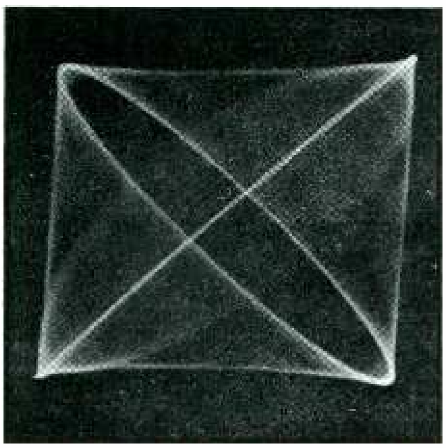
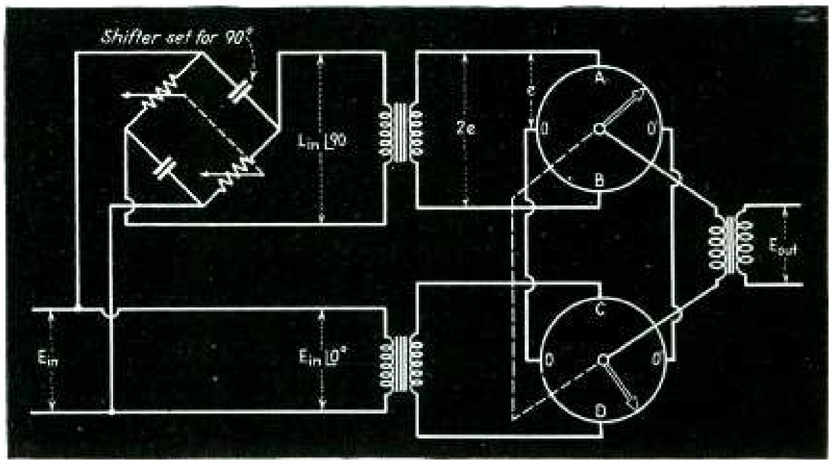


Fig. 7 — Three-arm phase shifter in which the input and output have common leads. The output voltage is about one percent of the input voltage





(Left) Fig. 6 — Superimposed Lissajous figures to show the constancy of output voltage of the phase shifter of Fig. 4

Fig. 8—The 360-degree phase shifter in which are used two ganged potentiometers whose contact arms are set 90 degrees apart

Three-Arm Phase Shifter

All of the phase shifters described so far, and many others, have double-ended characteristics. It is often very necessary to carry a common lead (ground, perhaps) from the input to the output. The phase shifter of Fig. 7 does this. The input voltage is applied to three arms in parallel, one predominately inductive, another resistive, and another capacitive. The current through the *L* arm lags the applied voltage almost 90 degrees, that through the *R* arm is in phase with it, and the current through the *C* arm leads the input voltage by almost 90 degrees. The voltage appearing across the coupling resistors, then, bear similar relationships to the input voltage, because their resistances are low compared to the main reactance or resistance, so that their presence is not disturbing. A center-tapped potentiometer whose resistance is high compared to the coupling resistors is used to vary the phase of the output voltage from nearly + 90 degrees to nearly − 90 degrees.

One of the chief characteristics of this phase shifter is that the output voltage is very much smaller than the input voltage. For this reason, the impedance of the center-tapped potentiometer should be as low as possible consistent with coupling resistor size to minimize hum pickup. The component values shown in Fig. 7 are satisfactory for 1000-cps operation. For this case, the output voltage is about 1/100 of the input. For constant voltage out, $X_L = R = X_c$ and $R_L = R_R = R_c$. This phase shifter will work after a fashion without the *R*-arm. The input impedance is essentially constant, although the output impedance varies with potentiometer setting.

360-Degree Phase Shifter

Inasmuch as a maximum of 90-degree phase rotation can be obtained with an inductive reactance, and a rotation of close to 90 degrees in the opposite direction with a capacitive reactance, special arrangements must be made to obtain greater than a 180-degree phase shift. The diagram of the 360-degree phase shifter to be described is shown in Fig. 8. The heart of the device is a pair of potentiometers with a continuous resistance element and a slider that can rotate 360 degrees. The resistance element has a tap every 90 degrees. The two potentiometers are ganged and arranged so that, if corresponding

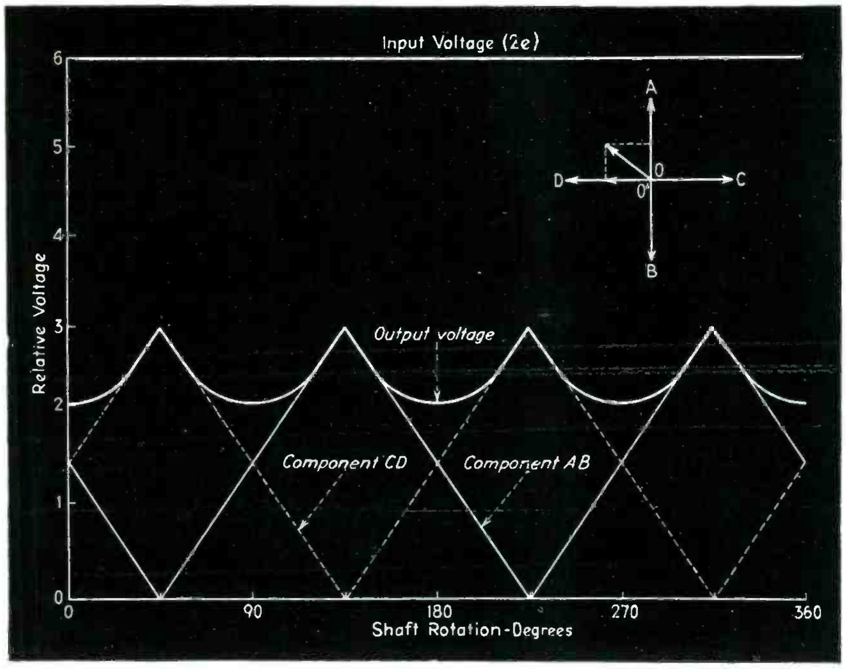


Fig. 9—Voltage curves of the 360-degree phase shifter showing variation in output voltage as the phase is shifted

taps are in line, the sliders are mutually perpendicular. A voltage is applied to terminals *C* and *D* on one potentiometer, and the same voltage shifted 90 degrees is applied to the corresponding taps (*A* and *B*) of the other unit.

Any voltage appearing between terminals *A* and *B* will cause equal currents to flow down each side of the potentiometer, establishing midpoints at *O* and *O'*. The midpoints of both potentiometers will be at the same potential provided the resistance elements are constructed uniformly and the taps located accurately. Therefore, we know that if the slider moves between *A* and *B* the voltage between the slider and the midpoints will vary in magnitude but not in phase. The same applies to the voltage from the other potentiometer, but there will be a

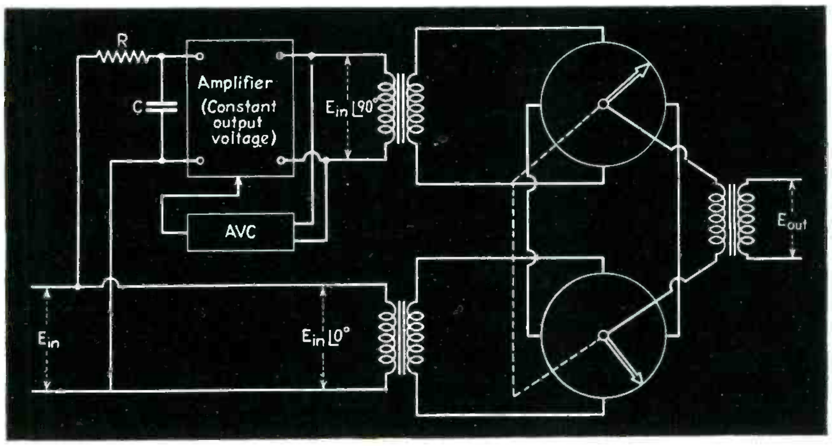


Fig. 10—Circuit of a 360-degree phase shifter which is independent of frequency

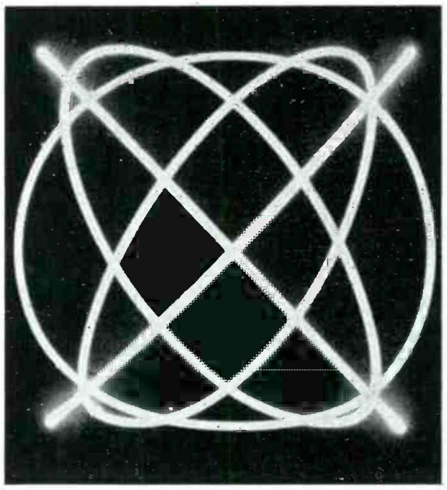
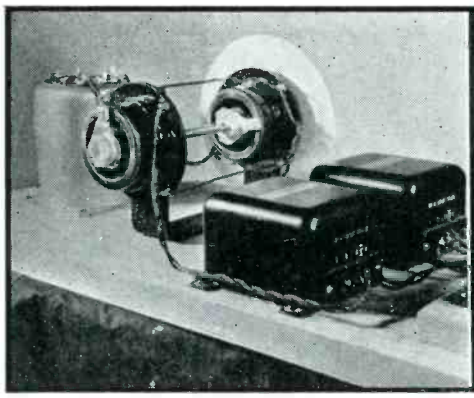
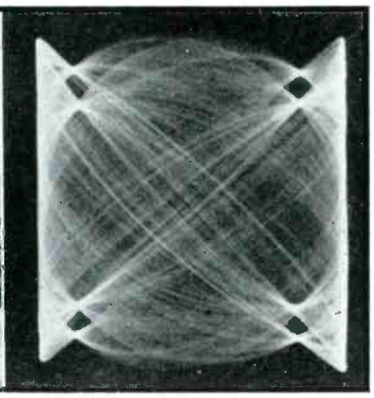


Fig. 13—Composite Lissajous figures showing constant input voltage and changing output voltage of the circuit of Fig. 10

(Left) Fig. 11—Laboratory model of the 360-degree phase shifter whose circuit is shown in Fig. 8. (Right) Fig. 12—Lissajous figures taken with the 360-degree phase shifter

phase difference of 90 degrees between any *AB* voltage and any *CD* voltage. Therefore, the axes shown as an insert to Fig. 9 may be set up. If the sliders are in the positions shown in Fig. 8, one voltage component will be half of *O'A* and the other half of *O'D*. These two components are in quadrature and combine to give a resultant which is the output voltage. As the shaft is rotated through 360 degrees, the *CD* and *AB* components vary as shown in Fig. 9, assuming 0 degrees shaft rotation is the position shown in Fig. 8 and that the rotation is clockwise. The output voltage varies be-

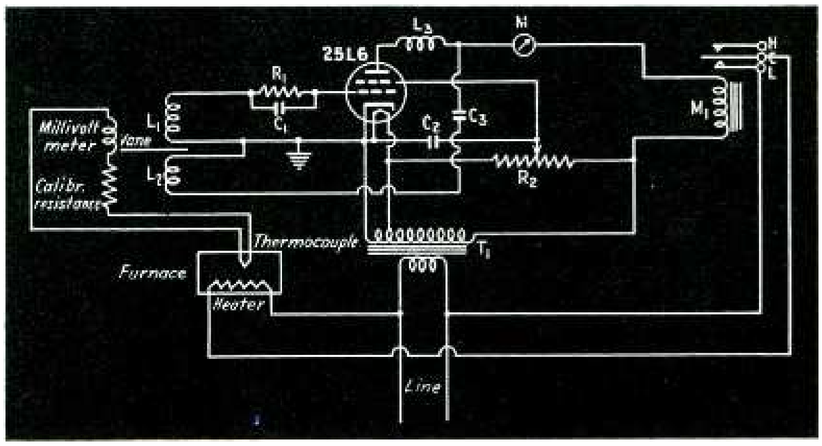
(*Continued on page* 122)

Electronic Pyrometer Control

A single tube control circuit automatically controls temperatures up to 3300 deg. F. in industrial furnaces using a thermocouple to measure temperature and a meter movement which sets the circuit into oscillation

By F. B. MacLAREN

Formerly with The Bristol Company, Waterbury, Conn.



Schematic wiring diagram of the electronic pyrometer control unit

THE application of electronic circuits to industrial apparatus has simplified and improved the performance of many electrical and mechanical control systems. In the field of pyrometry, for example, mechanical devices have been used for a number of years to regulate the fuel supply of industrial ovens and furnaces where constant temperature is required. These employ a motor-driven chopper bar to engage the pointer of a millivoltmeter pyrometer and thereby actuate an electrical contact as the temperature varies above and below the set control point. Although satisfactory operation is obtained, there are several disadvantages to this method.

Electron tube control circuits will eliminate most of these disadvantages; for example, mechanical engagement of the pyrometer pointer and objectionable time lag. In addition all of the moving parts are eliminated, making for much simpler construction.

The control circuit is shown in the accompanying diagram. It consists of a single-tube oscillator, plate and filament voltages being supplied by transformer T_1 fed from the a-c line. A relay M_1 controls the load circuit and is actuated by the plate current of the 25L6 tube. A screen potentiometer R_2 is used to adjust the normal half-wave plate current to an average value of 10 milliamperes, as indicated by meter M. The oscillating circuit itself constitutes an untuned grid coil L_1 and plate coil L_3, forming a type of Hartley oscillator capacity coupled through condenser C_3 and inter-electrode capacity within the tube. Another coil L_2, which is effectively a portion of L_3, by virtue of its connection through condenser C_3, is degeneratively coupled to L_1 to normally prevent oscillation. When an aluminum vane attached to the millivoltmeter pointer enters the field between L_1 and L_2 it acts as a shield to isolate them electromagnetically and prevent the degenerative action of L_2, thereby allowing the circuit to oscillate. Through the action of grid leak resistor R_1 and condenser C_1 the plate current then drops to its minimum value of 0.5 ma. Another condenser C_2 acts as an r-f by-pass for the screen grid.

When the temperature is low, the control circuit is not oscillating; the plate current is at its maximum value of 10 ma average; relay M_1 is energized; and fuel is being supplied to the oven or furnace under control. As the vane attached to the millivoltmeter pointer enters the field of the coils L_1 and L_2, oscillation gradually increases as the coils are more completely shielded from each other, until the plate current reaches its minimum value. This region of current variation is, of course, determined by the width of the coils, which is normally 1/16 inch, and the shape of the leading edge of the vane. The relay M_1 is adjusted to operate at an average current of 5 ma or at the mid-point of the coils, to give a factor of safety in each direction. Since the milliammeter M indicates at all times the operation of the circuit, it provides a check on the condition of the vacuum tube so that it may be replaced before it fails. The screen voltage may be adjusted by means of R_2 to increase the plate current as emission drops off, or to compensate for regional difference in line voltage. Tubes have operated continuously in this circuit for over four years without serious loss of emission, or any change in the control point.

This particular type of circuit was chosen for several reasons: (1) it is extremely simple and stable, (2) any failure of the tube or line voltage will shut off the fuel to the furnace, and (3) it eliminates all electromagnetic and electrostatic force on the millivoltmeter pointer. With a sensi-

(*Continued on page* 78)

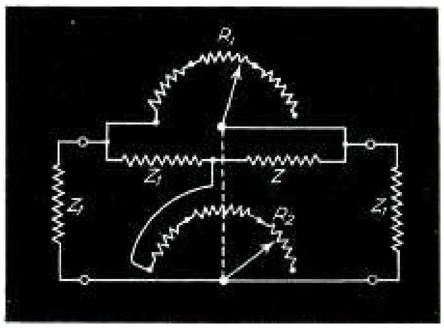
ATTENUATOR DESIGN

Formulas for Calculating Resistance Networks

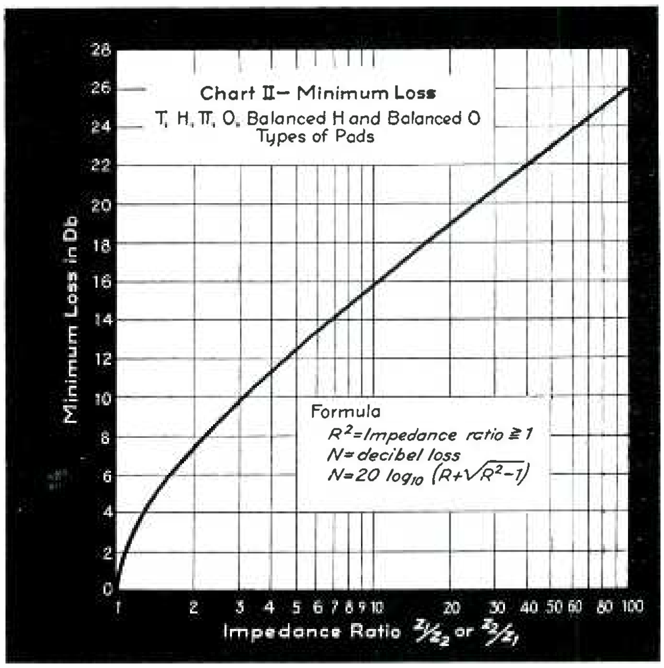
The design of resistance networks, or pads, for matching the impedances of two connected circuits, or for inserting a definite attenuation in a circuit, is simplified through the use of design charts applicable to a wide variety of networks

By DAWKINS ESPY

KFI-KECA, Hollywood, Cal.



Simple voltage dividing network having given input impedance and specified loss, design data for which is worked out as Problem I



The minimum loss of any pad inserted in a circuit is given in decibels for impedance ratios, Z_1/Z_2, of from 1 to 100. The range may be extended for values of from $Z_1/Z_2 = 0.01$ to $Z_1/Z_2 = 1.0$ by forming the ratio Z_2/Z_1 which will be greater than unity

NETWORKS whose elements consist of pure resistances and whose attenuation does not vary with frequency are known as attenuator pads. There are two common uses of these resistance pads, namely, to match the impedance between two circuits and to insert a definite loss in a circuit. The physical interpretation of a pad is a transmission line which has no reactive characteristics, but rather may be considered as a group of series and shunt elements which are pure resistances.

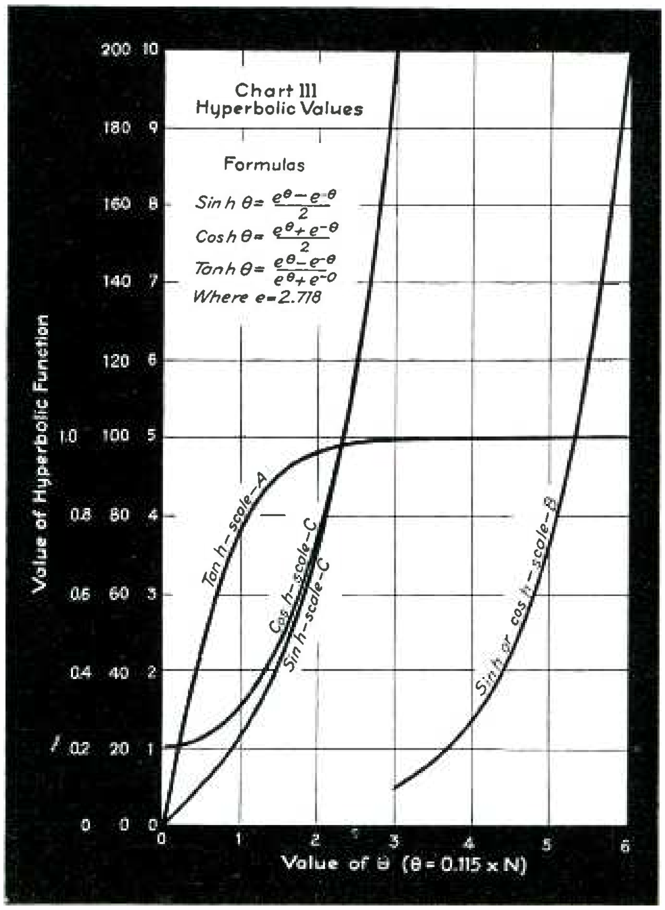
Three factors determine the design of a pad. They are: (1) the input impedance, (2) the output impedance, and (3) the loss in decibels. For every input to output impedance ratio there is a definite minimum loss for which the pad can be designed so that (2) and (3) are not completely independent. To attempt to design a pad with less than this critical loss would require that at least one of the resistances be negative, which is physically meaningless for attenuators built of customary resistor elements.

In order to know which pad to employ for a particular use it is necessary to know the electrical characteristics of the various networks. When working into a high impedance device, it is usually possible to use the simplest form of attenuator, the potentiometer. In this type the sum of the two resistance arms is constant, but their ratio is varied. When it is not necessary that the impedance, looking back into the output terminals of the attenuator be equal to the load impedance, an L type of attenuator may be used.

Pads of the T, H, π, and O types are useful where the attenuator impedance must match the load impedance. Such a situation occurs in low level, low impedance mixing and, in amplifiers with critical input impedance. When a pad is in a circuit which must be balanced to ground such as the input of a push-pull amplifier, the balanced U, O or H attenuators may be used. Formulas are also included for the bridged T, bridged H and bridged-balanced H.

The resistance values actually used may deviate from the calculated values by 5 percent without mismatching the impedance by more than that amount, and varying the loss more than 0.5 db. Since the T and π pads occur most frequently a second set of formulas which are easier to work with than the algebraic type, are included.

Very often it is desirable to have a volume control which reflects a constant impedance in both directions. It is for this purpose that the bridged version of the pads are most frequently used. The bridged T, for example, has the advantage over the ordinary T that one less resistance must be varied, yet it still retains the advantage of the T in having zero insertion loss for matching equal impedances.

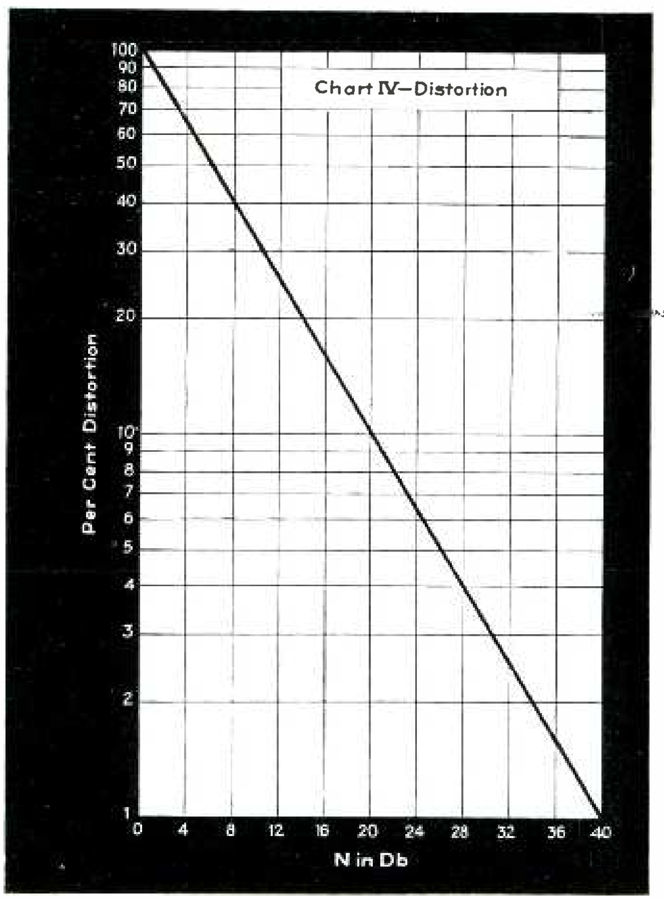


Graph of hyperbolic functions, which are used in many design equations of resistance networks. Note that multiple scales for the functions are given, and that the sinh and cosh functions are broken at $\Theta = 3$ so as to obtain greater accuracy

Design Procedure

The steps in the design of any pad may be summarized as follows:

1. Determine from Chart I the type of pad best suited for a particular use. In some cases particular networks will be required; in other cases several network arrangements are possible, as indicated above.
2. Calculate the ratio of input to output impedance (or output to input, whichever is the larger), and by using Chart II determine the minimum loss possible for the given impedances. Chart II holds for T, H, π, O balanced H, and balanced O types of pads.
3. From Table I find the value of K corresponding to the desired loss in decibels which must be equal to or greater than the minimum loss determined in step 2.
4. Calculate the values of resistance for the various elements from the formulas given in columns 2 or 4 of Chart I. If the hyperbolic form of the formulas are used in the case of the T, H, π, O, balanced H, and balanced O pads, it is first necessary to check the desired loss as explained in step 2 and then determine Θ from the formula $\Theta = 0.115N$, where N is the loss in db. Then values of sinh Θ and tanh Θ in the case of the T, H, or balanced H, or the sinh Θ and cosh Θ in the case of the π, O, or balanced O can be found on Chart III. It will be noticed that the curves for the sinh Θ and the cosh Θ are broken up into two sections for increased accuracy.
5. When it is necessary to insert a loss of more than 30 or 40 db it is usually advisable to use two pads in series such that the sum of their losses is equal to the required amount rather than a single pad.

