GENERAL ELECTRIC REVIEW

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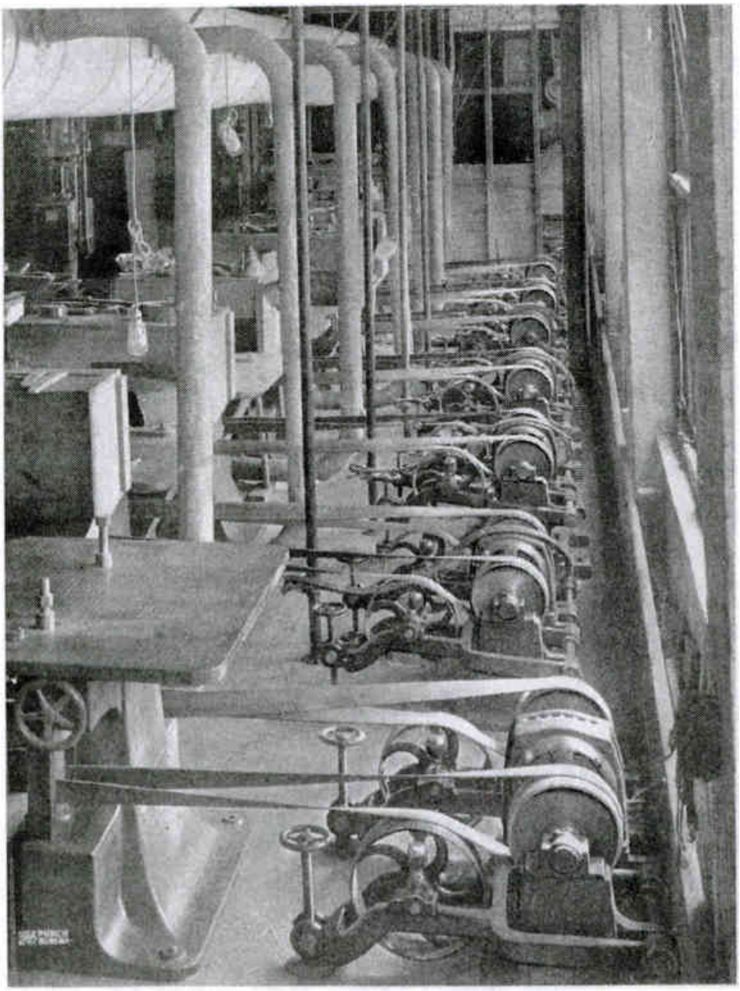

Group of Two-Spindle Shapers Driven by 5 H.P. Induction Motors

Heywood Bros. & Wakefield Company, Gardner, Mass.

(See page 251)

World Radio History

GENERAL ELECTRIC REVIEW

THE 1200 VOLT RAILROAD

The transportation facilities of a country are an accurate criterion of that country's condition; no form of public improvement is more far-reaching in its effects than are the improvements in these facilities. For this reason, the use of electricity for transportation is probably of more importance to the public at large than any other application of this form of energy.

In the building of an electric road or the electrification of a steam road, one of the first matters that requires consideration is the choice of the system to be employed. At the present time this choice is practically confined to the 600 volt and the 1200 volt (or higher) systems with the direct current, and the single-phase (15 or 25 cycle) and the three-phase systems with the alternating current. In any case any one of these would be entirely operative, and each has its specific advantages. The selection is therefore a matter calling for the highest engineering ability; the ability to weigh the several advantages and disadvantages of the different systems, considered in relation to the conditions of the specific case in mind, and to select that one which, all things considered, best meets the requirements. For, while data from existing roads are not lacking, the local conditions under which the roads operate have so important a bearing upon the matter as to largely modify any conclusions that might be drawn from such information. Thus, it is difficult or impossible to compare the different systems by means of the data taken from different roads, the local conditions always being dissimilar.

On account of the increasing importance of the subject, authoritative articles that help to determine which of the various systems is best adapted to particular fields are of much interest.

In the REVIEW for June, 1909, an article by Mr. G. H. Hill was published, comparing the 1200 volt direct and the single-phase alternating current systems, and showing the advantages of the former for a certain class of interurban service. At that time, it was pointed out that, whereas the chief claim of the single-phase system for recognition is the low first cost of the distributing system, this saving is obtained at the expense of much complication of the motor car equipments, oil switches being necessary to control the circuits, a heavy transformer to supply the low potential, and an additional winding being required on the motors to make commutation possible. Both the first cost and the maintenance charges for these equipments are therefore considerably greater than the corresponding items for the 1200 volt system. Again, on account of inductive drop in track and line and the starting characteristics of the single-phase alternating current motor, a much higher potential is demanded than in the case of the 1200 volt system, for the same operating results.

Mr. Hill summarizes the situation as follows: "All things considered, the average interurban road will cost less to install, will be operated for a less amount, and will give a more reliable and satisfactory service when equipped with 1200 volts direct current than it will with an alternating current system of 6600 or 11000 volts."

In the present issue of the REVIEW we print a paper on The 1200 Volt Railroad, which was read by Mr. Charles E. Eveleth before the Philadelphia section of the A.I.E.E., and which compares the 1200 and 600 volt direct current systems. Mr. Eveleth indicates clearly the service for which the 1200 volt system is particularly adapted. He shows that the adoption of this system not only largely decreases the first cost, through a material saving in sub-stations and secondary distribution conductors, but also greatly reduces the operating expenses, as it calls for fewer operators, and also decreases the power

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consumption, the improvement in load factor effecting a corresponding increase in efficiency.

Another important consideration is the fact that the motors may be run two in series on the 1200 volt trolleys, and two in multiple on 600 volt trolleys. Thus the speed on the low voltage can be equal to that on the high, and the economy resulting from 1200 volt operation may be secured without in any way interfering with existing 600 volt systems in cities or elsewhere, over which it may be desired to run the cars.

The many advantages of the 1200 volt system, and the fact that despite its recent origin it has been selected by over a dozen different roads that are in operation or under construction, indicate that its adoption will be wide spread. Even in Europe, which has generally been considered the stronghold of the single-phase system, there are nearly as many direct current roads operating at 900 volts and over, as there are single-phase systems.

ELECTRIC HAULAGE IN COAL MINES

Although electric haulage for coal mines was introduced as long ago as 1887, its employment to any considerable extent is a matter of comparatively recent date. Until within the past few years, coal mine operators looked askance at its introduction, fearing that it would prove a fruitful source of accidents by causing explosions and by injuring men and horses or mules that in the confined spaces might come in contact with the live wires.

As the exigencies of the industry increased, however, the hauls becoming longer and the demands for an ever greater output more and more difficult to meet, the necessity for improved methods was realized, and electricity was gradually introduced; until today its pre-eminence for both power and transportation purposes is well recognized. In fact, as soon as it became evident that the employment of electricity was not accompanied by risk of accident, its rapid adoption was inevitable, on account of its obvious advantages.

In his article entitled Electricity in the Mines of the Davis Coal and Coke Company in this issue of the REVIEW, Mr. R. Neil Williams shows that these advantages are both numerous and important. He states that with the exception of gravity, which, under certain conditions, is, of course, the cheapest power, but the use of which is circumscribed by many limitations, electricity as a motive power is without a competitor.

The high mortality among horses and mules in mining work militates seriously against their employment; the electric mining locomotive, on the contrary, is exceedingly durable —the first one that was manufactured in the United States being still in active daily operation. Again, the mining locomotive is capable of much longer hauls at higher rates of speed, the result being that, on an average, one of these will accomplish as much work as 15 horses, and in so doing will require the services of one man instead of 15 boys.

In his article Mr. Williams describes the various applications of electricity to the different processes of the mine and plant. Several electrical systems are used and the reasons for their adoption are explained.

The development of the mining locomotive has called for much thought on the part of designing engineers and today there are many different types, suitable for every variety of service and for use on a large number of different gauges, varying from 17 to 56½ inches. Some of these are simply intended for direct haulage, while others are in addition provided with hoisting drums for drawing coal cars from the rooms. The REVIEW for August, 1908, contains an article by Mr. C. W. Larson describing a number of different types.

THE SINGLE-PHASE INDUCTION MOTOR

Part II

By Profs. J. H. Morecroft and M. Arendt

Columbia University

Characteristic Curves

The preceding torque equation, while valuable in that it indicates the general characteristics of single-phase induction motors, is not readily applied to the detail study of any specific machine. The working curves are most accurately determined by actual test. They may, however, be derived with moderate accuracy by means of a circle diagram somewhat similar to that utilized in connection with the study of the polyphase motor.

The particular diagram described herein (Fig. 7) is that developed by A. S. McAllister, and its construction is as follows:*

Let the vertical line *OE* (Fig. 7) represent the line voltage. Draw at their proper phase positions and scale values the no-load as well as the locked currents *OM* and *OF* respectively.

MN and *IF* represent the energy components of the corresponding currents and are therefore directly proportional to the respective inputs. Through *M* draw a line *MK* perpendicular to *OE*, join *M* and *F*; draw also a line perpendicular to the middle of *MF* intersecting *MK* at *X*. With *X* as a center and either *XM* or *XF* as a radius describe the circular arc *MPF*, this being the locus of the primary current. The distance *IG* represents the added primary or stator loss existing with the rotor locked, its length = (added primary copper loss + total locked watts) × *HF*. Draw the line *GM*. With this construction completed the performance of the motor may be determined by inspection.

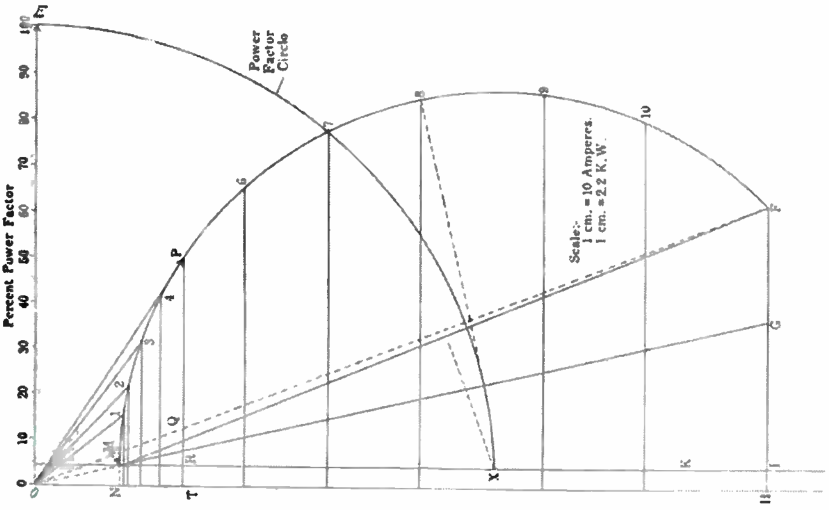

Fig. 7. McAllister Circle Diagram for a 10 H.P. Single-Phase Induction Motor

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*"Alternating Current Motors." A. S. McAllister, pages 113-119. McGraw Co., New York, 1909.

For example, the factors determining the performance of the motor with a current P are as follows:

OP to scale represents the primary current.
$\cos POE$ is the power factor of current OP.
PT represents the watts input at current OP.
MN represents the watts input at no load.
TQ represents the watts loss at current OP.
TR represents the total primary loss at current OP.
QR represents the added secondary copper loss.
QP represents the watts output at current OP.
$QP \div PT$ represents the efficiency of the motor at current OP.
$100(PQ \div PR)^{\frac{1}{2}}$ represents the per cent. slip.
$7.05\ QP \div$ r.p.m. represents the torque at current OP.

The field set up through the motion of the rotor varies as the speed ω, consequently the torque T for a given rotor input W' will be proportional to the product of $\omega\ W'$, or

$$T = K_1 \omega W'. \qquad (19)$$

The torque, however, is also proportional to the secondary output W'' divided by the speed ω, or

$$T = K_2(W'' \div \omega)$$

whence

$$\omega = K(W'' \div W')^{\frac{1}{2}}. \qquad (20)$$

The secondary input, from the circle diagram, is proportional to PR; the output is similarly represented by PQ; consequently $(PQ \div PR)^{\frac{1}{2}}$ corresponds to the rotor speed as above stated.

The diagram shown in Fig. 7 has been applied to the determination of the characteristic curves of a standard 220 volt, 60 cycle, 4 pole, 10 horsepower single-phase induction motor. The fundamental data employed in the construction of this diagram were derived by test, and are as follows: Stator resistance .304 ohm, current with motor running free 19 amperes, corresponding input 1 kw., and power factor 24 per cent. The current with rotor at standstill is 170 amperes, input 13.4 kw., power factor 36 per cent. Line potential in both instances is 220 volts.

The values derived from the diagram are given in Table I and presented in the form of curves in Fig. 8.

Comparison of these characteristic curves of the single-phase induction motor with those of the standard polyphase induction motor brings out the fact that the former has zero torque, not only at synchronous speed but also at standstill, whereas the latter has a starting torque in excess of that developed at rated load.

Table II gives characteristics of operation attained by standard single-phase induction motors.

Comparison of the values in this table with the characteristics of polyphase induction motors shows that in general the power factor, efficiency and pull-out torque are higher for polyphase than for single-phase motors, while the speed regulation of the single-phase machine is better. This latter feature of the single-phase induction motor is accounted for by Dr. C. P. Steinmetz as follows.*

> "Since in the single-phase motor one primary and a multiplicity of secondary circuits exist, all secondary circuits are to be considered as corresponding to the same primary circuit. Thus the joint impedance of all secondary circuits must be used as the secondary impedance, at least at or near synchronous speed. Thus, if the armature has a quarter-phase winding of impedance Z_1 per circuit, the resultant secondary impedance is $\frac{Z_1}{2}$; if it contains a three-phase winding of impedance Z_1 per circuit, the resultant secondary impedance is $\frac{Z_1}{3}$. In consequence thereof, the resultant impedance of a single-phase motor is less in comparison with the primary impedance than in the polyphase motor. Since the drop in speed under load depends upon

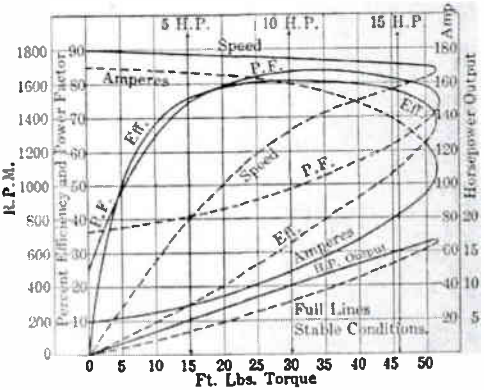

Fig. 8. Characteristic Curves of 4 Pole, 10 H.P., 220 Volt, 60 Cycle, Single-Phase Induction Motor

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*Elements of Electrical Engineering, page 284.

the secondary resistance, the decrease in speed in the case of the single-phase motor is generally less than that in the polyphase motor."

Methods of Starting

As already shown, the simple single-phase induction motor cannot exert any starting torque. In practice, however, (except in the smallest sizes which may be started by hand), the conditions of service which this motor is to meet require a starting torque as high as 150 per cent. of the rated value; consequently some device to produce this feature must be connected with or incorporated into the machine. The methods of accomplishing this result may be grouped into two general classes. The first is technically known as *phase-splitting* and the second as the *repulsion-motor* method.

Split-phase Starting

Two-phase currents may be obtained on a single-phase circuit by dividing it into two branches, one of which is inductive and the other non-inductive. If supplied with two-phase currents, even though these be less than 90 degrees apart, an induction motor is self-starting; thus when synchronous speed is approximated, the phase-splitting device may be cut out and the machine will continue to operate. There are many other ways to obtain such two-phase currents. The two parts of the circuit may be in series, one being shunted by inductance or capacity (Fig. 9). They may also be put into inductive relation to each other to produce a phase difference.*

Motors employing the above starting methods are provided with two stator windings, a *working* winding and a *starting* winding. The two windings are displaced from each other by about ninety electrical degrees, just as in the ordinary two-phase motor. The working winding, however, is of more

TABLE I

CHARACTERISTICS OF A 220-VOLT, 60-CYCLE, 10 HORSE-POWER, SINGLE-PHASE INDUCTION MOTOR

Point	Amp.	P.F.	Kw. Input	H.P. Output	Eff.	R.P.M.	Pounds Torque
M	19	24	1	0	0	1800	0
1	25	65	3.56	3.4	.70	1782	10
2	30	75	4.95	5.05	.76	1772	15
3	40	81	7.13	7.65	.80	1760	23
P	50	83	9.24	10	.81	1745	30
5	60	85	11.2	12	.80	1735	36
6	80	81	14.2	14.75	.78	1715	45
7	100	78	17.2	16.5	.72	1690	51
8	119	70	18.7	16	.64	1640	51
9	140	61	18.8	13.4	.52	1550	45.5
10	155	51	17.6	8.8	.37.5	1400	33.0
F	170	36	13.4	0	0	0	0

TABLE II

DATA OF STANDARD SINGLE-PHASE INDUCTION MOTORS—110 TO 440 VOLTS

H.P.	Poles	Per cent Slip	Pull-out Torque*	PER CENT POWER FACTOR LOAD				PER CENT EFFICIENCY LOAD			
				½	¾	Rtd	1¼	½	¾	Rtd	1¼
½	4	6	1.5	46	58	66	68	53	60	63	60
1	4	4	1.6	55	69	73	75	60	65	68	62
2	4	2.5	1.8	56	65	77	76	71	75	78	77
5	4	2.5	1.8	78	83	86	86	71	76	77	76
10	4	2.5	1.8	75	81	84	83	75	79	80	79
20	6	2	1.9	78	80	86	87	85	88	86	85
30	8	2	1.9	68	80	85	84	77	84	83	82
50	4	2.3	2.0	91	91	93	91	82	84	86	86

*Pull-out torque in terms of rated load torque.

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*U.S. Patent No. 401,520, April 16, 1889, to Nickola Tesla.

turns, being spread over a larger surface, and is of heavier wire than the starting winding, because it remains in circuit as long as the motor operates, whereas the starting coils are only in use momentarily.

