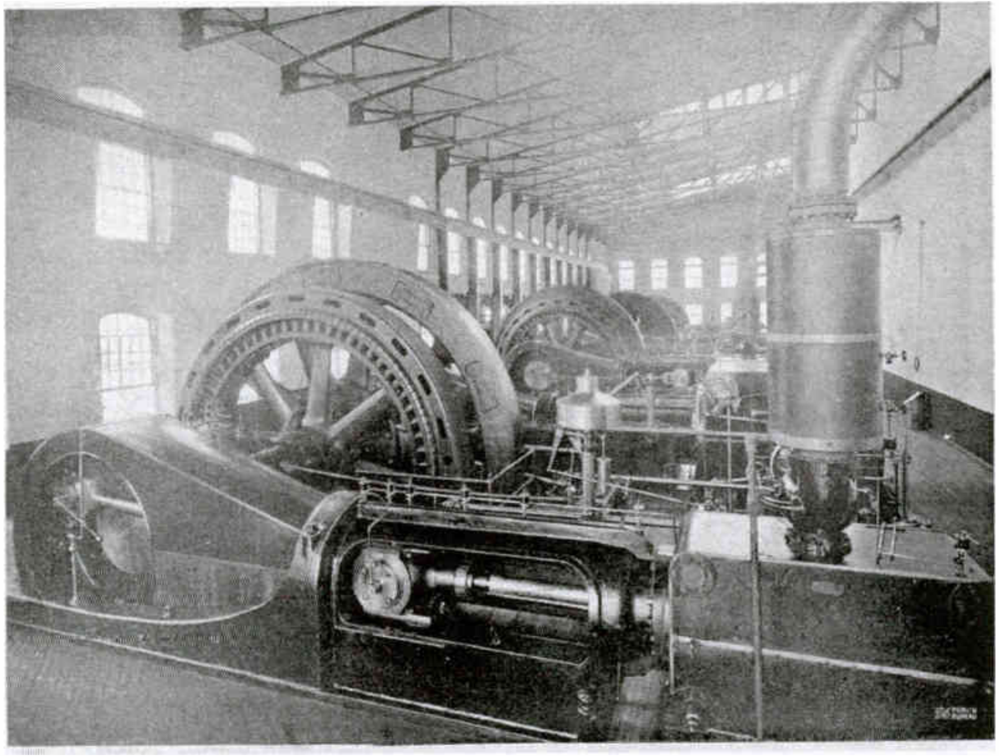
GENERAL ELECTRIC
REVIEW

VOL. XIII, No. 10

OCTOBER, 1910

CONTENTS



Power House of The Proximity Manufacturing Company, Greensboro, N. C.

(See page 472)

GENERAL ELECTRIC
REVIEW

CURVES OF REACTIVE POWER

The advantages in transmission possessed by the alternating current and the simplicity and durability of the induction motor have led to the adoption of these motors in ever-increasing numbers for all kinds of power purposes that do not require great variations in speed. For this reason, the various features of their installation and operation are of much importance.

One of the characteristics of these motors that requires consideration is their action in lowering the power factor of the circuits on which they operate, through taking a magnetizing current that is practically wattless. While this wattless or magnetizing current can be generated with little expenditure of power on the part of the prime mover (only enough to account for the I^2R loss), it is by no means negligible, as it adds to the heating, and thus increases the generator capacity required for a given load as well as the size of the distributing conductors, and in addition affects the regulation by increasing the IR drop.

An effective remedy for this condition of low power factor is found in the synchronous motor, which, when operated with over excited fields, supplies a leading component that, by properly selecting the synchronous machine, can be made to raise the power factor of the system as much as is desired.

A simple explanation of the use of these so-called "rotary condensers" was given by Mr. A. L. Jones in the March, 1909, issue of the Review, from which we quote the following:

"It should be remembered that the power factor of the generator is determined by the wattless magnetizing current required by the inductive load, and further, that a power factor of less than unity value has the effect or rendering unavailable part of the generator capacity. If all the magnetizing current can be supplied from some source external to the generator, the latter will operate at unity power factor and its whole output will be available for power.