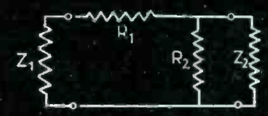
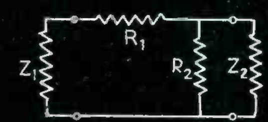
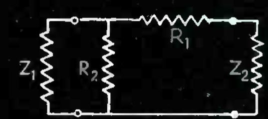
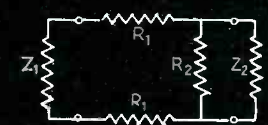
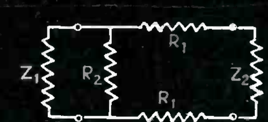
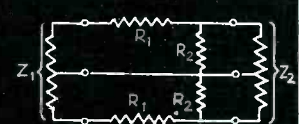
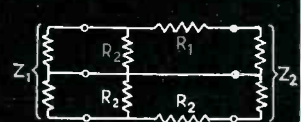
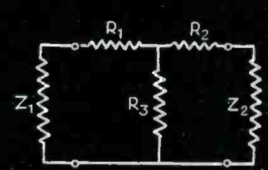
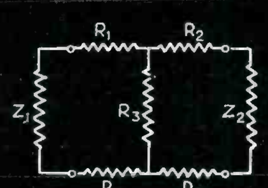


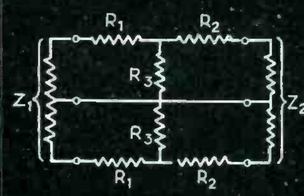
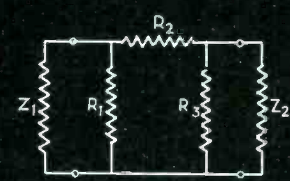
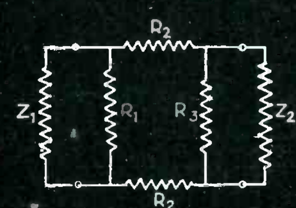
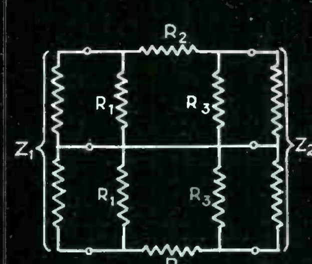
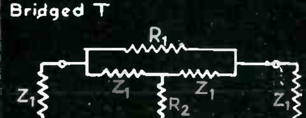
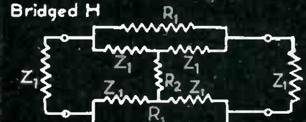
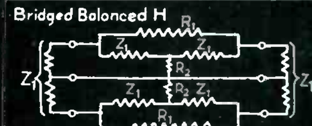
Graph for determining percent distortion by noting the gain required to produce the original output of a network, when the fundamental frequency is removed by use of high pass filter

Distortion Measurements

For measuring harmonic distortion a good method is to adjust the output of the amplifier to the desired level with a constant frequency input. A frequency of 400 cps is usually used for this purpose because the distortion at this frequency represents a good average of distortion throughout the audio range. Then a high pass filter of good characteristics is inserted to eliminate the fundamental, and the amplification in db necessary to bring the level back up to the previous value is determined. This may be accomplished by removal of pads of known loss. Then by referring to Chart IV, the harmonic distortion corresponding to this attenuation may be found. For example, if it were necessary to remove a 30 db pad to regain the original level, there would exist in this particular amplifier 3.16 percent harmonic distortion.

Chart I, at the right, shows the most common resistance networks for communication uses, together with the design equations for both equal and unequal impedances between which the pad works

TYPE AND CONFIGURATION	UNSYMMETRICAL FORMULAS $S=\frac{Z_1}{Z_2}$ or $\frac{Z_2}{Z_1}$ $(S \geqq 1)$	SYMMETRICAL FORMULAS $(Z_1 = Z_2)$ or $(S=1)$ Z_1 Used for Input and Output Impedance
Potentiometer 	$R_1 = Z_1\left(\frac{K-1}{K}\right)$ $R_2 = \frac{Z_1}{K}$	
L 	$R_1 = \frac{Z_1}{S}\left(\frac{KS-1}{K}\right)$ $R_2 = \frac{Z_1}{S}\left(\frac{1}{K-S}\right)$	$R_1 = Z_1\left(\frac{K-1}{K}\right)$ $R_2 = Z_1\left(\frac{1}{K-1}\right)$
L 	$R_1 = \frac{Z_2}{S}\left(K-S\right)$ $R_2 = \frac{Z_2}{S}\left(\frac{K}{KS-1}\right)$	$R_1 = Z_1\left(K-1\right)$ $R_2 = Z_1\left(\frac{K}{K-1}\right)$
U 	$R_1 = \frac{Z_1}{2S}\left(\frac{KS-1}{K}\right)$ $R_2 = \frac{Z_1}{S}\left(\frac{1}{K-S}\right)$	$R_1 = \frac{Z_1}{2}\left(\frac{K-1}{K}\right)$ $R_2 = Z_1\left(\frac{1}{K-1}\right)$
U 	$R_1 = \frac{Z_1}{2S}\left(K-S\right)$ $R_2 = \frac{Z_1}{S}\left(\frac{K}{KS-1}\right)$	$R_1 = \frac{Z_1}{2}\left(K-1\right)$ $R_2 = Z_1\left(\frac{K}{K-1}\right)$
Balanced U 	$R_1 = \frac{Z_1}{2S}\left(\frac{KS-1}{K}\right)$ $R_2 = \frac{Z_1}{2S}\left(\frac{1}{K-S}\right)$	$R_1 = \frac{Z}{2}\left(\frac{K-1}{K}\right)$ $R_2 = \frac{Z}{2}\left(\frac{1}{K-1}\right)$
Balanced U 	$R_1 = \frac{Z_2}{2S}\left(K-S\right)$ $R_2 = \frac{Z_2}{2S}\left(\frac{K}{KS-1}\right)$	$R_1 = \frac{Z}{2}\left(K-1\right)$ $R_2 = \frac{Z}{2}\left(\frac{K}{K-1}\right)$
T 	$R_1 = \frac{Z_1}{\operatorname{Tanh}\theta} - \frac{\sqrt{Z_1 Z_2}}{\operatorname{Sinh}\theta}$ $R_2 = \frac{Z_2}{\operatorname{Tanh}\theta} - \frac{\sqrt{Z_1 Z_2}}{\operatorname{Sinh}\theta}$ $R_3 = \frac{\sqrt{Z_1 Z_2}}{\operatorname{Sinh}\theta}$ or $R_1 = Z_1\left(\frac{K^2+1}{K^2-1}\right) - 2\sqrt{Z_1 Z_2}\left(\frac{K}{K^2-1}\right)$ $R_2 = Z_2\left(\frac{K^2+1}{K^2-1}\right) - 2\sqrt{Z_1 Z_2}\left(\frac{K}{K^2-1}\right)$ $R_3 = 2\sqrt{Z_1 Z_2}\left(\frac{K}{K^2-1}\right)$	$R_1 = R_2 = \frac{Z_1}{\operatorname{Tanh}\theta} - \frac{Z_1}{\operatorname{Sinh}\theta}$ $R_3 = \frac{Z_1}{\operatorname{Sinh}\theta}$ or $R_1 = R_2 = \left(\frac{K-1}{K+1}\right)Z_1$ $R_3 = 2Z_1\left(\frac{K}{K^2-1}\right)$
H 	$R_1 = \frac{1}{2}\left[\frac{Z_1}{\operatorname{Tanh}\theta} - \frac{\sqrt{Z_1 Z_2}}{\operatorname{Sinh}\theta}\right]$ $R_2 = \frac{1}{2}\left[\frac{Z_2}{\operatorname{Tanh}\theta} - \frac{\sqrt{Z_1 Z_2}}{\operatorname{Sinh}\theta}\right]$ $R_3 = \frac{\sqrt{Z_1 Z_2}}{\operatorname{Sinh}\theta}$ or $R_1 = \frac{Z_1}{2}\left(\frac{K^2+1}{K^2-1}\right) - \sqrt{Z_1 Z_2}\left(\frac{K}{K^2-1}\right)$ $R_2 = \frac{Z_2}{2}\left(\frac{K^2+1}{K^2-1}\right) - \sqrt{Z_1 Z_2}\left(\frac{K}{K^2-1}\right)$ $R_3 = 2\sqrt{Z_1 Z_2}\left(\frac{K}{K^2-1}\right)$	$R_1 = R_2 = \frac{1}{2}\left[\frac{Z_1}{\operatorname{Tanh}\theta} - \frac{Z_1}{\operatorname{Sinh}\theta}\right]$ $R_3 = \frac{Z_1}{\operatorname{Sinh}\theta}$ or $R_1 = R_2 = \frac{Z_1}{2}\left(\frac{K-1}{K+1}\right)$ $R_3 = 2Z_1\left(\frac{K}{K^2-1}\right)$

TYPE AND CONFIGURATION	UNSYMMETRICAL FORMULAS $S=\frac{Z_1}{Z_2}$ or $\frac{Z_2}{Z_1}$ $(S \geqq 1)$	SYMMETRICAL FORMULAS $(Z_1 = Z_2)$ or $(S=1)$ Z_1 Used for Input and Output Impedance
Balanced H 	$R_1 = \frac{1}{2}\left[\frac{Z_1}{\operatorname{Tanh}\theta} - \frac{\sqrt{Z_1 Z_2}}{\operatorname{Sinh}\theta}\right]$ $R_2 = \frac{1}{2}\left[\frac{Z_2}{\operatorname{Tanh}\theta} - \frac{\sqrt{Z_1 Z_2}}{\operatorname{Sinh}\theta}\right]$ $R_3 = \frac{\sqrt{Z_1 Z_2}}{2\operatorname{Sinh}\theta}$ or $R_1 = \frac{Z_1}{2}\left(\frac{K^2+1}{K^2-1}\right) - \sqrt{Z_1 Z_2}\left(\frac{K}{K^2-1}\right)$ $R_2 = \frac{Z_2}{2}\left(\frac{K^2+1}{K^2-1}\right) - \sqrt{Z_1 Z_2}\left(\frac{K}{K^2-1}\right)$ $R_3 = \sqrt{Z_1 Z_2}\left(\frac{K}{K-1}\right)$	$R_1 = R_2 = \frac{1}{2}\left[\frac{Z_1}{\operatorname{Tanh}\theta} - \frac{Z_1}{\operatorname{Sinh}\theta}\right]$ $R_3 = \frac{Z_1}{2\operatorname{Sinh}\theta}$ or $R_1 = R_2 = \frac{Z_1}{2}\left(\frac{K-1}{K+1}\right)$ $R_3 = Z_1\left(\frac{K}{K^2-1}\right)$
π 	$R_1 = \frac{Z_1 Z_2 \sinh\theta}{Z_2 \cosh\theta - \sqrt{Z_1 Z_2}}$ $R_2 = \sqrt{Z_1 Z_2}\,\sinh\theta$ $R_3 = \frac{Z_1 Z_2 \sinh\theta}{Z_1 \cosh\theta\ \sqrt{Z_1 Z_2}}$ or $R_1 = Z_1\left(\frac{K^2-1}{K^2-2KS+1}\right)$ $R_2 = \frac{\sqrt{Z_1 Z_2}}{2}\left(\frac{K^2-1}{K}\right)$ $R_3 = Z_2\left(\frac{K^2-1}{K^2-2\frac{K}{S}+1}\right)$	$R_1 = R_3 = \frac{Z_1^2 \sinh\theta}{Z_1 \cosh\theta - Z_1}$ $R_2 = Z_1 \sinh\theta$ or $R_1 = R_3 = Z_1\left(\frac{K+1}{K-1}\right)$ $R_2 = \frac{Z_1}{2}\left(\frac{K^2-1}{K}\right)$
O 	$R_1 = \frac{Z_1 Z_2 \sinh\theta}{Z_2 \cosh\theta - \sqrt{Z_1 Z_2}}$ $R_2 = \frac{\sqrt{Z_1 Z_2}\,\sinh\theta}{2}$ $R_3 = \frac{Z_1 Z_2 \sinh\theta}{Z_1 \cosh\theta - \sqrt{Z_1 Z_2}}$ or $R_1 = Z_1\left(\frac{K^2-1}{K^2-2SK+1}\right)$ $R_2 = \frac{\sqrt{Z_1 Z_2}}{4}\left(\frac{K^2-1}{K}\right)$ $R_3 = Z_2\left(\frac{K-1}{K^2-2\frac{K}{S}+1}\right)$	$R_1 = R_3 = \frac{Z_1^2 \sinh\theta}{Z_1 \cosh\theta - Z_1}$ $R_2 = \frac{Z_1 \sinh\theta}{2}$ or $R_1 = R_3 = Z_1\left(\frac{K+1}{K-1}\right)$ $R_2 = \frac{Z}{4}\left(\frac{K^2-1}{K}\right)$
Balanced O 	$R_1 = \frac{1}{2}\left[\frac{Z_1 Z_2 \sinh\theta}{Z_2 \cosh\theta - \sqrt{Z_1 Z_2}}\right]$ $R_2 = \frac{\sqrt{Z_1 Z_2}\,\sinh\theta}{2}$ $R_3 = \frac{1}{2}\left[\frac{Z_1 Z_2 \sinh\theta}{Z_2 \cosh\theta - \sqrt{Z_1 Z_2}}\right]$ or $R_1 = \frac{Z_1}{2}\left(\frac{K^2-1}{K^2-2KS+1}\right)$ $R_2 = \frac{\sqrt{Z_1 Z_2}}{4}\left(\frac{K^2-1}{K}\right)$ $R_3 = \frac{Z_2}{2}\left(\frac{K^2-1}{K^2-2\frac{K}{S}+1}\right)$	$R_1 = R_3 = \frac{1}{2}\left[\frac{Z_1^2 \sinh\theta}{Z_1 \cosh\theta - Z_1}\right]$ $R_2 = \frac{Z_1 \sinh\theta}{2}$ or $R_1 = R_3 = \frac{Z_1}{2}\left(\frac{K+1}{K-1}\right)$ $R_2 = \frac{Z_1}{4}\left(\frac{K^2-1}{K}\right)$
Bridged T 		$R_1 = Z_1(K-1)$ $R_2 = Z_1\left(\frac{1}{K-1}\right)$
Bridged H 		$R_1 = \frac{Z_1}{2}(K-1)$ $R_2 = Z_1\left(\frac{1}{K-1}\right)$
Bridged Balanced H 		$R_1 = \frac{Z_1}{2}(K-1)$ $R_2 = \frac{Z_1}{2}\left(\frac{1}{K-1}\right)$

Mismatch Loss

If it is desired to calculate the loss incurred by mismatching two circuits, this can be determined from the following equation:

$$N = 20 \log_{10} \left[(R^2 + 1)/2R \right]$$

where N is the loss in db, and R is the impedance ratio. This is shown graphically in Chart VI. If, for example, the mismatch was from a 1000-ohm circuit to a 500-ohm circuit, or a 500-ohm circuit to a 1000-ohm circuit, the impedance ratio would be 2:1 and would correspond to a loss of 0.51 db.

Examples

Problem I. Design a potentiometer having an input of 100,000 ohms and a loss of 15 db.

Solution

1. From column 2 of Chart I the formulas are:

$$R_1 = Z_1 (K - 1)/K$$
$$R_2 = Z_1/K$$

2. From Table I the value of K for a 15-db loss is found to be 5.62.

3. Using this value of K in the formulas above, the values of R_1 and R_2 are found to be:

$$R_1 = 100{,}000\ (4.62)/5.62 = 82{,}200 \text{ ohms}$$
$$R_2 = 100{,}000/5.62 = 17{,}800 \text{ ohms}$$

Problem II. Design a 20-db T pad having input and output impedances of 500 and 200 ohms, respectively

Solution:

1. The impedance transformation ratio is 500/200 = 2.5. From Chart II the minimum loss = 9 db.

2. From Chart I the formulas to be used are:

$$R_1 = \frac{Z_1}{\tanh \theta} - \frac{\sqrt{Z_1 Z_2}}{\sinh \theta}$$

$$R_2 = \frac{Z_2}{\tanh \theta} - \frac{\sqrt{Z_1 Z_2}}{\sinh \theta}$$

$$R_3 = \frac{\sqrt{Z_1 Z_2}}{\sinh \theta}$$

3. To use the hyperbolic functions it is necessary to know the value of Θ, from which the hyperbolic functions can then be found from Chart III.

$$\theta = 0.115\ N = 0.115 \times 20 = 2.3$$
$$\therefore \tanh \theta = 0.98$$
$$\therefore \sinh \theta = 4.9$$

4. The values of the required resistors are then:

$$R_1 = \frac{500}{0.98} - \frac{\sqrt{500 \times 200}}{4.9}$$

$$= 510 - \frac{318}{4.9} = 510 - 65 = 445 \text{ ohms}$$

$$R_2 = \frac{200}{0.98} - 65 = 204 - 65 = 139 \text{ ohms}$$

$$R_3 = \frac{318}{4.9} = 65 \text{ ohms}$$

Problem III. Design a bridged T pad with 25 db loss and 500 ohms input and output impedances.

Solution:

1. The formulas in column 6 of Chart I are used.

$$R_1 = Z\ (K - 1)$$
$$R_2 = Z/(K - 1)$$

2. From Table I the value for K for 25 db loss is found to be 17.78. Thus

$$K - 1 = 16.78$$
$$R_1 = 500 \times 16.78 = 8390 \text{ ohms}$$
$$R_2 = \frac{500}{16.78} = 29.6 \text{ ohms}$$

Problem IV. Design a T network to work between two 500-ohm circuits and having a loss of 10 db.

Solution:

1. Formulas for the T network in column 3 of Chart I indicate the desired resistances are

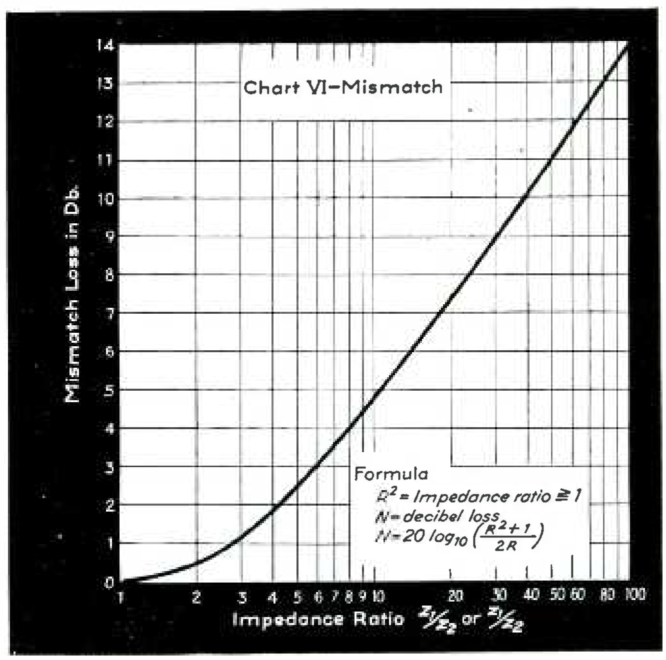
$$R_1 = R_2 = Z_1\ (K - 1)/(K + 1)$$
$$R_3 = 2Z_1K/(K^2 - 1)$$

2. From Table I, $K = 3.162$

3. The resistances of the arms is:

$$R_1 = R_2 = 500 \times 2.162/4.162 = 341 \text{ ohms.}$$

$$R_3 = 1000 \times 3.162/(10 - 1) = 352 \text{ ohms.}$$



The loss incurred by joining together two circuits of different impedance may be determined by finding the impedance ratio and then reading off the mismatch loss, K, above

TABLE I—TABLE OF K VALUES

Loss in db N	K	Loss in db N	K	Loss in db N	K	Loss in db N	K
1.0	1.122	18.0	7.943	35.0	56.234	51.0	354.81
2.0	1.259	19.0	8.912	36.0	63.096	52.0	398.11
3.0	1.412	20.0	10.000	37.0	70.795	54.0	501.19
4.0	1.585	21.0	11.220	38.0	79.433	55.0	562.45
5.0	1.778	22.0	13.335	39.0	89.125	56.0	630.96
6.0	1.995	23.0	14.125	40.0	100.000	57.0	707.95
7.0	2.238	24.0	15.849	41.0	112.202	58.0	794.33
8.0	2.512	25.0	17.783	42.0	125.89	60.0	1,000.0
9.0	2.818	26.0	19.953	43.0	141.25	65.0	1,778.3
10.0	3.162	27.0	22.387	44.0	158.49	70.0	3,162.3
11.0	3.350	28.0	25.119	45.0	177.83	75.0	5,623.4
12.0	3.981	29.0	28.184	46.0	199.53	80.0	10,000.
13.0	4.467	30.0	31.623	47.0	223.87	85.0	17,783.
14.0	5.012	31.0	35.481	48.0	251.19	90.0	31,623.
15.0	5.623	32.0	39.811	49.0	281.84	95.0	56,234.
16.0	6.310	33.0	44.668	50.0	316.23	100.0	10^5
17.0	7.079	34.0	50.119				

Conclusion

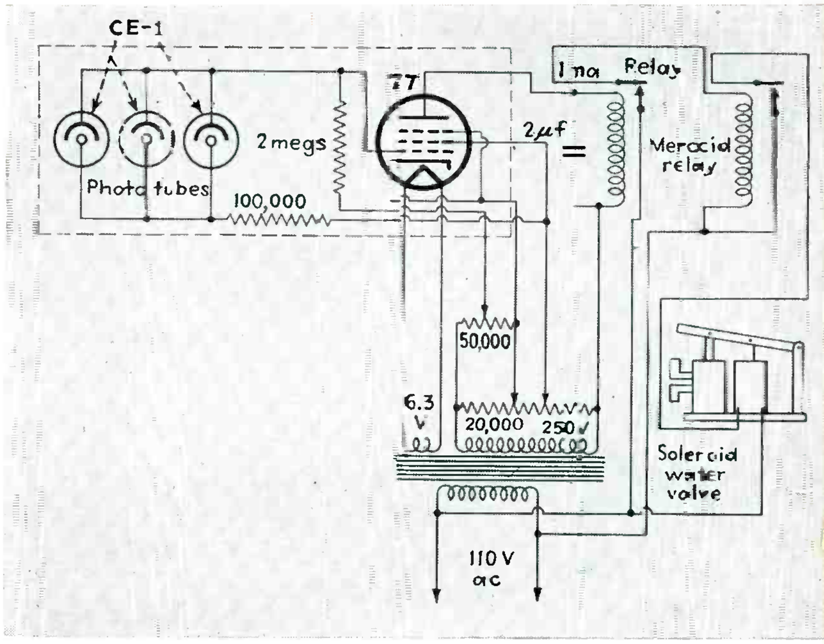
It is hoped that the foregoing will afford the reader the necessary data for an intelligent approach to the design of any attenuator pad which he may require. The author believes that much of the material given here is original with him, but mention should be made of the article, "Designing Resistive Attenuation Networks" by P. K. McElroy in the March 1935 issue of the *Proc. I. R. E.*, and the section on Pads and Attenuators in the "Engineering Handbook of the N. A. B."

Photoelectric COOLING CONTROL

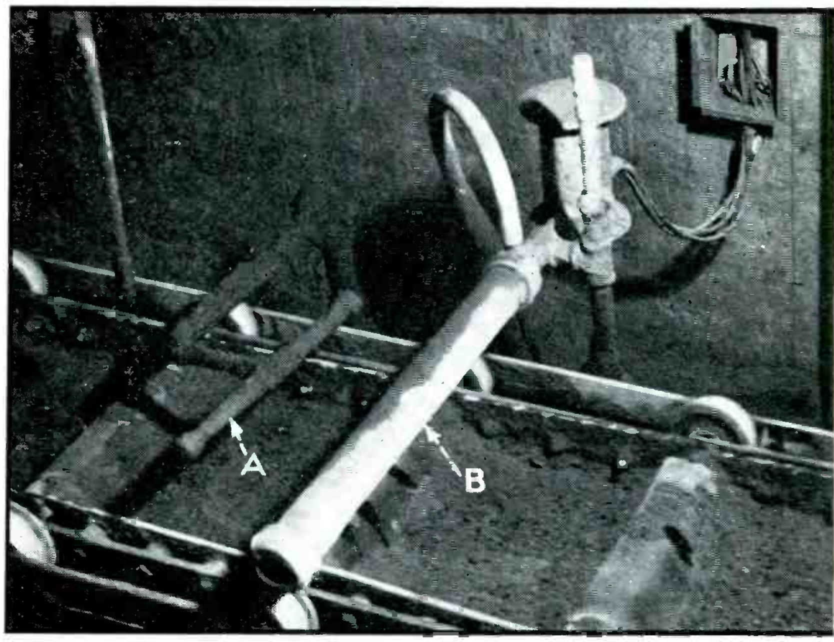
Hot ore on a conveyor passes under an infrared sensitive photoelectric relay which operates a solenoid valve to spray cooling water on the ore as it is needed

By PHILIP EWALD

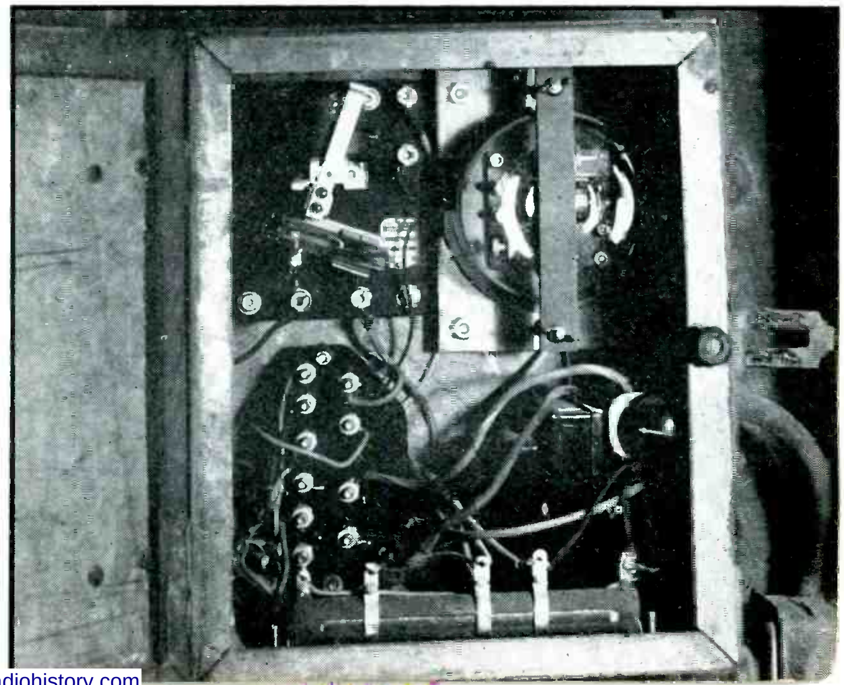
Tennessee Valley Authority, Wilson Dam, Ala.



Circuit diagram of the infrared sensitive photoelectric relay. The three phototubes connected in parallel are mounted within a Pyrex glass cylinder. (Below) The ore moves from right to left on the pan conveyor. The water spray (*A*) is mounted away from the phototubes (*B*) to permit the ore to reach it before the water flows



The wall-mounted relay unit. Note that the sensitive relay is enclosed in glass for protection against dust particles commonly found at an ore treating plant



CERTAIN industrial processes involve the calcination of ore in a kiln with subsequent cooling, crushing, and finally, transportation of the product on a conveyor. The cooling presents no complications when material of uniform particle-size is discharged from the kiln. The cooling problem is more difficult, however, when lumps varying in size from dust fines to large lumps are discharged.