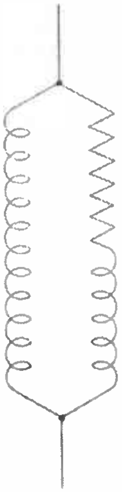

Fig. 9. Split-Phase Circuit, using Resistance and Inductance

The method illustrated in Fig. 10 has been developed by Brown, Boveri and Co. of Baden, Switzerland. At starting, the two windings are placed in series across the supply lines, the starting winding *S* being shunted by the condenser. The current consequently lags more in that winding, the difference in phase between the currents in *R* and S being sufficient to set up an elliptically formed rotating field. The starting winding and its condenser are cut out and the working winding placed directly across the line by means of the double-throw switch *T*, when the motor has approximately attained synchronous speed. This method is slightly modified when machines of over 5 h.p. capacity are to be started. The two windings in such instances are placed in parallel, as shown in Fig. 11. By this means the working coil circuit is not broken and the flash occurring upon cutting out the auxiliary winding is eliminated.

An excellent method for starting single-phase motors has been developed by the General Electric Company under patents granted to Dr. C. P. Steinmetz, the connections for which are shown in Fig. 12.[*] Two terminals of the stator winding, which is substantially of standard three-phase construction, are connected directly to the supply lines. The third terminal is also connected to either one of the mains through an auto-transformer, the order depending upon the direction of rotation desired. The ends of this compensator are placed across a condenser. This combination is technically known as a *condenser-compensator*, and is employed because a condenser of given volt-ampere capacity is more economically constructed for high than for low voltage. The starting winding can be cut out by opening the switch at *S* after the motor is up to speed. It may, however, be advantageous to keep the starting coil in circuit, if of sufficient current capacity for continuous service, because the increased power factor at light loads thus obtained more than compensates for the losses occuring in the transformer.

The use of external phase-splitting apparatus may, however, be dispensed with if the two stator windings are arranged to have different time constants. This is accomplished by having the auxiliary winding of larger self-inductance than the main coil. Heyland devised a very successful motor of this type, utilizing the scheme suggested in the Tesla patent cited above. The working winding *P* is distributed in a series of semi-closed slots. The starting coils *S* are short-circuited upon themselves and placed in closed ducts, the result being a highly inductive secondary circuit, the general arrangement of which is

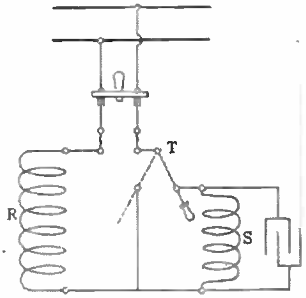

Fig. 10. Connections for Starting Small Single-Phase Induction Motors

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[*] U.S. Patent Nos. 602,920 and 602,921, April 26, 1898.

illustrated in Fig. 13. The current induced in the secondary winding lags almost 90 degrees with respect to the primary current, producing a field component similar to that caused by the second phase of a two-phase current. The starting torque thus produced is large, though the power factor of the machine is necessarily low, and therefore the starting coil should be cut out as soon as the machine has come up to speed. *

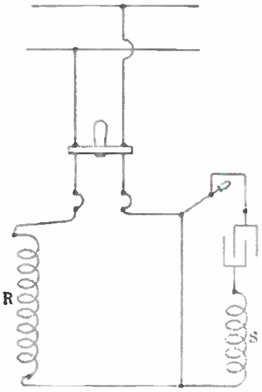

Fig. 11. Phase Splitting Method Devised by Brown, Boveri & Co. for Use with Large Motors

The rotor windings employed in connection with any or all of the preceding methods for starting may be of the standard squirrel-cage or slip-ring type.

Repulsion Motor Starting

A very interesting type of self-starting single-phase induction motor is one that is provided with an armature of the ordinary direct current drum type, having a disk commutator with radial bars.† The brushes bearing upon the commutator are displaced about 45 degrees from the corresponding neutral zones and short-circuited upon each other. The stator winding is connected to the supply lines, and at starting the machine speeds up as a repulsion motor. In the annular space between the armature core and the shaft are two governor weights *w* (Fig. 14) which are forced outward, further and further, by centrifugal force as the machine accelerates. When synchronous speed is nearly attained, the force acting upon these weights is sufficient to push the heavy copper ring *R*, against the action of spring *S*, into contact with the inner cylindrical surface of the commutator

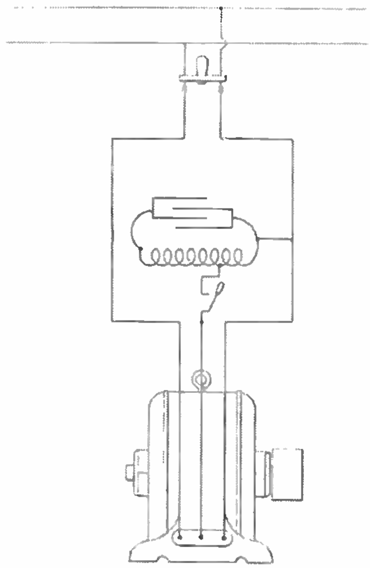

Fig. 12. General Electric Company Condenser Compensator Method of Starting Single-Phase Motors

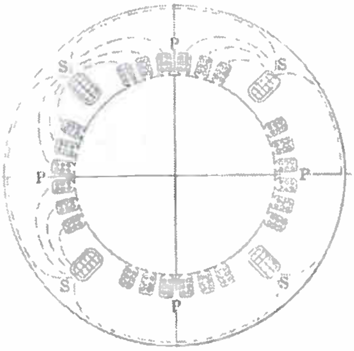

Fig. 13. Arrangement of Working and Auxiliary Stator Coils, Heyland Self Starting Single-Phase Induction Motor

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*Electrical Engineer, Vol. XXXVI, page 308. London, 1898.

†U. S. Patent No. 543 836, Dec. 4, 1894

bars *G*, thus completely short-circuiting the armature winding. Simultaneously with this action the sleeve *P* is forced to the left sufficiently to lift the brushes *B* from the commutator. This series of automatic actions transforms the machine from a repulsion to a single-phase induction motor, having in the latter form what is substantially a squirrel-cage armature winding. The starting torque thus obtained may be readily adjusted to about twice the normal value, without an excessive current being required.

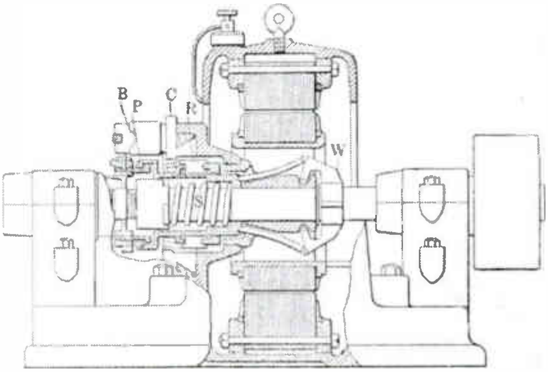

Fig. 14. General Arrangement of Wagner Motor, Showing Automatic Short Circuiting Devices

A very interesting feature of this motor, and one equally pertinent to repulsion motors, is the relation between torque and thickness of rotor brushes. The series of curves shown in Fig. 15 were determined from the tests of a 5 h.p., 220 volt Wagner motor. Curve *A* shows the speed torque relation on accelerating with normal brush thickness, this being substantially that of a commutator bar. Curve *B* represents the relations existing with a brush of twice normal thickness, etc. It is apparent from these curves that the normal thickness of brush gives the highest starting and synchronous speed torques. Further study of Fig. 15 indicates that use of a brush thinner than normal might tend to produce starting and synchronous speed torques of greater value than occur with normal brush thickness. Practical questions, however, as regard mechanical strength limit the reduction of brush thickness.

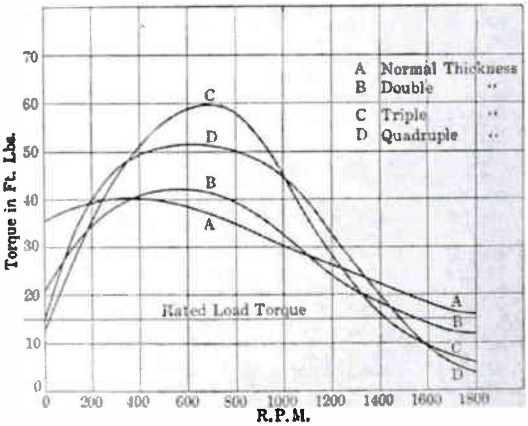

Fig. 15. Speed Torque Curve with Various Brush Thicknesses

Single-phase induction motors, in addition to being provided with one or another of the preceding means for developing starting torque, require, when above moderate size (3 or 5 h.p.), the introduction of starting compensators, or the use of wound rotors with slip-ring control. This precaution is necessary as the inrush of current otherwise occurring would be considerable and likely to react upon the line, producing voltage fluctuations.

HIGH SPEED MOTORS FOR WOOD WORKING MACHINERY

By John Liston

The specialization to which the construction of modern wood working machinery has been subjected in order to obtain results commensurate with the improvement in the mechanical equipment of other industries, has tended to concentrate the attention of practical operators of wood working machinery on the various factors entering into the power costs of production.

The rapidly extending use of motors in practically every industry indicates that the superiority of the electric drive as compared with mechanical drive for application to all forms of machinery is now generally acknowledged, and a discussion of the relative merits of the two methods in the present case is unnecessary.

The system of motor drive adopted, however, directly affects the percentage of the initial power which is actually applied at the machine, as well as the speed of operation, the cost of installation and the amount of floor space required. The problems to be met by the manufacturers of wood working machinery and those specializing in electric motor applications, will, in the future, deal largely with the question of obtaining the highest possible efficiencies for each given set of operating conditions represented by the varying demands peculiar to the industry.

Fig. 2. 3/4 H.P. Induction Motor with Spindle Chuck Mounted on Motor Shaft

The relative values of group and individual drive must be determined in every instance by a careful analysis of the requirements of the installation, and while there are many successful examples of economical group drive, it is now the concensus of competent opinion that in a large majority of cases the highest efficiency, both for the machinery to be driven and for the electrical equipment, can be best obtained by the application of separate motors to each unit. This is especially true where the operation of the machines is intermittent, as in this case the cost of current, if obtained from an outside

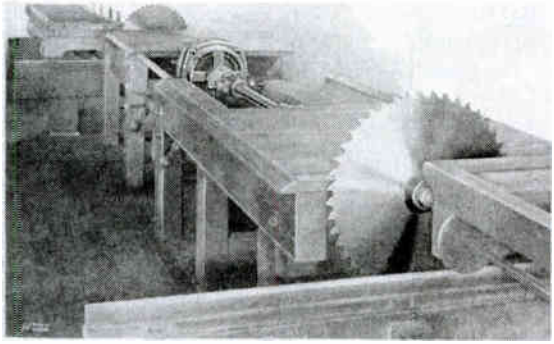

Fig. 1. 7 1/2 H.P. Induction Motor Direct Coupled to Two 20 in. Circular Cross Cut Saws

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source, is entailed only during the actual operation of the machine, so that by the use of instruments the actual cost of the current consumed by each machine or group of machines can be accurately determined.

Fig. 3. 1 H.P. Induction Motor with Dowel Cutting Saw Mounted on Motor Shaft

If, on the other hand, the plant utilizing motor drive is provided with an isolated generating outfit, the size of the prime mover and generator, as well as the power factor in the case of alternating current plants, will be appreciably affected by the choice of group or individual drive. In the latter case, each machine can be equipped with a motor which will most nearly meet the exact requirements in regard to the maximum desirable speed and the amount of power delivered at the driving shaft.

Where the operation of the various units is intermittent, the individual drive system will, in practically every case, permit the successful operation of a plant when equipped with a much smaller generating outfit than would be required with motors driving the machinery in groups, even if there is considerable variation in the length of time that the units are in service; for, in the latter case, power is wasted through the unavoidable operation of shafting and belting which, during varying periods, performs no useful work.

There is perhaps no industry in which the electric motor has been so successfully applied as in that of wood working. This is due to the fact that the average wood working machine operates at relatively high speed, and therefore lends itself readily to the most economical application of the electric motor; *i.e.*, by direct connection to the driving shaft of the machine.

In designing motor drive for wood working plants, there should be active co-operation between the manufacturers of wood working machinery, the practical operator, and the designing electrical engineer, to the end that each individual machine may be constructed and operated as a compact, self-contained unit capable of positive and ready control by the class of labor generally found in wood working plants.

In order to obtain the high speeds required for the application of individual motors to wood working machinery, practice has in many instances included the use of short belts between the motor pulley and the driving shaft of the machine. It was with the object of eliminating this characteristic feature of mechanical drive that the General Electric Company developed its line of high speed motors designed for coupling direct to the driving shaft.

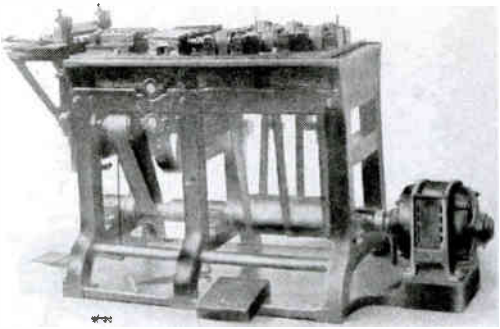

Fig. 4. 5 H.P. Induction Motor Direct Connected to Driving Shaft of 6-Spindle Automatic Dowel Boring Machine

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As a large majority of the operations carried on in wood working plants demand constant speed, and as the characteristics of the induction motor render it especially suitable for constant speed work, it was decided to adopt the three-phase induction motor as a standard type for this service in those places where alternating current is available.

This motor is compactly and strongly constructed, its rotating element being as simple in form as the ordinary hanger bearing; and, as it has no commutator, its operation does not involve any fire risk and the motor may therefore be safely installed in wood working plants without being enclosed. No special foundations are required and the motors may be mounted on the floor, wall or ceiling, or on the framework or headstock of the wood working machines.

The use of high speed motors in wood working plants is not merely a question of power efficiency, but one of economy in the cost of equipment, and for this reason should receive the careful consideration of all persons interested in increasing the volume and lowering the cost of production in this industry. By the adoption of high speed motors, the size, weight and cost of motors of a given horse-power are greatly reduced as compared with the same capacity in motors of lower speed.

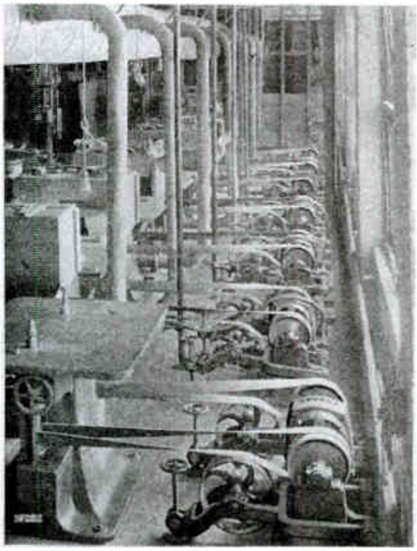

Fig. 5. Seven Two-Spindle Shapers, Motor Driven Through Special Countershaft by 5 H.P. Induction Motors

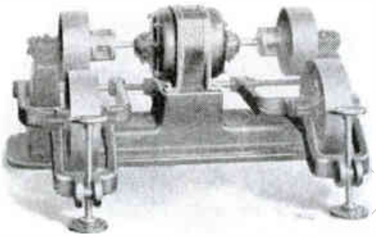

Fig. 6. Special Countershaft Device with Motor Base and Belt Tighteners Used for Driving Two-Spindle Shapers shown in Fig. 5

The accompanying illustrations show some very successful adaptations of high speed motors of small and medium size to wood working machinery, and indicate the results which may be obtained by considering each unit in a wood working plant as a separate problem, to be worked out with the idea of obtaining the highest possible efficiency for each manufacturing operation.

These machines are installed in the plant of Heywood Brothers & Wakefield Company, at Gardner, Mass., which is the largest chair factory in the world. This factory has been partially equipped with motor drive for a number of years, during which time the electrical outfit has been constantly added to, as its superiority to the previously existing drive was demonstrated.

The plant is equipped with a 600 volt, three-phase, 60 cycle, engine driven generator, and at the present time 107 motors are installed, about 80 per cent. of these being of General Electric manufacture. The equipment includes examples of belt connected group drive, and belt connected and direct connected individual drive. There are also some high speed motors direct coupled to overhead and floor shafting, from which small groups of machines, practically in continuous operation, are driven.

Many of the wood working machines in this plant are of original design, and most of those illustrated herewith were either designed throughout or were equipped with special features under the direct supervision of the Heywood Brothers & Wakefield Company's engineers. The motors installed in this plant are all of small or medium size, ranging in capacity from ½ h.p. to 35 h.p., with initial speeds varying from 540 r.p.m. to 3600 r.p.m.

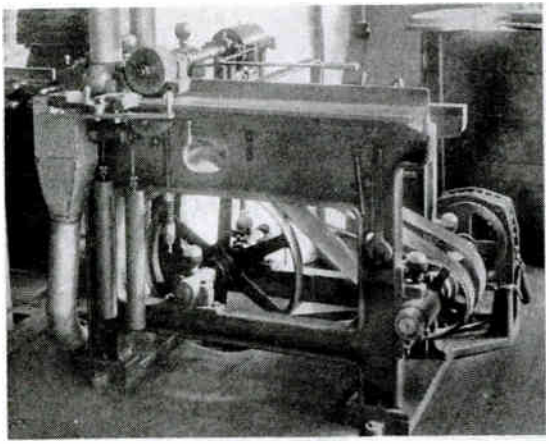

Fig. 7. 5 H.P. Induction Motor Driving Spline Cutting Machine

While accurate figures in regard to the saving in power which has been effected by the adoption of motor drive in this plant are not available, a competent estimate indicates that the operating expense for a given amount of production has been reduced by more than 30 per cent.

A careful consideration of the following instances of the direct application of high speed motors will give a comprehensive idea of the possibilities of this method of drive for wood working machinery:

Fig. 1 shows a 7½ h.p. motor which drives two 20 inch circular saws at 1800 r.p.m., the motor being mounted between the saws and direct coupled to the saw shafts. These saws are used for cutting up large stock, and the shafting is therefore relatively long. Both the motor and the saw bearings are mounted on a common cast iron bed-plate, thereby avoiding any tendency to distortion of the shaft. In addition to the equipment shown, there is another double saw set of a similar type but larger size, and two single saws, all utilizing direct coupled motors.