"Synchronous motors * * * can be used to supply magnetizing current to induction motors, thereby removing this burden from the generators. Such a motor, of course, has to be separately excited from some direct current source. There is, however, a critical value of field current at which the current taken by the synchronous motor is at unity power factor. If excitation below this value is supplied, the current taken from the line becomes lagging, and the effect on the generator supplying the motor is the same as if the motor were of the induction type; that is, the generator must make up the deficiency in excitation. If on the other hand the field current is in excess of the proper value, the motor draws leading current, and the effect is as if it had more excitation than it needed; this excess being delivered to the system, where it serves to excite or magnetize induction motors and relieve the generators. It follows that if enough leading current is supplied by over-excited synchronous motors to furnish magnetizing current to all the induction motors of the system, the generators will operate at 100 per cent power factor.

"A synchronous motor without mechanical load, and having its field over-excited to deliver leading current for exciting induction motors in other parts of the system, is called a rotary condenser. Such a machine may be located near the induction motors and used to supply the excitation needed by them, thus avoiding the flow of this wattless current through the transmission system and the burdening of generators therewith. In cases where a considerable number of induction motors are concentrated at some distance from the generating station and the conductors necessarily become of considerable size, by supplying the magnetizing current practically at the motors the line current will be reduced and a considerable saving in copper effected. What is more important, however, the generator is not burdened with this wattless current, and its full capacity is available for power. Locating the condenser at the generating station relieves the generator, but the wattless current still has to be transmitted over the conductor net work."

The article by Prof. Karapetoff, in the present issue, furnishes a simple means of determining the size of synchronous motor that is necessary to meet the requirements of any given case, in which the load and existing power factor being given, it is desired to raise the latter to any predetermined value.

SOME NOTES ON THE BEHAVIOR OF D.C. MACHINES

On page 456 of this issue we reprint an interesting article from ELECTRICAL ENGINEERING of London, on the behavior of d.c. machines. Little has been published on this subject, and the article contains suggestions regarding the starting of commutating pole motors that should prove of value to those operating these machines.

It should be particularly noted, however, that a number of the troubles discussed in this article are apparently due to the very small air gap or the narrow interpolar spaces (or both), that are present in the case of many of the foreign-built machines.

The General Electric motors are liberally proportioned in respect to both of these features, and a tendency for the speed to rise on load (as noted on page 459) does not exist in these machines, nor is there any evidence of surging; in consequence, the brushes are run in the neutral position, or as nearly so as that point can be determined. For this same reason, the second remedy is unnecessary, the placing of accumulative series windings on General Electric commutating pole motors not being required, except when the nature of the service demands a markedly drooping speed characteristic.

Again, it would appear from the article that only variable speed motors are furnished with commutating poles, in American practice, however, constant speed machines are quite generally so supplied.

NOTES ON ELECTRIC LIGHTING

In the present issue we print the first of a series of articles on Electric Lighting by Mr. Caryl D. Haskins, Manager of the Lighting Department of the General Electric Company. The articles are taken from a course of four lectures delivered to the students of civil and electrical engineering at the Rensselaer Polytechnic Institute, Troy, N. Y.

In covering a subject of such scope within the limits of four lectures, it was manifestly impossible to enter into a discussion of engineering details, and in these "talks" as the author prefers to call them, the effort was made to avoid technicalities, in so far as possible, and to treat the general subject of public service lighting in a purely practical way; to present to the students a bird's eye view of the field into which they were about to enter.

The first lecture was devoted to an analysis of the political and economic relations of the electric industry to the community; it has been omitted from the present series, which is confined to the engineering aspects of electric lighting, commencing with the second lecture.

It is assumed that a plant is to be installed capable of generating from 300 to 1000 kw. to supply a town of 10,000 to 20,000 inhabitants. With this as a starting point, the author takes up the subject of the power plant under the heads of water power, internal combustion engines, and steam, and discusses the criteria that lead to the selection of each form of motive power. Thus, under water power, the general conditions that make for success or failure in such installations are described; while under steam, the relative advantages of the reciprocating engine and the turbine for different cases are clearly presented.