At the TVA Fertilizer Works, phosphate is agglomerated before it is used in the electric furnaces for the production of phosphorous and phosphoric acid. In the preparation process, raw phosphate is passed through a kiln, cooled in a rotating drum, and crushed to lumps two inches or less in diameter. The hot crushed material is discharged into a pan conveyor and subsequently onto a rubber belt conveyor. The pan conveyor between the crusher and the belt proved to be too short for adequate cooling of very hot material, resulting in the discharge of red hot lumps onto the rubber belt with consequent burning. A continuous water spray of sufficient capacity to cool the hot pieces flooded the finer, cooler material, making a mud that clogged the equipment.

An automatically controlled water spray located over the pan conveyor transporting the crusher product to the belt conveyor proved to be a satisfactory solution to the problem. The spray was arranged to turn on when hot material actuated a phototube relay that was installed directly above the pan conveyor and was sensitive to radiant heat from hot particles passing beneath it.

The phototube relay operates a 110-volt solenoid water valve, which controls the flow of water to the spray head that is located far enough behind the phototube assembly to compensate for the time lag in the relay circuit. The sensitive relay in the tube circuit has a drop-out 80 percent of its take-up value, which provides satisfactory spray regulation. The equipment may be adjusted to operate at any desired radiant heat by adjustment (*Continued on page* 80)

TUBES AT WORK

Life of receiving tubes in aircraft equipment, adapting television receivers to new standards, dew-point recorder and antenna coupler in this issue

Receiver Tube Operation in Aircraft

By J. E. M. Lagasse, *Radio Technician*
W. W. H. Dean, *Radio Engineer*
Trans-Canada Airlines

There has been a recent tendency among airlines on this continent to set a definite maximum life limit on receiver tubes in aircraft equipment. This has been as low as 500 hours in certain cases, although the average is 1000 hours. A careful record of 28 months operation has indicated that this figure is much too low and that tubes may be run in excess of 3000 hours without trouble. In fact, it can be shown that much more reliable service may be obtained by this method of operation.

In June 1939, a card was set up for each type of receiver carried in the aircraft and a column provided for each tube. Each time a tube was removed because of a complaint, a notation was made in the proper column giving date, aircraft number, hours and type of complaint. The type of complaint was given a code number, hence a very brief notation was required to cross-index all tube troubles.

TABLE I

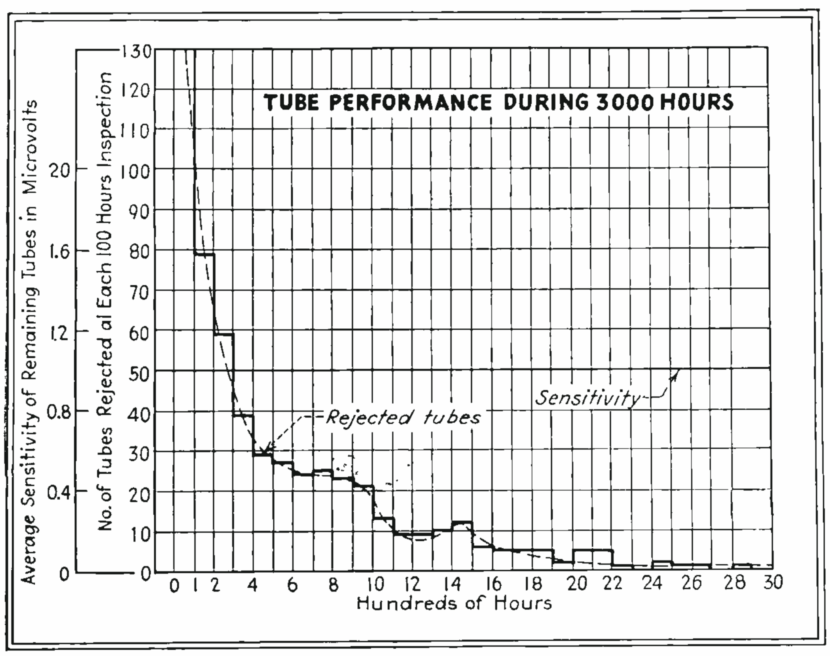
Total number of tubes tested	1912
Total number of tubes rejected	548
Time at Which Tubes Were Rejected	
On installation	24.0%
During first 100 hours	14.4%
During second 100 hours	10.8%
Beyond 200 hours	50.8%
Function of Tube Rejected	
Audio	63.5%
All others	36.5%
Reason For Rejection	
Microphonic	58.1%
Noisy	22.8%
Weak	8.5%
Open heater	3.2%
Erratic	2.5%
Dead	2.0%
Internal short	2.0%
Mechanical damage	0.9%

In all, 1912 tubes were checked and of these, 548 were rejected, either at the installation test or during subsequent operation. Table I is a summary of the rejected tubes, showing the accumulated hours on rejection, type of operation giving most trouble and the types of trouble encountered. It will be noted that 25 percent of the bad tubes were caught on installation and an additional 25 percent rejected during the first 200 hours. This indicates that careful checking in the early life of an installed tube will reduce by 50 percent its chance of subsequent failure. Audio tubes are much the worst offenders, as twice as many of this type were replaced although they only represent 35 percent of the total receiver tubes in use. The reason for this is undoubtedly that most of the rejections are due to microphonics or other noise which might not affect the operation of the same tube in an r-f. circuit. Indeed, only 10.5 percent of all the rejects have been for reasons which would cause complete failure of the receiver.

A more detailed survey of the number of tubes rejected during each 100 hours of service is shown in Fig. 1. The first step of the graph is the rejections at "zero hours," or on installation. Each of the following steps represent the number removed during each 100 hours up to a total of 3000 hours. A broken line joins the midpoint of each 100 hour step to illustrate the rapid elimination of poor tubes early in their life. This is quite marked during the first 200 hours then, for some reason, slows up until the 800 hour mark is passed, when it again falls to a low and almost constant level. The pronounced peak between 1200 and 1400 hours was caused by an epidemic of heater failures. A number of the receivers under observation have passed the 3000 hour mark but others are still between 2200 and 3000 hours. When all units have passed 3000 hours, it is expected that the latter part of the curve will be raised to show a constant rejection of two or three tubes per 100 hours. This is extremely low, representing less than 0.25 percent of the number in use.

That the tubes are still in good condition electrically and have not lost any emission power is shown by the sensitivity curve of Fig. 1. This is the average sensitivity of a representative group of communication receivers. No change in sensitivity has yet been noted up to the 3000 hour mark. Indeed, it is not known whether emission failure or mechanical fatigue will eventually make replacement necessary.

One fault which suddenly appeared after about 1200 hours life was the burning out of tube heaters. As all commercial aircraft use 12- or 24-volt storage battery electrical systems, it is standard practice to connect two 6-volt tube heaters of the same current rating in series. A number of series groups are then connected in parallel to give a 12-volt bank of heaters. For 24 volt operation, two such 12 volt banks would be connected in series. When heaters are connected in series, if the resistance of each is not the same, there will be an unequal distribution of voltage across the two.



Graph showing the number of tubes rejected after each hour of operation in aircraft receiving equipment. Emission was maintained throughout, as indicated by curve marked sensitivity

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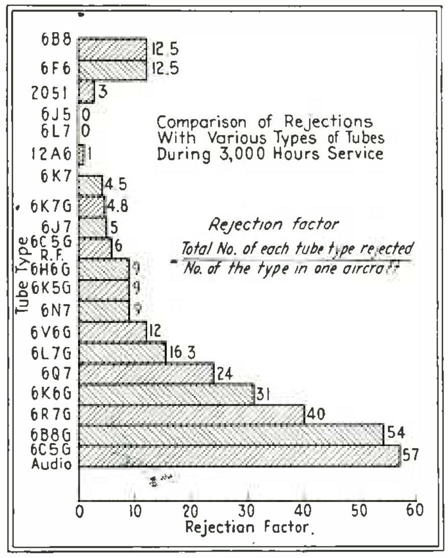
The current being the same, the tube with the higher resistance will have the higher voltage across it and will dissipate more power. It has been found that the resistance of all tube heaters increases somewhat with use and if one heater is running hotter than the other, its resistance will increase more rapidly, thus aggravating the situation. Tests of new tubes have shown as much as 0.5 volt difference between a series pair; 3.5 volts difference has been observed after considerable service. The worst unbalance occurs when the series mate of a high resistance tube is replaced with a new tube.

This unbalance in voltage between tubes causes greatly reduced life for



Rejection factor of a variety of tubes used in aircraft equipment. Tubes for audio service gave the most trouble

the higher resistance heater. The distribution of voltage may be equalized very conveniently by connecting together the midpoints of each series group. This is equivalent to connecting a number of tubes in parallel to give a 6-volt bank, then connecting the banks in series. As all aircraft receivers have at least six tubes, this places a minimum of three tubes in each bank (for 12-volt operation) and, with random selection of tubes, the chance of having an excessive voltage difference between the banks is negligible. All the receivers under observation were so modified and no further heater failures occurred.

Several other steps have been taken to reduce the number of tube complaints. All tubes are given a vibration test by the manufacturer. When checked on a mutual conductance bridge, any change in reading after vibration rejects that tube. On installation they are again checked in the receiver by tapping the tube vigorously and listening for noise in the receiver output. The emission is checked in an emission checker and also by comparing receiver sensitivity with the previously recorded value.

A chart was made of the number of

(*Continued on page 62*)

Briareus, Machinist?

With his hundred arms the mythical giant Briareus no doubt could have accomplished a great deal of work . . . say as a lathe operator. ¶There is no information, however, that Briareus was a brainy fellow and that he could skillfully employ any one of his hundred arms. ¶Here at Collins we believe that fine craftsmanship does not arise alone from good tools or keen workmen but is a result of the coordination of both. ¶Our factory, equipped with modern machine tools, utilizes nearly every process for the finished fabrication of transmitter materials. Processing not satisfactorily procured from outside sources is done in our own plant; thus, we are able to control quality and to speed production. ¶Complementing our equipment is a large corps of highly skilled workmen who know how to use the tools to advantage. These men are instilled with the idea of doing the best possible job. They are inspired to have achieved the highest standard of craftsmanship.

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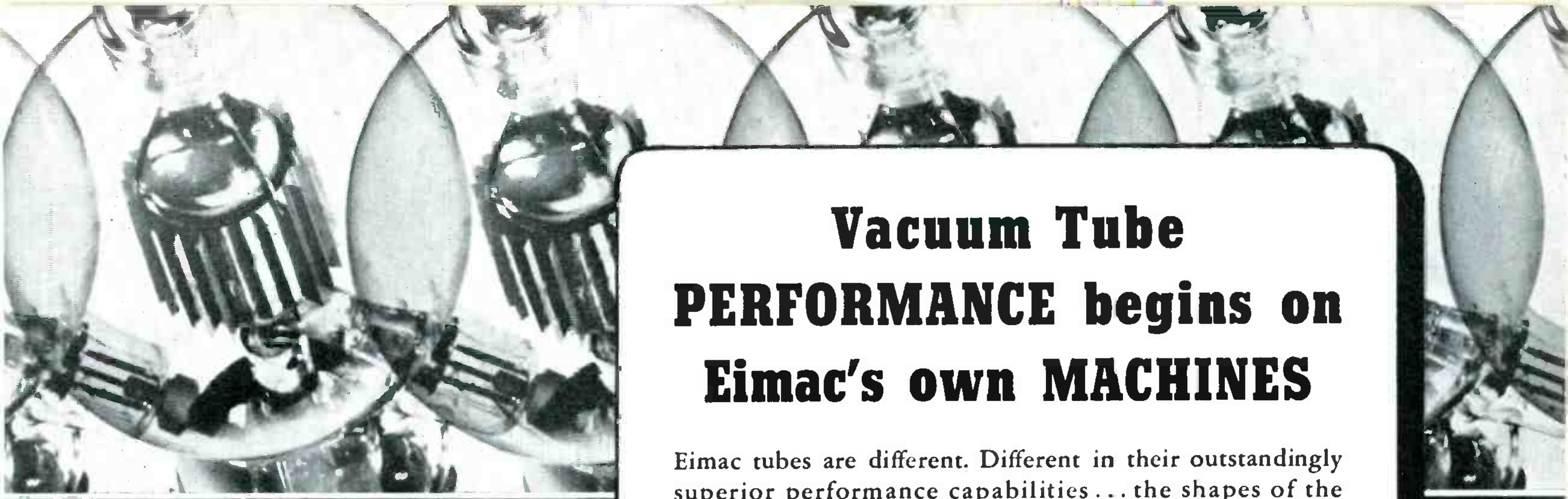

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Export Agents: Frazar & Co., Ltd., 301 Clay Street, San Francisco each type of tube replaced divided by the total number of that type in one aircraft installation, bringing each type to a common denominator. This is shown in Fig. 2 and quickly reveals the tube types giving most trouble. The metal types shown (12A6 to 6B8) have been in use for nine months only but the figures have been multiplied by a factor to extend them as for 28 months service.

The greatest comparison is between the 6K6G and 12A6 tubes. The latter is a beam output tube having a 12 volt heater but otherwise interchangeable with the 6K6G as used in the aircraft receivers. As the 12A6 is so much superior in performance, all output tubes have now been changed over to this type. The 6B8 metal tube also shows up as superior to its glass twin, with the result that the glass type are now being replaced. It will be noted that the 6C5G tubes are divided into r-f. and audio service classes with the audio tubes making a very poor showing. Investigation is under way toward using metal types for this purpose.

As mentioned above, the greatest source of trouble is with microphonics and noise in audio tubes. Investigation has shown that some types of audio tubes perform better than others. It is often possible to change the type of tube in a receiver with a minimum of modification. The cause of the noise is vibration, hence, with metal, glass and bantam tubes all available in most types it should be possible to find one less susceptible to this source of complaint. In some cases, tubes of different manufacture employing different element structure may prove superior.

In conclusion, it might be said that this report is not complete in that it does not arrive at actual life figures. However, proof has been presented that the maximum reliability is obtained by operating receiver tubes beyond 3000 hours. It will now be necessary to watch the operation of these tubes until complaints begin to increase due to mechanical fatigue or until emission begins to drop. It would then be desirable to set a maximum life figure safely below that which could be expected of the poorest type tube. All tubes in a unit would be changed at that time to simplify records and yet provide the greatest service.

Tubes are now starting to play an increasingly important part, not only in aircraft radio, but in other industrial applications where they are subjected to severe vibration. It is felt that with continued improvement in manufacture, careful selection of tube type and structure and thorough testing before installation, tubes may be as dependable as any other part of the circuit. This is particularly true when it is realized that once a tube has graduated from the first few hundred hours of service, it is actually better than a new tube and has an excellent chance of giving several thousand hours of trouble-free service.

Adapting Television Receivers To the New Standards

SEVERAL READERS HAVE REQUESTED information concerning the modification of television receivers, originally designed for the RMA Standards, so that they will operate satisfactorily on the NTSC standards, recently adopted for commercial broadcasting by order of the FCC. The changes in the standards which affect receiver operation are the increase in the number of lines per frame from 441 to 525 and the adoption of frequency-modulation for the sound channel. Fortunately, both of these changes may be accommodated in existing receivers with minor adjustments of the circuits. The performance of receivers so modified will not be equal to that of a receiver especially designed for the purpose, but it will be satisfactory as a temporary measure until opportunity is found for extensive alterations.

Increasing the Number of Lines

The increase in number of lines per frame from 441 to 525 is accomplished simply by increasing the frequency of the horizontal scanning generator from 13,230 cps, which produces a 441-line picture, to 15,750 cps, which produces a 525-line picture. In most receivers, the range of the frequency control of the horizontal scanning generator (horizontal hold control) is sufficient to permit reaching the new value merely by turning the knob. This has been found to be the case with the two receivers described in recent years in the pages of ELECTRONICS. In the "laboratory" receiver (ELECTRONICS, December, 1938 page 16, Fig. 1), the adjustment is made with R_6 and R_7 in

• • •

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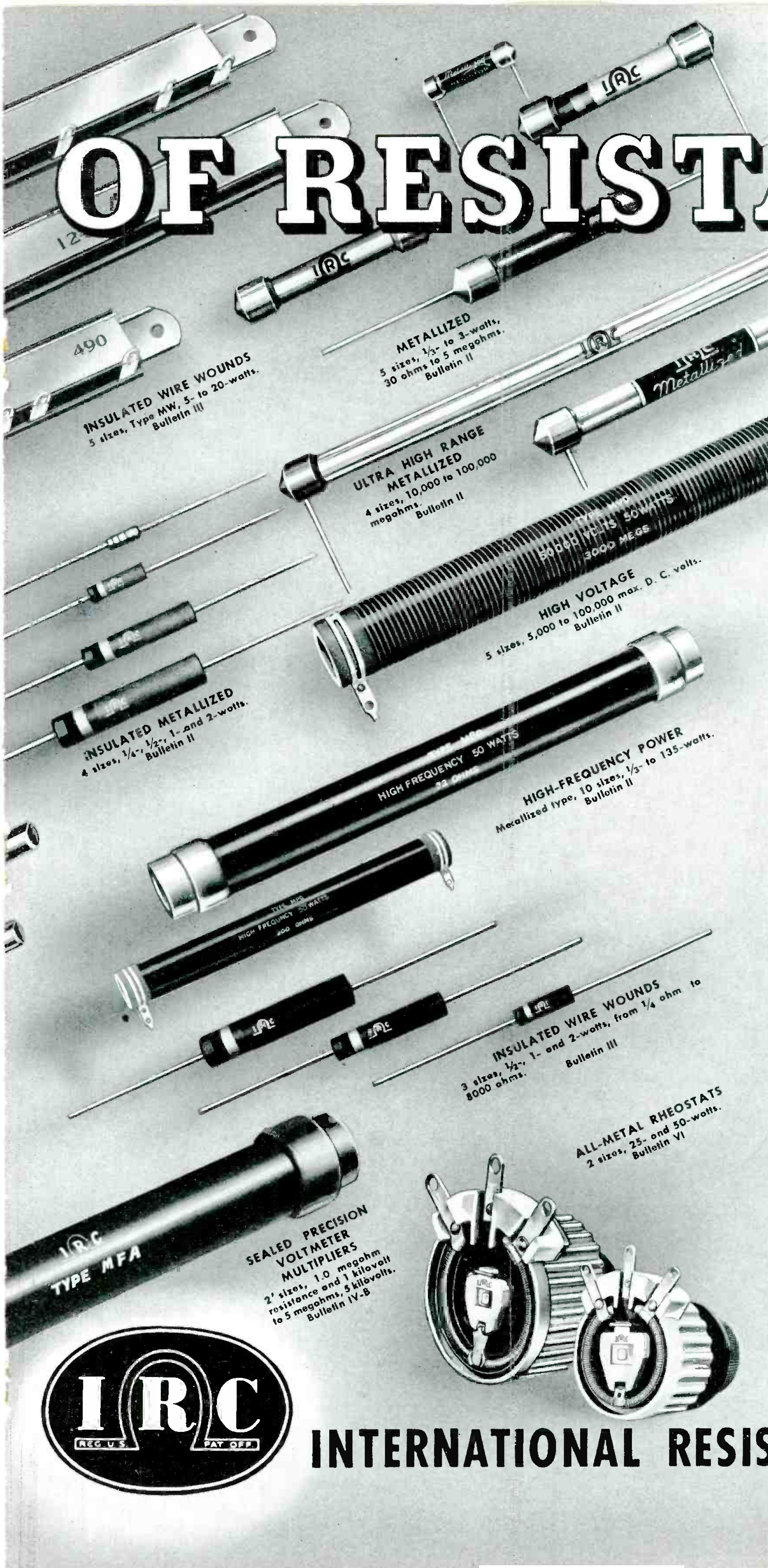

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the horizontal blocking oscillator circuit. In the "home" receiver (ELECTRONICS, September 1939, page 16, Fig. 1), the adjustment is made with R_{80}.

In receivers employing electric deflection, this increase in the horizontal scanning frequency should have no detrimental effect except that due to shortening the scanning retrace. This effect may be recognized as an irregular brightening of the left-hand edge of the picture. It is due to the fact that the scanning spot does not fully retrace during the blanking interval, and hence resumes normal brightness before the end of the retrace. Part of the left hand edge of the picture is thereby cut off and "tucked under," so to speak. Usually this defect is not serious. It can be corrected only by a thorough redesign of the scanning generator.

In receivers employing magnetic deflection, increasing the horizontal scanning frequency from 13,230 cps to 15,750 cps causes a corresponding reduction of the horizontal scanning amplitude. The scanning amplitude is reduced to about 16 percent. The effect arises because the current flowing through the inductance of the scanning coils is inversely proportional to the frequency. This effect can be counteracted by increasing the setting of the horizontal width control (R_8 in the laboratory receiver, R_{80} in the home receiver). If the range of this control is not sufficient to bring the picture width to full size, the plate supply voltage of the horizontal scanning generator may be increased by adjustment of the plate or screen voltages of the 6L6 horizontal output tube (tap G on the power supply bleeder in the laboratory receiver, tap C in the home receiver) or both. If these measures fail, the second anode voltage on the picture tube may be reduced (by adjustment of the auto-transformer in the laboratory receiver, adjustment of

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ZWORYKIN RECEIVES RUMFORD MEDAL

Dr. Vladimir K. Zworykin, center, associate director of the research laboratories of the Radio Corporation of America, is shown as he received the award of the Rumford Medal of the American Academy of Arts and Sciences from Dr. Harlow Shapley for "outstanding contributions to the subject of light." Dr. Norton Kent, chairman of the Rumford Committee, is an interested spectator

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R_{102} in the home receiver). The reduction in second anode voltage will reduce the picture brightness slightly and will increase the deflection in both horizontal and vertical directions. A slight reduction in the vertical scanning amplitude will be necessary to preserve the proper aspect ratio in the latter case.

In magnetic deflection, the previously mentioned irregular brightening of the left-hand edge of the picture, due to reduction in horizontal retrace time, may also occur. Adjustment of the horizontal damping rectifier circuit resistor (3500-ohm resistor in series with the plate of the 1-V tube in the laboratory receiver, R_{93} in the home receiver) will correct this condition to some extent.

The principal differences which will be noted in the picture, after the change in number of lines has been made, are an increase in the vertical detail by about 19 percent, and a reduction in the horizontal detail by 16 percent. These changes will be clearly evident when viewing a test chart, but will not be noticeable when viewing program images, unless the maximum effective video frequency is less than 3 Mc. The increase in number of lines makes it highly desirable that the maximum video frequency be as close to 4 Mc as possible. The horizontal definition with 525 lines is about 84 lines for every megacycle in the maximum video frequency, that is, $4 \times 84 = 336$ lines for 4 Mc maximum video frequency.

Readjustment of the Sound Channel

Adapting the receiver to frequency modulation in the sound channel involves a complete redesign of the sound second detector system. However, if an increase in distortion is permissible, a compromise measure may be adopted

• • •

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which involves merely retuning the r-f circuits. In most receivers the sound i-f amplifier has a band-pass characteristic extending over several hundred kilocycles to allow for oscillator drift. If the slope of the edge of the i-f pass band is approximately linear and extends over a region 100 kc wide, frequency modulation may be converted into amplitude modulation by tuning the oscillator so that the intermediate frequency carrier falls in the middle of the low-frequency slope. When the frequency of the incoming signal deviates under the influence of the modulation, the carrier runs up and down the slope, producing amplitude variations at the output of the i-f amplifier which are detected by the second detector in the usual way. If the transmitter frequency deviation reaches high values (plus or minus 75 kc is the legal limit) the carrier may ride up onto the flat top portion of the i-f pass-band, or down into the cut-off region. This will produce severe distortion, but at low modulation levels surprisingly good quality may be obtained. The adjustment is made by tuning the local oscillator until the sound is heard free of distortion.

The sound i-f system may be retuned to produce the necessary width of slope at the edge of the pass-band if sufficient width does not already exist. A frequency-modulated signal generator and cathode-ray oscilloscope should be used for this purpose.

This compromise method of converting the f-m to a-m does not offer the noise-reducing properties of f-m transmission, since no limiter is used, and since the receiver is fully sensitive to the amplitude modulation components of whatever noise is present. However in areas of strong signal strength it will often serve satisfactorily. The audio output of the second detector depends on the gain of the i-f amplifier, since the peak audio output corresponds to the peak i-f voltage developed by the last i-f stage. Usually it will be found that the audio level, for a given input signal, is somewhat lower than that offered by an a-m signal. Usually there is sufficient reserve audio gain to make up the difference in level.

If full advantage of the f-m system is desired, three steps must be taken: the i-f amplification must be increased to a gain of 100,000 or more; a limiter amplifier must be inserted; and the second detector must be replaced by a frequency discriminator detector. The reader interested in following this procedure should refer to the articles by J. R. Day, "A Receiver for Frequency Modulation" ELECTRONICS, June, 1939, page 32, or Marvin Hobbs "F-m Receivers, Design and Performance," ELECTRONICS, August, 1940, page 22.

A receiver specifically designed for the new standards and incorporating such additional features and as gamma control is now under construction. It is expected that a description of this receiver will appear in ELECTRONICS in some future issue.—D.G.F.

Photoelectric Dew-Point Recorder Safeguards Against Freezing

By J. A. Setter

Industrial Department, General Electric Co. Denver, Colorado

To prevent condensation of moisture and possible freezing of its gas lines during the winter months, the Colorado Interstate Gas Company, which furnishes Denver with natural gas from Texas fields, has built a novel dew-point recorder utilizing a photoelectric relay. With the recorder, continuous readings of temperature at which condensation occurs are made where the gas enters the Denver metering plant. If calculations based on the readings show the dew point to be too high, instructions are dispatched to dehydrating plants to remove more moisture before trouble occurs.

The equipment consists of a small tank filled with anti-freeze solution into which is immersed a U-shaped highly polished gold-plated tube. Through this tube passes a continuous flow of natural gas from a by-pass valve in the main pipe line. Both ends of the tube are provided with plate-glass windows. Above the windows, a light source and phototube relay are mounted so that the light shines through the tube and is reflected to the phototube.