The illustration, Fig. 2, suggests one of the benefits of individual motor drive; *i.e.*, the location of auxiliary machinery where it will be most effective in insuring the continuity of progressive operations. Each unit may be placed wherever desired and connected to the feeder wires without regard to the location of the rest of the machinery. Fig 2 shows a small cutting chuck for chucking ⅜ in. chair

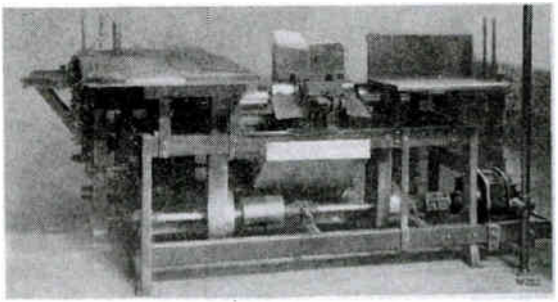

Fig. 8. 7 1/2 H.P. Induction Motor Direct Connected to Driving Shaft of Frame Machine, and Belt Connected to a Four-Spindle Dowel Boring Machine

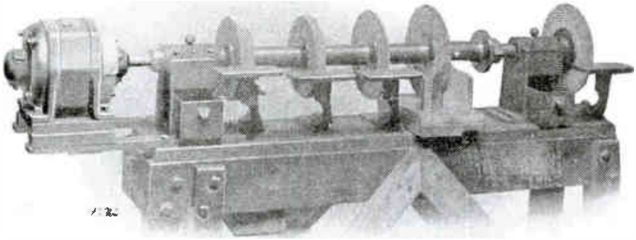

Fig. 9. 1 H.P. Induction Motor Driving Six-Wheel Grinding Set

spindles, mounted on the shaft of a ¾ h.p. motor which operates at 3600 r.p.m.; while Fig. 3 shows a circular saw, mounted on the shaft of a 1 h.p. motor and used for cutting dowels, also operating at 3600 r.p.m.

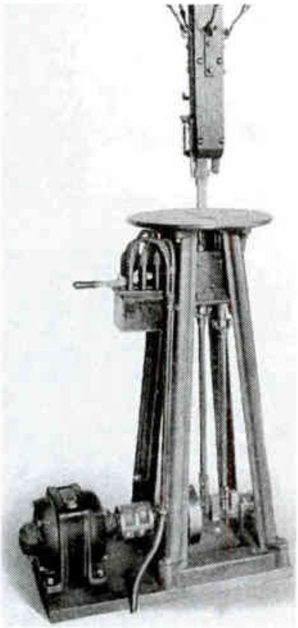

Fig. 10. 3 H.P. Induction Motor Direct Connected to Driving Shaft of Jig Saw

An example of the special machines designed and built by the wood working company's engineers is shown in Fig. 4. This consists of a special six-spindle automatic dowel boring machine with a 5 h.p., 1800 r.p.m. motor direct connected to the driving shaft, which is equipped with a broad pulley from which belts are run to the small driving pulleys for the individual drills. The proper spacing of the six drills, which are located in a horizontal row at the top of the machine, is effected through universal joints.

For shaping and moulding chair seat frames, ten two-spindle vertical shaft shapers are used, each double shaper being driven by a 5 h.p., 1800 r.p.m. motor, and provided with a specially designed countershaft device in which the motor and the driving pulleys are mounted on a common cast iron bed-plate. These driving pulleys are direct coupled to the motor shaft, the coupling and pulley being made in halves, thus insuring a simple, compact and strong driving mechanism. A group of seven of these shapers is shown in Fig. 5, while the motor driven countershaft is shown separately in Fig. 6.

That this factory has an enormous output is indicated by the fact that it has facilities for the production of 6000 chairs of one type per day. For cane seated chairs a very large number of splines are required, and as the ordinary machine for this work cuts only one spline at a time, it was decided to increase the production of this detail part by constructing

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the machine shown in Fig. 7, which is driven by a 5 h.p., 1800 r.p.m. motor, and cuts ten splines in one operation.

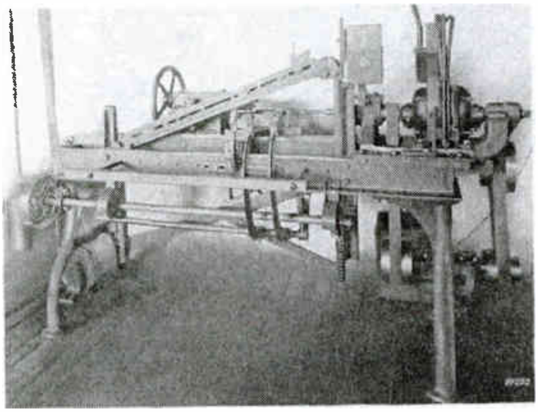

Fig. 11. 3 H.P. Induction Motor mounted on Head Stock of Back Knife Gauge Lathe

An instance of two interconnected machines involving two consecutive manufacturing operations and driven by a single motor is shown in Fig. 8. This set consists of a frame cutting machine and a four-spindle dowel boring machine; the former being utilized for cutting wood for seat frames to the proper size and angle, and the latter for boring the holes for the dowels. A 7½ h.p., 1800 r.p.m. motor is direct connected to the driving shaft of the framing machine, which is in turn belt connected to that of the dowel boring machine.

For grinding tools a compact grinding set arranged for holding six wheels and direct driven by a 1 h.p. motor at 1800 r.p.m. is shown in Fig. 9, while Fig. 10 shows an auxiliary device consisting of a small jig saw driven by a ¾ h.p., 1200 r.p.m. motor, direct connected to the crank shaft. There is a similar jig saw installed in the plant and equipped with a small self-contained centrifugal blower, which is also operated by the driving motor, thereby rendering this particular unit independent of the air exhaust system of the factory and avoiding the expense of running an air conduit to the machine.

The light weight of the high speed induction motor makes it possible, in many cases, to mount the motor directly on the machine when there is no driving shaft to which it may be coupled. An example of this is shown in Fig 11, which illustrates a back-knife lathe used for shaping chair spindles and having a 3 h.p., 3600 r.p.m. motor mounted on the headstock.

The compactness and strength of the mounting which has been adopted as a standard for motor driven circular saws is well illustrated in Fig. 12, which shows a 1 h.p., 3600 r.p.m. motor direct connected to two 12 in. circular cross cut saws, used for trimming seat frames. The general

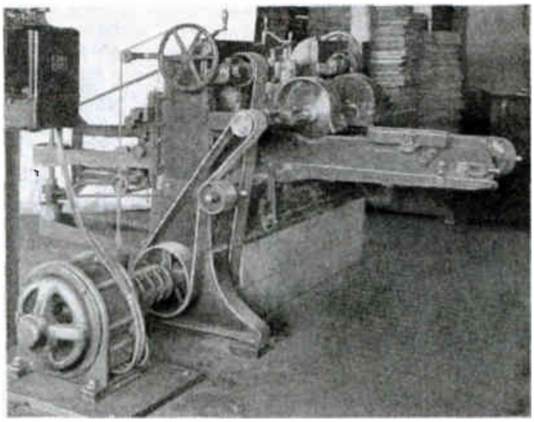

Fig. 13. 10 H.P. Induction Motor Driving Double End Tenoning Machine

LIST OF MOTORS

	No. Motors	H.P.	R.P.M.
Group A	1	.75	3000
	1	3	3000
	1	1	3000
Group B	1	3	1800
	3	5	1200
	2	5	1800
	3	7.5	1800
	2	10	900
	2	10	1200
	3	15	1200
	2	20	900
	3	20	1200
	1	5	570
	1	5	1730
	4	10	1145
	2	15	1145
	3	20	1150
	1	30	1150
Group C	3	5	1800
	1	7.5	1800
	2	10	1200
	1	15	1200
	1	20	900
	2	25	1200
	1	3	1730
	1	10	1145
	1	15	1145
	1	20	1150
	1	25	870
	1	7.5	1200
Group D	2	.75	1200
	1	1	1800
	1	2	3600
	3	3	3600
	1	4	900
	2	5	1800
	1	5	3600
	6	7.5	720
	1	7.5	900
	2	7.5	1800
	2	10	900
	1	25	600
Group E	1	1	3600
	1	2	1800
	2	3	1800
	1	5	1200
	13	5	1800
	1	5.5	900
	1	7.5	1200
	6	7.5	1800
	2	3	1730
	1	7.5	1145
	1	10	1145
	1	15	1145
	1	.2	3400

Group A. Operating tool directly connected to rotor shaft; as for example, a saw or chuck on the extended end of the rotor shaft.

Group B. Shaft driving a group of machines belted to the shaft of the motor.

Group C. Shaft driving a group of machines coupled to the shaft of the motor.

Group D. Driving shaft of the machine direct coupled to the shaft of the motor.

Group E. Driving shaft of the machine belted to the shaft of the motor.

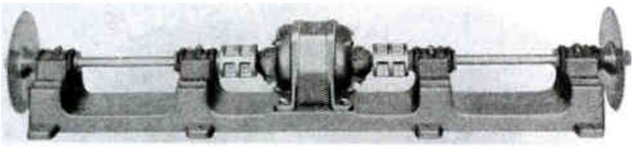

Fig. 12. 1 H.P. Induction Motor Direct Coupled to Two 12 in. Cross Cut Trim Saws

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arrangement of the saws and motors in this instance is similar to that in the installation shown in Fig. 1. The convenience of a compact set mounted on a rigid bed-plate will be readily appreciated by those who have had to line up machinery of this character with motor shafting when installing motors and saws provided with separate bases.

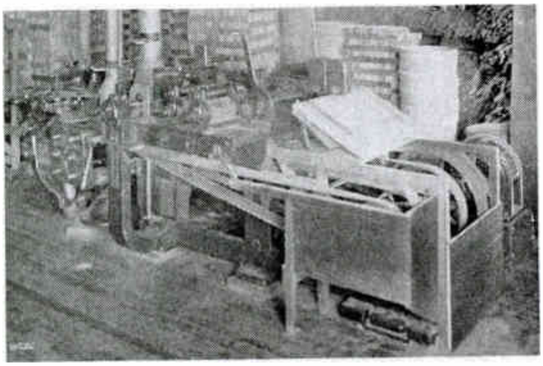

Fig. 14. 10 H.P. Induction Motor Direct Connected to Driving Shaft of Four-Sided Moulder

In addition to the set illustrated, there are two 3 h.p. sets and one 5 h.p. set, the latter being used for cutting up stock for the gauge lathes. All of these saws operate at 3600 r.p.m.

In the above description, we have considered only those motors having speeds of 1200, 1800 and 3600 r.p.m. There are, in addition to these, some good examples of direct drive utilizing motors of somewhat larger capacity and lower speed. These are considered below.

A centrifugal blower for supplying the exhaust system of the factory employs a 25 h.p., 600 r.p.m. motor for driving, the complete set being mounted on a platform suspended from the ceiling beams, thereby rendering the space beneath the set available for storage.

In Fig. 13 a double end tenoner, used principally for the manufacture of school furniture, is shown. This machine cuts stock to length, and makes groove and tongue, tenon and special joints. It is driven by a 10 h.p. motor operating at 900 r.p.m., the motor being securely mounted on a flat iron bed-plate having sufficient surface to avoid disturbance of the shaft alignment. A motor of similar capacity and speed is direct connected to the driving shaft of a four-sided moulder, as shown in Fig. 14.

Six rip band saws are used for cutting stock, all of them being provided with direct motor drive. One of these saws, a 42 in. No. 1, is shown in Fig. 15 and is direct connected to a 7½ h.p., 720 r.p.m. motor with belt connection from the driving shaft to the feed mechanism.

The applications above described illustrate some of the unusual features of the Heywood Brothers & Wakefield Co.'s installation, which are due to the initiative of their engineers; the extent to which motor drive has been adopted in this factory being graphically shown by the tabulation on page 257, which gives the capacity and speed of all the motors in service and the methods of connection used.

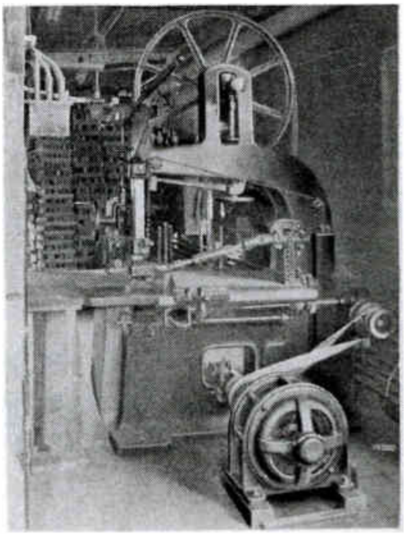

Fig. 15. 7 1/2 H.P. Induction Motor Direct Connected to Driving Shaft of 42 in. No. 1 Self Feed Band Rip Saw

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COMMERCIAL ELECTRICAL TESTING

PART VIII

BY E. F. COLLINS

INDUCTION MOTORS

The test usually made upon induction motors for checking guarantees and determining characteristics for engineering information are given under the following headings. Wherever these tests differ from those employed for other alternating current motors they are described in detail.

The preliminary tests made on induction motors include the measuring of the air gap, bearing and end play, slip and resistance, as well as the tests for starting, running light, excitation and static impedance.

Special measuring scales are used for taking induction motor air gap and considerable care should be exercised in making this measurement both with the rotor in a given position and in different positions.

Bearing play is taken by measuring the gap at the top, bottom and on each side. With the rotor in the same relative position to the stator, that is, without turning the rotor, the motor is turned over in all four positions of the quadrant and the same measurements of air gap taken. Any defects in the bearings which will affect the air gap of the machine are thus disclosed.

A starting test on Form K motors is made by switching the machine onto the line at a low voltage and then increasing the voltage until the motor starts, the current and voltage at this point being recorded. The starting current should not exceed 200 per cent. normal current. This test is occasionally made with a compensator.

With all the internal resistance in the rotor circuit, full line voltage should be impressed on Form L motors and the starting current recorded. This current should not exceed normal current.

Form M motors are started at full line voltage with all the external resistance in the rotor circuit, and the starting current is recorded, which should not exceed normal value. Sometimes the collector rings on Form M motors are short circuited and the starting test made at reduced voltage, as in the case of Form K motors.

Slip is usually measured at full load and running light by means of the slip indicator. During this test, constant speed must be held on the driving alternator, and constant voltage on the motor.

To take slip by the lamp method, an arc lamp is connected in the circuit from which the motor is running. On the end of the motor shaft a disk is placed which has as many white and black sectors as there are poles in the motor. (See Fig. 37, which is used for a six-pole motor.) As the lamp is running from an alternating current source, the current wave passes through zero twice in each complete cycle. At the zero instant, the light given out by the lamp is a minimum.

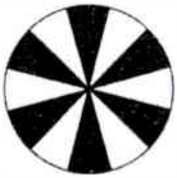

Fig. 37. Slip Disk

Consider a six-pole 60 cycle motor running at 1200 r.p.m., that is to say, at 20 revolutions per second; then 20×6 = 120 black sectors passing a stationary point on the circumference of the disk in one second. As the frequency is 60, the number of maximum illuminations will be 120. At each maximum illumination, therefore, the black strips will always occupy the same positions. However, the slip which always occurs in an induction motor will cause the black strip to lag by a small angle behind the position occupied at the previous illumination. These successive differences in position appear as a sector rotating backwards, which can be followed by the eye. The slip, that is, the difference between the actual speed and the synchronous speed of the motor per minute, can thus be counted.

The resistance of the stator should be measured cold and hot.

Running light is taken by applying normal voltage to the stator and reading the amperes input to the motor. Static impedance is taken by blocking the rotor and applying such a voltage to the stator as will give about full load current, reading the current in each leg, together with the voltage between each of the legs. If the motor is of the Form L type, impedance is taken with the resistance all in and then all out, always holding the same voltage across the stator. This practice has been found to give the best results. End play should be tested both with and without voltage on the stator, and on all motors particular care should be taken to see that the rotor is in perfect balance.

When cutting out the internal resistance, the starting switch of Form L motors should be watched closely for sparking or any other defects. The brushes must make good contact on the resistances in all positions and the switch must not work too easily, otherwise the resistance may be cut out too rapidly.

On Form M motors, the brushes must fit the collector rings perfectly, as a successful test on this type of motor depends considerably on a good fit. The voltage ratio should be taken on Form M motors by impressing normal voltage on the stator and measuring the voltage between the rings of the rotor on open circuit. Volts and amperes stator, and volts between rotor rings should be read and recorded.

Two speeds on a motor can be obtained by changing the connections on the stator by means of a switch and connection board, these changes altering the number of effective poles. The rotor must have the correct number and ratio of slots in the stator and rotor, otherwise dead points may occur at certain starting positions, or again the motor may operate at subsynchronous speeds. These machines are usually run at the lower speed during test.

Excitation

The tests for excitation and impedance are important, and the following precautions must be observed in all cases. The calculation of the characteristic curves of induction motors depends entirely on test results, and great care must therefore be taken to obtain accurate measurements.

The motor should be located so that all the conditions affecting its operation during test remain unchanged throughout the run. A solid foundation is necessary to prevent vibration at full speed, and the table must not be near any source of stray field. The driving alternator should be at least ¾ the kw. capacity of the motor. The transformers and other apparatus must be connected so that the alternator will work under normal conditions, since satisfactory wattmeter readings cannot be obtained if the alternator is run too low on the saturation curve. Transformers, when used, must be well balanced and not forced beyond their voltage range, otherwise unsatisfactory results may be obtained.

The table must be adapted for wattmeters by providing a special wattmeter switch connected on two of the three phases, as shown in Fig. 38. A and B are the terminals for the current leads to the wattmeters, X and Z being the short circuiting switches. Calling the phases 1–2–3, then phase 1 is on the current coil of wattmeter R, connected at A, and the pressure coil is connected across 1 and 2. Likewise with the other meter S, the current coil of which is on phase 3 at B, with its pressure coil between 2 and 3. If the voltage is too high for direct use on wattmeters, multipliers (non-inductive coils of known resistance) or potential transformers must be connected between the meter and the volt lines at the table.