Following the selection of the type of prime mover and the number of units to be installed, the conditions governing the choice of the direct current or the alternating current system are discussed, together with the determination of the frequency to be employed.

In the lecture following, distribution and translation are considered, both underground and overhead construction being discussed. The Edison "ring" and three-wire systems are described and the phenomena of electrolysis and interference with telephone lines are briefly touched upon, as are also the subjects of lightning arresters and line insulators.

The final lecture has to do with the utilization of the electric current for illuminating purposes. The author first considers the development of the incandescent lamp and its culmination in the tungsten lamp, following this account with a description of the improvements in arc lamps, from the Jablochkoff candle to the high power flame arc of today.

The lecture closes with a brief reference to some of the important features of the modern meters.

ELECTRIC DRIVE IN PULP AND PAPER MILLS

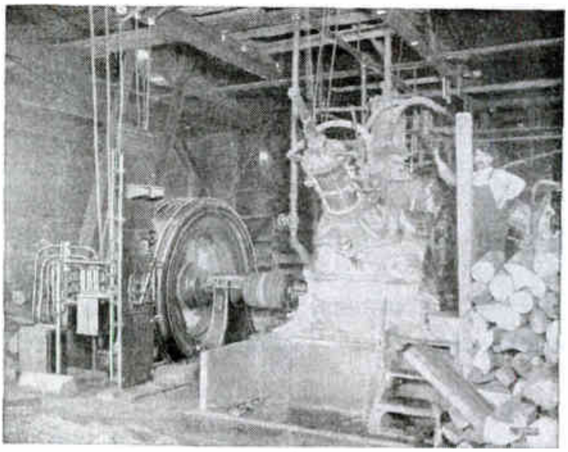
By John Liston

The ideal of modern production is the attainment of a maximum output for a given investment in plant and power. Owing to the relatively large amount of power required in pulp and paper mills, it is essential in order to secure the most economical operation, to carefully scrutinize all factors which enter into the power costs of production and to determine in every instance the relative values of the different methods of power application. The extensive adoption of electric drive in this industry is due to the growing appreciation of the inherent reliability, economy and high efficiency of motor drive as compared with the mechanical application of power for this class of service.

In considering the adoption of electric drive in a new plant, or the replacement of mechanical drive in an old one, the practical operator must be assured that he will thereby obtain uninterrupted service and a definite saving in the cost of production; either by a low installation expense, by lessening the power losses (thus securing for useful work a greater percentage of the initial power developed) or by a reduction in operating expenses. It has been demonstrated in numerous installations, some of which are illustrated herewith, that electrical drive combines all the advantages outlined above, and the following statement outlines briefly its points of superiority when compared with mechanical drive for the operation of pulp machinery.

With electricity the location of the power plant, whether steam of water driven, may be selected to obtain the greatest economy in the generation of power, without regard to the arrangement or location of the manufacturing buildings. These in turn may be erected at the point most advantageous to production and the shipment of finished material without reference to the location of the power plant.

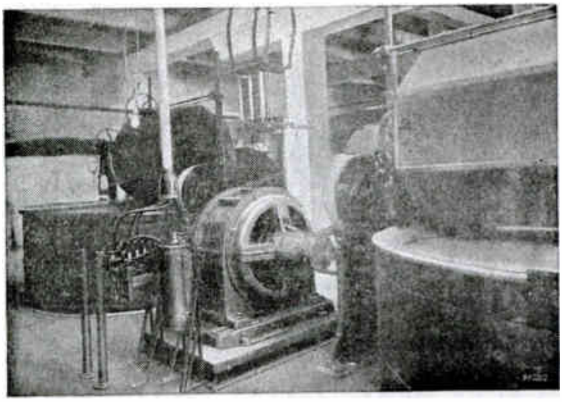
In a new mill, the adoption of electric drive will considerably reduce the building construction cost, due to the elimination or reduction of the heavy shafting and belting inseparable from mechanical drive. The structural work can therefore be of a much lighter character, and in the average mill the saving effected in this way will amount to about five per cent of the total cost of the building.