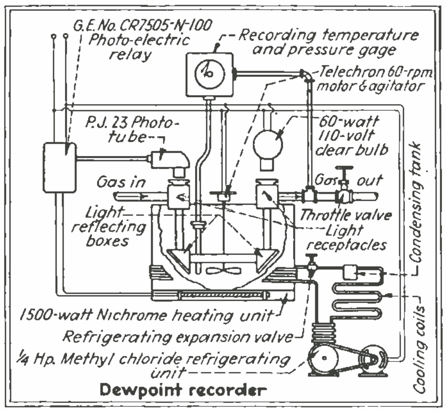
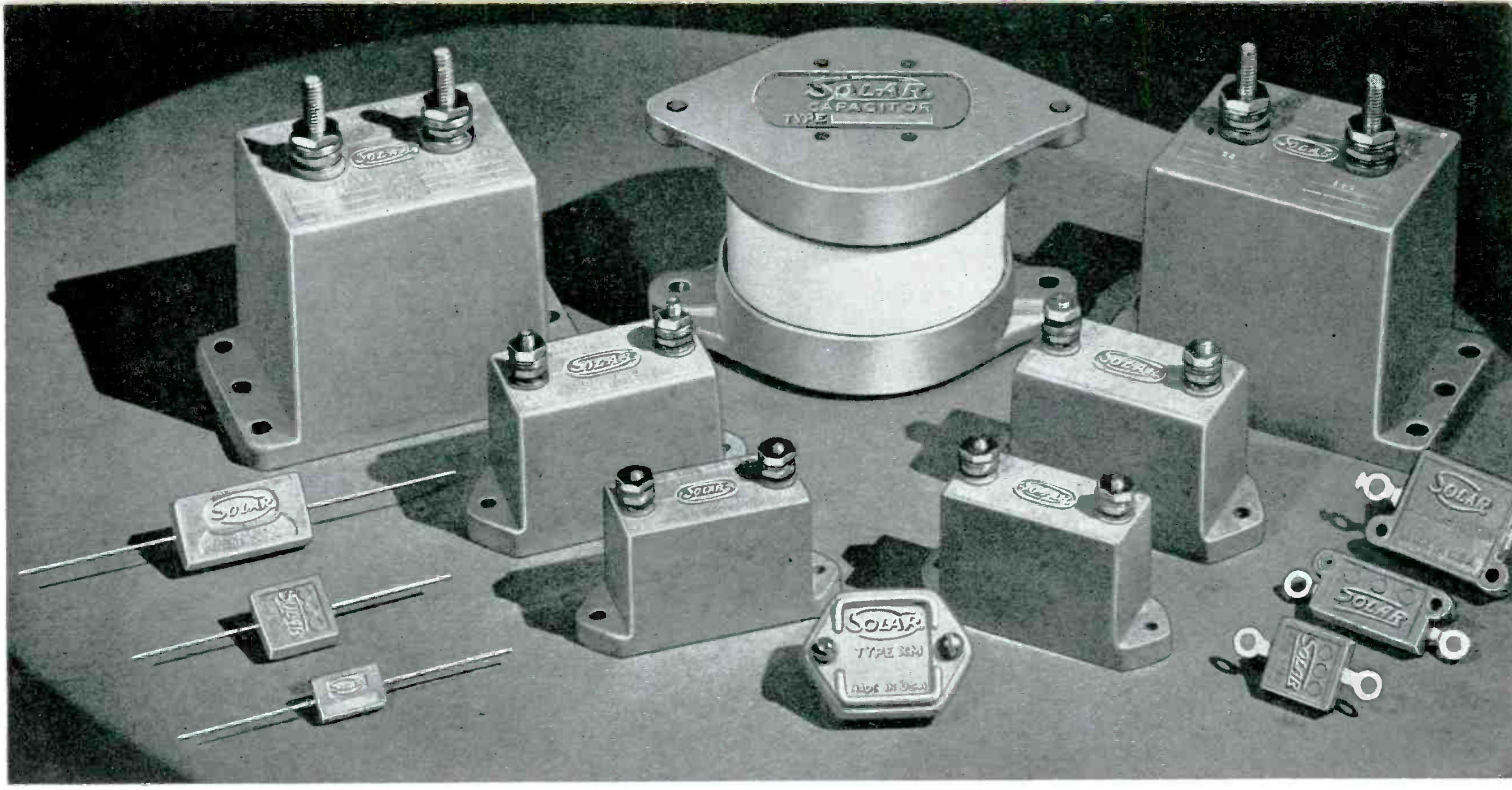


Diagram illustrating the equipment in which the photoelectric dew-point recorder is used

For controlling the temperature of the anti-freeze solution, the tank is cooled with coils of a small domestic refrigerator and heated with suitable strip heaters. As the cooling system reduces the temperature of the solution, the gas is chilled until a film of condensate is deposited on the inside of the highly polished tube, thus reducing the reflection of light to the phototube.

Being sensitive to a change of ½ foot-candle, the phototube operates to disconnect the cooling coils and connect the heaters to warm the solution. When the solution is warm enough, the condensate disappears and the process is repeated. A small motor-driven stirring paddle in the anti-freeze solution equalizes the temperature of the bath.

A recording-bulb thermometer immersed in the solution records the temperature of the solution. On the same


SOLAR
CAPACITOR
TYPE RM

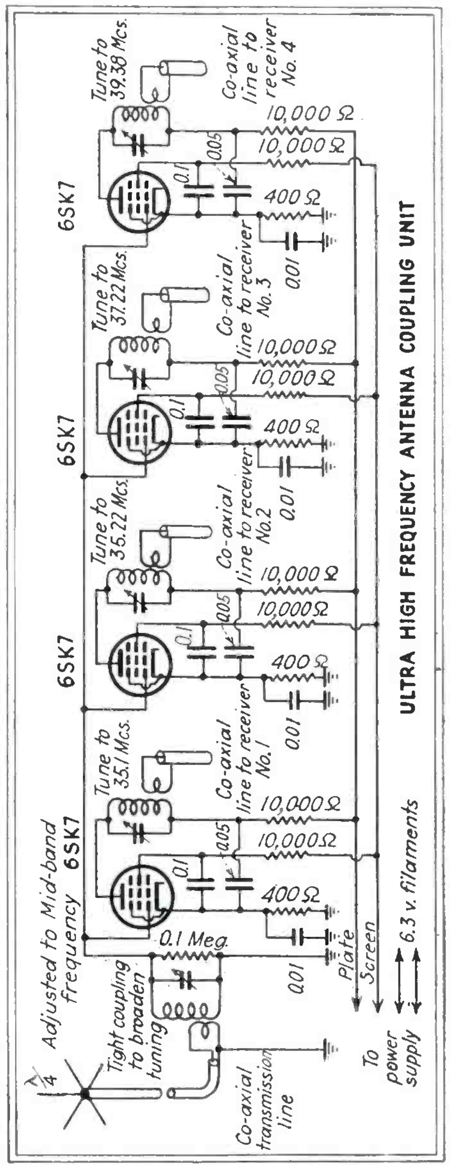
chart, the natural gas pressure is also recorded. From these two records, the dew point is calculated. The temperature chart curve looks like a sine wave, with the tops and bottoms of the loops about two to three degrees apart, and with a frequency of about one cycle every 10 to 15 minutes depending on the rate of flow of gas, change of pressure, and other variables. The apparatus was conceived and constructed by W. R. Beardsley and L. F. Carter, of the Colorado Interstate Gas Company.

• • •

Ultrahigh Frequency Antenna Coupling Unit

By ROBERT D. RIETZKE,
Communication Engineer
Radio Technical Bureau, Police Department
Los Angeles, California

THIS UNIT WAS DEVISED to permit electronic coupling for four ultrahigh frequency receivers operating on different frequencies, to a single antenna and provide a proper match at the receiving end of the coaxial line.



Circuit diagram of antenna coupling unit

This system of coupling, although a compromise, has worked out very satisfactorily with the installation of a single antenna on the top of the 137-foot quarter-wave grounded vertical radiator employed to communicate with the cars using a medium frequency.

The gain in this unit more than offsets the advantage of separate receiving antennas. The antenna is an RCA ground plane type adjusted to a mid-band frequency of 37,220 kc. The coaxial cable from the antenna to the antenna coupling unit is Communications Products $\frac{3}{8}$-inch gas filled type. The receivers are two Fred M. Link Type 9-UAR-Ed 2 on one rack, and a Pierson DeLane 30-41 MC Type PR-15 UH in the other rack.

The frequencies employed are: 35,100; 35,220; 37,220 and 39,380 kc.

The coaxial line from the antenna is inductively coupled to the tuned circuit which is connected to the grids of four 6SK7 tubes. The tubes are operated with 100 volts on the screen and 150 volts on the plate. The bias of −3 volts is obtained from a cathode resistor. The plates of the 6SK7 tubes are individually tuned and link-coupled to the receiver operating on the frequency to which they are tuned. Amphenol connectors and flexible coaxial cable is used between the coupler and the receivers.

This unit makes it possible to operate one hundred and fifty two-way police units covering an area of more than 300 square miles, each unit of which operates satisfactorily for distances up to 25 miles from the receiving point. The mobile units operate with 28 watts output, and are a product of the shops of the Radio Technical Bureau of this Department. Considering the terrain which includes mountains, desert, metropolitan area, industrial areas, and harbor waterways the operation of the unit has proved very satisfactory.

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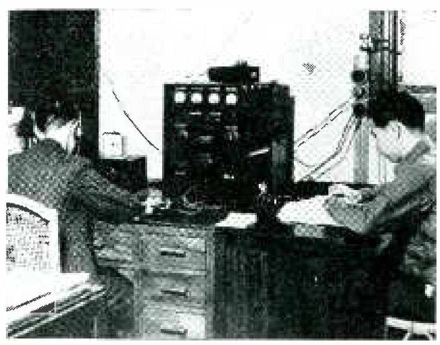
BANK OF CHINA CARRIES ON



A two-way radio communication service is one of the features of the Bank of China's head office in Chungking. When this picture was made, the equipment was in operation although Japanese airmen outside were dropping bombs on the city

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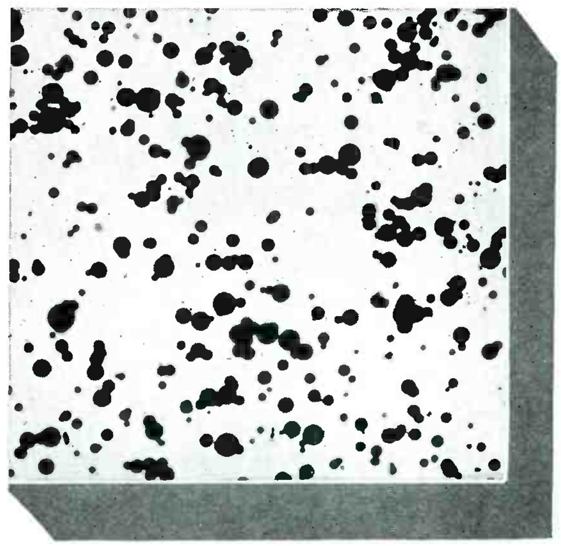

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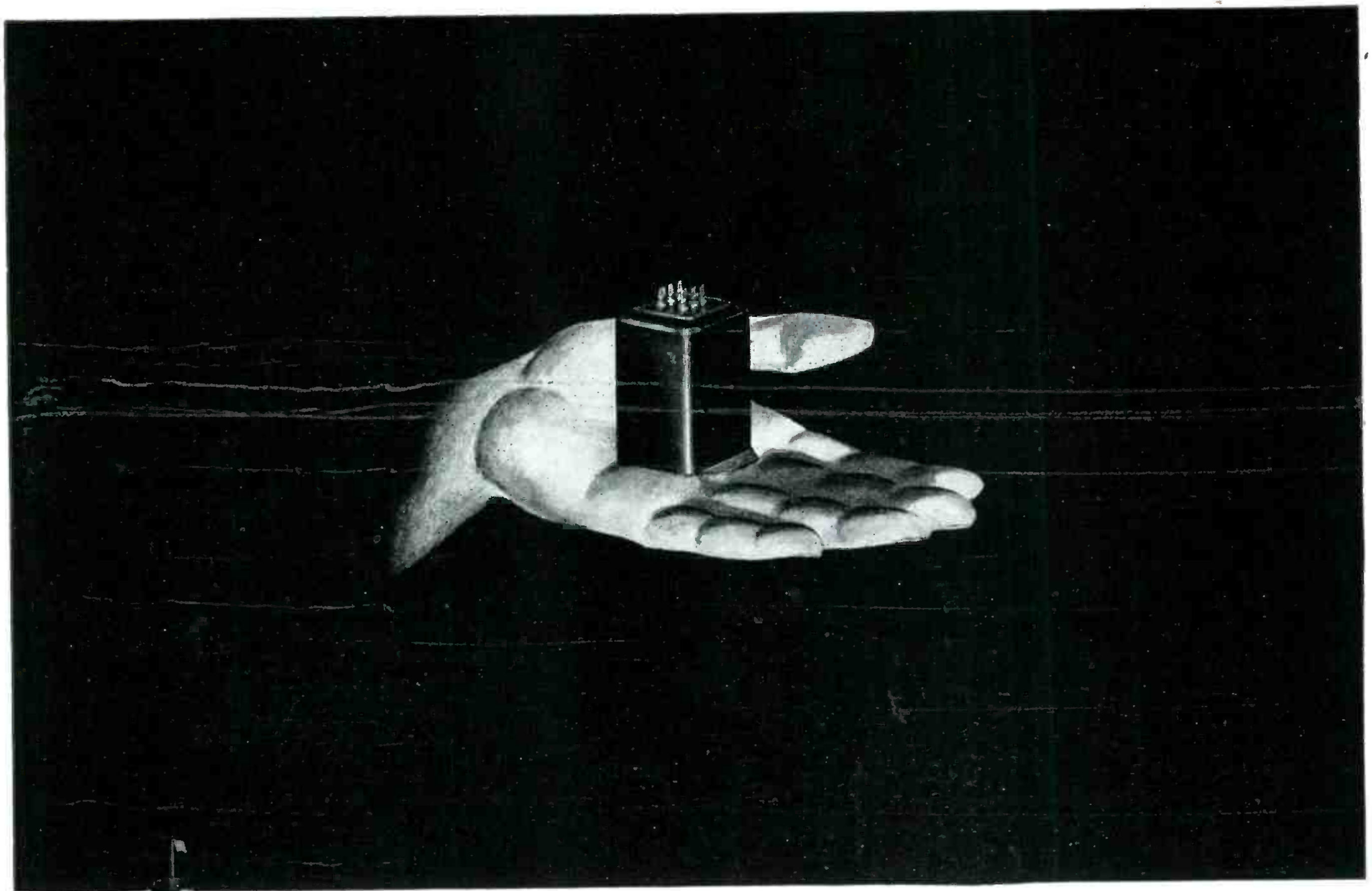
Electronic Pyrometer Control

(*Continued from page* 50)

tive measuring element even a small potential difference between the coils L_1 and L_2 will cause electrostatic forces on the vane which affect the accuracy of the reading. The schematic diagram shows coils L_1 and L_2 electrically connected to ground so that no appreciable voltage can exist between them. To make the electromagnetic forces negligible the untuned coil L_2 has very few turns so that its field is very weak, but will still effect operation of the oscillator circuit. Grid current flowing in coil L_1 is limited by resistor R_1 and therefore produces a negligible flux density, and no electromagnetic force on the vane. The frequency of oscillation is in the neighborhood of 10 Mc although it is not critical since the amplitude of oscillation is the only important factor. It should be noticed that no tuning condensers are used and the circuit is therefore not subject to variation with ambient temperature or humidity. The coils themselves are not extremely critical although for maximum plate current change they must be held within a few turns to maintain the proper feedback ratio. The coil forms are narrow and rectangular in shape for maximum sensitivity, and are made of polystyrene in order to minimize dielectric losses. The spacing between the coils is 1/16 inch for best performance, although a wider gap may be used with increased high frequency flux.

Many other applications of this type of control circuit are apparent where movement of a sensitive member is required to actuate a control mechanism at some point in its travel. The range of plate current change may also be increased to 25 or 30 ma by increasing the screen potential, although tube life will be somewhat decreased. The small number of parts required and extreme stability of the circuit make it readily adaptable to many applications where more complicated circuits are now used, as, for example, phototubes or variable capacity systems.



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Absolute dependability at all times and under the most severe conditions is required of all parts that go into the making of a battleship — the most important single unit of our first line of defense.

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Cooling Control

(*Continued from page* 55)

of the grid bias control on the vacuum tube. The accompanying diagram shows the circuit of the photoelectric system.

Three phototubes sensitive to infrared rays, connected in parallel and spaced inside a length of 2½-inch pipe cut away on the underside to allow entry of radiation, constitute the heat-sensitive element of the apparatus. Since it is necessary to mount the assembly close to the conveyor to attain the sensitivity required, the tubes should be enclosed in a Pyrex glass cylinder and a current of air blown past them to prevent overheating by the hot material directly beneath.

The major part of the relay equipment, with the sensitive relay housed in glass as a protection from dust, is mounted at a convenient wall location, about 20 feet from the phototube unit. The relay vacuum tube and the 2-megohm and 100,000-ohm resistors are mounted in a box close to the phototube assembly to reduce the capacity between the leads. Excessive capacity would prevent operation of the equipment should the vacuum tube be placed at any great distance from the phototubes. The phototube pick-up, vacuum relay tube housing, spray head, and the wall-mounted relay equipment are

• • •

AURORA BOREALIS

The Aurora Borealis or northern lights which caused radio and communication disturbances throughout the East on Sept. 18 is shown as they appeared over New York from atop the RCA building. New York City is in the foreground and New Jersey in the background beyond the Hudson River. The ribbon of light at the right is the George Washington Bridge

SO FISHERMEN TAKE THEM, TOO

THE Captains of tuna boats go where the fish are and that means rough weather much of the time. Radio is vital because one captain radios others when he finds a school. Radios must work perfectly through shivers and shakes and terrific impact.

It is under conditions like these that the Sylvania Lock-In Tube is designed to perform its most vital service. Once in place it stays in, regardless of position, vibration or impact. The Lock-In Tube is locked in place and performs under unbelievable punishment, so that is why it is a better tube for small boats and big boats—battleships, destroyers, dive bombers, fighting planes, tanks, jeeps, home radios, automobile radios, in fact everywhere where service requirements are tough. It is the big answer to consumer satisfaction no matter whether the consumer is the Army, Navy or you.

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Also makers of Hygrade Lamp Bulbs, Hygrade Fluorescent Lamps and Miralume Fluorescent Light Fixtures shown in the photographs. The spray control is a ½-inch solenoid water valve, actuated by the relay equipment. In operation, the valve is either completely open or completely shut.

Operation of Equipment

In adjusting the equipment for operation, the controllable grid bias on the type 77 tube is increased until the spray comes on, and then, while no hot material is immediately beneath the phototube assembly, the grid bias is reduced to the point where the spray shuts off. To maintain sensitivity, the glass protection tube around the phototubes should be wiped clean periodically, after which the grid bias control usually should be reset. It is essential that the flow of cooling air be maintained as long as the phototube apparatus is in position near the hot material, otherwise the heat would cause the tubes to fail. The apparatus had operated satisfactorily for two years until changes in operating procedure eliminated its need. Some improvement in operation could have been attained by the use of a grid-controlled rectifier tube to actuate a throttling valve on the water line to vary the flow of spray water according to the radiant heat from the hot material.

• • •

CONTROL TOWER OF WASHINGTON AIRPORT

The glass inclosed tower atop the airport building at Washington, D. C., provides an angle of view of 360 degrees for directing the traffic of planes into and out of Washington. The station is also used as a local weather bureau

THE ELECTRON ART

Methods of conserving tin, an automatic road sign, the use of ceramics in tubes, communication systems necessary for airport operation, an application of phototubes to meteorology, and resistance tuning are discussed in this month's review of the technical literature

Conserving Tin

SOLDER IS USED in the manufacture of almost all communication equipment. Ever since tin, an important ingredient of solder, was placed on the government priority list much attention has been given to ways of conserving and possibly developing a substitute for this valuable material.

The *Dutch Boy Quarterly*, house organ of the National Lead Company contains an article which briefly covers the present status of the search to conserve or eliminate tin in solder. It is called "Conserving Tin in Solder" and appears in Vol. 19, No. 3, 1941.

The article points out that there is no known substitute for tin which will produce a solder having the characteristics of tin-lead solder. However, if it is feasible for a given job, to use solder with a relatively high melting point, or one with a low melting point, but with less strength, then it is possible to reduce and in some instances actually eliminate the tin content of solder. One suggestion recently made was that silver be substituted for tin in solder. Silver-lead solders have been known and used for some time. The 2½ percent silver-97½ percent lead alloy is the eutectic composition, and the melting point is 580 degrees F. An outstanding quality of this solder is its strength at high temperatures. A 6 percent silver alloy has three times the shear strength of "half and half" tin-lead solder at 350 degrees F. The suitability of silver-lead solder for a particular job depends on the allowable soldering temperature. Some materials now being joined with tin-lead solder would be seriously damaged if not destroyed completely by the high heat necessary to melt silver-lead solder.

Other substitute solders which have been suggested include lead-free alloys of cadmium and zinc, and cadmium and silver. However, these have high melting points, they are more costly, and at present are not available. Aside from these, no practical tin-free substitute is available. The only alternative is the use of solders in which a portion of the tin has been replaced by some other metal or in which the tin content has been held to a minimum. Only two tin-reduced solders have been developed so far. One is a wiping solder containing 68 percent lead, 23 percent tin, and 9 percent cadmium. The other is one containing 45 percent tin, 45 percent lead, and 10 percent bismuth.

As for the expedient of using more lead and less tin in solder, it has its limitations too. The strength of solder, and its fluidity is generally proportional to the tin content. Since these factors are important they cannot be neglected. On the other hand, where it is possible to relieve the strain on solder by reinforcement of the joint by bolting, riveting, or the use of interlocking seams, or for the wide variety of applications where solder is used merely as a filler and strength is secondary, solders containing a higher proportion of lead than now used might prove entirely satisfactory.

• • •

Automatic Road Sign

A NEW INNOVATION in automatic road signs is described in the *Engineering News Record* of August 28th, 1941. The device, perfected by George E. Sykora of Minneapolis, Minn., is used to warn drivers that a junction or other traffic interference is ahead. At the same time the speed of the moving car is flashed on the sign so that the driver may reduce his rate accordingly.

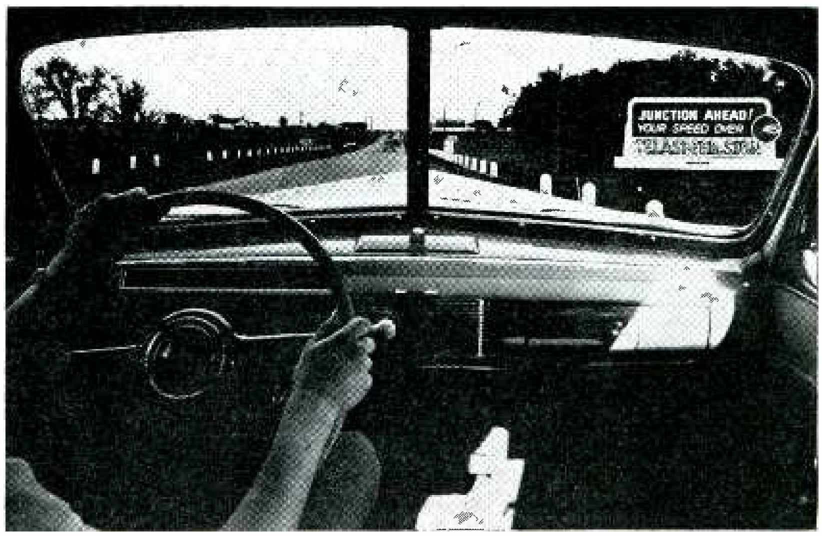
The sign is actuated by means of two detectors which may be phototubes or some magnetic detectors. These are placed from 750 to 1,000 feet ahead of the sign, about 40 feet apart. When the car passes the first detector the sign lights up, and after the second detector is passed the sign records the speed of the vehicle. Thus the driver is able to note his speed, and has plenty of time to reduce it if necessary. Another feature of the sign is that traffic counters may be placed on the equipment to record the number of cars travelling at various speeds. At the end of any given period, highway officials can determine the total number of cars that travel on the roadway, and also the speed at which they were travelling. The device is directional so that cars which come from the left side of the road, opposite to the direction facing the sign, do not operate the sign.

• • •

The Use of Ceramics in Tube Construction

MUCH WORK has been done in Germany along the lines of using ceramics in tube construction. The advantage in using ceramics becomes apparent at ultrahigh frequencies where the losses introduced by the glass in ordinary tubes are quite large. The result of an investigation into the use of low-loss ceramic material for tube seals, with particular reference to the work which has already been done in Germany appears in the August 1941 issue of *Electronic Engineering* (a British journal). The article is entitled "Ceramics in Valve Construction" and was written by R. Howard.

Apparently the electrical advantages in using ceramics are somewhat offset by the special techniques necessary for sealing the tubes. In many cases glass is used as the sealing means. For example, in Fig. 1A is shown a method



When a car approaches this automatic sign a photoelectric speed measurement circuit informs the driver of his speed

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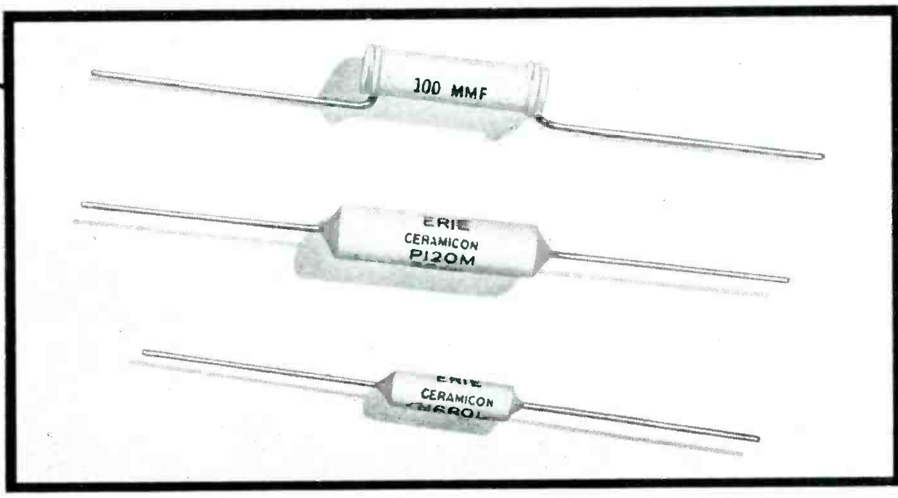
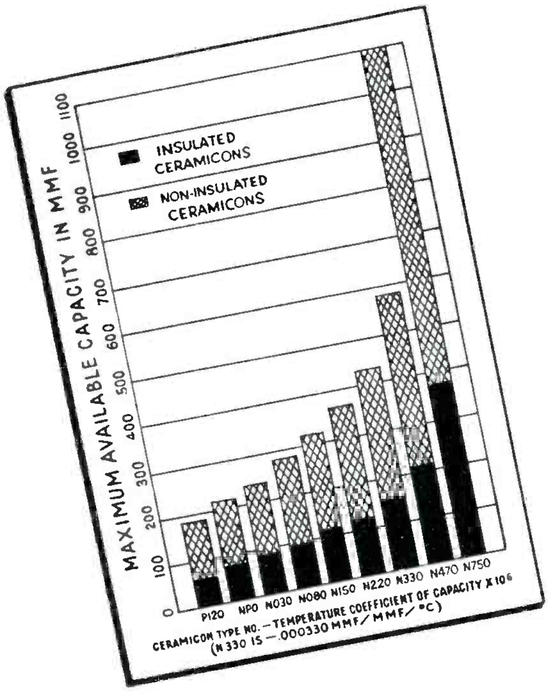


Changed to conform with tentative R. M. A. standards



WHEN Erie Ceramicons were first developed over 5 years ago, the engineering department of Erie Resistor standardized on 19 different temperature coefficients ranging from +.00012/°C to —.00068/°C. A recent analysis of the sales of these ceramic dielectric fixed condensers revealed that a large portion of user's requirements called for certain temperature coefficients not included in this original Ceramicon set-up, and that many original temperature coefficients were not in demand.