On motors of less than 20 h.p. the lines to the primaries of the potential transformers must be attached to the generator side of the lines coming to the top of the dynamometer board. If placed on the motor side of top of the board, or on the motor terminal block, the excitation current of the potential transformer passes through the wattmeters. Although this current is small, with a small motor it may be an appreciable percentage of the excitation current. Hence an error is caused

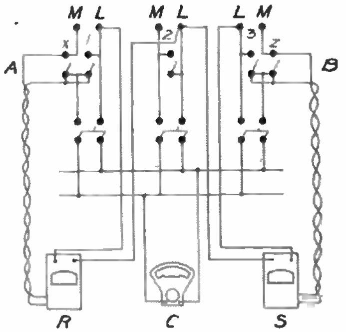

Fig. 38. Wattmeter Connections for Excitation

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and an abrupt break made in the excitation curves every time the ratio of the potential transformer is changed. On large motors the excitation current of the potential transformer is so small in comparison with the motor current that the incidental errors are negligible. The above does not apply to multipliers because they are non-inductive.

On large motors the volt leads should always be attached at the terminal block in order to eliminate the line drop in switches and leads from the table to the motor. The current leads to the wattmeters should be twisted together throughout their length and come direct from the terminal to the meter without loops or sharp turns. All connections must be kept tight and clean.

The air gap should be taken before the test is started. On voltages above 500 volts all instruments must have any static charge thereon discharged and a small fuse connected between the current terminal and the nearest volt terminal of the wattmeter. Do not ground the secondaries of the transformer.

As soon as the machine is wired and ready to start, the switches on the dynamometer board should be closed. (Always see that the wattmeter switches are closed whenever a change in the field current is made.) The exciter field switch is then closed and the voltage brought up slowly until the motor starts and reaches normal speed. The machine should then be inspected to see that it is operating normally and the amperes and volts in the different phases read and any unbalancing corrected or its cause discovered.

The end play of the motor should be tested next, since the rotor must always run centrally in the frame. A slight pressure against one side will change the friction watts and give an incorrect value to the core loss. Small motors should be run about one hour and a half and large ones two hours and a half or more, to obtain constant friction before starting tests. If the wattmeter needle goes off the scale in a negative direction when connected in circuit, the current leads on the current terminals should be interchanged. On a two-phase circuit, with a machine under load, both wattmeters should read positive.

For running light readings on a three-phase machine the sign of the meter must be determined, since one reads negative on the upper part of the curve. With both meters reading positive, one of the phases containing the current coil of the wattmeter should be opened and the other meter observed. If the needle drops off the scale below zero the meter reads negatively. If the needle drops to some value above zero the reading is positive. This process must be repeated for determining the readings of the other wattmeter.

The alternator speed must be held constant during the test and about 130 per cent. normal volts used for the first reading; volts amperes, watts and speed of generator and motor being read and recorded. The volts should then be decreased in steps so as to obtain about 20–25 points on the curve, down to 10 or 15 per cent. of normal volts. Here the conditions are no longer stable. The meter with the negative sign will read less than the other, and its readings will fall off more rapidly, becoming less and less until zero is reached and its sign changes. When it becomes positive, the current leads must be interchanged.

After the volts have been reduced from the starting point of curve to normal, three single-phase wattmeter readings, one above, one below and one at normal voltage, should be taken on the two legs to check the results. Check readings should also be taken with a different voltmeter and ammeter.

The single-phase excitation amperes are theoretically 1.73 times the three-phase and twice the two-phase values; that is, the kv-a. has equal values for the motor, whether single-phase or polyphase. Practically, the single-phase amperes are from 1.6 to 1.7 times the three-phase, instead of 1.73 times. The same ratio holds for quarter-phase. The watts excitation is the same for polyphase or single-phase, so far as core loss is concerned. The increase in watts single-phase over the watts polyphase is equal to the polyphase C^2R. For instance, if the three-phase excitation requires 1000 watts and the C^2R three-phase is 100 watts, the single-phase excitation will be 1100 watts.

Before shutting down, a curve should be plotted with volts as abscissæ and the algebraic sum of the watts as ordinates.

Wattmeter work is somewhat uncertain, and accurate results can only be obtained under good conditions. An endless belt on the driving alternator is necessary, a laced belt making the wattmeter needle swing with a steady beat corresponding to the striking of lacing on the generator pulley. Any belts running near the table must have their static charges drawn off by a grounded wire and the cases of all transformers should be connected together and grounded. Wattmeters must be carefully handled on high voltages, since all three phases of the alternator are connected on the table and contact between two of the instruments short circuits one of the phases.

TABLE XVI—Excitation on a 100 H.P., 2080 V., 6-Pole, 60 Cycle, 3-Phase Induction Motor

Volts	Amps.	Watts +	Watts −	Total Watts
2510	11.5	18300	12150	6150
2370	10.4	15500	9900	5600
2175	9.5	12900	8000	4900
2105	9.2	12090	7380	4710
2075	8.8	11470	6920	4550
2020	8.6	10870	6370	4500
1830	7.7	9060	5060	4000
1610	6.76	6950	3450	3500
1440	6.03	5740	2670	3070
2160	15.4	5150	—	
2070	14.6	4750	—	
2000	14.2	4550	—	
2070	14.6	—	4950	
2200	15.85	—	5140	
2255	15.9	—	5540	
1366	5.78	5440	2310	3130
1185	5.08	4390	1540	2850
988	4.3	3185	685	2500
816	3.75	2550	178	2372
585	3.35	1670	+380	2050
485	3.25	1370	530	1900
292	3.9	1200	644	1844
244	4.83	1210	673	1883
176	5.8	974	500	1474

The two important points on an excitation curve are the watts at normal voltage and friction watts. These points determine the percentage core loss for the motor. Several readings, only a few volts apart, should be taken on each side of normal voltage and the volts and amperes in the different phases at two or three other points in the curve should be carefully read and recorded as a check on the balance of the motor. As the lowest point of the curve, or friction reading is approached, many readings should be taken. This portion is the most difficult part of the curve to locate, especially in the case of large motors, as in many instances "hunting" begins at a low voltage. A reading taken when the motor is accelerating is of greater value than the steady reading.

Hunting usually makes the meter needle swing with a slow beat, the range of the beat varying with the size of motor and degree of hunting. Bad cases of hunting are not numerous and reliable readings can generally be secured between beats. To test successfully, the speed of the driving generator must be kept constant and no reading taken until the speed is properly adjusted. The tachometer used must be carefully checked.

The excitation tests on all forms of induction motors are the same.

The Form M motor is provided with collector rings for the external resistance. These must be short circuited at the brush-holder terminal and the brushes carefully sandpapered until they fit the rings accurately.

Calculation of Excitation Test on Induction Motors

All readings must be corrected for the instrument constants and ratios used. Special care should be taken to use the proper signs for the wattmeter readings. Table XVI shows the form used in calculating an excitation test, and Fig. 39 the method of plotting it. The friction and windage watts are obtained from the excitation curve by producing the watt curve to zero volts.

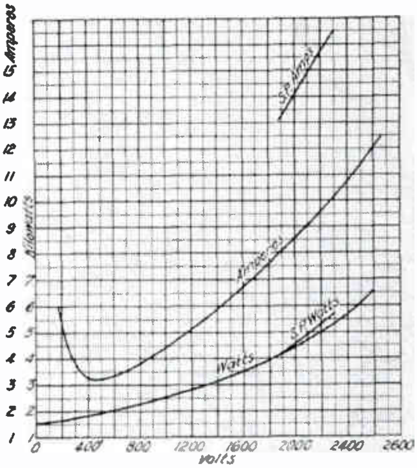

Fig. 39. Excitation Curve on a 100 H.P., 2080 Volt. 1200 R.P.M., 60 Cycle, 3-Phase Induction Motor

Impedance

The Form K motor has a symmetrical bar winding in the rotor and therefore the impedance is the same for any position of the stator relative to the rotor.

In Forms L, M and P, which have wound rotors, a position curve is first taken.

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Two-thirds of the distance between two consecutive poles on a three-phase motor and one-half that distance on a quarter-phase motor are marked off on the bearing bracket, this space being divided into about eight parts. A pointer should be attached to the motor shaft or pulley so that its outer end will pass over the division marks; it is then set on mark 1 and the rotor blocked so that it cannot move from that position. The switches are next closed and the impressed voltage increased gradually until about normal current is obtained. Volts and amperes should be read and recorded on all three phases to make sure that no unbalancing occurs. Holding the same volts as for position 1, the pointer is moved to mark 2, and the amperes read; this procedure being repeated on each of the succeeding marks and a curve plotted, giving amperes and pointer position. The motor is then blocked in the position which gives an average value of the current. Form K induction motors are blocked in any position.

The current is then increased until 150 per cent. normal current is obtained, and the amperes, volts and watts are read. The sign of the wattmeter must be determined in the same way as at the beginning of the excitation test. About six or eight readings should be taken between zero and 150 per cent. normal current, but the current should not be held on the motor longer than necessary to secure a reading. After each reading the exciter field should be opened, until ready for the next reading, otherwise the motor will get too hot. As soon as the readings are taken, curves should be plotted with volts as abscissæ, and amperes and the algebraic sum of the watts as ordinates. The ampere curve should be a straight line, though sometimes the top portion curves upward very slightly.

TABLE XVII—Impedance on a 100 H.P., 2880 V., 6-Pole, 60 Cycle, 3-Phase Induction Motor

Volts	Amps	Watts +	Watts −	Total Watts
146	11.9	1230	445	785
188	15	1870	660	1210
220	18	2825	1080	1745
263	21.5	4060	1485	2575
301	24	5260	1930	3330
355	28.5	7255	2845	4410
384	30.7	8360	3190	5170
410	33	9450	3710	5740
455	36	11680	4450	7230
297	20.6	—	1460	
272	19.1	—	1190	
322	22.2	—	1680	
273	19	1255	—	
297	20.5	1500	—	
322	22.2	1720	—	

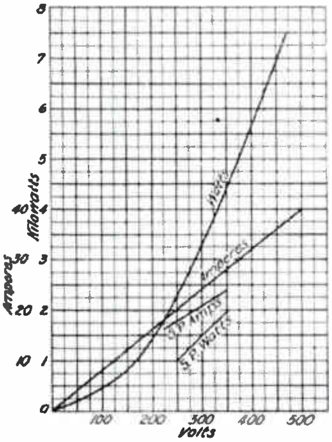

Fig. 40. Impedance Curve on a 100 H.P., 2080 Volt, 1200 R.P.M., 60 Cycle, 3-Phase Induction Motor

Single-phase check readings should be taken, one above, one below and one at normal amperes, on the two phases containing wattmeters.

The single-phase impedance current should be 86.5 per cent. of the three-phase (line) values. The single-phase impedance watts should be approximately half of the three-phase watts. In a quarter-phase motor single-phase impedance is the impedance of one of the two phases.

On Form M motors, when taking impedance, the collector rings should be short circuited either by metal brushes or by metal strips, as the contact resistance varies with carbon brushes. The ratios between the primary and secondary voltage should be taken with the secondary open circuited.

Calculation of Impedance Test on Induction Motors

Table XVII shows the form used in calculating an impedance test, and Fig. 40 the method of plotting it.

(To be Continued)

HYPERBOLIC FUNCTIONS AND THEIR APPLICATION TO TRANSMISSION LINE PROBLEMS

Part III

By W. E. Miller

Transmission Line Characteristic Curves

To illustrate how the volts, amperes and power factors vary along a transmission line, the electrical conditions being determined at the receiving end, various curves have been plotted for a line 400 miles long operating at 60 cycles and using three No. 0000 hard drawn stranded copper wires triangularly spaced 10 ft. apart. In all cases the volts received are assumed constant at 60,000 volts between wire and neutral, *i.e.*, 104,000 volts between wires.

Fig. 10 shows the variation of the volts along the line with unity power factor at the receiving end for the following cases: 3600 kw. and 7200 kw. delivered per phase—equal current values at the generating and receiving ends—unity power factor maintained at both ends. Fig. 11 shows how the current varied along the line in the above cases.

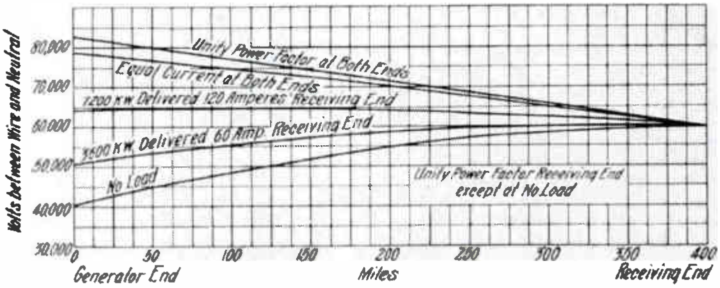

Fig. 10. Variation of Volts along 400 Mile Three-Phase Line, Using Three No. 0000 B.&S. Wires 10 ft. apart. Operating at 60 Cycles, 104,000 Volts between Wires at Receiving End. Unity Power Factor at Receiving End, and conditions as stated on curves

It should be noted that when 3600 kw. is delivered the current at the generating end is more than double that at the receiving end; when, however, the power delivered is doubled, the generator current is only increased 20 amperes. To maintain unity power factor at both ends, the current at the receiving end must be 197 amperes, which is slightly greater than that at the generator end. When the received current is 179 amperes, the generator current has the same value.

The volts at no load, Fig. 10, rise from the generator towards the receiving end. With a current of 102 amperes receiving end at unity power factor, the generator and received volts become equal, a maximum voltage occuring about halfway along the line. When the received current is greater than 102 amperes, the voltage drops along the line from the generator towards the receiving end.

Fig. 12 shows the variation of volts and current along the same line when 120 amperes are delivered at .90 leading and lagging power factors respectively. With a leading power factor at the receiving end, the current at the generator end is very much larger than that at the receiving end, whereas the volts rise slightly towards the receiving end. Thus a leading power factor at the receiving end means a high transmission loss along the line. On the other hand, when the power factor is .90 lagging at the receiving end, the current is nearly equal at both ends, being minimum half way, and the transmission efficiency is nearly maximum. The volts in this case drop slightly from the generating end towards the receiving end.

ERRATA.—Table XIII, page 17 of "Review" supplement, column a, x = .8[illegible] should read [illegible] not 1 909.

Equation numbers on page 223 of May "Review" should read 30, 31, 32 and 33 in place of 23, 24, 25 and 26 respectively.

Curves C and A, Fig. 13, illustrate the variation of the power factor along the line for the two cases just mentioned. When the power factor is .90 leading at the receiving end, it has minimum value about 280 miles from the generating end, rising to .94 leading at the latter end. Thus, only a small variation of power factor occurs along the line. When, however, the power factor is .90 lagging at the receiving end, it is .90 leading at the generator end and unity halfway along the line, that is, a considerable variation occurs. The transmission efficiency in this case is 85 per cent., whereas, with the power factor leading at the receiving end, the efficiency is only 74 per cent., the same kw. being delivered in both cases.

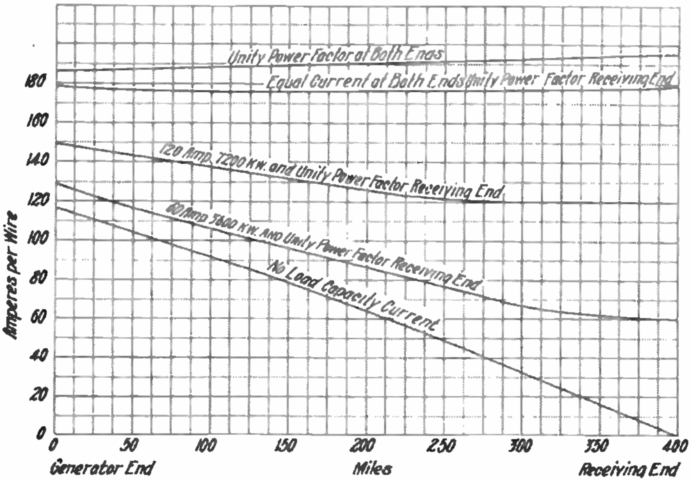

Fig. 11. Variation of Current along 400 Mile Three-Phase Line, Using Three No. 0000 Wires 10 ft. apart, Operating at 60 Cycles, 104,000 Volts between Wires at Receiving End. Unity Power Factor at Receiving End, and conditions as stated on curves

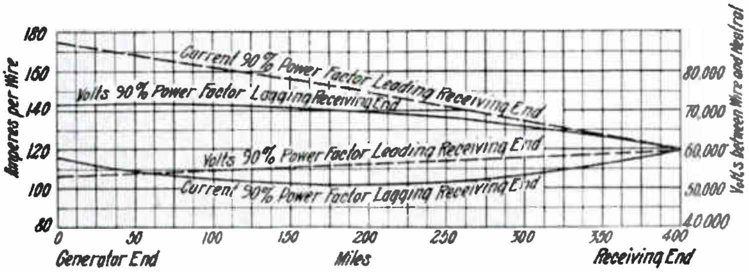

Fig. 12. Variation of Amperes and Volts along 400 Mile Three-Phase Line, Using Three No. 0000 B &S. Wires 10 ft. apart, Operating at 60 Cycles, 104,000 Volts between Wires at Receiving End. Power Factor Receiving End .90 Leading and Lagging

Curve B, Fig. 13, shows the variation of power factor when 7200 kw. at unity power factor are delivered and Curve D shows the variation of power factor when 3600 kw. are delivered. In the latter case, the power factor is only .68 leading at the generator end.

Curve E shows the variation of power factor with no load at the receiving end, the line loss being 540 kw. per phase and the power factor .115 leading at the generator end.