300 H.P. Motor Direct Connected to Grinder and Provided with Individual Switch and Control Panel. Carolina Fibre Co., Hartsville, S. C.

The machinery can be located with a view to the elimination of all unnecessary handling of the product, as each machine or group of machines can be supplied with its own motor and operated as an independent unit. The average motor used for driving paper mill machinery does not require special foundations, and as the adoption of motor drive eliminates a large percentage of the long shafts and heavy hangers and belting that are required for mechanical drive, their original cost and maintenance should be considered when comparing the initial expenditure required by the two systems.

Subdividing the power application, where numerous motors are used, permits the starting or stopping of any machine, or group, without interfering with the operation of the remaining machinery.



100 H.P. Induction Motor Driving Two 1000 lb. Beaters Through Belts
Elkhart Paper Mills, Elkhart, Ind.

Great economy in power can be obtained where individual motor drive is adopted, by the elimination or reduction of the friction loss involved in the operation of shafting, belts, gears, idlers and other consumers of energy. The power consumed by the different sections or different machines can be readily measured by connecting a recording instrument in the motor circuit; the graphic record will show at once whether the power consumed is normal, and this will frequently serve as an indication of the condition of the machinery and will insure a prompt detection of any defects. As the power can be conveniently measured, all machinery may be operated at such speeds as will produce the best results without unnecessary consumption of power.

The use of recording instruments will permit motors of various capacities, temporarily installed, to be tested in operation, so that the exact size motor required for the most efficient operation of any machine, or group, can be accurately predetermined. This will enable any errors of installation to be corrected and will eliminate haphazard methods of ascertaining the power necessary for driving the machinery required for additions to the plant.

Electric drive has great flexibility, in that additions to an existing plant may be made without interfering with the operation of the original equipment.

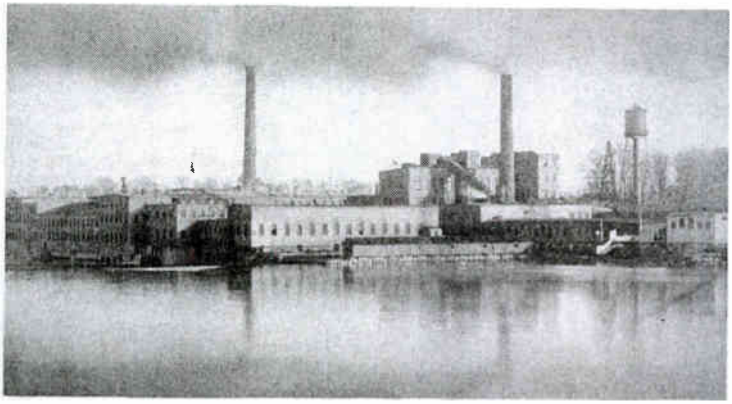
The generating plant may be economically divided into two or more units, thus insuring against a complete shut down in case of accident and permitting economical operation with individual sections of the plant. If there are a number of small water powers in the vicinity which can not be profitably utilized for mechanical drive, small generating plants may be established at these places and the power transmitted and applied at the mill.

In supplementing water power with steam power, the engine and generator may be located at a distance from the water power, so as to facilitate the receiving and handling of fuel; and, without other connections than the wires between the generators, can be arranged to automatically supply any deficiency in the power of water-driven plants. This method is especially valuable during periods of low water.

In a plant already equipped with reciprocating steam engines, a low pressure steam turbine can be installed which will utilize the exhaust steam of the reciprocating engine to good advantage. So efficient is this turbine that in many cases its adoption has practically doubled the power output of the reciprocating engine plant without increasing the boiler capacity.

Where a properly equipped central station exists within a feasible transmission distance of the mill, it will be found in many cases more economical to purchase electric current than to generate it. The steady demand of the paper mill renders it an attractive proposition for the central station and as a rule low rates can be obtained. By using central station power in a new mill, the investment expense for power house equipment and the cost of maintenance are avoided, while the possibility of interrupted service due to the breakdown of a machine in an isolated plant is overcome, as the modern central station is, as a rule, amply equipped with reserve machinery.