As a result of R.M.A.Committee meetings new standards of temperature coefficient ratings more nearly paralleling user's requirements were drawn up. The new temperature coefficients which range from +.00012/°C to —.00075/°C with available maximum capacities of insulated and non-insulated Ceramicons is shown at the left. Units listed as N750 are identical in all respects to those formerly designated as N680.

It is believed that this greatly simplified classification will fit practically all normal applications of Erie Ceramicons and provide dependable compensation for reactance drift due to temperature change. For those isolated cases that require other temperature coefficients, Erie Resistor will continue to manufacture special Ceramicons having the desired coefficient. A complete catalog giving specifications and characteristics of the new ratings of Erie Ceramicons is available on request.

The complete line of Erie Resistors, Condensers and Molded Plastics will be on display at Booth 26, Rochester Fall I R E Meeting.

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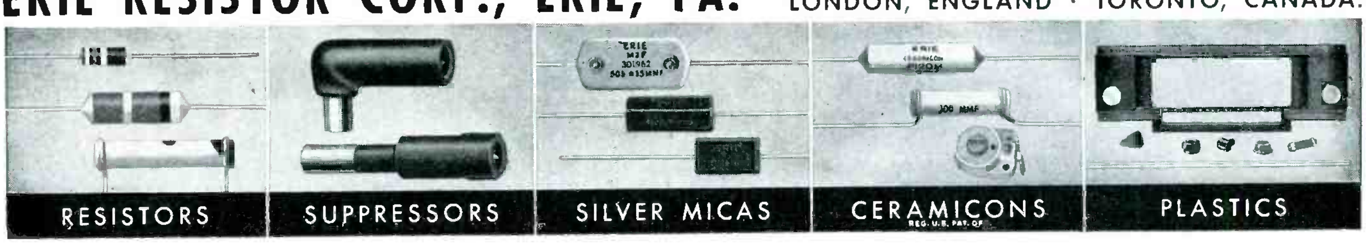


of sealing a metal lead to a ceramic envelope by means of a glass seal. The lead is wetted, jigged into position, and sealed to the ceramic, usually in an atmosphere of hydrogen. Hard glasses are mainly used for these small seals because soft glasses of similar coeffi-

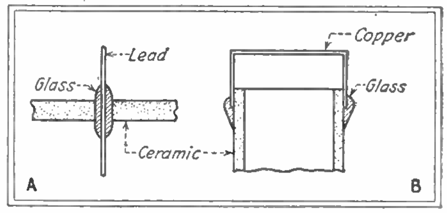


Fig. 1—Glass is used to seal the joints between a metal wire or cap and the ceramic

cients of expansion as the ceramic prevent effective heating of all the materials to be interconnected, and create difficulties in the choice of materials to be used for leads. Where large seals have to be made, the metal part is shrunk on to the ceramic material, and the glass is used to make the joint vacuum tight rather than the joint itself. This is shown in Fig. 1B. A joint where the glass actually does form the seal is shown in Fig. 2A.

Metal-ceramic seals are more expensive to manufacture but they have

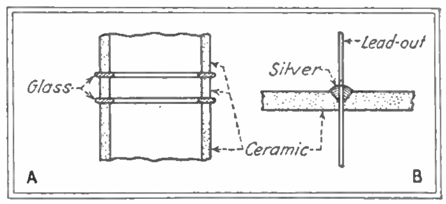


Fig. 2—Illustrations of glass-ceramic and silver-ceramic vacuum tight joints

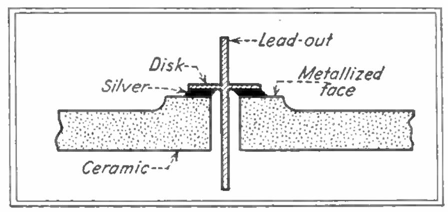


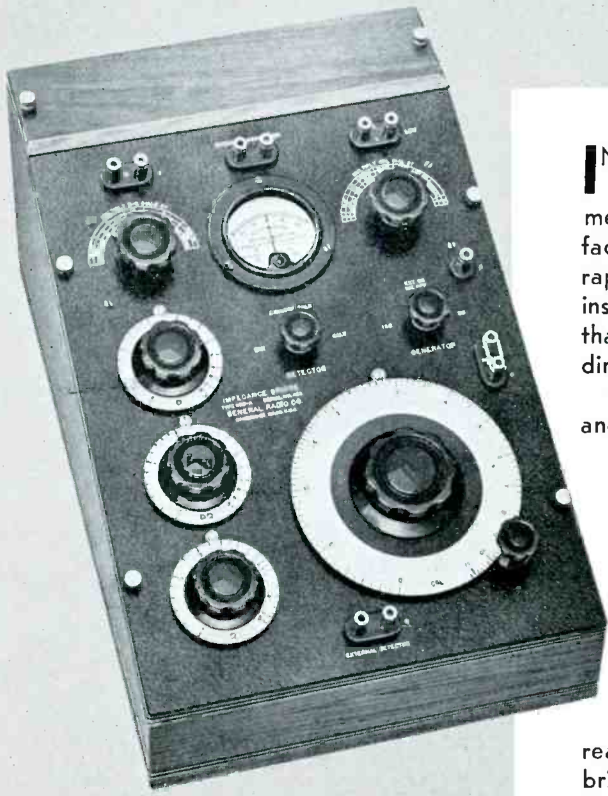
Fig. 3—A silver-ceramic joint making use of a metallized ceramic surface

many advantages over glass seals. There is no loss at ultrahigh frequencies, they are not sensitive to critical temperature changes and so are easier to de-gas, and they are not prone to cracking or seepage with the subsequent loss of vacuum. There are two main types of metal-ceramic seals. The first is similar to the glass seal shown in Fig. 1A except that silver is used as the sealing material, and the seal does not extend for the entire length of the lead in the ceramic. It is shown in Fig. 2B.

The second type of seal is more complicated. If two surfaces of ceramic are to be joined together, they should fit as precisely as possible at the point of contact. An adherent layer of metal

MAKING INSTRUMENTS DIRECT READING

with VARIABLE RESISTORS



Type 650-A Impedance Bridge, direct-reading over these ranges:—
Resistance: 1 milliohm to 1 megohm; Capacitance: 1 micromicrofarad to 100 microfarads; Inductance: 1 microhenry to 100 henrys

The cam on the CRL potentiometer. The contact arm is not connected directly to the potentiometer shaft, but turns freely on it. At the outer end a spring is pressed against a follower which rides on the cam. The cam follower rocking up and down on the cam changes the angular position of the contact arm and the scale. Adjustment of the eight screws will take up all differences between individual potentiometers and the master potentiometer which itself is an average.

IN RESEARCH and production testing the convenience of having instruments read directly in the quantities they measure has been appreciated for some time by the manufacturer and the user of electrical measuring instruments. So rapid have been the improvements in most direct-reading instruments that they now have considerably greater accuracy than similar units manufactured several years ago without the direct-reading feature.

In general, direct-reading scales are used only with resistors and capacitors; the accuracies obtainable are high, frequently as great as 0.1% of full-scale. In order to maintain high accuracy in a direct-reading instrument, *constant* fractional accuracy must be obtained and the rate of variation of the unknown should be logarithmic. In any *linear* scale the fractional accuracy decreases directly with the quantity varied.

The circuit used with any direct-reading instrument has to be chosen so that the magnitude of the variable element is proportional to the unknown.

One of the most interesting examples of a direct-reading instrument is the Type 650-A Impedance Bridge. This bridge measures five quantities over exceptionally wide ranges with the following *maximum* errors: for resistance, 2%; for capacitance, 2%; for inductance, 10%; for dissipation factor (R/X) 20% and for storage factor (X/R) 20%.

For the measurement of so many different quantities and for the very large ranges obtainable from this bridge, four circuits and a number of multipliers are selected by two multi-position switches. The balances are obtained by the use of two of the four variable resistors.

The semi-logarithmic scales on the four dials . . . the CRL, D, DQ and Q dials . . . are direct-reading. The potentiometers used with these dials are wound on tapered cards. The scales can be made direct-reading either by hand calibration of each point to fit the irregularities introduced by variations in wire size and spacing, or these irregularities can be controlled to fit a pre-engraved scale.

Originally the CRL dial of this bridge was hand calibrated with every line set to its proper resistance value. Later, the calibrations on a production lot were averaged and a master constructed. From this master calibration, other dials were engraved on a pantograph engraving machine. These dials are now photo-etched. In the quantities in which these instruments are now manufactured, it has proven much more economical to provide the CRL potentiometers with the photo-etched dial scale and to compensate for irregularities by means of a flexible cam, than to engrave each dial separately.

Many other General Radio direct-reading instruments use resistors as the variable element. The dial scales are calibrated in a manner similar to those on the Type 650-A Bridge.

GENERAL RADIO COMPANY
Cambridge, Massachusetts

is then applied to the two faces, either by sputtering on in a vacuum, by electrolysis, or by sintering powdered tungsten or molybdenum or carbonyl iron on to the surface of the ceramic. The two surfaces are then ground so that they fit accurately. The ground faces are then pressed together and heated to the melting point of the metal used and the joint is made. If it is not desired to heat the joint to a high temperature, a metal or solder

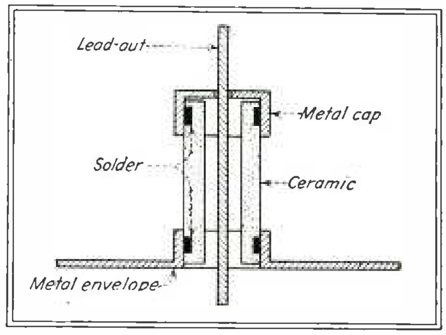


Fig. 4—A metal-ceramic-solder joint made without matallizing the ceramic

with a low melting point can be used to join the two faces. A variation of the latter method is used to seal tube leads to the ceramic envelope. It is shown in Fig. 3. A bush is formed by metallizing the surface of the ceramic as has been described. An annular ring is soldered to the lead coming out of the tube. This ring is then soldered to the metallized ceramic by means of silver.

A method of soldering metal directly

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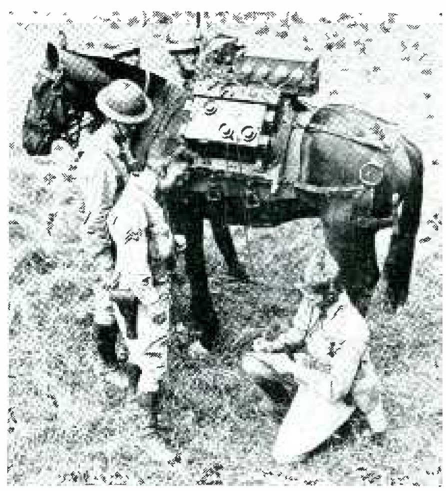
CAVALRY RADIO



Soldiers of Troop B of the 107th Cavalry Regiment of Ohio sending and receiving radio messages using a portable pack radio set at the recent army maneuvers in Arkansas. This equipment can be used on the ground as well as on the pack and has a range of from 25 to 50 miles. It weighs approximately 170 pounds

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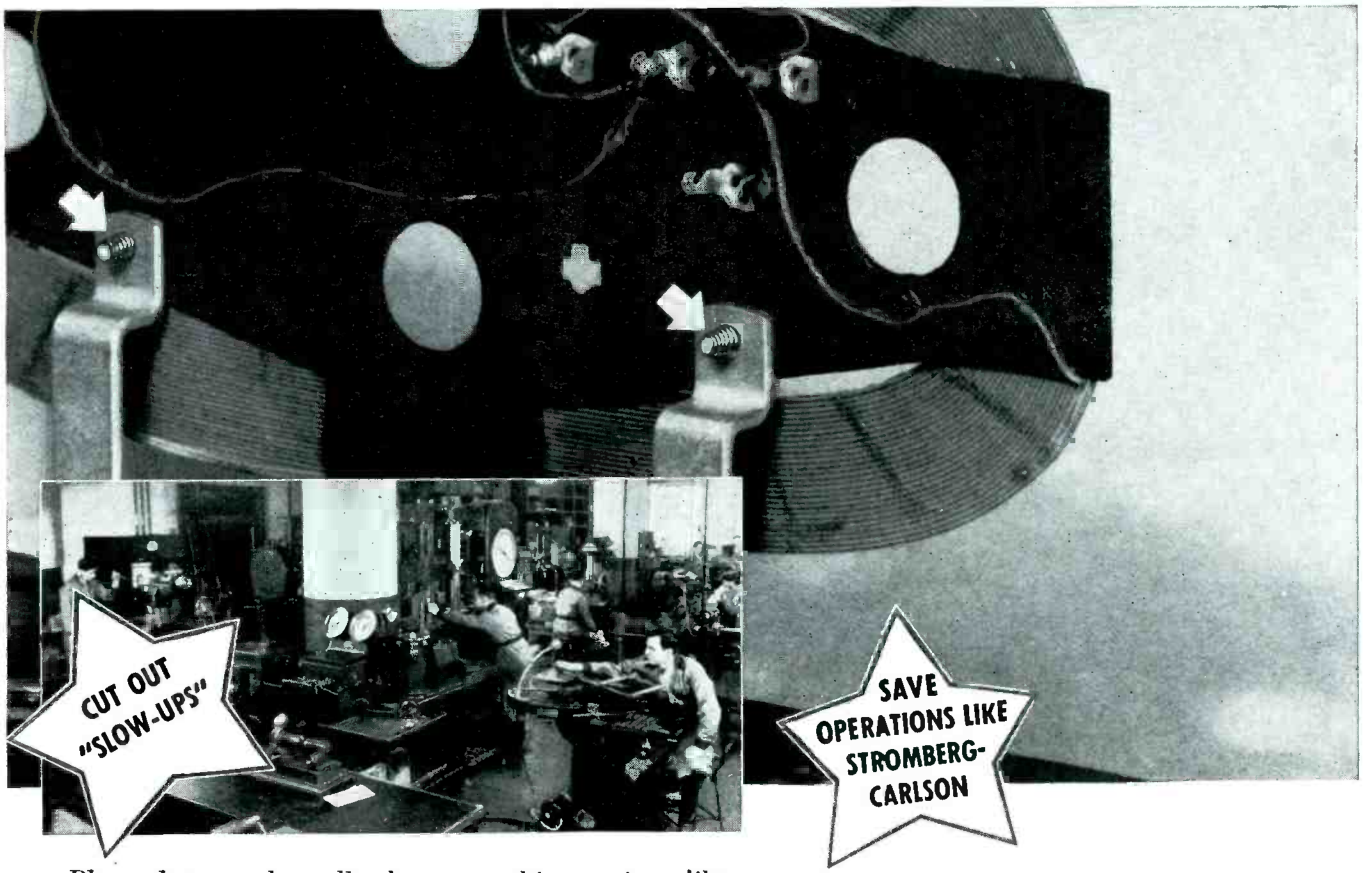

Here's one of the many uses Stromberg-Carlson makes of Parker-Kalon Self-tapping Screws. Type "F" Screws are used to fasten a cardboard loop to .096" steel brackets. Replacing machine screws in tapped holes, or bolt, nut and lock-washer fastenings, these screws save Stromberg-Carlson an estimated 60% in labor! Add security, too.

Plants large and small who are making savings like Stromberg-Carlson's by *eliminating operations* with Self-tapping Screws have a right to be pleased. But happiest of all are the production men who are making those savings *stick* through the use of *Parker-Kalon Quality-Controlled Self-Tapping Screws.*

Assurance of saving comes with rigid laboratory control of Parker-Kalon Self-tapping Screw quality. A laboratory —without counterpart in the screw industry—eliminates "doubtful screws" . . . screws that *look* all right but some of which fail to work right. It means that you can *drive* every screw you *start*. And count on it to *hold!*

So, when you specify "Parker-Kalon", you can add the advantages of eliminating "doubtful screws" to the outstanding advantages of Self-tapping Screws themselves. No tapping costs. No lock washers. No fumbling with bolts and nuts. No riveting. No tapping plates for thin sheet metal. No inserts in molded plastics. And, with genuine P-K, *no slow-ups for "doubtful screws"* in assembling sheet metal, heavy steel, die cast or plastic parts. Parker-Kalon Corp., 192-194 Varick St., New York.

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Quality-Controlled
SELF-TAPPING SCREWS

Give the Green Light to Defense Assemblies

SELF-TAPPING SCREWS FOR EVERY METAL AND PLASTIC ASSEMBLY . . . AND OTHER FASTENING DEVICES to ceramic without premetallizing the ceramic surface is shown in Fig. 4. A ceramic tube with annular grooves at either end fits into two metal caps. Into the grooves is placed solder in powder or wire form. The lead may be fastened to one or both of the metal caps. The entire joint is heated in a reducing atmosphere, or a vacuum, the solder taking to the metal and to the ceramic, thus forming a vacuum-tight joint. The problem of the exhaust tube through which the air is pumped out of the tube is also discussed.

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Airport Communications

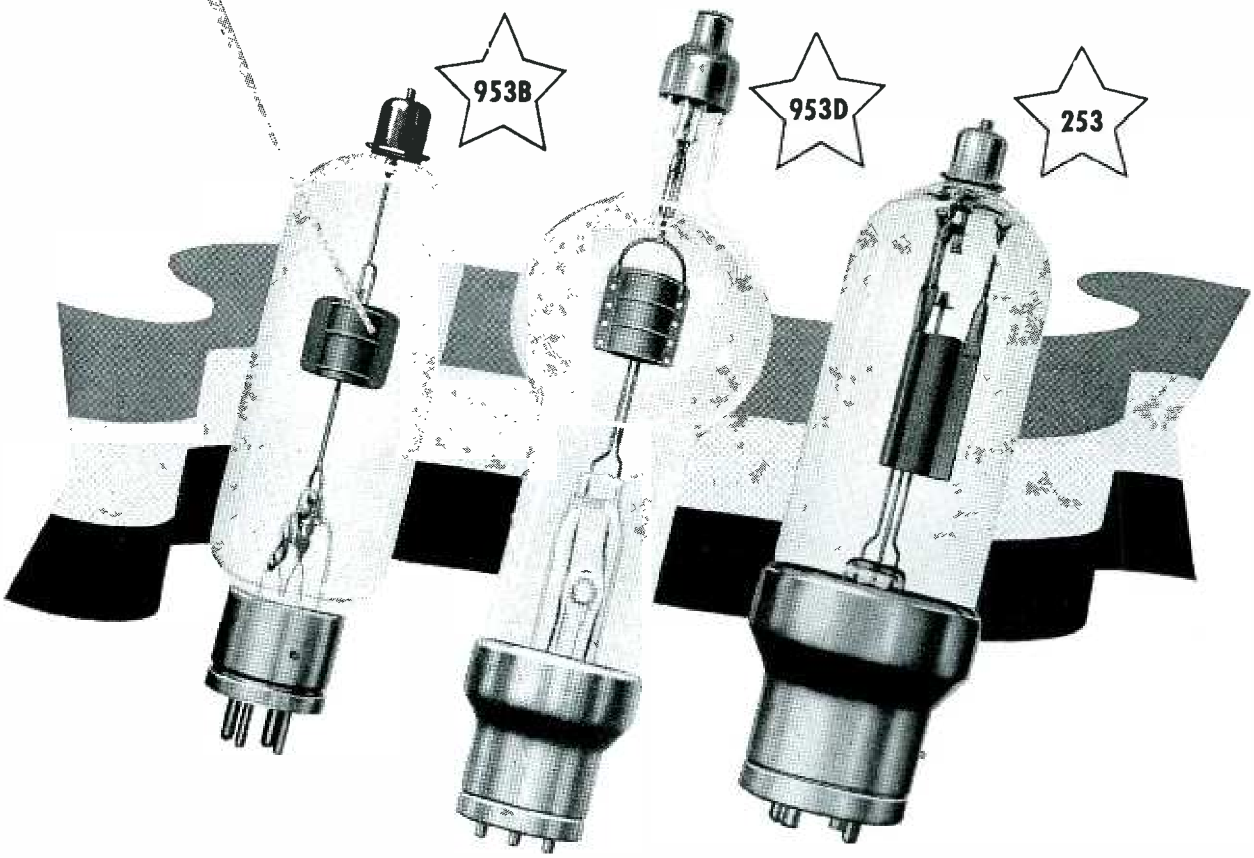
The principal communication requirements of an airport, and a description of some of the most modern equipment now in use are given in an article called "Airport Communications" in Vol. 20, No. 1, 1941 of *Electrical Communications*. Particular reference is made to the facilities at La Guardia Field, the Municipal Airport of the City of New York, including those provided by governmental agencies and the commercial airlines.

Airport communications facilities fall into four groups; internal communication, communication with outside fixed points and with other airports, communication with aircraft, and auxiliary services such as radio direction finding on land, instrument landing and radio beacons. Internal communication is usually effected by means of a private automatic branch telephone exchange. Intercommunication between departments is sometimes carried on by means of intercommunicators, but it has been found that the advantages of such a system decrease with expansion of the number of interphones involved. Experience indicates that interphone systems should be used to supplement, but never to supplant an internal telephone system. The latter system also makes connection with the public telephone exchange easy. At La Guardia airport a PAX system is used for inter-office communication and a PBX system for interdepartmental communication and connection with the local central office exchanges. A loudspeaker interphone system serves the general offices, the communication center, ticket center, agents, and air mail and baggage offices. There is also a teletype service which is used to communicate with airports over short distances when traffic is heavy; to disseminate flight information relayed from planes to the Airways Traffic Control; and to link the ticket, sales, reservations, and general offices.

To keep in constant touch with aircraft in flight, most airports use both the radiotelephone and the radiotelegraph. The airport must be equipped to maintain contact with aircraft within the perimeter of its particular zone. If individual equipment is not installed by the commercial airlines, alternative arrangements must be made for governmental or other agencies to

New Electronic Tools

GAMMATRON high vacuum rectifiers



New . . . Gammatron High Vacuum Rectifiers to meet the expanding needs of the electronic industry. This series of Gammatrons is designed by the pioneers of tantalum tubes specifically for high voltage rectification. They are suitable for a wide range of new applications because they are not affected by temperature extremes and no warm up period is required. Rugged mechanical and electrical construction assure long life and great stamina. Write for full data.

Type	253	953-B	953-D	953-E
Peak Inverse Volts	15,000	30,000	75,000	150,000
Max. Peak Current, ma	1,500	80	120	400
Max. Average Current, ma	350	40	60	200
Filament	Thor. Tungsten	Tungsten	Tungsten	Tungsten
Filament Volts	5.0	7.5	7.5	15
Filament Amps	11	6.5	11	15
Length, Inches	8½	7⅝	12½	22½
Diameter, Inches	2½	2	3¾	5
Base	50 Watt	M. 4 Pin	50 Watt	50 Watt
Net Price	$18.50	$12.00	$30.00	$75.00

GAMMATRONS of course!

HEINTZ AND KAUFMAN LTD.
SOUTH SAN FRANCISCO CALIFORNIA U·S·A·

render this service and to keep in contact with aircraft at least until the zone of the next airport is reached. All flight activity in this country is subject to instructions from Airways Traffic Control of the Federal Civil Aeronautics Administration. At La Guardia Field, it supervises flight operations in the New York area. Instructions to commercial airplanes while in flight between airport control tower areas are relayed through the ground-airplane radio facilities of the airline concerned. However, contact with military and itinerant planes is made directly by radio from Airways Traffic Control until the plane comes within the airport control tower area. For this latter service a transmitter which operates on a fixed frequency of 209 kc is used. It is modulated continuously with tone at a level which permits speech to be imposed on it with adequate intelligibility. One receiver monitors 3,105 kc for reception from itinerant planes, and another monitors 4,495 kc from military planes. In addition, the tone signal of the range transmitter is monitored (on 209 kc) and the local control tower on 362 kc.