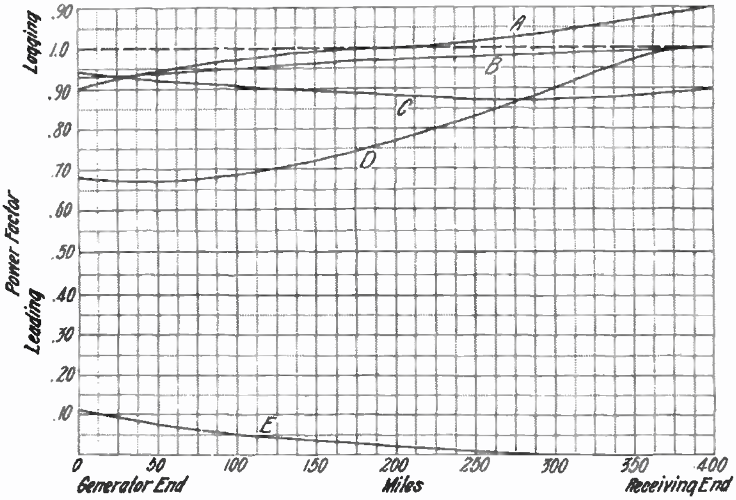

Fig. 13. Variation of Power Factor along 400 Mile Three-Phase Line, Using Three No. 0000 B.& S. Wires 10 ft. apart, Operating at 60 Cycles, 104,000 Volts between Wires at Receiving End. Curve A, 120 Amperes Delivered at .90 Power Factor Lagging. Curve C at .90 Power Factor Leading. Curve B, 7,200 Kw. Delivered and Curve D, 3,600 Kw. Delivered at Unity Power Factor Receiving End. Curve E No Load Delivered

Transmission Efficiency

It is of some interest to discover what power factor should be maintained at the receiving end for a given voltage and load delivered to obtain maximum transmission efficiency. Unlike transmission by direct current, the efficiency does not necessarily increase with decrease of load delivered. In fact, for every transmission line, there is one particular load delivered for which the transmission efficiency is an absolute maximum for that line. This load in the case of long lines may represent a considerable amount of power; the load current at receiving end must have a fairly large value at a small lagging power factor to give equal current at both ends.

Maximum efficiency for a given load delivered occurs when the currents at each end are equal, this condition being always obtainable by varying the power factor at the receiving end.

Curve C, Fig. 14, shows how the current varies with the power factor at the receiving end for 7200 kw. delivered; this curve being, of course, immediately obtained from the relation between k.v.a. and kw. delivered, the voltage at the receiving end being held

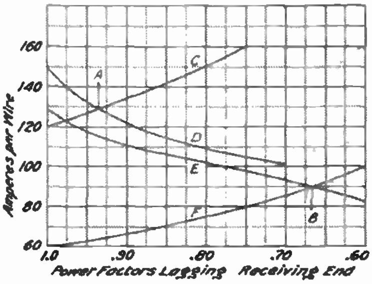

Fig. 14. Curve C Gives Values of Received Current for Various Power Factors at Receiving End, and Curve D Values of the Generated Current for the Same Power Factors, with 7,200 Kw. Delivered. Curve F and E Represent Values of Received and Generated Current for Various Power Factors, with 3,600 Kw. Delivered. Three-Phase Line 400 Miles Long, Using Three No. 0000 Wires 10 ft. apart, Operating at 60 Cycles, 104,000 Volts between Wires, Receiving End.

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constant at 60,000 volts between wire and neutral. Curve D is obtained by calculations from the transmission line equations and connects the generator amperes with various power factors at the receiving end for the given load and voltage delivered. The intersection point of Curves C and D determines the receiving end power factor at which the currents at each end become equal, *i.e.*, at 128 amperes. On Fig. 15, curves have been plotted connecting volts at the generator end with the power factor at both the receiving and generator ends. These curves were calculated from the transmission line equations, the conditions being 7,200 kw. delivered at 60,000 volts.

The intersection point A occurs at a power factor .935 lagging (receiving end) (see Fig. 14), the corresponding volts at the generator end being 72,500 volts at a power factor .935 leading (see Fig. 15). Hence, the maximum transmission efficiency obtainable with this line, for 7200 kw. delivered per phase, is

$$\frac{7200\times1000}{72{,}500\times128\times.935}=.80.$$

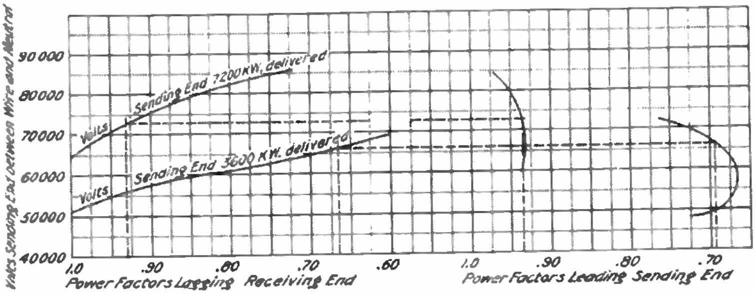


Fig. 15. Values of Volts at Sending End for Different Power Factors at Receiving and Sending Ends. 7,200 Kw. and 3,600 Kw. per Phase Delivered. 400 Mile Three-Phase Line, Using Three No. 0000 B.&S. Wires 10 ft. apart, Operating at 60 Cycles, 104,000 Volts between Wires, Receiving End

The curves E and F have also been drawn for 3600 kw. per phase delivered, point B being the intersection of the ampere curves drawn for the generator and receiving ends. This point corresponds to 89 amperes at .67 power factor lagging (receiving end), the generator volts being 66,500 and the power factor at the generator end .695 leading.

The transmission efficiency in this case is, therefore,

$$\frac{3600\times1000}{66{,}500\times89\times.695}=.875.$$

Thus, to obtain maximum efficiency for this line when delivering 3,600 kw. per phase or a total of 10,800 kw., a low lagging power factor must be maintained at the receiving end, *i.e.*, .67. With twice the delivered power, *i.e.*, a total of 21,600 kw., the power factor at the receiving end must be .935 lagging and the load need only be slightly inductive to obtain this value. It follows, therefore, that the condition for maximum efficiency can be obtained for fairly high loads along transmission lines, but when light loads are in consideration, the highest efficiency is impracticable.

Note on Capacity Calculations

As it is generally easier to calculate the self induction between wires or between wire and neutral than the capacity, the following method for obtaining the value of the capacity from the value of the self induction is sometimes useful. It is based on the fact that the expression $\frac{1}{\sqrt{LC}}$ represents (in the case of commercial transmission lines) the velocity of light in miles per second when L is expressed in henrys per mile and C in farads per mile. In using this formula L should be calculated, neglecting that part of the self induction due to the flux within the wires. Then

$$C=\frac{1}{v^2L}=\frac{2.87\times10^{-11}}{L} \qquad (34)$$

This method was used for calculating the capacity between wire and neutral for three-phase lines when the wires lie equally spaced in a plane, and are transposed to balance the phases.

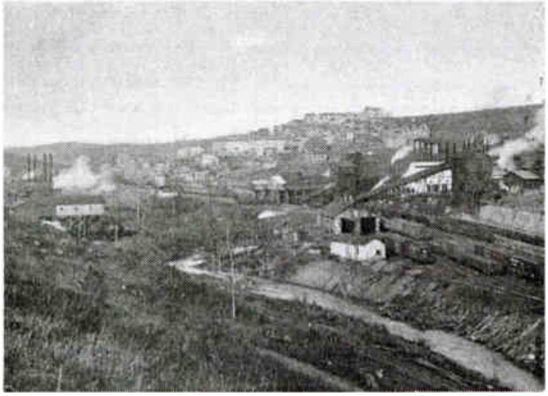
(To be Continued)

ELECTRICITY IN THE MINES OF THE DAVIS COAL AND COKE CO.

By R. Neil Williams

Consulting Engineer

The causes which have led to the general adoption of electricity as a motive power in mining work are mostly obvious. The only logical competitor of electricity is gravity, which is, of course, the cheapest power as long as its use does not involve too much loss of time, or its inflexibility necessitate an expenditure for labor of a sum sufficiently great to offset the saving in investment and that effected by the elimination of the fuel bill. Where conditions do not permit of making use of gravity, either horses, mules or electric locomotives must be employed; advantages being much in favor of the latter, especially when the thinner seams of coal are exploited. The horse as a factor in coal-mining became of minor importance with the advent of electric haulage in 1887. The mortality of horses used in mining work is extremely high, while the first mining locomotive built in the United States, for the Lykens Valley Coal Co., is still hauling coal in everyday service. This feature is accentuated by the necessity of using very small horses in mining work and of their working in the dark and in bad air.


Power Plant of Davis Coal and Coke Co., West Virginia Central Junction

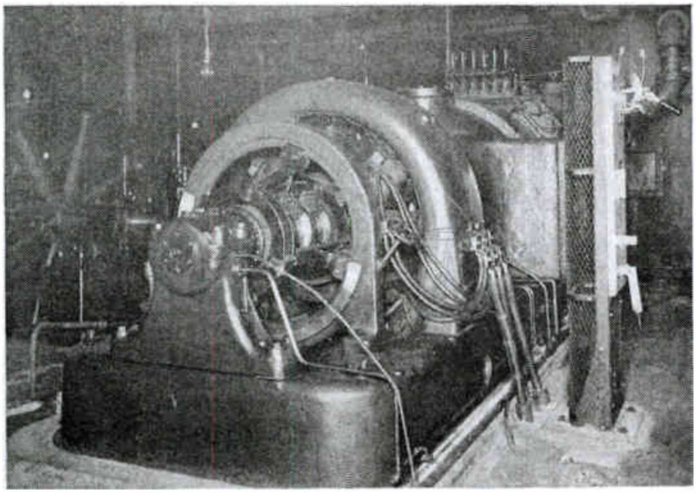
The economic advantage of electric operation becomes evident from an inspection of the pay roll, for with electric locomotives longer trips can be made at higher rates of speed, with the result that one locomotive will do the work of fifteen horses on the average. This means the employment of one good man instead of fifteen boys, and the expenditure of $2.50 to $3.00 for power instead of $7.50 for feed.

The advantages of electricity as a source of power in coal mines where the electric installation has been properly made and is wisely managed are exemplified in the equipment of the Davis Coal and Coke Co., which operates bituminous mines in West Virginia along the lines of the Western Maryland Railroad Company. At the present time this company owns 160,000 acres of coal land and operates mines at West Virginia Central Junction, Elk Garden, Harrison (Harrison being included in the Elk Garden district), Henry, Thomas, Coketon and Weaver; these places being situated, in the order named, along the West Virginia C. & P. Division of the Western Maryland Railroad, which begins just above Piedmont, W. Va., at the junction of this railroad and the B. & O. In the Fairmount region the company also owns 30,000 acres of coal lands, which, however, are not being worked.

It is interesting to follow the development of this company through the various stages of its growth and to note how systematically the various managements have worked to a well thought out plan of electric operation. While the use of electric power in the first place was made imperative by the nature of the working, its advantages in other directions than those which compelled its adoption became apparent and led to the introduction of electricity for other purposes.

Realizing that the distances over which it would be necessary to transmit electrical energy were, in many cases, already too great for the economical use of direct current, and that as the operation in the mines extended all these distances must necessarily become greater, it was decided to use alternating current wherever possible. The greater economy of alternating current for long distance transmission was not, however, the only consideration which was influential in the adoption of this policy. The alternating current system is very much more flexible than any direct current system, and is adapted readily to any distance of transmission by means of the simple alternating current transformer. Furthermore, the induction motor is admirably suited for use in coal mines, particularly for driving pumps and fans which run continuously. As it requires no brushes or other devices for making electrical connection with the secondary circuit, the rotor revolves very freely and there is no friction other than that of the bearings. This arrangement requires a minimum of attention and ensures absolutely no sparking. A motor of this type will operate for long periods of time with no further attention than an occasional inspection of the oil gauges and air gap.

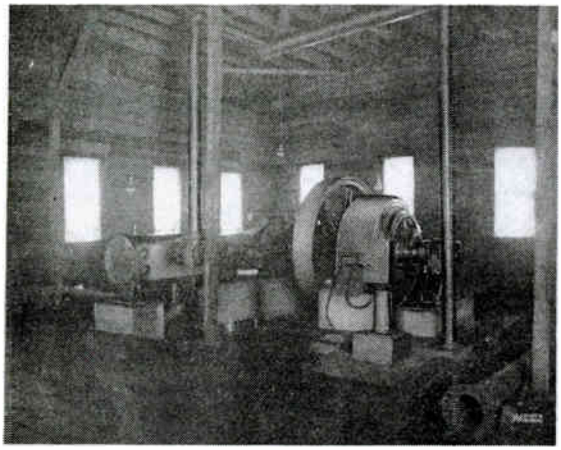
For haulage and hoisting purposes, the direct current series motor was adopted, due to its characteristic of maximum torque at starting. Owing to the long distances to which direct current had to be transmitted, it was decided to generate it at a potential of 600 volts. The objection which might be raised to this high potential, due to the danger to men and animals, where the latter are still used for gathering, is more imaginary than real, owing to the fact that the current is turned off while the shifts are changing. In fact, there has been no loss of human life from electric shocks in the company's entire history, and only a few instances in which animals have come into contact with live wires and were electrocuted. In these cases, the accident was due to the slowness of the drivers in getting back into the workings.



500 Kw., 600 Volt. Curtis Turbine Generator Set at Thomas, W. Va.

The electrical development has been consistently carried out throughout all of the various workings with 600 volts direct current for haulage and three-phase alternating current, at a frequency of 60 cycles, for all other purposes, with the exception of the lighting of the various mining towns. For this purpose, single-phase alternating current is used, constant current tub transformers being employed for the lighting of streets.

This policy of buying uniform apparatus for all mines, even to standardizing the make of machinery, has resulted in an almost entire absence of an electrical junk pile. It is a case of the pitcher going to the well till it is broken, and but for the advent of greatly improved steam motive power in the form of the Curtis steam turbine, there would have been very little noticeable depreciation in any of the apparatus. As it is, the increase of power required by the rapid developments in the last year or two has made it necessary to operate the older reciprocating steam units in multiple with the steam turbines; but it is hoped that in a short time it will be able to discontinue some of the less efficient steam engines and use the corresponding alternating current generators as synchronous condensers to improve the power factor of the general system.



150 Kw., 600 Volt Engine Driven Direct Current Generator

The importance of the work being done by the induction motors in mine ventilation and pumping is so great that these motors must of necessity be selected amply large for the duty. Stinting in this respect would be poor policy, but naturally the result of having partially loaded motors continuously in operation results in a very poor power factor for the whole system. The main objection to low power factor in mining work is not the necessity of providing transmission lines large enough to carry the excess idle current, but chiefly one of station economy. A unit consisting of steam driver and electric generator designed to deliver an output of, say, 100 kilowatts at 100 per cent. power factor can only be called on for 55 kilowatts at 55 per cent. power factor, and not even for this unless the fields and armature have been specially designed for such operation. Even assuming this to be the case, the steam end of the unit would be operating at but little more than half load, and consequently with very poor efficiency. It is, therefore, desirable to bring up the general power factor as near as possible to 100 per cent. by means of units independent of the generators. Rotary condensers, or synchronous motors, operating as motors, are suitable for this purpose, whether running idle or with load. It is not always possible to provide a suitable load for a synchronous motor in the interior of the mine itself, as this type of machine will not operate with the small amount of attention required by an induction motor, and is more susceptible to fluctuations in the supply of electric energy. However, there is no reason why fans outside the mines and not too far from the power station or repair shops, where expert attention is available, should not be driven by synchronous motors. If the motor runs idle, the improvement in power factor is gained at the expense of an amount of energy representing the losses in the motor.

In the following history of the Davis Coal and Coke Co. and its development, the electrical equipment will be discussed in conjunction with the description of the various workings.

In 1884 some prospectors in the employ of H. G. Davis & Bro. discovered the Davis vein of coal near Thomas, W. Va. This was the beginning of the present company and of operations at Thomas. In 1886 H. G. Davis & Bro. and S. B. Elkins formed a partnership for the purpose of opening the Davis coal at a point about a mile south of Thomas, at what is now known as Coketon, W. Va. In 1887 the first coke ovens were built and experiments made as to the coking qualities of the coal,

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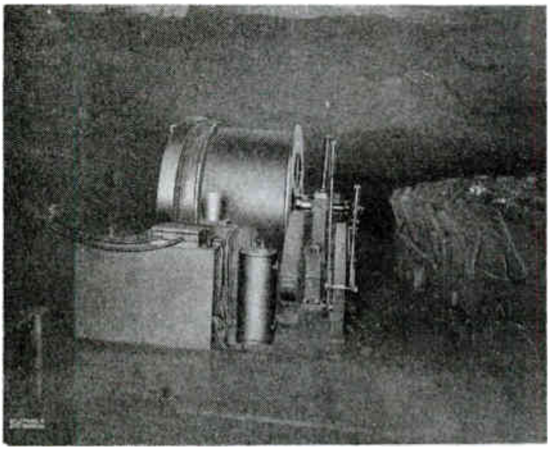
which was found to be indeed an excellent coking, steaming and smithing product. In 1888 the Davis Coal and Coke Company was incorporated with an authorized capital stock of $250,000, which in 1893 was increased to $3,000,000 to enable the company to acquire controlling interests in several other mines operating on the line of the W. Va. Central Railway. From this time on, until the taking over of the road by the Goulds as the coal operating department of the Western Maryland Railroad, the development of the company from a technical point of view has been systematic and comprehensive.