Even in an old mill already equipped with a steam plant, it may be true economy to discontinue the use of the steam plant, and disregard the investment already made that it represents, as in some instances this results in a reduction in the cost of power. When utilizing central station power the cost of operation of any machine or group is incurred only during the time the machinery is in service and the cost of running the machine is directly proportional to the amount of production.



Kimberly-Clark Paper Mill at Kimberly, Wis.

Motor-Driven Grinders

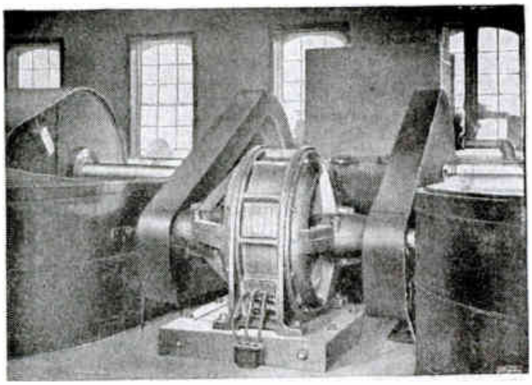
The average pulp mill is operated by water power and as this power can not always be depended upon, the grinder room is usually equipped with a larger number of machines than would be required if constant operation were assured. In some mills it has been found advisable to operate the grinders as shown in the illustration on page 437; that is, by direct connecting the motor to the grinder shaft, each motor operating one, two or four grinders. Where the supply of water power is intermittent it has been found economical to utilize the water power while available and to supplement this with motor drive during periods of low water, either connecting the motor to the grinder shafts by means of removable couplings, or through belts.

The fact that wood pulp can be stored for future use, brings up the question as to whether or not motors can be profitably employed for auxiliary power. If a waterwheel mill is located near other sources of water power, generators can be installed at these points and the power transmitted to the mill as described above; so that the capacity of the mill may be largely increased with little or no additional building construction. In some instances this has been done so successfully that the utilization in this way of what would otherwise be waste power has obviated the necessity of building other mills to increase production.

Many central stations, especially those that are dependent upon a variable water supply, will grant low rates for current during the flood seasons; at other times low night rates may be obtained, as the use of power at that time will enable the central station to bring up its load factor. By taking intelligent advantage of these conditions, which will vary somewhat in different localities, the average water-driven wood pulp mill can largely increase its productive capacity with a minimum of additional investment.

Motor-Driven Jordans

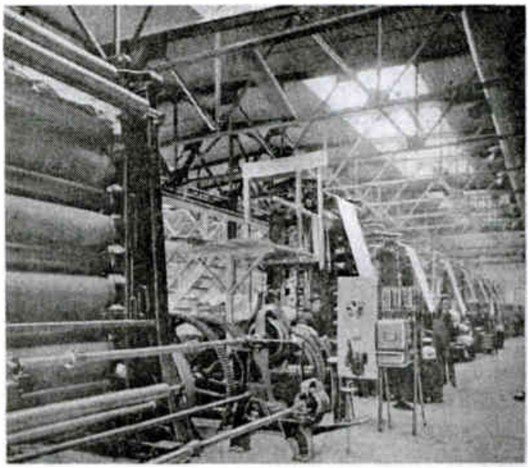
For the operation of Jordan engines by induction motors a highly efficient and compact equipment has been designed, an installation of which is illustrated on the first page of the cover. This consists of a regular wound rotor induction motor with self-contained starting resistance, mounted on a sliding base and direct coupled to the Jordan shaft. In order to permit the adjustment of the Jordan without affecting the efficiency of the motor, a shaft is run under the Jordan and connected at one end to the motor base, the other end being geared to the adjusting hand-wheel; thus any change in the adjustment of the Jordan may at once be compensated for by the movement of the motor on the sliding base. In this way there is no displacement of the rotor with respect to the field, as in some methods of motor-driven Jordans, and the motor will therefore operate under normal conditions at all adjustments of the Jordan.