Thirteen sets of teletype equipment are used by the weather reporting service at the field. Each set consists of a printer with its associated reperfora-

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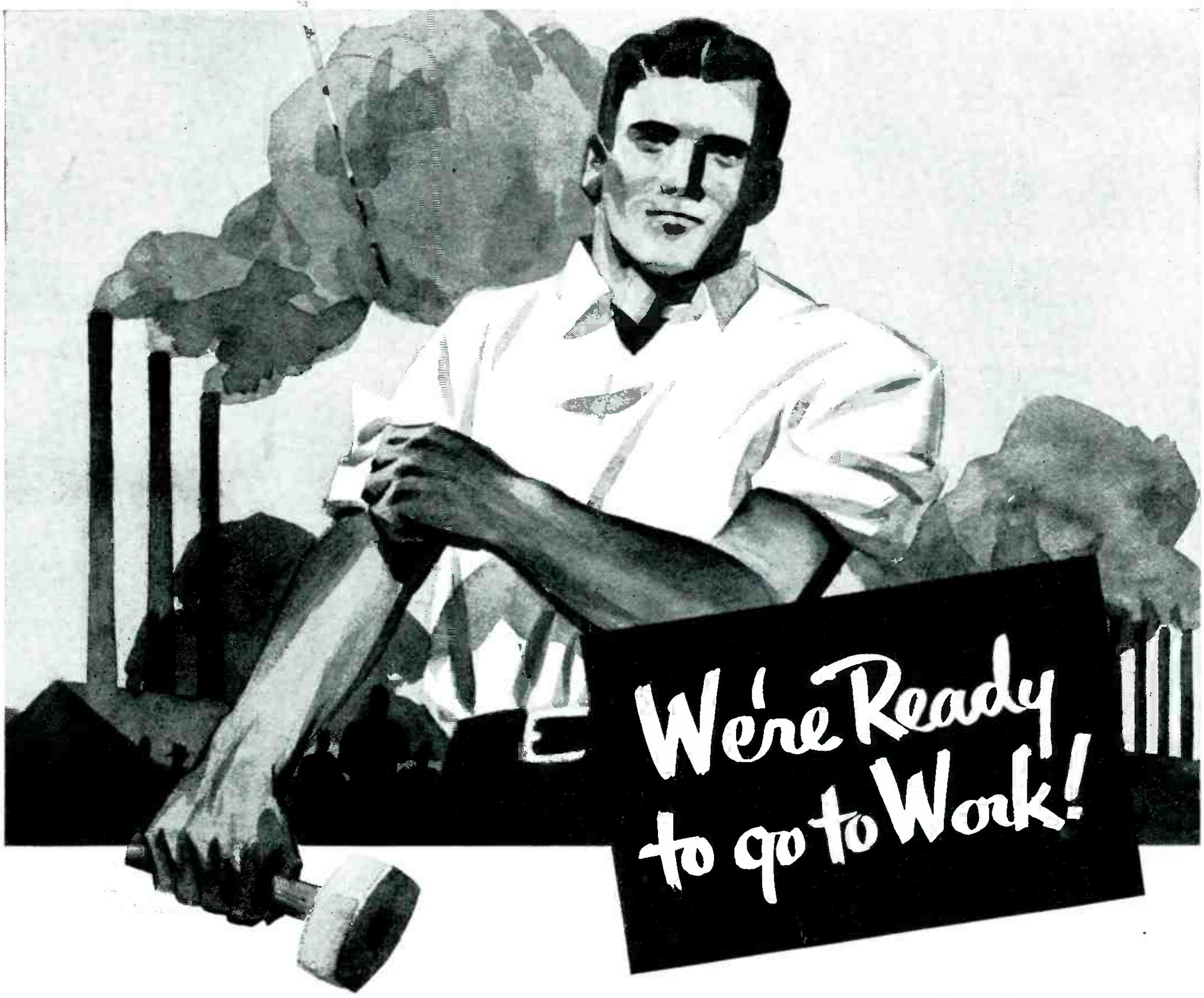
UNIVERSITY OF CALIFORNIA MICROSCOPE

Completing seven months of work, 24-year-old Floyd Luther graduates at the University of California, realizing the fruit of investigation in foreign laboratories with the completion of the electron microscope shown above. Assisting Mr. Luther is Don MacFarland. We cannot resist the temptation to pass on to our readers the fact that the original caption for this photograph announces that in the construction of this microscope was utilized "revolutionary new grinding process employed in the construction of three sets of electric lenses"



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As the demand for increased defense production grows greater and greater, the sub-assembly service offered by Stackpole becomes of particular importance. Our entire resources are available for making small parts and sub-assemblies under your defense contracts and to help solve production problems involving Switches, Resistors, Iron Cores and other units for use in radio and electrical instruments, motors, etc. We invite manufacturers to share our experience and efficiency in designing and producing various types of small units.

MAY WE DISCUSS YOUR DEFENSE PROBLEMS WITH YOU? Our engineers will be glad to go into full details. This service is yours, of course, without obligation.

BRING YOUR PRODUCTION PROBLEMS TO STACKPOLE

STACKPOLE CARBON CO.

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tor and a transmitter. The reperforators are used when required to perforate a tape simultaneously with the reception of information in printed form on the printer. The tape may then be transferred to the transmitter for transmission of the reports to other distribution points and to local subscribers. A similar set of equipment is used for the flight control and progress report circuit.

The American Airlines communication facilities are covered in some detail. Four transmitters are located at the Jamaica Bay Station, about 10 miles south of the airport. Two are multi-channel transmitters made up of a power unit, one telephone radio frequency unit and two c-w telegraph units. Each of the r-f units is rated at 3-kw antenna output and is arranged for selection of six operating frequencies by remote control. The third transmitter is a single channel c-w or telephone unit with an output rating of 1 kw, and is arranged for remote selection of ten frequencies. The fourth is a 250-watt unit for remote selection of six frequencies on c-w telegraph only. In addition, three auxiliary transmitters for telephone use only, rated at 50 watts and operating only on two frequencies, are installed near the operating positions in the communications center.

Seven receivers, each crystal controlled for two frequencies, are located at the station on nearby Rikers Island. Four similar auxiliary receivers are installed near the operating positions in the communications center. All of the transmitters and receivers are wired into a jack field where circuits from the operating positions also terminate. The remotely

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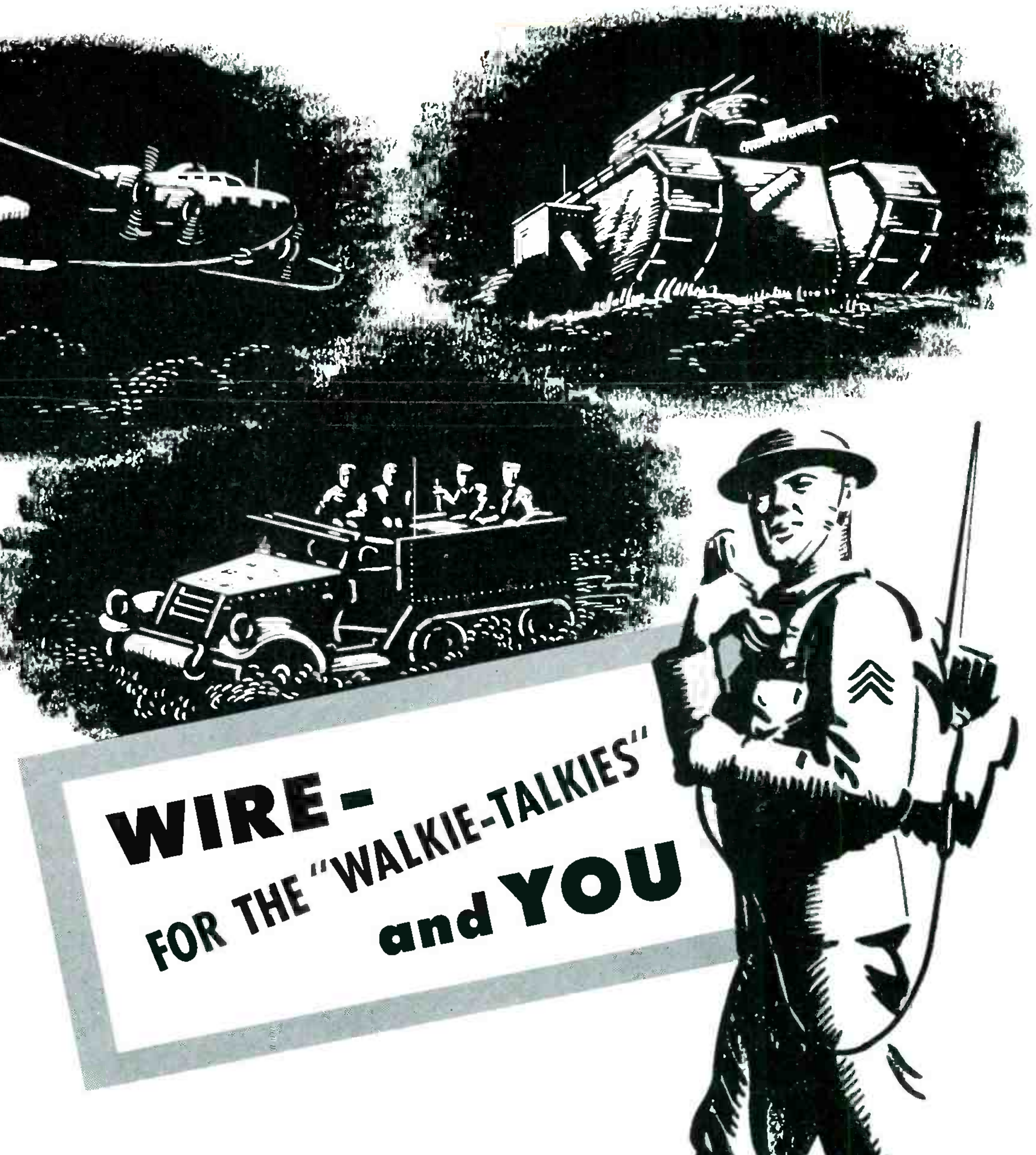
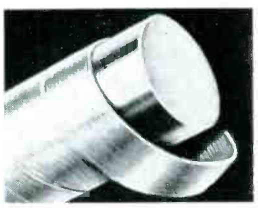
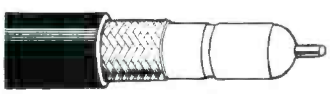
PLANE SOUND LOCATER

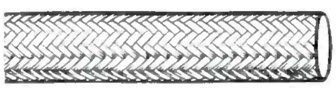
A trio of soldiers from Fort Totten, N. Y., operate a plane sound locater on exhibit at the National Defense Exposition in Grand Central Palace




Magnet Wires


Microphone Cables


Transmission Cables


Shielding


Hook-up Wires

Millions of feet of Belden wire are being used in radio communication equipment for the Signal Corps, in tanks, planes, and in many other necessary defense operations.

Through the years, Belden wires have been developed to meet just such unusual requirements. Specialized experience in wiring all types of electrical equipment is back of each product. Performance records show what each wire is designed to do. Close inspection in every step of manufacturing maintains each essential characteristic.

On your orders for defense equipment, specify Belden—your wire insurance.

Belden Manufacturing Company
4625 W. Van Buren St., Chicago, Ill.

The Rauland Corporation uses Belden Wire in the manufacture of "Walkie-Talkies," tank transmitters, and similar communications equipment for the United States Army.

Belden

WIRE • CABLE • CORDS

installed radio equipment is under complete control of the operators through the remote control units at each operating position. A teletype operating section is also included in the facilities of the American Airlines.

A number of new type radio instrument landing systems are being installed at the airport. Through beams of ultrashort wave energy transmitted from highly directive equipment at the airport the pilot, by means of an instrument on the instrument board of the plane, can determine the exact line of approach laterally to the concrete runway and also the exact line of descent when five miles or more away. Two marker beacons along the line of approach to the landing runway indicate to the pilot when he should be at a predetermined altitude and when he passes the boundary of the airport. The marker beacons operate at a frequency of 75 Mc, and the horizontal and vertical guide beams which use separate transmitters and antennas, radiate at 109.9 and 93.9 Mc respectively. The use of ultrahigh frequency permits smaller antennas, thus reducing obstacle hazards. In fact the horizontal guiding beam antenna may even be located underground, with a slight reduction in range. The vertical guiding antenna is placed to one side of the field thus does not constitute a hazard, and the marker beacons can be placed beyond the danger zone.

The article is quite comprehensive and merits the attention of ELECTRONICS readers since almost all types of communications equipment is used at airports. There is also included a radio direction-finding system installation. The indicating device is a cathode-ray oscillograph having a 360-degree azimuth scale around the periphery of the screen. In the absence of signal and noise the light spot is centered with respect to the azimuth scale. As soon as a carrier wave reaches the collector system the spot is deflected toward the azimuth indication corresponding to the arrival azimuth of the wave itself. The indication is instantly and automatically unilateral eliminating 180-degree uncertainty, and the deflection can be read to within two degrees when receiving from planes up to a few hundred miles away under favorable conditions.—E.E.G.

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Phototubes in Meteorology

THE PROBLEM OF ATMOSPHERIC HAZE, a phenomenon which results in a "false horizon" which confuses aviators is being studied at Stanford University. Some of the obstacles encountered in this problem and the results of the investigation are outlined in an article entitled "The False Horizon," by Volney Finch which appears in the October 1941 issue of *Aviation*.

In seeking data on the cause of haze, an effort was made to determine its relationship to relative humidity, condensation nuclei density, dust count, and the time of day. The method used was to project a light beam down an open field to a phototube, and measure continuously the intensity of the beam as it varied by reason of its light scattered by the particles constituting the haze. The nuclei density was obtained and recorded by an apparatus previously used by Professors Bradbury and Meuron for measuring the variation of the number of condensation nuclei in the atmosphere throughout the day. In this apparatus an air sample is drawn into a Wilson cloud chamber and expanded. The expansion cools the air to below the saturation point with the result that the water vapor in the sample condenses upon the nuclei present. A light beam through the cloud chamber is directed onto a phototube, and a relationship has been established between the amount of light extinction and the number of nuclei present. A galvanometer is arranged to measure and record the result on a photographic paper mounted on a rotating drum. The apparatus examines the sample in fifteen minutes, and since it is operating continuously the record shows the number of condensation nuclei present in the atmosphere at the field at intervals of fifteen minutes throughout the day.

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FOREIGN LANGUAGE BROADCASTS RECORDED

With intense radio broadcasting activity under way by every major national government in the world, propaganda activities are continually being studied and recorded in this country. Here are shown a complete battery of multilingual listeners who are tuning in to a number of European broadcasts. It has become practice for European nationals to transmit the same news on two or more transmitters simultaneously to insure that it gets through the jamming of a hostile nation

Resistance Tuning

THE IDEA of varying the frequency of an oscillator by means of changing the resistance in the inductance or capacitance portion of the circuit is not new. This scheme has not been widely applied because of the limited frequency range afforded by using this expedient. However, recently several interesting papers on the subject of resistance tuning have appeared in various journals. One of these is called "Theory and Application of Resistance Tuning", by Cledo Brunetti and Eric Weiss, and appears in the June 1941 issue of *Proceedings of the I.R.E.*

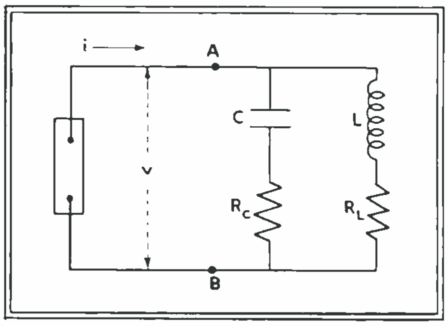

Fig. 1—Circuit of simplified ideal oscillator

From the viewpoint of priorities and technical interest, it merits our attention here.

A simplified diagram of a resistance-tuned oscillator is shown in Fig. 1. The element to the left of *A—B* is a negative resistance of constant value r_n. For this circuit, it can be shown that oscillations will occur when

$$\frac{1}{r_n} + g_c + g_L = 0 \qquad (1)$$

The frequency of oscillation will be

$$f = \frac{1}{2\pi\sqrt{LC}}\sqrt{\frac{1 - \frac{C}{L}R_L^2}{1 - \frac{C}{L}R_C^2}} \qquad (2)$$

Inserting Eq. (2) into Eq. (1) gives

$$-r_n = \frac{L}{C(R_L + R_C)} + \frac{R_L R_C}{R_L + R_C} \qquad (3)$$

Thus if either R_L or R_c or both are

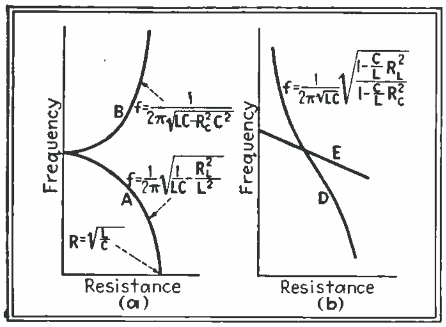

Fig. 2—Frequency of resistance-tuned oscillator. Curve A: $R_c = 0$, R_L varied from 0 to $\sqrt{L/C}$. Curve B: $R_L = 0$, R_c varied from 0 to $\sqrt{L/C}$. Curve D: $R_L + R_c = k < \sqrt{L/C}$, R_L varied from 0 to k. Curve E: $R_L + R_c = k/2$; R_L varied from 0 to $k/2$

varied and r_n adjusted to maintain Eq. (3) the frequency will vary in the manner given by Eq. (2).

The curves in Fig. 2 show how the frequency varies as the resistance is changed in either leg of the circuit, or in both legs simultaneously. It is seen that by proper choice of L and C the frequency may be varied over any desired range for any predetermined range of variation of resistance. In practice however, certain limitations prevent complete attainment of the theoretical behavior.

A large variation in frequency requires so much resistance that waveform becomes distorted. The theoretical aspects of the nonlinear factors which influence the frequency are discussed by the authors. They also consider tuning by means of a variable resistance in the inductance arm, in the capactive arm, extended range tuning by adding variable resistors to both arms, straight-line tuning, the effect of supply voltages on frequency, and applications. The table summarizes resistance-tuned transitron oscillator performance. The resistance-

Summary of Resistance-Tuned Transitron Oscillator Performance

Tuning Resistance in	Ratio of Frequency Variation	Wave Form
L arm	25 to 1	Variable***
L arm	5 to 1	Good
C arm	2 to 1	Good
Both L and C arms	50 to 1	Variable
Both L and C arms	20 to 1*	Variable
Both L and C arms	1.5 to 1**	Good

* Near-linear relationship between frequency and resistance.

** True linear relationship between frequency and resistance.

*** Waveform good over large portion of range; approaches relaxation oscillations over remainder of range.

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WHITE HOUSE BROADCAST

A battery of remote pick-up units installed in the Oval Room at the White House at Washington, D. C., on Sept. 12 when President Roosevelt made his historic speech

TUBES

For the first time no new tubes have been registered by the RMA Data Bureau during a calendar month. Characteristics of a number of phototubes are presented

Tube Registry

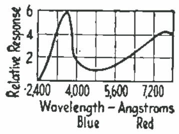
No new tube types were registered by the RMA Data Bureau during September 1941

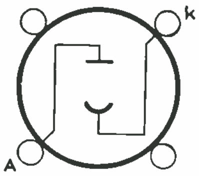
Phototubes

Types G-1 and V-1

General Scientific Corp.

PHOTOTUBES, gas-filled (G-1) and vacuum (V-1), cathode area $1\frac{3}{8}$ sq inch (approx), seated height to center line of cathode $1\frac{15}{16}$ inch, overall seated height $3\frac{1}{16}$ inches (max), diameter $1\frac{3}{16}$ inch (max), 4-pin base.



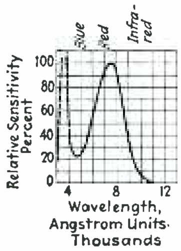


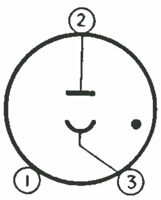
Sensitivity
Gas-filled phototube = 63 μa/lumen
Vacuum phototube = 10 μa/lumen
Operating Voltage = 90 v

Type 927

R.C.A.

GAS phototube, window area 0.4 square inch, seated height to center line of cathode $1\frac{1}{4}$ inch, overall length 2 15/32 inches (max), overall diameter 23/32 inch (max), 3-pin base.





Gas Amplification Factor — Not over 7

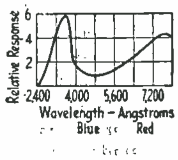
Luminous Sensitivity
0 cps (dc) = 75 μa/lumen
1000 cps = 70
5000 cps = 65
C(cathode-anode) = 2.0 μμf
Max Ambient Temp = 100° C
Max Anode Supply Voltage = 90 v
Max Anode Current = 2 μa
Sensitivity (E anode supply = 90 v and R_l = 1 megohm) = 0.0050 μa/μwatt radiant flux at 7500 A. See curve.

Types G-4 and V-4

General Scientific Corp.

PHOTOTUBES, gas-filled (G-4) and vacuum (V-4), cathode area $\frac{1}{2}$ sq inch (approx), seated height to center line of cathode $1\frac{1}{8}$ inch (aprox), overall seated height 2 inches (max), diameter $\frac{11}{16}$ inch (max), supplied without base.

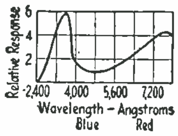
Sensitivity
Gas-filled phototube = 63 μa/lumen
Vacuum phototube = 10 μa/lumen
Operating Voltage = 90 v

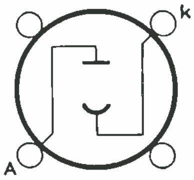


Types G-6 and V-6

General Scientific Corp.

PHOTOTUBES, gas-filled (G-6) and vacuum (V-6), cathode area $1\frac{1}{4}$ sq inch, (approx), seated height to center line of cathode $1\frac{7}{8}$ inch, overall seated height $2\frac{7}{16}$ inches (max), diameter $1\frac{1}{2}$ inch (max), 4-pin base.

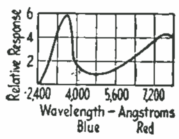


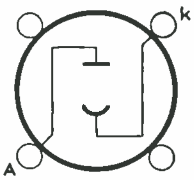


Sensitivity
Gas-filled phototube = 63 μa/lumen
Vacuum phototube = 10 μa/lumen
Operating Voltage = 90 v

Types G-7 and V-7

PHOTOTUBES, gas-filled (G-7) and vacuum (V-7), cathode area $1\frac{9}{16}$ sq inch (approx), seated height to center line of cathode $2\frac{1}{2}$ inches, overall seated height $3\frac{7}{8}$ inches (max), diameter $1\frac{3}{4}$ inch (max), 4-pin base.





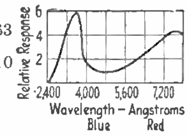
Sensitivity
Gas-filled phototube = 63 μa/lumen
Vacuum phototube = 10 μa/lumen
Operating Voltage = 90 v

Types G-5 and V-5

General Scientific Corp.

PHOTOTUBES, gas-filled (G-5) and vacuum (V-5), cathode area $\frac{5}{8}$ sq inch (approx), seated height to center line of cathode $1\frac{3}{16}$ inch, overall seated height $2\frac{1}{8}$ inches (max), diameter 1 inch (max), supplied without base.

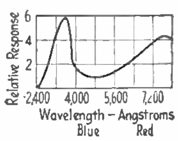
Sensitivity
Gas-filled phototube = 63 μa/lumen
Vacuum phototube = 10 μa/lumen
Operating Voltage = 90 v

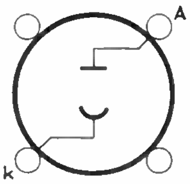


Types G-8 and V-8

General Scientific Corp.

PHOTOTUBES, gas-filled (G-8) and vacuum (V-8), cathode area $\frac{7}{8}$ sq inch (approx), seated height to center line of cathode $2\frac{3}{16}$ inches, overall seated height $3\frac{5}{16}$ inches (max), diameter $1\frac{3}{16}$ inch (max), 4-pin base.



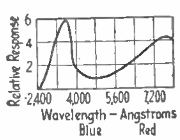


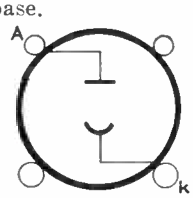
Sensitivity
Gas-filled phototube = 63 μa/lumen
Vacuum phototube = 10 μa/lumen
Operating Voltage = 90 v

Types G-9 and V-9

General Scientific Corp.

PHOTOTUBES, gas-filled (G-9) and vacuum (V-9), cathode area $\frac{7}{8}$ sq inch (approx), seated height to center line of cathode $2\frac{3}{16}$ inches, overall seated height $3\frac{1}{16}$ inches (max), diameter $1\frac{3}{16}$ inch (max), 4-pin base.





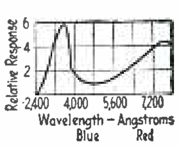
Sensitivity
Gas-filled phototube = 63 μa/lumen
Vacuum phototube = 10 μa/lumen
Operating Voltage = 90 v

Types G-10 and V-10

General Scientific Corp.

PHOTOTUBES, gas-filled (G-10) and vacuum (V-10), cathode area $1\frac{9}{16}$ sq inch (approx), seated height to center line of cathode $2\frac{11}{16}$ inches, overall seated height 4 inches, diameter $2\frac{5}{16}$ inches, flexible leads.

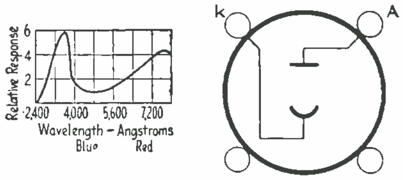
Sensitivity
Gas-filled phototube = 63 μa/lumen
Vacuum phototube = 10 μa/lumen
Operating Voltage = 90 v



Types G-11 and V-11

General Scientific Corp.

PHOTOTUBES, gas-filled (G-11) and vacuum (V-11), cathode area 1¼ sq inch (approx), seated height to center line of cathode 1⅜ inch, overall seated height 2¾ inches (max), diameter 1½ inch (max), 4-pin base.

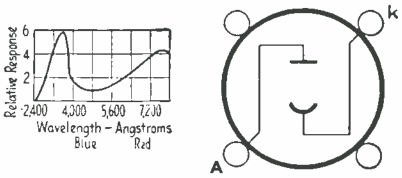


Sensitivity
Gas-filled phototube = 63 μa/lumen
Vacuum phototube = 10 μa/lumen
Operating Voltage = 90 v

Types G-12 and V-12

General Scientific Corp.

PHOTOTUBES, gas-filled (G-12) and vacuum (V-12), cathode area ⅝ sq inch (approx), seated height to center line of cathode 1⅞ inch, overall seated height 2⅛ inches (max), diameter 1$\frac{3}{16}$ inch, 4-pin base.