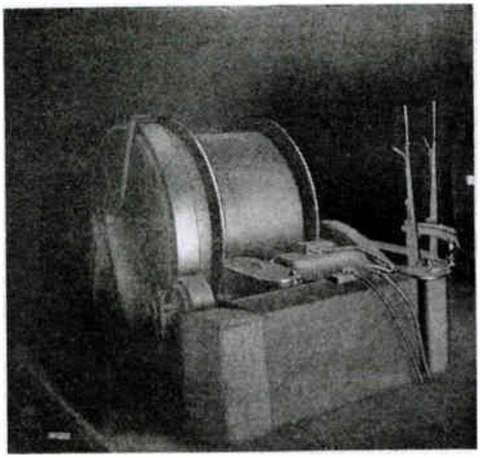
Taking the various operations in geographical rather than historical order, we will begin with the mines nearest to Tidewater. At West Virginia Central Junction there are four operations, two in what is known as the Bayard formation, which carries the Bakerton seam of coal and is locally known as the "four foot;" and the "three foot" coal, operated elsewhere as the upper Freeport seam. These mines are operated by the General Electric system of rope haulage. As the mines are on the extreme eastern outcrop, the pitches are very heavy and haulages are located at the extreme end of the headings on the inside of the mines. Empties are hauled in with the rope and the loaded cars dropped out by gravity, dragging the rope behind them. The loaded cars are controlled by brakes on the hoisting drums, which are operated by 550 volt direct current motors. The Bakerton seam is at the very top of the Bayard formation and, since the north branch of the Potomac river cuts the valley deep at this point, the above two mines are opened very high on the hillside and require inclined planes 2100 feet in length to reach the railroad track. Mine No. 19 is operated at the base of these planes, on the lower Kittanning seam, known locally as the "six foot." This mine also requires rope haulage, which is placed on the inside of the mine as in the case of the two mines above referred to, Nos. 50 and 51. The power station for this group is equipped with a 150 kw. General Electric generator driven by a Buckeye engine. These three mines, together with number 17 on the opposite side of the river in Maryland, which uses endless rope haulage, constitute the West Virginia Central Division, under the direction of Mr. O. Tibbets, Superintendent.



Hoisting Drum Operated by Direct Current Motor

The next group of mines, located at Elk Garden, are principally in the Pittsburg formation. These mines are Nos. 6 and 9 in the Pittsburg formation; No. 10 in the upper Sewickly, which is known locally as gas coal; No. 20 in the upper Freeport seam on a line with the railroad; and No. 14 four miles west of No. 20 on Abrams creek, producing a very high grade coal. With the exception of No. 6, which has a gravity rope haulage, this group is not provided with mechanical haulage other than steam trains. Mr. Robert Grant is superintendent of the Elk Garden district with headquarters at Elk Garden.

At Henry, about 8 miles east of Thomas, is located one of the later and, consequently, one of the more modern of the company's operations. The complete Bayard and Savage formations are accessible from this plant, the upper Freeport and the lower Kittanning being in good workable condition. It is operated by shafts 1 and 2 tapping the upper Freeport at a depth of 250 feet and the lower Kittanning at 450 feet. Tipples and hoisting towers are built of steel, while the power house, engine houses, blacksmith shop and all buildings in connection with the mine are of brick. The plant is equipped with electric haulage throughout and the coal is mined with compressed air punching machines. The power house contains two 24"x26"x30" Ingersoll air compressors, one belted 150 kw. alternating current generator, one 250 kw., 600 volt direct current generator for haulage purposes, and a synchronous motor direct current generator set, which acts as connecting link between the two generating units, permitting either one or the other to be shut down. This set can be operated from either end so as to provide direct or alternating current. On the main roads of this mine the hauling is done with one 13 ton and one 10 ton locomotive (the latter of General Electric manufacture), while the coal is gathered with two General Electric gathering locomotives of 4½ tons each. In portions of the mine the coal is still gathered by mule haulage. Mr. W. J. Christopher is superintendent of this division.


Hoisting Drum Operated by Direct Current Motor

The next operation is at Thomas, where the upper Freeport coal is mined by drift mines at tipple height above the railroad. No. 23 mine has been operated for a number of years and has become quite extensive in its workings; it is, however, still a good mine, producing 1200 tons of coal per day from a seam 8½ ft. thick, and is free from any noxious gases. Mine No. 25 is directly opposite mine No. 23, with a drift opening slightly to the dip in the same seam of coal. Mine No. 24 is in this same group, and is worked from a shaft 200 ft. deep penetrating to the Davis seam of lower Kittanning. The seam is divided horizontally by a rock, the portion above the rock being 8 ft. thick and that below 3 ft. thick. The rock serves the purpose of a pavement and, therefore, the coal below it is not worked to any extent in this mine. The coal is of an exceptionally good quality, running less than 1 per cent. in sulphur and seldom over 6 per cent. in ash, making No. 1 coke equal to the Connelsville. This group of mines is operated entirely by electric haulage and all pumps are driven by alternating current motors.

The 114 coke ovens at this plant are served by electrically operated coke larries, the electrical equipment of which is of General Electric manufacture. The results obtained with these larries, which run along the top of the ovens where the heat is at times excessive and where the fumes from the ovens would be injurious to horses or mules, have been excellent. It has also been found that they are much quicker in operation, for the control is so much better that, when about to discharge into the oven, they can be moved backward or forward an inch at a time. They are used either independently or with trailers and offer a flexibility not otherwise obtainable.

The electric equipment of the larries has given virtually no trouble at all. On the other hand, as the workings in these mines have become more and more extensive, trouble has been experienced with the haulage locomotives, as the length of hauls is very great and some steep grades are necessary. The capacity of the trolley line was increased by the addition of copper in order to reduce the drop in voltage resulting when heavy loads were started up at the working face, far back in the mine, and the track bonding was also overhauled and rails put in condition; but the troubles did not disappear entirely until a 500 kw., 600 volt direct current steam turbo-generator was installed in the Thomas power house. This turbine has demonstrated the particular suitability of this type of prime mover for handling the enormous fluctuations in load

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which occur in mining work. The normal current of this machine at full load is 833 amperes, but the unit is continually called upon to handle variations from 0 to 1450 amperes, which recur sometimes at intervals of a minute or less, when a train is picking up cars at the far end of the mine. The installation of prime movers possessing sufficient steadiness to stand up to this severe requirement has resulted in the entire disappearance of the former frequent burnouts of motor armatures.

The electrical apparatus in the power house at Thomas comprises two 100 kw., single-phase alternators with tub transformers for town and house lighting; one 200 kw., three-phase, 60 cycle alternator for supplying power to motors operating endless belts in the breaker and those operating the pumps, of which there are four 5 in. suction 4 in. discharge, one 3 in. suction 2½ in. discharge, one 6 in. suction 5 in. discharge, and one 10 in. suction with 8 in. discharge. All of these motors are designed for operation at 550 volts. The direct current equipment consists of one 204 kw., 600 volt and one 136 kw., 600 volt General Electric generator. The 500 kw. Curtis turbine provides current for eight 13 ton and one 20 ton General Electric locomotives, and the coke larries.

Mr. L. S. McDowell is superintendent of this division.

In the Coketon division, one mile west of Thomas, mines Nos. 35, 36 and 37 are operated in the lower Kittanning seam. This coal comes to the surface at a good height for tipples with drift openings. Nos. 24 and 26 are operated in the same group on the upper Freeport seam. The mines at Coketon are all equipped for electric operation throughout. Five 14 ton, two 13 ton and two 10 ton locomotives, as well as four 4½ ton gathering locomotives and two electrically operated coke larries, are supplied with current from two 250 kw., 600 volt generators of the belted type. A 100 kw. Curtis turbine direct current generator and a 300 kw. Curtis turbine alternator supply current to this mine. There is also an older General Electric Form "D" alternator which has seen hard service for many years and can now be used either as additional power, running in multiple with the turbines, or, by simply dropping off the belt and starting from the turbines as a motor, can be used as a rotary condenser for improving the power factor of the system. At Coketon there are two pumps of 10 in. suction 8 in. discharge, two of 6 in. suction 5 in. discharge, and two of 5 in. suction 4 in. discharge. The fans at Coketon are also electrically driven. Mines Nos. 35 and 36 are connected with mine No. 34 at Thomas, and No. 35 is therefore ventilated by a split from No. 34, while No. 36 is ventilated by a 15 foot Crawford and McCrimmon fan driven by a variable speed induction motor. Mine No. 26 is ventilated by a similar unit.

Practically the entire output of these mines is used for the manufacture of coke, the remainder being shipped West for smithing purposes. There are 500 ovens here and all are charged electrically. The coal that is shipped West for smithing purposes is loaded in box cars with box car loaders driven by alternating current motors.

The power house is further equipped with two Norwalk air compressors for the coal punching machines. Mr. M. L. Garvey is superintendent.

The next group of mines at Weaver, Randolph County, consists of Nos. 1, 2 and 3 in the lower Kittanning bed, which here shows up 9 feet thick and provides an excellent coking coal. The three mines are operated by gravity rope haulage and have 235 coke ovens. Mr. W. W. Brewer is superintendent of this section.

The main office of the operating department is located at Thomas, W. Va., where Mr. Lee Ott, the general superintendent, resides. Mr. Ott has been with the company for many years and has, therefore, seen the company expand territorially and make great progress along technical lines. The former of these is a simple process, but to guide an undertaking of this magnitude in such technical channels, that all the best and most improved inventions and developments in the engineering world can be made available and used without accumulating a huge scrap heap at a large expense, is an achievement which requires unusual foresight and judgment.

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THE 1200-VOLT RAILROAD—A STUDY OF ITS VALUE FOR INTERURBAN RAILWAYS*

By Charles E. Eveleth

The various 1200-volt interurban railways have now been operating a sufficient length of time to prove that there are no material objections to the use of this voltage on passenger cars. The nature of such minor difficulties as have been experienced have been such that their correction has required only detail changes of design which have been readily made. The important items of reliability and low cost of upkeep have met all expectations.

A single statement regarding the motors may explain the reason for this successful performance. On the Pittsburg, Harmony, Butler & Newcastle line, where the service is unusually severe on account of unusual grades and curves, a considerable number of the brushes originally shipped in the motor brush-holders are still in service, though many motors have now run over 150,000 car miles, and the wear on the commutators is hardly perceptible. It can be stated from the performance of the 1200-volt system that nothing is jeopardized by the adoption of this system, and such economies as are possible by its use can generally be obtained without offsetting disadvantages.

We may therefore assume that the 1200-volt system has "found itself" and a new system is thereby made available for consideration when studying the requirements of new railroads or extensions to existing systems. If desired, the cars may be run at equal efficiency over tracks equipped for 600 volts.

This being the case, the question naturally arises, what gains may be expected from the use of this higher voltage?

The primary object of any railway is to pay dividends and these are limited by the amount of receipts which must be expended for two items—fixed charges and operation. The most inflexible item is fixed charges. This works twenty-four hours a day whether business is good or bad and never gives up any ground once gained. Its only vulnerable point is the first cost of the railway. The 1200-volt system now offers a practical way of reducing the first cost of electrification through the material saving in substations and secondary distribution conductors. This gain becomes a permanent asset of the railroad making a definite decrease in the fixed charges at a place which cannot be reached in any way except by raising the voltage.

The other item is cost of operation. This item may be controlled to a certain extent by the personal ability of the manager, but having once selected the type and size of cars and the voltage of the system it is practically impossible for him to materially change the cost of getting power to his cars, which depends upon the distribution efficiency of his system and the cost of substation operation. The 1200-volt system decreases the cost of getting power to the cars in two ways: first, reducing the number of substations, and second, increasing the substation efficiency by improving the load factor. This latter result may seem unreasonable at first thought until one considers upon what grounds substation units are selected. They are not selected on the basis of heating, for it is probable that there are few interurban stations in this country running with 50 per cent. average load factor, and the average is certainly below 30 per cent. for the ordinary interurban conditions. It is generally necessary for the station unit to commutate within its overload guarantees, the maximum starting current of at least two trains starting simultaneously. As the running current of a train is about one-third of the starting current, and there are considerable periods during coasting and stops when the train is taking no current, and, furthermore, there are generally times when no trains are on the section fed by an individual substation, the low load factor can readily be accounted for. If then the units are selected for peak conditions the capacity of each station will remain constant, independent of the number of stations. It is evident when decreasing the number of substations, that is, increasing the track mileage fed by each station, that the average load will be greater and the substation load factor and efficiency improved. The total substation cost and operation will be decreased practically in proportion to the reduction in the number of stations. These advantages are net advantages since they are, in the 1200-volt system, obtained without being offset by extraordinary car equipment maintenance.

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* A paper presented before the Philadelphia Section of the American Institute of Electrical Engineers, on January 10, 1910.

DESCRIPTION OF RAILROADS

	A	B	C	D
Length of road, miles, all single track	100	100	100	100
Time between trains each direction, minutes	60	60	60	60
Cars per train	3	1	1	1
Seating capacity per car	65	60	50	40
Distance between stops, miles	5	2	1	0.5
Schedule speed, miles per hour	45	33	25	15
Maximum speeds, miles per hour	60	48	38	28
Car-miles per day	9000	3000	3000	3000

Any railway is complex, but there are certain fundamental differences, namely, track mileage, size of trains units and schedule speeds, which have a definite influence on the cost of electrification. In order to obtain an idea of the advantages which may be expected with the use of 1200 volts as contrasted with 600 volts, let us consider some concrete applications to different classes of conditions from which we may be able to draw some general conclusions. (Table above.)

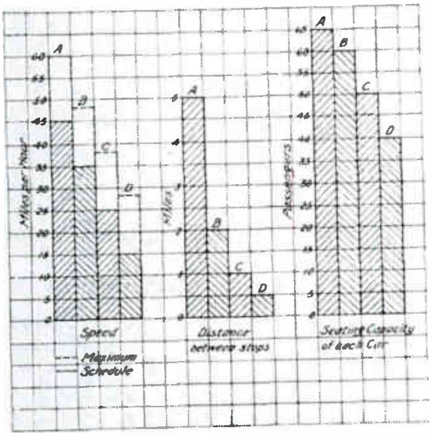

Fig. 1. Interurban Railway Systems. Single Track. Length of Road 100 Miles. Cars Every Hour in Each Direction.

In making these comparisons conservative values have been used, such as low substation cost, high cost of 1200-volt car maintenance, etc., so that the results will be conservative and the advantage rather less than might actually be achieved.

It will be seen that the roads vary greatly in conditions, from the heavy railroad conditions of *A*, through heavy interurban *B*, light interurban *C*, and very light traffic *D*. In fact, the cars of *D* will be no heavier than many city cars. (See also Fig. 1).

Cars. Based upon the requirements, the data in the table below may be considered reasonable for the cars:

It will be noticed that the power consumption which is "at the train" is slightly more for the 1200-volt cars on account of the greater weight of their equipments.

In the first table on following page, 10 per cent. greater maintenance is allowed for the upkeep of the 1200-volt electrical equipment. As a matter of fact, up to the present time no noticeable increase has been observed.

Substations. In selecting the size of synchronous converter units for the stations, they are in this case based on a maximum momentary demand of two cars starting simultaneously, except in the case of system A

CARS—GENERAL DATA

	A		B		C		D	
	1200 Volt	600 Volt	1200 Volt	600 Volt	1200 Volt	600 Volt	1200 Volt	600 Volt
Number	60	60	15	15	17	17	20	20
Cost each	$15,000	$13,000	$11,000	$10,000	$8,000	$7,000	$5,000	$4,500
Weight, tons	46.5	45	36	35	27	26	18	17
Amperes starting	1200	2200	280	520	200	370	120	220
Amperes run	300	574	94	174	66	124	40	74
Kw-hr. per train mile	11.16	10.8	2.88	2.80	1.89	1.82	1.08	1.02
Car-miles per day per car	150	150	200	200	176	176	150	150

where the size is based on the demand of one train starting and one train running. In each case a reasonable margin is allowed for occasional additional service.

The number of substations is dependent upon the maximum economical spacing, considered in conjunction with the cost of feeder copper and the allowable line drop with the assumed conditions of load. In each case it will be found that the addition of another substation to the number given in the data will not save its equivalent in cost of feeder copper. This brings up the question as to what may be considered equivalent feeder copper. The table below gives these equivalents:

The actual amount should be somewhat greater than these values, for with the addition of a substation there is a reduction in load factor on each substation, lowering the distribution efficiency. A curve is given (Fig. 2) to show the change in substation efficiency with change in the load factor on individual synchronous converters. This curve is for a station having 150 kw. to 300 kw. unit. For the larger machines the curve would be about two per cent. higher.

It will be seen that the investment in feeder copper which must be saved to justify an additional substation will be approximately 2½ times the cost of the substation.

An examination of the diagram (Fig. 3),

CARS—COST OF MAINTENANCE

Cents per Car-Mile

	A		B		C		D	
	1200 Volt	600 Volt	1200 Volt	600 Volt	1200 Volt	600 Volt	1200 Volt	600 Volt
Mechanical	1.25	1.25	1.00	1.00	.90	.90	.75	.75
Electrical	.99	.90	.77	.70	.60	.55	.55	.50
Total	2.24	2.15	1.77	1.70	1.50	1.45	1.30	1.25
Yearly cost	$73,500	$70,500	$19,400	$18,600	$16,400	$17,000	$14,300	$13,700

	A		B		C		D	
	1200 Volt	600 Volt	1200 Volt	600 Volt	1200 Volt	600 Volt	1200 Volt	600 Volt
Number of substations	6	14	4	9	3	6	3	5
Est. momentary demand, kw.	1440	1320	448	416	370	300	250	200
Number of units	2	2	2	2	2	2	2	2
Size of each unit	1,000	1,000	300	300	200	200	150	150
Cost of station, each	$60,000	$56,000	$26,400	$24,000	$20,200	$18,400	$17,100	$15,600

EQUIVALENT FEEDER COPPER TO REPLACE ONE SUBSTATION

		A		B		C		D	
		1200 Volt	600 Volt	1200 Volt	600 Volt	1200 Volt	600 Volt	1200 Volt	
Annual cost of labor and material		$2,500	$2,500	$1,900	$1,000	$1,800	$1,800	$1,700	$1,700
Fixed charges									
Interest	5%								
Depreciation	3%								
Taxes and insurance	3%								
Total	11%	6,600	6,160	2,904	2,640	2,222	2,024	1,881	1,716
Total		$9,100	$8,760	$4,804	$4,540	$4,022	$3,824	$3,581	$3,41
For feeder copper the interest, etc., will be approx. 8½ per cent. Investment in feeder copper equivalent to each substa. will be		$110,000	106,000	$58,300	$55,000	$38,800	$46,400	$43,400	$41,400

showing the "location of substations" will give a fairly comprehensive view of the railroad layout and the location of the cars at any hour.

Primary Distribution. This in each case will be the same for either system, except that the total length of the 600-volt transmission line will be slightly longer on account of the greater distance between the terminal stations. A flat price of $3,500 per mile of transmission line is taken for system *A*, and $1,000 per mile for systems *B*, *C* and *D*.