150 H.P. Induction Motor Driving Two Beaters Through Chain Belts
Kimberly-Clark Co., Kimberly, Wis.

As a heavy starting torque is sometimes required the type of motor chosen for this service will give approximately 150 per cent of full load torque at starting.

So efficient is this method of operating Jordans that it has practically superseded all belt-driven motor equipments.



10 Super-Calendars Driven by Back Geared Induction Motors, Provided with Individual Compensators and Control Panels
Kimberly-Clark Co., Kimberly, Wis.

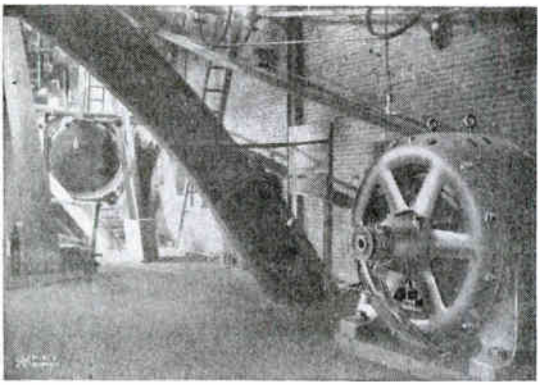
Alternating versus Direct Current

In choosing between alternating and direct current motors for pulp and paper mills service, the requirements of the individual machines should be considered. A large percentage of the machinery operates at constant speed and for this work the alternating current induction motor can be used to advantage. Where a wide variation in speed is required, as in the operation of the finishing end of a paper machine, a direct current motor will insure a ready control and a prompt variation of the speed. As a rule, direct current motors should not be used for the remainder of the machinery. In order to supply direct current for the operation of the variable speed machinery, a motor generator set may be employed and operated from the alternating current power circuit.

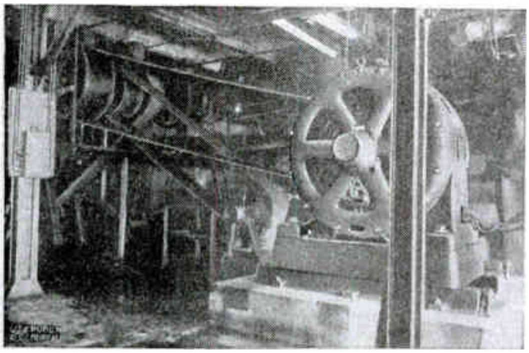
After many years practical experience in the equipment of pulp and paper mills, the General Electric Company decided to adopt the polyphase induction motor as a standard for this service where constant speed is required. This motor is built to withstand hard usage and to operate continuously in exposed locations and under disadvantageous conditions. The parts are few in number and have been carefully designed, so that a minimum of attention is required when the motor is in operation, and the cost of maintenance and repairs is practically negligible. The electrical design is such that high efficiency is obtained over a wide load range, and the motor is capable of withstanding heavy overloads for considerable periods without serious overheating.

The induction motor having no commutator the danger of sparks from this source is avoided, a feature that is especially valuable when motors have to operate rag cutters, dusters and thrashers or are used in any location exposed to inflammable dust.

This motor is easily controlled and will start readily under full load. Its rigid construction and light weight enables the user to mount it wherever desired, and in many cases where floor space is valuable and a machine is belt connected to a motor, space economy can be effected by suspending the motor from the ceiling or wall. For special applications these motors can also be arranged to operate on vertical shafts with the same high efficiency as that obtained with the horizontal shaft type.



300 H.P. Induction Motor Driving Chipper Room Machinery
Berlin Mills Co., Berlin, N. H.

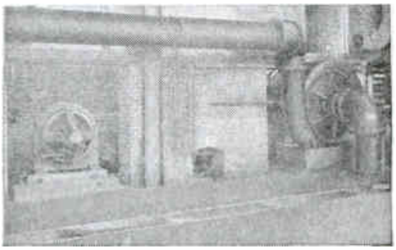


250 H.P. Induction Motor Driving Stock and Water Pumps for Ground Wood Screen. Berlin Mills Co. Berlin, N. H.

Group versus Individual Drive

In the application of electric drive, two general systems are now in vogue, namely, the operation of each individual machine by a single motor, commonly termed "individual drive," and the operation of machinery in groups by means of line shafting, which in turn is driven by a motor, this plan being generally designated as "group drive."