Sensitivity
Gas-filled phototube = 63 μa/lumen
Vacuum phototube = 10 μa/lumen
Operating Voltage = 90 v

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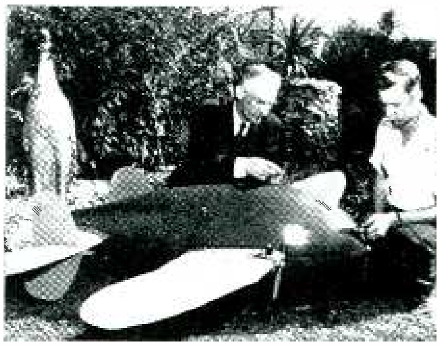
AERIAL WEAPON

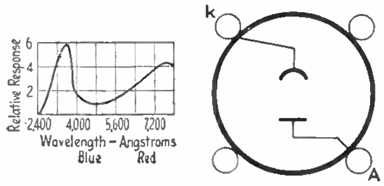


A strange looking radio controlled aerial weapon developed by a Mare Island Navy Yard engineer has aroused the interest of Army officials at Vallejo, Calif. The winged torpedo shown above operates on the principle of the gyroscope and is designed to fly at an altitude of 30,000 feet, carrying a load of bombs. John Hodgdon, the inventor, is shown at the left, with Bob Polson, who built the working model shown

Types G-13 and V-13

General Scientific Corp.

PHOTOTUBES, gas-filled (G-13) and vacuum (V-13), cathode area $\frac{7}{8}$ sq inch (approx), seated height to center line of cathode $1\frac{15}{16}$ inch, overall seated height $3\frac{1}{16}$ inches, diameter $1\frac{3}{16}$ inch (max), 4-pin base.

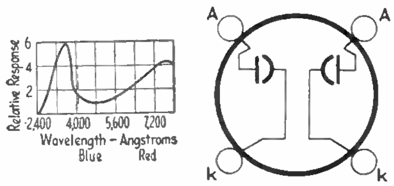


Sensitivity
Gas-filled phototube = 63 μa/lumen
Vacuum phototube = 10 μa/lumen
Operating Voltage = 90 v

Types G-14T and V-14T

General Scientific Corp.

TWIN phototubes, gas-filled (G-14T) and vacuum (V-14T), cathode area $\frac{1}{2}$ sq inch (approx) each cathode, seated height to center line of cathodes 2 inches (approx), overall seated height 3 inches (approx), diameter $1\frac{1}{16}$ inch (approx) 4-pin base.

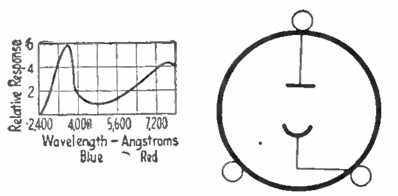


Sensitivity
Gas-filled phototube = 63 μa/lumen
Vacuum phototube = 10 μa/lumen
Operating Voltage = 90 v

Types G-15F and V-15F

General Scientific Corp.

PHOTOTUBES, gas-filled (G-15F) and vacuum (V-15F), cathode area $\frac{1}{4}$ sq inch (approx), seated height to center line of cathode $1\frac{1}{16}$ inch, overall seated height $1\frac{7}{8}$ inch (approx), diameter $\frac{5}{8}$ inch, 3-pin base.

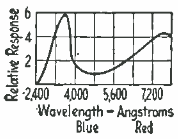


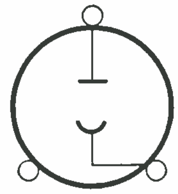
Sensitivity
Gas-filled phototube = 63 μa/lumen
Vacuum phototube = 10 μa/lumen
Operating Voltage = 90 v

Types G-16 and V-16

General Scientific Corp.

PHOTOTUBES, gas-filled (G-16) and vacuum (V-16), cathode area ½ sq inch (approx), seated height to center line of cathode $1\frac{3}{16}$ inch, overall seated height $1\frac{1}{8}$ inch (approx), diameter ⅝ inch, 3-pin base.





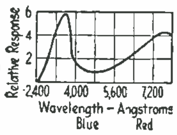
Sensitivity
Gas-filled phototube = 63 μa/lumen
Vacuum phototube = 10 μa/lumen
Operating Voltage = 90 v

Types G-18T and V-18T

General Scientific Corp.

TWIN phototubes, gas-filled (G-18T) and vacuum (V-18T), cathode area 0.25 sq inch (approx) each cathode, overall seated height 2¼ inches (approx), diameter 1 inch (approx), supplied without base.

Sensitivity
Gas-filled phototube = 63 μa/lumen
Vacuum phototube = 10 μa/lumen
Operating Voltage = 90 v



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NEW ACOUSTIC THEORY TESTED

Dr. Vincent Salmon, mathematical physicist of the Jensen Radio Mfg. Co., at Chicago, inspects a plaster paris model of one of the Hypex horns which he has developed. It is believed that this is the first time that experimental horns have been cast of plaster paris in this manner

D-C AMPLIFIER

(*Continued from page* 31)

perfect regulation with respect to line-voltage variations. The addition of the connection AA' puts in a forward-acting correction and perfect regulation with respect to line-voltage variations is possible.

In order to consider the circuit further, let us refer to Fig. 10. In this figure the generator V represents the line-voltage variation, the generator $\mu_3 e_g$ represents the equivalent generator of the 2A3, the symbols μ_{20} and μ_{10} represent the voltage gains of the amplifying stages in the regulator, and the k's represent the fractions of the total voltages which are picked off on the potential dividers. The output e_g of μ_{20} is proportional to the algebraic sum of the three input signals. Using the symbols defined in the figure, we may write:

$$V - \mu_3 e_g - E = 0 \qquad (6)$$

Also,

$$e_g = \mu_{20}(\mu_{10} k_1 E + k_3 E + k_2 V) \qquad (7)$$

Then, on eliminating e_g we find

$$\frac{E}{V} = \frac{1 - \mu_3 \mu_{20} k_2}{1 + \mu_3 \mu_{20} \mu_{10} k_1 + \mu_3 \mu_{20} k_3} \qquad (8)$$

Hence we obtain perfect regulation for

$$k_2 = \frac{1}{\mu_3 \mu_{20}} \qquad (9)$$

Slight variations from the ideal in values of k_2, μ_3, or μ_{20} still leave a very large stabilization ratio due to the large factors in the denominator of Eq. (8). Thus, errors in the forward-acting portion of the regulator are greatly reduced through a high-gain feedback amplifier. The effect is that the circuit parameters and tube constants are not at all critical, and essentially perfect regulation may be obtained over a wide range.

Measurements on the regulator of Fig. 2 gave the following results:

(1) Total a-c component of output voltage is approximately 0.5 millivolt in 250 volts, or 2 parts in a million.

(2) Variation of line voltage from 95 to 125 volts changes output by less than 0.4 millivolt. This is sufficient regulation to make the amplifier independent of line fluctuations over the range given.

(3) The output resistance of the supply is a fraction of an ohm.

(4) The regulator ceases to function at a line voltage of about 92 volts, under load of the amplifier.

It may be shown that the output voltage V_o of the regulator of Fig. 2 is very nearly given by

$$V_0 = E_{T7}(R_8 - R_{14})/R_{14} \qquad (10)$$

where E_{T7} is the voltage across tube T_7 and the resistors are those shown in Fig. 2.

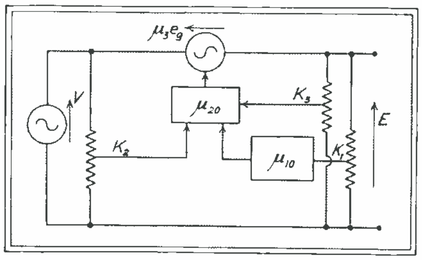

Fig. 10—Block diagram illustrating that the use of a feedback amplifier reduces variations in a regulated power supply

From this equation we see that any variation in resistors R_8 and R_{14} or variations in the reference voltage will appear directly in the output. Advance wire resistances have been used to minimize temperature drift effects, and a resistance-capacitance filter $R_{12}C_4$ used to eliminate the reference-tube noise-voltages. When the regulator is first put into operation it is necessary to adjust R_4 for a minimum of output hum; this operation will seldom need to be repeated.

Interstage Coupling Circuit

Another important problem in the design of this amplifier is that of

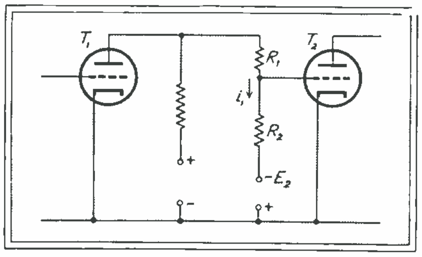

Fig. 11—A possible, but not too convenient solution of coupling two stages of a d-c amplifier, requiring a regulated supply

coupling the various stages in such a manner as to permit operation from a single 250-volt plate source. To get the net overall gain required, still maintaining a large feedback factor, it was necessary to have a gain without feedback of about one million. This required gain, together with the requirement of a voltage output sufficiently large to operate an oscilloscope, make direct coupling out of the question.

One possible solution is the use of the circuit shown in Fig. 11. The basis of this scheme is making the R_1i_1 voltage-drop approximately equal to the platedrop of T_1, thus obtaining the proper grid-bias for T_2. The transmission index of this coupling system is $R_2/(R_1 + R_2)$; therefore it is necessary to make R_2 large compared to R_1 in order to prevent excessive loss of gain. In order to make R_2 large compared to R_1 and at the same time make the R_1i_1 drop equal to the voltage drop across T_1, it is necessary that the negative voltage E_2 be large compared to the drop across T_1. This is generally inconvenient, particularly as it is necessary for E_2 to be regulated.

Mr. E. L. Norton of the Bell Telephone Laboratories pointed out to the writer that the resistance R_1 could be replaced by a cold-cathode glow-tube, but at first glance it appeared doubtful whether much would be gained since the minimum recommended current for these tubes is around one milliampere. For a milliampere of current through R_2 having a resistance of one-half megohm, E_2 would have to be about 500 volts.

The point which is seldom realized is that the cold-cathode glow-tube will function as a constant-voltage device for currents as small as 10 or 20 microamperes. This permits the use of a resistor for R_2 as large as 1 or 2 megohms, with an E_2 of only 30 or 40 volts.

As actually used in this amplifier design the coupling circuit has been altered as shown in Fig. 12. The drop across R_2 is made up in the cathode circuit as is conventionally done in resistance-capacitance coupled amplifiers. In fact, when the circuit is drawn in this form it is possible to view the gas tube as a blocking condenser which functions right down to direct current. The transmission index of this circuit is very nearly unity, and by a proper alteration it may be made to function over almost any desired frequency band.

Other Circuit Features

The first and second stages of the amplifier (Fig. 1) are of the cathode-control type, and have already been discussed. The selector switch in the cathode of T_8 is the gain control. The third stage, which employs T_{11}, T_{12}, and T_{13}, is a form of direct-coupled voltage amplifier. The tube T_{13} is used to obtain a low-impedance 40-volt drop in the cathode of T_{12}; the effective resistance R_{eq} between the cathode of T_{12} and ground is

$$R_{eq} = \frac{R_{43}/g}{R_{43} + 1/g} \qquad (11)$$

where g is the transconductance of T_{13}. In this manner the voltage across R_{43} can be made 40 volts with R_{eq} = 400 ohms, and using a current of only a few milliamperes. To get a similar voltage-drop using a voltage divider would of course require 100 milliamperes of current.

The output stage employing T_{15} and T_{16} is balanced in a forward-

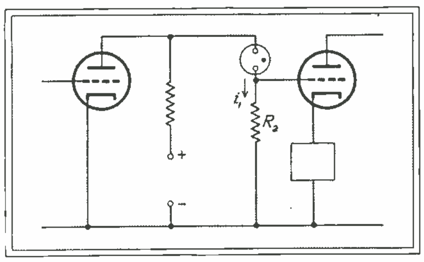

Fig. 12—By replacing the resistor, R_1 of Fig. 11 by a gaseous discharge tube, improved operation of the d-c amplifier is possible using a single voltage supply

acting manner through R_{39} and R_{40} and errors in resistance values and differences in tube constants are reduced through the degeneration caused by R_{41} and R_{42}. The resistance R_{38} is used to obtain the proper d-c bias on T_{16}. Using resistances with ±10 percent tolerance for R_{39}, R_{38}, and R_{40}, and resistances with ±2 percent tolerance for R_{36}, R_{37}, R_{41}, and R_{42} the output stage is balanced within 2 percent. The switch in the cathode circuit of T_{15} and T_{16} is used to connect an external current load in either of the two possible phases, or to connect an internal current meter into the circuit for the purpose of lining up the amplifier.

Construction

Due care in construction is absolutely essential in an amplifier of this type. It should be remembered that the maximum effective gain of the instrument is over 100 db, and that the output is a function of both a-c and d-c signals. Thus it is necessary to shield low-level leads adequately, to provide good ventilation, and to use low-temperature-coefficient resistors at points where small variations in resistance values will cause noticeable amplifier drift. There are few points in this circuit where the tolerance on resistance values need be less than ±10 percent, but there are numerous points where small variations in resistance during operation of the instrument will cause noticeable zero drift. In particular, it was found necessary to use Advance-wire resistances for the following: R_8, R_{14}, R_{16}, R_{19}, R_{21}, R_{22}, R_{24}, R_{45}, R_{46}, R_{47}, R_{48}. Tubes T_8 and T_6 were mounted on sponge-rubber cushions to eliminate microphonic effects.

In closing, the writer would like to express his sincere appreciation for the many helpful suggestions and criticisms given by Professor Truman S. Gray of M.I.T. and Mr. E. L. Norton of the Bell Telephone Laboratories, Inc.

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(1.) Black, L. J. and Scott, H. J., "A Direct-Current and Audio Frequency Amplifier", *Proc. I.R.E.* v 28, n 6, June 1940.

(2.) Goldberg, Harold, "A High Gain D-C Amplifier for Bio-electric Recording", *Electrical Engineering* v 59, n 1, Jan. 1940.

(3.) Landon, V. D., "Distribution of Amplitude with Time in Fluctuation Noise", *Proc. I.R.E.* v 29, n 2 pp 50-55, Feb. 1941.

Editor's Note—This article by Mr. Miller is an abridgement of a thesis submitted in partial fulfillment of the requirements for the degrees of Master of Science and Bachelor of Science in the Electrical Engineering Department of the Massachusetts Institute of Technology. We believe it well illustrates the point that a student need not necessarily be engaged in industry to make useful contributions in his chosen field.

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PHILIPPINE ARMY PRACTICE

Sergeant Juan Pablo of the Philippine 26th Cavalary Regiment puts up his sub-machine gun to man a telegraph key at the United States naval base of Olangapo, north of Manila

New Radiographic Unit Aids Industry

(*Continued from page* 37)

The photograph of the x-ray unit in the laboratory shows a general view of the device in the GE laboratory as it is used in actual operation for the examination of large castings. By means of the overhead crane, the tube is placed in position so as to irradiate that section of the casting which is to be examined. The x-ray film is placed in contact with the casting immediately below the target of the tube so as to make a contact print of any defects or irregularities in the composition of the casting. If welds are to be examined, the film is placed below the weld so that air pockets or other imperfections may be detected. Of course the x-ray film must be protected from light since it is also sensitive to radiations in the visible spectrum, as is practically all photographic film.

With the film appropriately affixed in position, the technicians operate the unit by remote control from a lead-lined operating room which houses the control equipment. The voltage and current are gradually brought up to the desired values and are maintained until the desired exposure has been given. The thickness and composition (density) of the material to be examined determine the voltage and current at which the radiographs are to be made as well as the time of exposure. The accompanying graph will indicate suitable exposure conditions as determined by one user of this equipment. The graph will also serve to indicate the relative place of the new x-ray unit with respect to older and lower-voltage radiographic units for industrial purposes, while for completeness some measured and calculated values of exposures with various amounts of radium are also indicated. Not only does the newer unit make possible the examination of castings and welds which are very much beyond the range of 200 kv and 400 kv units, but it greatly decreases the time of exposure required, and by so doing opens up a field of application for the radiographic examination of industrial materials.

The construction of the new unit is indicated in one of the drawings. The tube, illustrated in another photograph, is concentrically mounted in the resonance transformer, whose secondary winding is tapped at intervals to apply appropriate voltages to the sections of the tube to limit the voltage gradients between the various sections. The transformer also provides power to heat the filament. The construction of the radiographic unit can be determined from the sectioned drawing and the schematic wiring diagram, which has been somewhat simplified to indicate more clearly the function of the various parts of the circuit.

With the availability of x-ray equipment of higher voltage than has heretofore been commercially available, new avenues of industrial research and increased use of routine radiographic investigations are now possible, both of which are of extreme importance in these days of "all-out" defense activities. Units such as that illustrated are now in use by Babcock and Wilcox, Combustion Engineering, Ford Motor Co., and the General Electric Co. for the inspection of castings up to 6 inches thick, of boiler drums, pressure vessels, and of course, for weld uniformity. The American Steel Foundry Co. will shortly place one in operation, and additional units are scheduled for operation in two Navy yards and possibly also in one arsenal.

Speed of operating the flexible, convenient, portable unit, speed of making the individual exposures because of the high voltage, and the production of sharper images through the use of the focusing coil are all important factors in extending the possibilities of industrial radiographic examination. It should be pointed out, however, that the design and use of million volt equipment, such as is illustrated here has, by no means, replaced the lower voltage 100 and 200-kv units which have given excellent service in the past. Such units will continue to play an important part in the future for certain kinds of industrial radiographic work; their usefulness will be supplemented, and not supplanted, by the million-volt equipment.—B.D.

THE INDUSTRY IN REVIEW

News

✦ Metallic selenium of the absolute purity which is required in electric current rectifiers is now being refined in the United States in commercial quantities to meet the requirements of the International Telephone & Radio Manufacturing Corp. for the manufacture of IT&T selenium rectifiers. George Lewis, vice president of the International Telephone & Radio Manufacturing Corp., estimates that the requirements of ultra-refined selenium may be 10,000 pounds monthly next year compared with only 1,500 pounds monthly at present. Selenium is found chiefly in copper ore and years ago it was tossed on the slag pile. Inasmuch as the United States and Canada together normally produce more copper than the rest of the world combined, Mr. Lewis says that selenium is one metal of which a shortage seems unlikely in spite of its rapidly growing importance in the electrical industry.

✦ Dr. Jesse E. Hobson, who was named America's outstanding young electrical engineer for 1940, was recently named director of the electrical engineering department of the Illinois Institute of Technology at Chicago. Dr. Hobson is only 30 years of age and has been in charge of application engineering on electric power equipment for the Westinghouse Electric & Manufacturing Company in the northwestern district. He has taught at the California Institute of Technology, Earlham College and Armour Institute of Technology. . . . Further indications of the f-m audience came to light with the calculation of figures from manufacturers of f-m receivers, covering their actual sales of sets during August. The survey, conducted by FM Broadcasters, Inc. reports a national total increase of 47.6 percent during August.

✦ The Amplifier Company of America, New York, has recently increased its factory space at 17 West 20th Street. The enlarged facilities for manufacturing transformers, electronic equipment and similar devices was made necessary as the result of increased requirements in industry as well as for national defense program. . . . To supply a new present-day business need and one which will be increasingly important in the post-war world, Telecast Productions, Inc., has recently been organized at 30 Rockefeller Plaza, New York, according to Myron Zobel, its president. Telecast Productions is designed to render a personal service to agencies and advertisers by producing "packaged" television programs for commercial sponsors.

✦ Heintz & Kaufman announce the sale of their compressed gas condenser business to the Lapp Insulator Company, LeRoy, N. Y. This transaction involved the transfer of all tools, dies, patterns, designs, and stock of parts. Due to the pressure of national defense, all communications regarding H. & K. condensers should be directed to Lapp. Heintz & Kaufman is devoting its entire energy to the manufacture of transmitting tubes . . . J. S. Knowlson, president and chairman of the board of Stewart-Warner Corp. and since June 1940, president of RMA, was recently named OPM deputy director of priorities and chief aide to Donald M. Nelson director of priorities . . . The board of directors of the Radio Manufacturers Association elected Paul C. Galvin president of their Association on October 15 to assume the position vacated by James S. Knowlson, who recently resigned to take on OPM activities. Mr. Galvin, president of Motorola Radio, was formerly vice president of the RMA and is present chairman of the Association's Set Division and also chairman of the Association's Priorities Committee. Mr. Galvin will continue to direct the affairs of his company, the Galvin Manufacturing Corp., Chicago . . . Television played a part in broadcasting a fire prevention week film for the first time when the National Broadcasting Company went with mobile units to Newark on October 10 to put on the air a demonstration of modern methods of fire fighting. The demonstration, sponsored by the Newark Safety Council as part of its fire prevention week activities was held on the proving grounds of the Pyrene Manufacturing Company and the CO_2 Fire Equipment Company.

✦ George W. Bailey, president of the American Radio Relay League, has been appointed to the defense communications board committee XII on liaison matters for civilian defense . . . The radio division of Stevens College, Columbia, Mo. will tune in on national defense this year with programs plannned to make definite contributions to various phases of the government's emergency program, president James Madison Wood announced at the opening of the institution's 108th year. . . . Lawrence Freed of the Freed Transformer Company, 72 Spring Street. New York City, has recently announced the appointment of Mr. Stanley K. Wallace of Lutz, Fla. as representative in the States of Georgia, Florida and Alabama.

✦ I. J. Fox, a fur organization, has signed up with WOR to broadcast a concert of recorded light classics "Unbroken Melodies" on station W71NY.

✦ Dr. H. A. Jones has been named manager of sales of General Electric electronic tubes for non-radio application in industry, according to an announcement by Dr. W. R. G. Baker, manager of the radio and television department. The GE industrial tube division has been transferred from the special products section of the industrial department to the radio and television department. Dr. Jones, a native of Conshohocken, Pa. was graduated from Pennsylvania State College in 1918 with a Bachelor of Science degree, and from Princeton in 1922 with a Doctor of Philosophy degree. He joined the General Electric Company, Schenectady Works, in April 1922 as a chemist in the research laboratories and in 1928 was transferred to the commercial general section, selling special products developed in GE laboratories for use throughout the industry. The following year Dr. Jones was named manager of the special products section which in 1930 was made part of the industrial department. Dr. Jones assumed his new duties on October 1. The Keystone Carbon Company has just completed a large addition to its factory in St. Marys, Pa. . . . According to an announcement from the British Broadcasting Corporation, Mr. Lindsay Wellington has been appointed North American Director, with headquarters at 620 Fifth Avenue, New York. Mr. Wellington, one of the senior officials in the broadcasting organization in Great Britain, has already arrived in this country to take up his duties among which will be the maintenance of the BBC's relations with the Canadian Broadcasting Corporation. . . . William Kostka, publicity director of the National Broadcasting Company, has resigned effective September 26 to accept a position with the Institute of Public Relations.

✦ Mr. Earl Dietrich has resigned his position as manager of replacement tube division with the Raytheon Production Corporation. He will be succeeded by A. E. Akeroyd, formerly assistant manager of the replacement tube division of the company.

✦ The Recoton Corporation have recently moved to newer and larger quarters at 21-10 49th Avenue, Long Island City, N. Y. . . . The Southeastern District meeting of the American Institute of Electrical Engineers will be held on December 3, 4 and 5 at the St. Charles Hotel, in New Orleans, where the Louisiana Engineering Society maintains its club rooms and library. James M. Todd, general chairman, is arranging the technical program and visits to the various industrial plants in that area.

Literature

Plastic Molding. An article on plastic molding is the lead in the August, 1941 issue of *Wheelco Comments.* This is a new bulletin published by the Wheelco Instrument Company, Wheelco Building, Harrison & Peoria Streets, Chicago, Ill. Announced in this issue of *Wheelco Comments* is a data book and catalog on items of interest to users of thermocouples.

Temperature Control. A 32-page book and catalog on Wheelco instruments, published by the Wheelco Instrument Company, Harrison & Peoria Streets, Chicago, Ill. contains a listing of the various types of Wheelco instruments which are available on order. This condensed catalog describes temperature control units, portable potentiometers, recording thermometers, thermocouples, and similar equipment for the measurement of high temperatures.

Loudspeakers. Several bulletins have recently been issued by the Jensen Radio Manufacturing Company, 6601 South Laramie Avenue, Chicago, Ill. All of these describe the new Jensen Hypex loudspeakers which were described in the July issue of ELECTRONICS. One of the bulletins which is available is a reprint of that article. A condensed catalog of various types of Jensen loudspeakers is also available.

Glycerin Facts. Issued by the Glycerin Producers Association, *Glycerin Facts* is a mimeographed folder edited by George E. Leffingwell, 11 West 42nd Street, New York and describes a number of interesting uses of glycerin. In the September issue is a report on the new sulfonamide glycerin preparation for burns, a review of diversified low temperature uses of glycerin, and a variety of other items of practical value in and about industrial plants and office buildings.

Flexible Lacquer. A booklet entitled "The Blue Knight" which is an effort to provide entertainment and facts about finishes is published by the Roxalin Flexible Lacquer Company, Elizabeth, N. J. The September issue contains one of a series of articles written to give users of government specification materials a more complete understanding of the general physical properties of such lacquers.

Machine Tools. A bulletin entitled "Machine Tools" published by the National Machine Tool Builders Association of Cleveland, Ohio contains a number of articles on defense problems in its September issue. Among the articles may be mentioned those entitled 300,000 New Machine Tools for Defense, Machining Shells by the Million, and Tools and Skill Build Top of Defense. The magazine is devoted to the industry's part in the national defense program.

Test Equipment. A new 16-page catalog is available from the Precision Apparatus Company, 647 Kent Avenue, Brooklyn, N. Y. This catalog describes radio, television, electrical, industrial, and laboratory test and measuring equipment which will be of interest to the engineer as well as to the serviceman. Instruments described include voltmeters, oscillators, tube test devices, voltmeters, ammeters and similar units.

Transformer Replacement. The Thordarson Electric Manufacturing Company, 500 West Huron Street, Chicago, has recently issued a new book of transformer replacements for more than 400 receivers. This data is given in Thordarson's new edition of the Replacement Encyclopedia, No. 352-F. A special feature of the encyclopedia is the addition of electrical and physical characteristics of recommended replacement types listed in the book.

Precision Bearings. Radial, pivot and special bearings in miniature precision sizes are described in catalog No. 41 of Miniature Precision Bearings, Keene, N. H. The bearings described are offered primarily for use in fine mechanisms and precision instruments whose prices must necessarily conform to a predominant consideration of accuracy and quality throughout. Examples of the use of these bearings occur in motion picture mechanisms, laboratory test equipment, for engines, ordnance and the like, motors, generators, radio equipment, recording equipment and so on. Special bearings suitable for uses in watches have been designed.