It will make practically no difference where the power is fed to the high tension system. For the sake of simplicity it is assumed that power is purchased and delivered to the power house step-up transformers at one cent. per kw-hr.

Secondary Distribution. Track. For railroad *A*, 85 lb. rail is assumed. This has a resistance per mile, including bonding, of approximately 0.033 ohm. The other roads use 70 lb. rail having a resistance per mile of 0.04 ohm. A third-rail equivalent to a 1,000,000-cir-mil. feeder is assumed for *A*, and No. 0000 trolley wire for the other roads. The values used in obtaining the feeder copper necessary are based on a momentary maximum emergency drop of 250 volts for the 600-volt systems and 500 volts for the 1200-volt systems.

This will give an average secondary distribution efficiency of approximately 90 per cent.

In electrification material there is included under "first cost" and "fixed charges," (I and II) cars and car equipments, sub-

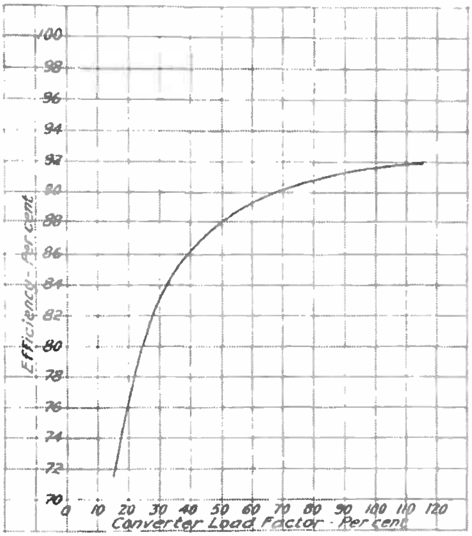

Fig. 2. Rotary Converter Sub-Station Efficiency Curve

FEEDER COPPER REQUIREMENTS

	A		B		C		D	
	1200 Volt	600 Volt	1200 Volt	600 Volt	1200 Volt	600 Volt	1200 Volt	600 Volt
Stub End Calculations:								
Trains starting and running	1-S	1-S	1-S	1-S	1-S-1-R	1-S	1-S	1-S
Total current, amperes	1200	2200	280	520	266	370	140	220
Length stub end miles	4.5	1.85	8	28	10	45	10	5.3
Size copper required	None	1,000,000	No. 000	No. 0000	No. 00	300,000	No. 0	No. 00
Between Substations:								
Trains starting and running midway	1-S	1-S	1-S-1-R	1-S	1-S-1-R	1-S	1-S-1-R	1-S
Amperes	1200	2200	374	520	266	370	160	220
Dist. between substations, miles	18.2	7.11	28	11.8	40	18.2	40	22.2
Size copper required	None	1,000,000	No. 0	No. 0000	No. 00	300,000	No. 0	No. 00
Total cost of feeder installed		290,000	53,200	80,000	60,000	100,000	50,000	60,000

FEEDER COPPER—COST PER MILE INSTALLED

Size	No. 0	No. 00	No. 000	No. 0000	300,000	1,000,000
Cost	$500	$600	$700	$800	$1,000	$2,000

For track bonding $450 per mile has been taken for *A* and $400 per mile for *B*, *C* and D.

POWER CONSUMPTION

	A		B		C		D	
	1200 Volt	600 Volt	1200 Volt	600 Volt	1200 Volt	600 Volt	1200 Volt	600 Volt
Kw-hr. per day at cars	$33,500	$32,400	$8,640	$8,400	$5,670	$5,470	$3,240	$3,000
Converter load factor	0.31	0.13	0.44	0.19	0.58	0.28	0.45	0.25
Efficiency (average)								
Substation	0.836	0.69	0.87	0.76	0.89	0.823	0.873	0.803
Secondary distribution	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Transmission	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
Step-up Transformers	0.98	0.98	0.97	0.97	0.97	0.97	0.97	0.97
Combined	0.722	0.595	0.745	0.632	0.761	0.705	0.718	0.688
Kw-hr. per day purchased	46,500	54,500	11,600	13,300	7,450	7,750	4,330	4,440
Cost per year at one cent. per kw-hr.	$169,000	$199,000	$42,400	$48,600	$27,200	$28,200	$15,800	$16,200

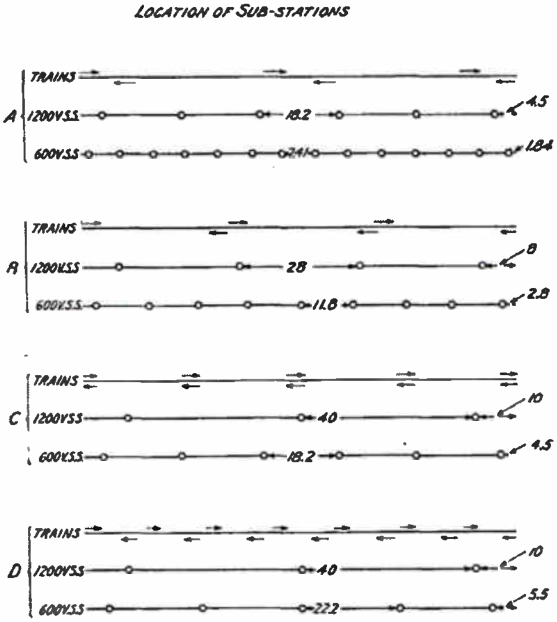

Fig. 3

stations complete, transmission line, trolley or third rail, low tension feeders and track bonding.

Under "operation and maintenance" (III) of electrification material there is included rolling stock, substations, trolley, feeders and track bonding, and cost of power; *i.e.*, all items which are affected by choice of system. Platform charges, general expenses, etc., common to both systems are not included.

SUMMARY OF COSTS—ELECTRIFICATION MATERIAL

	A		B		C		D	
	1200 Volt	600 Volt	1200 Volt	600 Volt	1200 Volt	600 Volt	1200 Volt	600 Volt
Cars	$960,000	$840,000	$172,500	$150,000	$136,000	$119,000	$100,000	$90,000
Substations	360,000	784,000	106,000	216,000	61,000	110,000	51,000	78,000
Transmission	318,000	340,000	84,000	94,000	80,000	91,000	80,000	88,000
Trolley*	625,000	600,000	160,000	150,000	160,000	150,000	160,000	150,000
Feeder	None	300,000	53,000	80,000	60,000	100,000	50,000	60,000
Bonding	45,000	45,000	40,000	40,000	40,000	40,000	40,000	40,000
	2,308,000	2,909,000	615,500	730,000	537,000	610,000	481,000	506,000
Track, roadway, etc	2,500,000	2,500,000	1,800,000	1,800,000	1,800,000	1,800,000	1,800,000	1,800,000
Total	$4,808,000	$5,409,000	$2,415,500	$2,530,000	$2,337,000	$2,410,000	$2,281,000	$2,306,000
Note.								
Substation buildings	45,000	105,000	20,000	45,000	14,000	29,000	14,000	23,000
Substation electric equipment	315,000	679,000	86,000	171,000	47,000	81,000	37,000	55,000
Cars and substations	1,320,000	1,624,000	278,500	366,000	197,000	229,000	151,000	168,000
Distribution materials	988,000	1,285,000	337,000	364,000	340,000	381,000	330,000	338,000

* Third rail used on *A*.

FIXED CHARGES—ELECTRIFICATION MATERIAL

	Life Years	Annuity 5 Per Cent.	A		B		C		D	
			1200 Volt	600 Volt	1200 Volt	600 Volt	1200 Volt	600 Volt	1200 Volt	600 Volt
Depreciation:										
Cars	15	46.31	$44,500	$39,000	$8,000	$7,000	$6,300	$5,500	$4,600	$4,200
Substation buildings	30	15.05	700	1,600	300	700	200	400	200	300
Substation apparatus	20	30.24	9,500	20,500	2,600	5,200	1,400	2,400	1,100	1,700
Transmission	20	30.24	9,600	10,300	2,500	2,800	2,400	2,700	2,400	2,700
Trolley	12	* 62.83	18,900	18,100	10,100	9,400	10,100	9,400	10,100	9,400
Feeders	20	30.24	—	9,100	1,600	2,400	1,800	3,000	1,500	1,800
Bonding	10	79.50	3,600	3,600	3,200	3,200	3,200	3,300	3,200	3,200
			86,800	102,200	28,300	30,700	25,400	26,600	23,100	23,300
Interest: 5 per cent. on total cost of electrification material			116,000	143,000	31,000	36,000	27,000	30,000	24,000	25,000
Taxes: 1½ per cent. of total cost of electrification material			30,400	43,700	9,200	11,000	8,000	9,100	7,200	7,600
Insurance: 1½ per cent. of cost of rolling stock and substations			19,800	24,300	4,200	5,500	2,000	3,400	2,300	2,500
Total fixed charges			$339,000	$313,100	$72,700	$83,200	$62,400	$69,100	$56,600	$58,400

* Third-rail depreciation based on 20 years life.

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On examination of these results, which are based on conservative figures on account of the relative newness of the 1200-volt system, it is apparent that the higher voltage effects economies at points that can only be reached by a change more fundamental than is possible with the lower voltage.

The saving of 1½ to 2 cents per car mile will permit a very material increase in dividends.

COST OF OPERATION AND MAINTENANCE

	A		B		C		D	
	1200 Volt	600 Volt	1200 Volt	600 Volt	1200 Volt	600 Volt	1200 Volt	600 Volt
Transmission	$9,000	$9,500	$3,000	$3,300	$2,800	$3,200	$2,800	$3,100
Trolley and feeders	15,000	15,000	9,000	9,000	9,000	9,000	9,000	9,000
Rolling stock	73,500	70,500	19,500	18,500	16,500	17,000	14,500	15,000
Substations	15,000	35,000	7,600	17,000	5,500	11,500	5,000	8,500
Cost of power	169,000	199,000	42,400	48,600	27,200	28,200	15,800	16,200
	281,300	329,000	81,500	97,100	61,000	68,400	47,100	51,800
Total operation and maintenance of items listed	282,000	329,000	82,000	97,000	61,000	68,000	47,000	51,000
Statistics indicate that the items listed on 600 volt roads constitute approximately 44 per cent. of the total operating cost. Based upon this there should be added to each of the above	421,000	421,000	123,000	123,000	87,000	87,000	65,000	65,000
Total yearly cost of operation, and maintenance of 3,283,000 car-miles per year for *A* and 1,093,000 car-miles per year for *B*, C and *D*	$703,000	$750,000	$205,000	$220,000	$148,000	$135,000	$112,000	$116,000

COMPARISON OF SYSTEMS

	A		B		C		D	
	1200 Volt	600 Volt	1200 Volt	600 Volt	1200 Volt	600 Volt	1200 Volt	600 Volt
I.—First Cost:								
Track, roadway, etc.	$2,500,000	$2,500,000	$1,800,000	$1,800,000	$1,800,000	$1,800,000	$1,800,000	$1,800,000
Electrification material:								
Car equipments	960,000	840,000	172,500	150,000	136,000	119,000	100,000	90,000
Substations	360,000	784,000	106,000	216,000	61,000	110,000	51,000	78,000
Distribution	988,000	1,285,000	337,000	364,000	340,000	381,000	330,000	338,000
Total	$4,808,000	$5,409,000	$2,415,500	$2,530,000	$2,337,000	$2,410,000	$2,281,000	$2,306,000
In favor of 1200 volts		601,000	—	114,500	—	73,000	—	25,000
II.—Fixed Charges:								
Track, roadway, etc., 7 per cent.	175,000	175,000	126,000	126,000	126,000	126,000	126,000	126,000
Electrification material	259,000	315,000	73,000	83,000	62,000	69,000	56,300	58,500
Total	$434,000	$490,000	$209,000	$209,000	$188,000	$195,000	$182,300	$184,500
In favor or 1200 volts	—	56,000	—	10,000	—	7,000	—	2,000
III.—Operation and Maintenance:								
Miscellaneous	421,000	421,000	123,000	123,000	87,000	87,000	65,000	65,000
Electrical	282,000	329,000	82,000	97,000	61,000	68,000	47,000	51,000
Total	$703,000	$750,000	$205,000	$220,000	$148,000	$155,000	$112,000	$116,000
In favor of 1200 volts		47,000	—	15,000	—	7,000	—	4,000
IV.—Annual Cost II + III	1,137,000	1,240,000	414,000	429,000	336,000	350,000	294,300	300,500
In favor of 1200 volts	—	103,000	—	2,500	—	14,000	—	6,200
V.—Revenue:								
Additional receipts per car-mile necessary to pay additional cost of operation, etc., for 600 volts	—	3.1c.	—	2.28c.	—	1.28c.	—	0.55c.

NOTE.—3,283,000 car-miles per year for *A*
1,093,000 car-miles per year for B, C and *D*.

It is further clear that the relative value of the higher voltage increases as the demand for power increases, and that below a certain size of equipment there would be practically no justification for the adoption of the higher voltage. Results are shown for convenience in graphical form in Fig. 4, as this indicates clearly how the economies change with the change in the system.

The place where the application of the 1200-volt system may be looked for in the immediate future is that field of interurban railroading where it has already made its successful start.

Conclusion. In conclusion it appears that a conservative estimate of the economy obtained by a 1200-volt system as compared with the 600-volt system in the elements of a railroad which are affected by the choice of system, that is, all of the electrification material, would place these savings approximately as follows:

1. First cost .... 10 to 20 per cent.
2. Fixed charges... ... 10 to 18 per cent.
3. Operation and maintenance.......... 10 to 15 per cent.

Furthermore, experience has shown that

4. The 1200-volt system is just as reliable as the 600-volt system.
5. Substations may be operated from a system of any commercial frequency.
6. In specific cases the saving has been found materially greater than indicated in conclusions 1, 2 and 3, notably where the length of road is such that no substations are required for the 1200-volt system while substations are required for the 600-volt system. In some instances, the savings have been as great as 25 or 30 per cent. in the electrification material.

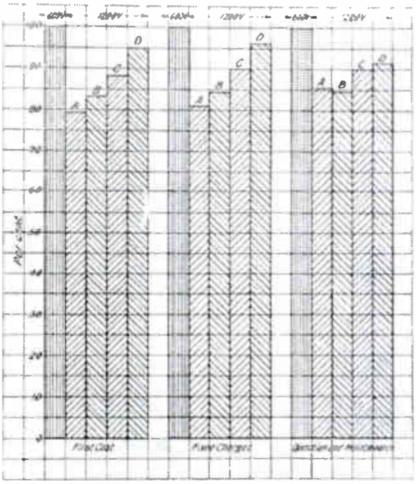

Fig. 4. Comparison of 600 Volt and 1200 Volt Railway Systems

COMPARISON OF SYSTEM

	600 Volt Per Cent.	A 1200 Volt Per Cent.	B 1200 Volt Per Cent.	C 1200 Volt Per Cent.	D 1200 Volt Per Cent.
I.—First Cost: All electrification material . .	100	79.4	85.5	88.0	93.0
II.—Fixed Charges: All electrification material . .	100	82.3	87.3	90.0	96.5
III.—Operation and Maintenance All electrification material . .	100	85.8	84.5	89.9	92.0
IV.—Annual Cost II+III: All electrification material . .	100	84.0	86.0	90.0	94.0

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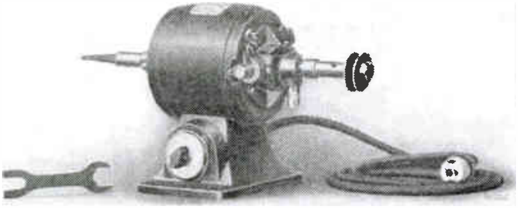
SMALL BUFFING AND GRINDING MOTORS—DRAWN SHELL TYPE

By R. E. Barker

Small Motor Department—General Electric Company

In modern life many things are considered necessaries which only a generation ago were regarded as luxuries. It is evident to the student that this change in view is a natural one, going hand in hand with progress. Inventive genius is being constantly applied to the devising of new and improved mechanisms for lightening our tasks in the factory, shop and home by the replacement of hand work by power. It is now recognized that electric power has several advantages over all other forms, particularly for the smaller applications, of which buffing and grinding are good examples.



Small Power Motor Designed for the Use of Jewelers, Dentists, etc.

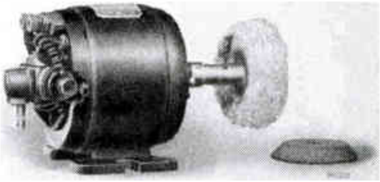
The art of polishing has been known from the most ancient times, but until the advent of power driven rotary wheels, a satisfactory polish could be accomplished only after a slow and laborious operation. The electric motor applied to this work offers a way of performing certain tasks satisfactorily and quickly which were often very poorly done by the earlier and slower methods.

Small buffing and grinding motors are offered in three distinct forms, each of which has a particular field of usefulness. For the light work of the ordinary household a motor with a simple extension shaft is found to be satisfactory. This machine is styled the "Domestic" buffing and grinding motor. It is developed from a standard small power motor and has a removable shaft extension substituted for the pulley. The extension is supplied with a rag wheel for buffing and an emery wheel for grinding, and these may be used interchangeably. The wheels are clamped between the nut and washer on the free end of the shaft extension.

This little apparatus serves the double purpose of polishing silverware and grinding knives for the household, and when used intelligently does much better work and in a shorter time than is possible by the antiquated hand method. The expense of operation is very small — less than one cent per hour, at the average prevailing rate for current.

The use of buffing and grinding motors is not limited to the home, however; they have an important place in jewelers' shops, dentists' laboratories, machine and test rooms, and the like. For such applications, motors of larger size and greater capacity are demanded and two types of these are therefore offered, namely, the "Jeweler's" and the "Commercial."

The Jeweler's motor is particularly devised for the use of jewelers and dentists. It is made in four sizes ranging from 1/15 h.p. to 1/6 h.p., and is complete with all the accessory parts necessary to form a satisfactory outfit. The motor is mounted on a high base or pedestal casting, in which a controlling switch is conveniently placed. The leading in wires are combined in a flexible reinforced cord, fitted with a screw plug adapted to the usual screw base lamp socket. The motor armature

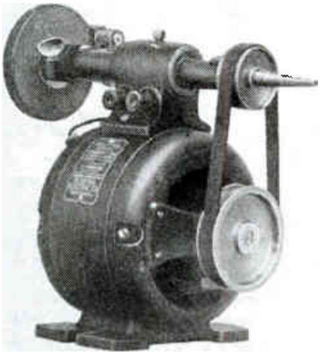


Small Power Motor for Domestic Purposes

or revolving part is made with a shaft extending from both ends of the frame. These ends are tapered to a standard dimension and are adapted to receive the two shaft extension. These, together with a combined wrench and removing tool, complete the outfit. One extension has a clamp nut and washers for taking grinding wheels, etc.; the other is taper-threaded to receive rag buffing wheels or wire scratch wheels with wooden hubs. All of these devices are well known to the jewelers and dentists.

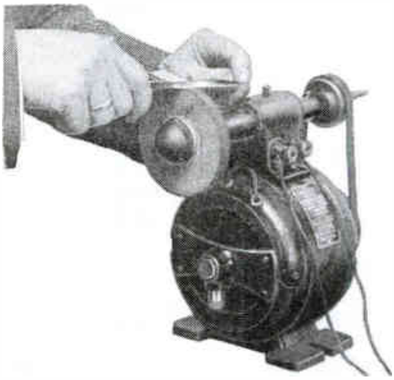

Jeweler's Motor without Accessories

Both shaft extensions are held on the motor shaft by friction on the taper fit described above. When it is desired to change or remove them, this may be easily accomplished by the use of the removing tool furnished with each outfit, as shown in the illustration on following page. The tool is inserted over the shaft and between the motor-bearing hub and back of the shaft extension. Using the tool as a lever, a light pressure on its free end is sufficient to start the extension, which will then drop off the shaft. The jeweler's motors are used for a wide variety of purposes, each of which requires a different grade of buffing or grinding wheel. These additional accessories are not furnished, as it is thought better to leave it to the individual user to secure for himself such wheels as are best suited to his work.


Small Power Motor for General Commercial Purposes

The jeweler's motors are particularly suited to dentists, jewelers and such others as have small pieces of work to be handled. To provide for the larger requirements of silversmiths, manufacturing jewelers, etc., a third form of buffing and grinding motor known as the "Commercial" is offered.

This machine is shown above. It consists of a small power motor of 1/10 h.p. or 1/6 h.p. capacity, on the top of which a cast iron bracket is fixed. The bracket carries a long counter-shaft support with a barrel shaped centre portion of enlarged diameter. The counter-shaft center is displaced with respect to the centre of the barrel for the purpose of providing an easy means of tightening the driving belt, which transmits power from the flanged pulley on the motor shaft to the counter-shaft above it. After the belt tension has been adjusted to the right amount, by turning the counter-shaft support in its eccentric bearing in the bracket, the square head set screw in the top of the bracket is tightened to lock the parts in place.


Showing Use of Commercial Motor for Grinding

The shaft is furnished with one end tapered and threaded for rag wheels, etc., while the other has check plates and nut to clamp the four inch emery grinding wheel that forms a part of the outfit. On the end of the counter-shaft support an adjustable tool rest is fitted, by means of which the work may be held at the correct angle while being ground. This is an important improvement, for without a guide or rest considerable skill is required to secure the best results. It will be noted that the Commercial buffing and grinding motor has no parts above the center line of the countershaft which will interfere with the free swing of large work; for this reason it is especially desirable for silversmiths and manufacturing jewelers, etc. Large salvers, candelabra and the like can be buffed and polished without difficulty by the use of this motor.

Method of Removing Extension Shaft

All the buffing and grinding motors that have been described are totally enclosed and protected from the dust, metal chips, dirt, etc., which surround them while in use. They are all carefully planned to the classes of work for which they are intended. The motors may be obtained with the different windings that suit them for operation on the more common commercial lighting circuits, both alternating and direct current.

GEARS FOR MOTOR-DRIVEN TOOLS WITH SPECIAL REFERENCE TO CAMBRIC PINIONS

By John Riddell

With electrically driven machinery the means employed for transmitting the mechanical energy of the motor to the machine is a matter of first importance. In the early days of the electric motor, this subject was given little attention, belts and countershafts, etc., being considered entirely satisfactory. With the growth of electric drive, however, increasing attention has been given to this branch of the subject in the endeavor to lessen friction losses, reduce maintenance and attention, and conserve floorspace.

The last of these considerations, together with a desire to improve the appearance of motor-driven tools, has tended toward the evolution of the more modern design in which the tool and its driving motor appear as practically one machine.

When possible, direct connection is, of course, the simplest method of drive. For various reasons, however, this method is frequently inexpedient and in these cases, recourse must be had to belts, chains, gears or some similar means of drive.

In the case of machine tools, at least, the use of belting is generally precluded, as the proper utilization of floor space requires the motor to be so set that the pulley center would be too close for belt drive. For this work, therefore, chains or gears are generally employed.

Chains work fairly well where the sprockets are not in a vertical position and when the loads and speeds are not excessive, but these limitations, together with the fact that in most cases machine tools require something more positive, have made for the employment of gears.

The action of gears is, of course, dependent upon the material of which they are made; some of the more important varieties are as follows:

Steel Gears. These are usually very noisy and unless kept well lubricated are apt to cut and wear out quickly. Cast iron gears, on the other hand, generally give satisfaction, provided the load is not excessive and the back-lash, or shock, is not too great.

Brass for pinions is expensive and makes about as much noise as any other metal; it should be used only where greater toughness than can be had from cast iron is required, or where a pinion is to run with a steel gear for heavy work.

Rawhide has been used for many years and is often resorted to when other gears make too much noise. It is expensive, however, and shrinks badly in a dry, warm place. It will not stand moisture and, altogether, it is unsatisfactory for most work.

Fibre has also been used for reducing noise. The objection to it is that it is difficult to keep dry, as it absorbs moisture which causes it to swell and otherwise give trouble. This material seems also to deteriorate under the use of oil, which is a very serious drawback. It is not very strong, and while it is not so noisy as metal still the noise is sometimes objectionable.

In the above paragraph we have had spur gears in mind. Another style of gear is that known as the herring-bone type, its name being taken from the form of the teeth. This is a very expensive form to cut and assemble as both the gear and pinion are usually made in two pieces, which are later riveted together. When large quantities of these gears and pinions are made they are rough bored and faced where they join together. They are then assembled ten or a dozen halves on an arbor and cut right-handed. Another ten or a dozen are then placed on an arbor and cut left-handed. It will be readily seen that the slightest error between the different settings will result in inaccuracies, and it takes but a very slight error (sometimes only one or two thousandths of an inch) to cause trouble in the running of these gears.

The herring-bone pinions are cut in the same manner, but instead of using a gear cutter for this purpose, a milling machine may be employed.

As in the case of the gears, the machines must be set to cut hoth right- and left-handed, and errors are apt to creep in here as in the former case. If these errors happen to be in the opposite halves, so that the large halves of the gear and the pinion come together, trouble is apt to result. These gears do not allow of any end play in the revolving parts, as the angle of the teeth will not permit it without a corresponding shock to the opposite gear. This form of gear should be avoided except in very extreme cases, such as for heavy rolling mill machinery where very coarse pitches are used; where the rolling effect produced by the angle of the teeth will tend towards smoother running and give greater strength.

Most machine tools demand variable speeds, and the latest forms of variable speed drives require considerable gearing, which, if not properly made and installed, will cause more noise than is desirable. This noise can be entirely eliminated in any case fo' which cambric pinions can be made; these, while noiseless, are also extremely durable and efficient.

CAMBRIC PINIONS

A brief description and history of this invention may be of interest.

A large punch and shear, driven by a motor through a train of gears and installed in a blacksmith shop, where the work is very heavy and rough, had been giving a great deal of trouble, both from noisy gears and from stripping of the gear teeth.

As originally fitted up, the train of driving gears consisted of a brass pinion on the motor shaft which drove through a cast iron cut gear on a countershaft, and this, in turn, through another pinion connecting with the main gear of the machine. The countershaft carried a heavy flywheel, which, when running, caused a backlash that several times stripped the teeth from the cast iron gear. The brass gear also soon lost its shape and gave trouble. After this experience a street railway gear and pinion were used, but they made an intolerable noise and had to be discontinued. It was at this stage that the inventor, looking for a substitute which would stand up, and having in mind rawhide and fibre, bethought him of having a muslin pinion made. This pinion was accordingly made, and was put on the punch over a year and a half ago; up to the present writing, it has not given a particle of trouble, neither does it show any appreciable signs of wear.

Since that experience, a great many other troublesome machines have been similarly equipped, until at present there are 700 of these cambric pinions in active service, and as yet not one has failed.

In making these pinions, the following process is followed. The muslin is cut out in discs which are assembled and pressed between two steel washers, the whole then being securely fastened with rivets or tap bolts, following the same method as that of making rawhide pinions. The blank is next turned to the proper diameter and the teeth cut in a gear cutter. The gear is then soaked in a good quality of machine oil.

These pinions can be made in various forms, of any reasonable size, and either with or without metallic centers. It is absolutely necessary, however, for the shrouding to extend to the full diameter of the gear.

With these pinions, the use of lubricants is unnecessary, as the oil which was absorbed by the muslin in the oil bath will keep the teeth of the pinion lubricated for an indefinite length of time. In the actual running

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of these gears they seem to take a metallic coating on the teeth, which tends to protect them from excessive wear from the teeth of the other gear.

In addition to these features, there is also a certain amount of flexibility which is beneficial, as in all commercial gears there is apt to be some slight inaccuracy in the spacing from tooth to tooth. When such gears are run with other metallic pinions there may be, and frequently is, an excessive strain brought on one tooth, which tends either to bend or break it. With the cloth pinion, however, the flexibility afforded by the material tends to distribute the strain over at least two or more teeth, depending on the size and number of teeth in contact; these will stand any reasonable amount of this bending, there being no fibres to crystalize as in the case of the metallic gears.

Some engineers, when the matter was first brought to their attention, were inclined to be a little skeptical, but the pinions have given and are giving a practical demonstration of their merits by running every day in the hardest kind of service. An inspection of some of these cases would, I think, satisfy anyone as to their worth.

ANNUAL REPORT OF THE GENERAL ELECTRIC COMPANY

The latest report of the General Electric Company gives the shareholders full information about the work of the year under review, the present financial position, and the prospects of the Company in the immediate future.

The address of the President summarizes the financial result in the statement that after paying all expenses, making ample allowance for losses and depreciation, and authorizing 88 per cent. of the expenditure on factory plants ($2,447,984) the net profits were $6,493,670.

Out of this $5,214,352 was paid to the shareholders in dividends—being 8 per cent. on $65,179,600 of capital; the balance $1,279,318 was added to the surplus, which now amounts to $17,318,318.

The total assets are $102,440,988, and bearing in mind the drastic manner in which they have been shrunk in past years, it is evident why this industrial occupies the high rank among others that it does.

In the previous year's report the President intimated that the capacity of the factories was then far in excess of existing demands for their product and sufficient to provide for a much greater output than had ever been reached in the history of the Company. In the present report he states that there is still a surplus of factory facilities which cannot be fully employed until the volume of orders received is considerably increased. This may be partly accounted for by the fact that the various departments are not all equally busy. In 1909, some $2,878,942 was expended upon factory plants, which added considerably to the factory facilities. While the President calls attention to the fact that there is still room and to spare for more orders, Vice-President Lovejoy shows in his report that $54,360,562 in orders were received in 1909 (11 mo's) against only $42,186,917 in 1908, and that for the last five months of 1909 they were being booked at the rate of nearly $70,000,000 per annum, a figure almost as large as in the record year of 1907.

In the reports of Vice President Rice and Vice President Lovejoy, we have a record of achievement in many directions. The total turnover in 1909 (11 mo's) was $51,656,631 against $44,540,676 for the previous year, evidence clear enough that there has been a substantial recovery from the depression of 1908 and that the Company has resumed its phenominal progress from the annual "billed amounts" of $12,000,000 in the "nineties" towards the predicted turnover of $100,000,000 in 1914. As the field for electrical apparatus and appliances increases, the immense number of separate machines and parts to be catalogued and listed enlarges. This in turn means larger stock and more warehouse accommodation at distributing centers.

New triumphs for the Curtis steam turbines and the G.E. high voltage direct current railway system are announced—the natural result of simplicity, economy, reliability and safety in operation. Included in the expenditure on patents during the year was a considerable sum for U. S. patents on foreign inventions relating to incandescent lamp filaments and processes of manufacture.

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In consequence, immense strides have been made in the efficiency of metal filament lamps, the business in which grows apace. This is the more remarkable when it is considered that but few central stations have done more than advise their customers that these new Mazda lamps can be got by paying for them.

Vice President Rice mentions the engineering problems that have been solved and are being solved, and from his remarks it is apparent that the art is steadily progressing.

Apparatus for the economical transmission of current over very long distances is being constantly improved. Larger units at higher voltage, and the attendant devices to render their use safe and reliable afford a wide field for cultivation. Industrial power problems invite the highest skill of the electrical engineer, each successful solution leading to still greater triumphs.

The financial report which follows bears testimony to the magnitude of the transactions of the Company, and the care taken to have its accounts and records full and clear. The accuracy of the balance sheet is certified to by Marwick, Mitchell & Co., chartered accountants. Of this part of the report it may be said that every facility is at the command of the Company for the successful prosecution of its business.

Modern machine tools and machinery are employed throughout, and the physical condition of all the manufacturing plants is maintained at the highest point of excellence.

Large expenditures for these purposes, together with the purchase of raw materials and commodities at the lowest prices, can only be made with ample cash resources. The inventive genius of the Company's engineers, the enterprise of its commercial men, and the skillful administration of its financial affairs, command the business and warrant the confidence of the thousands of customers of the Company, who are now to be found in every quarter of the globe.

A comparison of accounts follows:

	1906	1907	1908	1909	1910 (Dec. 31 11 Mo.)
Net Profits	$7,319,161	$8,502,237	$6,948,682	$4,802,252	$6,403,670
Dividends and Interest	3,861,062	4,418,727	5,545,646	5,214,026	5,930,669
Balance	$3,518,099	$4,083,510	$1,403,036	* $411,773	$1,279,319
Sprague Account: Written off on account Stanley Company	750,651				
Patents written off	1,000,000	999,999			
Balance	$2,458,099	$3,083,501	$1,403,039	$411,773	$1,279,319
Previous surplus	9,569,196	12,027,295	15,110,796	16,513,836	$16,102,062
Stock Dividend					
Total Surplus	$12,027,295	$15,110,796	$16,513,836	$16,102,062	$17,381,381

* Loss.

We make further comparison:

	1906	1907	1908	1909	1910
Sales	$43,146,902	$60,071,882	$70,977,168	$44,540,675	$51,656,631
Royalties, dividends, etc.	798,539	417,586	1,010,961	703,942	1,260,847
Profits made by Security Holding Companies	....	675,000	....	750,000	..
Profits on sales of Stocks and Bonds	173,390	329,702	9,778	35,912	478,019
Interest and Discount	300,782	114,660	487,079	1,137,938	706,552
Total	$44,419,613	$61,608,830	$72,484,986	$47,168,469	$54,102,049
Cost of Sales	37,025,347	53,106,594	65,898,334	42,366,216	47,698,379
Net Profits	$7,394,266	$8,502,236	$6,586,653	$4,802,252	$6,403,670

The balance sheets as of January 31 compare:

ASSETS	1906	1907	1908	1909	1910
Patents, etc.	$1,000,000	1	1	1	1
Factory Plants	8,000,000	9,000,000	12,000,000	13,900,000	14,330,958
Real Estate	359,014	347,189	541,900	85,124	119,063
Stocks and Bonds	19,101,539	20,086,700	18,000,089	21,922,189	22,329,663
Notes and Accounts Receivable	16,287,018	22,860,789	29,857,726	18,873,057	19,377,972
Advances to Affiliated Cos.		2,922,675		....	....
Inventories	16,922,291	22,593,907	20,997,055	18,393,899	25,150,035
Work in Progress	2,490,206	3,853,321	1,276,294	607,276	462,223
Cash	6,356,094	3,910,709	12,250,720	22,233,671	17,623,466
Discounted Paper		666,608		....	....
Copper Mining Investment			2,701,976	3,174,380	3,048,604
Total	$70,525,162	$86,245,289	$98,525,765	$99,189,800	$102,440,988

LIABILITIES	1906	1907	1908	1909	1910
Common Stock	$54,286,750	$64,353,550	$65,167,400	$65,178,800	$65,175,600
Debentures	2,102,000	2,102,000	11,074,750	14,963,000	14,962,000
Accrued Interest	2,253	1,924	108,791	107,623	83,664
Accounts Payable	2,106,864	4,010,411	1,170,517	2,836,834	3,530,750
Purchase Curtis Patents					
Endorsements		660,608			
Profit and Loss Surplus	12,027,295	15,110,796	16,513,836	16,102,002	17,381,381
Total	$70,525,162	$86,245,289	$98,525,765	$99,189,800	$102,440,988

Sales and orders received during last nine years compare:

Year ending January 31.	Amount Billed	Orders Received
1900	23,370,463	26,323,626
1901	28,783,275	27,969,541
1902	32,338,036	34,350,840
1903	36,683,598	39,044,454
1904	41,699,617	39,060,038
1905	39,231,328	35,994,807
1906	43,146,902	50,044,272
1907	60,071,882	60,483,659
1908	70,977,168	59,301,040
1909	44,540,676	42,186,917
1910	51,650,031	54,300,562

During the year there were received 270,659 separate orders (not including contracts), an average of 902 per working day.

The following table shows approximately the floor space and the number of employes during the last eight years:

	Floor Space	Employes
1901	2,500,000	15,000
1902	3,000,000	15,000
1903	3,000,000	18,000
1904	3,700,000	17,000
1905	4,100,000	18,000
1906	4,350,000	22,500
1907	4,970,000	28,000
1908	6,400,000	20,000
1909	7,000,000	23,300
1910	7,180,000	30,000

The amount written off factory plants and equipment is substantially 82 per cent. of the cash expended thereon during the year.

The land area of all three plants is now about 521 acres.

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