Welding Equipment. A technical and reference bulletin, No. F-41, covering the complete line of the resistance welder heat control, synchronizers and synchronous timings, as well as its line of power and control units for welding equipment and machinery has been issued by the Weltronic Corp., 3080 East Outer Drive, Detroit. In addition to descriptions of the individual units, the bulletin also contains general technical material dealing with the application of welding control. Described in Weltronic bulletins are several new resistance welding control developments including an automatic preselective heat rise control as well as a control providing automatic regulation for heat electrodes on multiple electrode welding machines.

Neoprene. The Neoprene Notebook, 31, issued for September and October 1941 contains a number of articles illustrating the uses of Neoprene in industrial applications.

Precision Equipment. High quality precision signal generators and associated apparatus are covered in the general catalogue of the Ferris Instrument Corporation, Boonton, N. J.

Motors. The September 1941 issue of the *Bodine Motorgram* published by the Bodine Electric Company, Chicago contains an article on the use of motors in controlling traffic and a semi-technical story on reversing fractional horsepower motors.

Mycalex. A 12-page booklet entitled "Mycalex" is available from the General Electric Company. This booklet describes the general characteristics of Mycalex, its important properties, methods of molding Mycalex, the various commercial grades of this type of insulation which are available, and gives a complete full page table of the comparisons of Mycalex, porcelain, quartz and molded compounds.
Another booklet which is very well illustrated with a number of colored prints is entitled "One Plastic Avenue" and describes some of the uses of the various types of plastics made by the General Electric Company. Some of the best methods of using plastic as well as operations involved in fabrication are also outlined.

Carboloy Manual. A working manual covering the design of carbide tools, brazing, grinding, application, tool control, lubrication and so on has been brought out by the Carboloy Company, Detroit. The primary purpose of the manual (ET-133) is to assist defense industries. To speed instruction of new operators, to facilitate defense designs, brazing, heat and maintenance of carbide tools by new organizations is the purpose for which the manual has been prepared. For small manufacturers desirous of producing their own tools the manual provides complete instructions on parts brazing technique, materials and equipment. There are complete charts of recommended speeds, feeds, tool angles and depths of cuts for various material both ferrous and non-ferrous. In addition to a valuable list of new "do's and don'ts" for carbide tools, there are provided sketches of handling equipment found valuable in preventing accidental damage to tools.

Non-Ferrous Metals. A number of interesting items mainly directed to the problems of national defense are contained in the October 1941 issue of a new bulletin, *Ajax Metelectric Progress* with editorial offices at 46 Richmond Street, Philadelphia, Pa. A considerable amount of space of the first issue is devoted to the use of metals in submarines and the various methods of saving metal and properly heat-treating it.

Tubing. Precision Tools Company, 3824 Terrace Street, Philadelphia have announced the issuance of a new catalog covering precision metal shielded wire by their new process in protecting insulating wires inclosed in either seamless aluminum, copper or lead tubing, tinned or untinned.

Decimal Equivalents. The new giant Post decimal equivalent wall chart is ready for distribution for those who ask for it on their business letterhead. This Post chart is 29 in. by 39 in., is printed in large heavy type 1¼ in. high which can be easily read several feet away. It is printed in two colors, red and black, on a white background making it attractive and, more important, the color separation adds to readability. This chart giving all the equivalents from $\frac{1}{64}$ to $\frac{63}{64}$ within easy reading of your eye, should be of interest to draftsmen, designers and engineers. A copy may be obtained without obligation from the Frederick Post Company, 3650 North Avondale Avenue, Chicago.

Constant Voltage. An unusually well prepared 24-page textbook and catalog on constant voltage transformers has been prepared by the Sola Electric Company, 2525 Clybourne Avenue, Chicago. A particularly attractive feature of this catalog, especially for the engineer or designer, is the fact that a considerable portion of it is devoted to the principle of operation and the characteristics of the constant voltage transformers. Transformers having a capacity of from 30 volt amperes up to 10 kva or single phase 60-cps lines are listed. Constant voltage transformers for illumination applications are also shown.

Switches. Publication No. 4109, issued by the Delta-Star Electric Company, Chicago, describes and lists high pressure contact MK-39 switches for pole top and substation mounting. It contains catalog numbers and dimensions for group operated switches from 7.5 to 161 kv and ampere capacity up to 1,200.

Acoustic Products. A folder is available from the Dilks Acoustic Products Company, South Norwalk, Conn. describing their fluid flow speaker using a small pneumatic amplifier and suitable horn and amplifying equipment. While the exact principle of operation of the fluid flow system is not described in detail, it may be inferred from the folder that air pressure is provided to a suitable loudspeaking horn and that an air jet or valve, operated by a suitable amplifier modulates the sound issuing from the horn. Power output up to 500 acoustic watts and ample power to cover large areas are available, while the unit can be regulated to any power level.

Power Factor Determination. A chart (GES-2765) for determining power factors from line current has recently been made available by the General Electric Company of Schenectady, N. Y. This chart is in the form of a nomograph in which power factor determination can be made by means of a straight edge.

New Products

Marker

AN ACCURATE MACHINE for numbering and lettering name plates, parts, instruments, castings, gages and scales has led to the development of a new marker manufactured by the Acromark Corporation, 251 North Broad Street, Elizabeth, N. J. It produces results more quickly than with the usual hand stamping and accurately lines up the selected numerals. It is claimed that unskilled help can operate after a few hours practice from the simple instructions furnished with the machine. The Acromark Corporation has in stock dies in sizes $\frac{1}{16}$ inch, $\frac{3}{32}$ inch, $\frac{1}{8}$ inch, $\frac{5}{32}$ inch, and $\frac{3}{16}$ inch, from which orders can be filled immediately.

Aircraft Radio Equipment

A COMPLETE COMMUNICATION SYSTEM for aircraft developed by Lear Avia, Inc., Dayton, Ohio shows all evidences of reducing the weight to a minimum. The unit consists of a type T-36-AV transmitter, type RCBB receiver, loop antenna, and power supply. The transmitter has a frequency range of from 2900 to 6500 kc with two frequency crystal controls. Power output is between 20 and 30 watts. The frequency stability is plus or minus 5 cps per Mc per degree centigrade and frequency tolerance is plus or minus 0.01 percent. The complete antenna with cables and remote control unit weighs in the neighborhood of 20 pounds.

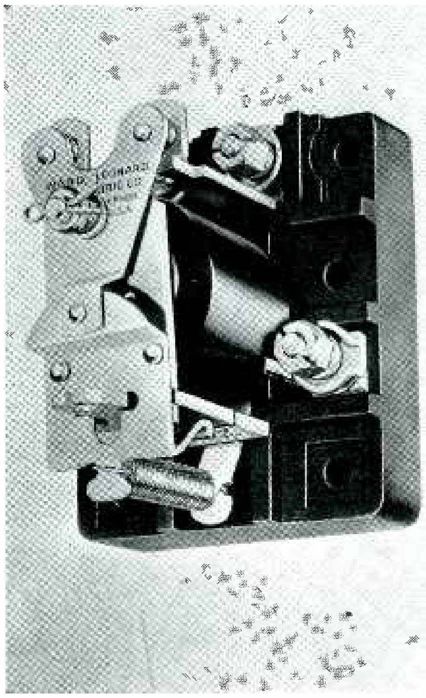
The type RCBB receiver has a frequency coverage of from 180 to 405 kc, 500 to 1200 kc and 2800 to 6700 kc in three bands, although special frequency arrangements are available to order. An output of 50 milliwatts is obtained with two microvolts per meter on the antenna or 40 microvolts per meter on the loop.

Koolohm Resistor Is New Line of Sprague

KOOLOHM RESISTORS WITH FERRULE end-type construction for fuse clip mounting and designed to meet specifications of the U. S. Navy has been announced by the Resistor Division, Sprague Specialty Company, North Adams, Mass. The units are available in 10, 20, 35, 50, 90 and 150 watt sizes in high resistance values heretofore unobtainable. They are supplied in either inductive or non inductive types, the latter having a residual inductance of very small value. An outer shell of $\frac{1}{8}$-inch thick, heat-treated pyrex glass provides high voltage insulation as well as additional protection against humidity in the new unit known as type F. Standard tolerance is 5 percent, although closer tolerances are available on special order at somewhat higher cost.

Relays

IMPROVED MIDGET MAGNETIC RELAYS manufactured by the Ward Leonard Electric Company, Mount Vernon, N. Y. are described in bulletin 106 of that company. Standard features of the relays are that they may be operated from either a-c or d-c supply, have low power consumption coils so as to be



suitable for continuous duty. The coils operate directly on standard voltages and frequencies up to 115 volts. Self-aligning, self-cleaning silver contacts are employed and all metal parts except the contacts are cadmium plated. Contact combinations are available up to and including double pole, double throw. With either two-wire or three-wire control, the magnet coil may be energized either from the main line circuit or from an independent circuit. Heavy duty circuit relays are also supplied and have the same general features as the midget magnetic relays except the greater power handling capability and the fact that they are available only with single pole, double break, normally open contacts.

Multi-Range Tester

THE SERIES 834 MULTI-RANGE tester is marketed by the Precision Apparatus Co., 647 Kent Avenue, Brooklyn, N. Y. provides a-c and d-c measurements for thirty-one ranges in an instrument no larger than a man's hand. Power output, a-c and d-c voltage, and current and resistance may be measured in addition to power ratios in db. The unit is completely self-contained, uses no external batteries or multipliers, and is provided with a 400 micro-ampere rectangular indicating meter with wire-wound multipliers accurate to within 1 percent.

Automatic Record Changer

A NEW DEVELOPMENT of the RCA Manufacturing Company, Camden, N. J. is an automatic record changer which plays phonograph records on both sides without the necessity of turning the records over. Two pickups are arranged in such a manner that when the

top side of a record has been played, the top tone arm swings clear, the motor reverses, and the bottom side of the record is played by another tone arm which has been brought into position automatically. When the under side of the record has been played, the lower tone arm swings clear and the record is deposited into a felt lined compartment, another record dropped into position, and the cycle is repeated. Simple controls permit adjustment of the mechanism for playing either one or both sides of the records. Provision is made for rejecting a record while it is being played by pushing the starting button.

Aircraft Transmitter-Receiver

A NEW FIVE-WATT PORTABLE transmitter-receiver for aircraft, Model PTR-5 has just been made available for delivery by the Jefferson-Travis Radio Mfg. Corp., 374 Second Avenue, New York. It is claimed that no installation work is involved except to install an antenna and to connect this to the unit. The weight of the entire unit, including the receiver, transmitter, dynamotor, power supply, and all batteries, is 31 pounds.

Limit Bridge

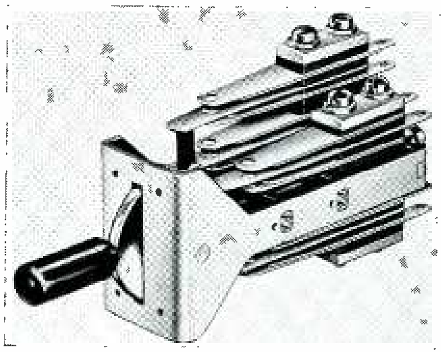
THE SHALLCROSS MANUFACTURING COMPANY, 10 Jackson Avenue, Collingdale, Pa. has designed and is now offering a highly specialized limit bridge for rapid and accurate testing of multi-tapped resistors with varying unit values. This special instrument is known as the No. 618 percent limit bridge. It has binding posts for connecting a galvanometer and battery, while special mercury wells provide a method for attaching a multi-tapped resistor. A rotary switch selects the unit of the multi-tapped resistor to be tested and at the same time places the appropriate standards in the circuits. A suitable key switch tests the unit for high and low power.

Cutting Tool

To MORE RAPIDLY MEET THE DEMAND for carbide tipped cutting tools, the Tungsten Carbide Tool Company, subsibiary of the Michigan Tool Company, Detroit, announces a complete line of standard stock tools comprising six styles and 46 stock sizes. All tools have diamond ground edges and are ready for immediate use. Types suitable for cast iron, non-ferrous metals and for steel are included in the line. Tools are designed to cover a large majority of all turning, boring and facing requirements and may be readily converted by the user by a simple grinding operation.

Lever Switch

A NEW TYPE OF LEVER SWITCH for electrical control purposes has recently been announced by Donald T. Mossman, Inc., 6031 Northwest Highway, Chicago. The No. 4101 lever switch is constructed to meet the needs for a heavy duty, multiple contact, positive action lever type of switch. The design affords flexibility and contact ar-



rangement in the locking or non-locking action. Consequently lever switches are available in an almost unlimited series of combinations of contact assemblies which may be built up to suit any specific requirements. Contact assemblies are limited to nine contact springs per pile-up, eighteen springs for position, or thirty-six springs per switch. Standard contacts $\frac{3}{16}$ inch in diameter of fine silver have a non-inductive rating of 10 amperes at 110 volts ac, whereas extra heavy duty contacts have a rating of double this current. The breakdown rating between ground and spring is 2,000 volts, alternating current.

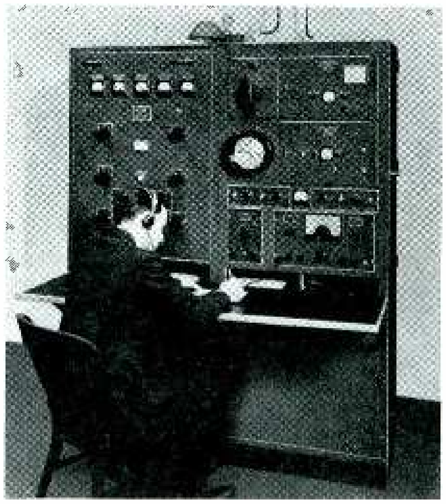
Smallest Transformers

AS SPECIALISTS in reducing the size of transformers for a given job, United Transformer Corporation, 150 Varick Street, New York City are now in quantity production on a new group of transformer components weighing only 3/10 oz. These coupling units have almost 10,000 turns, and an inductance of approximately 70 henries and have dimensions of $\frac{7}{16}$ x $\frac{7}{16}$ x $\frac{3}{4}$ inches. The units are in active use for hearing aid, aircraft and similar applications.

Marine Equipment

A NEW TYPE OF COMMERCIAL MARINE radio equipment of revolutionary design that can be installed on board ships in one fifth the time usually required has been developed in connection with the emergency shipbuilding program, by the International Telephone & Telegraph Corporation, 67 Broad Street, New York. Among the vessels on which it is to be installed are the 312 Liberty type ships now being built by the Maritime Commission. The new radio unit combines in a single cabinet radio equipment which ordinarily requires as many as twelve separate units and eliminates the intricate system of interconnecting wiring in the radio cabin. It includes all of the radio apparatus necessary for safety and communication purposes.

The equipment was designed by the



Federal Telegraph unit of the International Telephone & Radio Manufacturing Corporation to meet the speed requirements of the emergency shipbuilding program in making it possible to do at the factory practically all wiring and other work usually done on the ships at the building yards. The unit is practically ready to plug in at the power supply and the radio antenna system when it arrives at the ship. This not only results in a great saving of time but releases many hours of highly skilled labor for other national defense work since the installation job is comparatively simple. The combining of all apparatus in a single cabinet also means an important saving in space on ships.

The fact that all installations are standard is expected to save time in the training of new operators. Each switch and each button is in the same place on every ship carrying the equipment. The time-saving advantages and the great simplicity of design and operation combined in this new equipment are regarded by ship radio engineers as one more of the many permanent technical contributions made possible by the national defense program.

If this or other advertising does not supply the information concerning products or services wanted, please write:
ELECTRONICS,
New York City

Phase Shifters

(*Continued from page* 49)

tween e and $0.707e$ which is not serious for many applications.

The circuit of Fig. 8 would be independent of frequency within reasonably wide limits were it not for the fact that the 90-degree shifter is frequency sensitive. Obtaining the initial 90-degree rotation as shown in Fig. 10 makes this phase shifter essentially independent of frequency. The resistance R is made very much greater than the reactance of C throughout the desired frequency range. The voltage across C will then be very close to 90 degrees behind the voltage applied to the R-C combination. The magnitude of the voltage across C will be very small, however, because of the size of R. An amplifier will make up for this loss in voltage (or the voltage to the other potentiometer may be attenuated) so that the potentiometer voltages may be equal. This amplifier must have its gain adjusted for every frequency due to the change in reactance of C. This can be done automatically with an automatic volume control circuit of conventional type.

Author's note: In the course of the investigation of these phase shifters, the fresh viewpoint of students, as usual, has been fruitful. The basic idea of the 360-degree shifter was suggested originally by Mr. Lee Coe and the frequency-independent 90-degree shifter of Fig. 10 by Mr. William H. Huggins, both students in Electrical Engineering at Oregon State College.

• • •

SCHOOLING U. S. ARMY IN COMMUNICATIONS

A radio equipped command car at Fort Monmouth, N. J., shown in communication with headquarters. This car has equipment for both key and voice rad o communication

WANTED

AUDIO AND ELECTRONIC ENGINEER

Permanent position and opportunity for development and original work with established company doing national business in audio specialty field. One Senior engineer required. Salary $4,000 to $6,000 per year with bonus and advancement opportunities. Requirements: Electrical engineering degree and considerable audio and electronic experience in design, development. One Junior engineer, salary $200 to $300 monthly with bonus. Must be graduate electrical engineer with some experience in electronics.

State qualifications: academic, graduate, employment, experience in design, development, and production and any patents in audio and electronic fields. Also give any experience in production and supervision, acoustics, speakers and reproducers, tool and die design, plastics, etc. All replies strictly confidential. Interviews by appointment only. Employment to begin January 1st.

P-300, Electronics

330 West 42nd St., New York City

LEGAL NOTICE

STATEMENT OF THE OWNERSHIP, MANAGEMENT, CIRCULATION, ETC., REQUIRED BY THE ACTS OF CONGRESS OF AUGUST 24, 1912, AND MARCH 3, 1933

Of Electronics, published monthly at Albany, N. Y., for October 1, 1941.

State of New York } ss.
County of New York }

Before me, a Notary Public in and for the State and county aforesaid, personally appeared D. C. McGraw, who, having been duly sworn according to law, deposes and says that he is the Secretary of the McGraw-Hill Publishing Company, Inc., publishers of Electronics, and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management (and if a daily paper, the circulation), etc., of the aforesaid publication for the date shown in the above caption, required by the Act of August 24, 1912, as amended by the Act of March 3, 1933, embodied in section 537, Postal Laws and Regulations, printed on the reverse of this form, to wit:

1. That the names and addresses of the publisher, editor, managing editor, and business managers are: Publisher, McGraw-Hill Publishing Company, Inc., 330 West 42nd St., N. Y. C. Editor, Keith Henney, 330 West 42nd St., N. Y. C. Acting Managing Editor, Beverly Dudley (Donald G. Fink on leave), 330 West 42nd St., N. Y. C. Business Manager, H. W. Mateer, 330 West 42nd St., N. Y. C.

2. That the owner is: (If owned by a corporation, its name and address must be stated and also immediately thereunder the names and addresses of stockholders owning or holding one per cent or more of total amount of stock. If not owned by a corporation, the names and addresses of the individual owners must be given. If owned by a firm, company, or other unincorporated concern, its name and address, as well as those of each individual member, must be given.) McGraw-Hill Publishing Company, Inc., 330 West 42nd St., N. Y. C. Stockholders of which are: James H. McGraw, 330 West 42nd St., N. Y. C. James H. McGraw, Jr., 330 West 42nd St., N. Y. C. James H. McGraw, James H. McGraw, Jr., and Curtis W. McGraw, Trustees for: Harold W. McGraw, James H. McGraw, Jr., Donald C. McGraw, Curtis W. McGraw, 330 West 42nd St., N. Y. C. Edwin S. Wilsey and Curtis W. McGraw, Trustees for James H. McGraw, 3rd, Madison, N. J. Curtis W. McGraw, 330 West 42nd St., N. Y. C. Donald C. McGraw, 330 West 42nd St., N. Y. C. Anne Hugus Britton, 330 West 42nd St., N. Y. C. Mildred W. McGraw, Madison, N. J. Grace W. Mehren, 73 No. Country Club Drive, Phoenix, Ariz. J. Malcolm Muir & Guaranty Trust Co. of New York, Trustees for Lida Kelly Muir, 140 Broadway, N. Y. C.

3. That the known bondholders, mortgagees, and other security holders owning or holding 1 per cent or more of total amount of bonds, mortgages, or other securities are: (If there are none, so state.) None.

4. That the two paragraphs next above, giving the names of the owners, stockholders, and security holders, if any, contain not only the list of stockholders and security holders as they appear upon the books of the company but also, in cases where the stockholder or security holder appears upon the books of the company as trustee or in any other fiduciary relation, the name of the person or corporation for whom such trustee is acting, is given; also that the said two paragraphs contain statements embracing affiant's full knowledge and belief as to the circumstances and conditions under which stockholders and security holders who do not appear upon the books of the company as trustees, hold stock and securities in a capacity other than that of a bona fide owner; and this affiant has no reason to believe that any other person, association, or corporation has any interest direct or indirect in the said stock, bonds, or other securities than as so stated by him.

5. That the average number of copies of each issue of this publication sold or distributed, through the mails or otherwise, to paid subscribers during the twelve months preceding the date shown above is. (This information is required from daily publications only.)

McGRAW-HILL PUBLISHING COMPANY, INC.
D. C. McGRAW, Secretary.

Sworn to and subscribed before me this 29th day of September, 1941.

[SEAL] H. E. BEIRNE.

Notary Public, Nassau County. Clk's No. 93, N. Y. Clk's No. 974, Reg. No. 2-B-609.
(My commission expires March 30, 1942)

SEARCHLIGHT SECTION

(Classified Advertising)

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POSITIONS VACANT

EXPERIENCED ELECTRICAL ENGINEER thoroughly conversant with all types of transformers and reactors used by the Army, Navy and Air Corps desired by Midwestern transformer manufacturer. Excellent opportunity. P-293, Electronics, 520 N. Michigan Ave., Chicago, Ill.

ELECTRONIC ENGINEER young man under 35 as research and design engineer with Vacuum Tube hearing aid company, must be graduated EE with some electronic and acoustical experience desirable. Unusual opportunity to progress with company. Compensation secondary to proveable ability. Give age, complete education, experience and telephone number. Present staff know of this opening. Apply in complete confidence. P-296, Electronics 330 W. 42nd St., New York, N. Y.

LARGE NEW ENGLAND Radio Tube Manufacturer has openings for electrical engineers and physicists to work on production problems. Experience preferred but not essential. U. S. citizenship required. Excellent opportunity. P-297, Electronics, 330 W. 42nd St., New York, N. Y.

Wanted

Audio Transformer Designer

Should have education and experience necessary to establish basic designs and supervise production engineering on both "voice" and "control" applications. Work will be on interesting National Defense projects and expanded commercial products after the present emergency is over. Write giving information covering education and experience. Salary arranged. All communications will be treated confidentially.

RAYTHEON MANUFACTURING CO.

190 Willow St. Waltham, Mass.

We Want Electronic Engineers and Radio Technicians

Here is an opportunity to serve your country and travel to any point in the United States or possessions at liberal salary and all expenses paid. Employment guaranteed for minimum of one year or longer. Electronic engineers must be graduate electrical engineers with major in Electronics or equal—age 24-30. Radio technicians must be high school graduates with a minimum of four years experience—age 20-30. Single men preferred.

EMPLOYMENT AT ONCE

Write air mail, giving full personal history, personal and experience references, and including snapshot, if possible. Arrangements will be made for personal interview. Address: Chief Engineer, Minneapolis-Honeywell Regulator Company, Minneapolis, Minnesota.

POSITIONS VACANT

MECHANICAL ENGINEER WANTED. Experienced product designer having technical training. Work will be establishing design and supervision of production engineering for mechanical parts and mountings for interesting national defense radio and electrical products. This work will develop into a line of commercial electronics products after the present emergency is over. Write giving information covering education and experience. Salary arranged. All communications will be treated confidentially. Raytheon Manufacturing Company, 190 Willow Street, Waltham, Massachusetts.

RADIO ENGINEER WANTED. Interesting work on a national defense project for a technically trained man having experience in the design and operation of ultra high frequency radio apparatus. Write giving information covering education and experience. Salary arranged. All communications will be treated confidentially. Raytheon Manufacturing Company, 190 Willow Street, Waltham, Massachusetts.

POSITIONS WANTED

COMMUNICATION ENGINEER: Wide experience including design of radio and telephone circuits and production test equipment; test of military aircraft radio; quality inspection control; supervision installation, test, inspection of telephone exchange equipment, industrial applications thermionic tubes. Present position supervising Inspector Signal Corps material. Salary expected $225 month. PW-298, Electronics, 520 N. Michigan Ave., Chicago, Ill.

ELECTRICAL ENGINEER AND PHYSICIST excellent background, highly experienced and efficient, many patents, development, design, research wants adequate responsible position. PW-299, Electronics, 330 W. 42nd St., New York, N. Y.

FOR SALE

COMPLETE PROFESSIONAL Recording Equipment, well engineered amplifier, allied Tables, RCA, Amperite microphone, Miller Tuners, Jensen 15". Reasonable $1,500. FS-292, Electronics, 330 W. 42nd St., New York, N. Y.

COMPLETE RECORDING STUDIO Equipment for sale, professional quality, slightly used. Three 17¼" turntables, five channel mixer. Excellent purchase for educational institution or small radio station. FS-295, Electronics, 330 W. 42nd St., New York, N. Y.

HIGH GRADE USED

ELECTRON TUBE MACHINERY

Huge Stock of Every Type and Variety

KAHLE ENGINEERING CORPORATION

Specialists in Equipment for the manufacture of Neon Tubes, Radio Tubes, Incandescent Lamps, Photo Cells, X-ray Tubes, etc.

900 DeMott St., North Bergen, N. J.

DEPENDABLE

Used

ELECTRONIC TUBE EQUIPMENT

Complete line of used equipment for the manufacture of Radio Tubes, Neon Tubes, Incandescent Lamps, etc. Write for Bulletin showing 25 to 75% savings.

CALLITE TUNGSTEN CORPORATION

formerly Eisler Electric Corp.

534 39th Street, Union City, N. J.

FOR SALE—TRANSMITTER

Used as 500 watt experimental Television Transmission—Can be easily modified as 1000 watt broadcast transmitter (output now uses 4—833 tubes). Excellent condition. Complete with power supply tubes, meters, etc. Also other equipment—four Baird (British) Electron Multipliers, Cathode Ray Tubes—Transformers, etc. Offers to

FS-294, Electronics

330 West 42nd St., New York City

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