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 source, is incurred only during the actual operation of the machine.



60 H.P. Induction Motor Driving No. 15 Morris Centrifugal Pump in Grinder Room. Great Northern Paper Co., East Millinocket, Me.

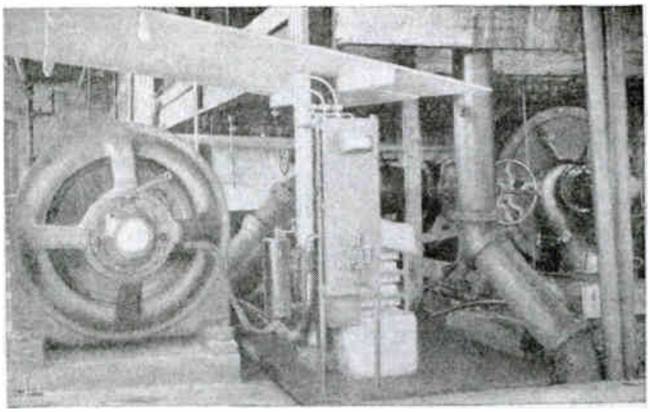
If, on the other hand, the plant generates its own current, the size of the prime mover and generator, as well as the power factor in the case of alternating current plants, will be appreciably affected by the choice of group or individual drive; as in the latter case, each machine can be equipped with the motor that most nearly meets the exact requirements in regard to speed and power.

Where the operation of the various units is intermittent, the individual drive system will, in practically every case, permit of a much smaller generating outfit than group drive, 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.

The motor operated plants illustrated herein are typical of the large number of pulp and paper mills which are similarly equipped, the entire success with which they have utilized motor drive constituting a potent argument for its general adoption throughout the industry.

KIMBERLY-CLARK PAPER COMPANY
KIMBERLY, WIS.

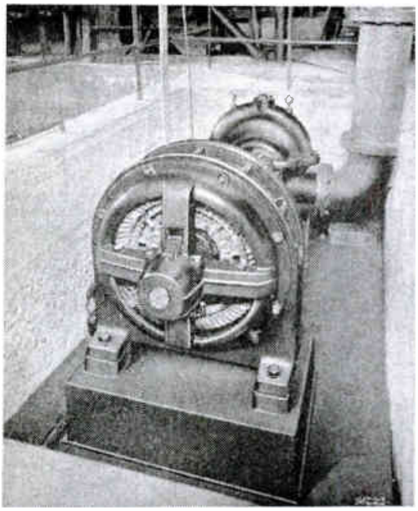
The Kimberly Mill of the Kimberly-Clark Paper Company is located on the Fox River



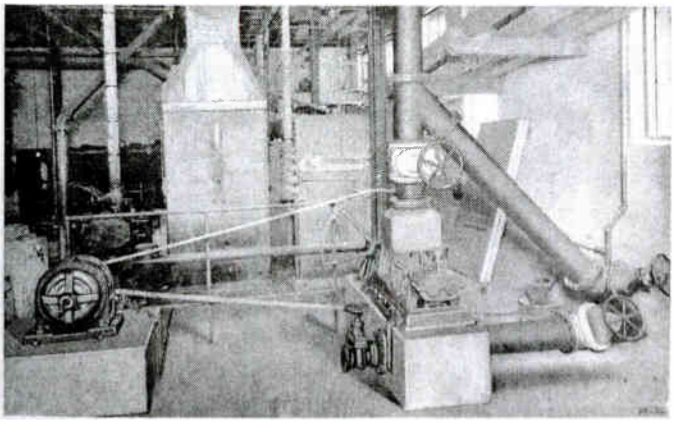
300 H.P. Induction Motor with Controller and Individual Panel, Driving Two Centrifugal Pumps for Filters. Great Northern Paper Co., East Millinocket, Me.

and manufactures book paper by the sulphite process, the capacity of the mill being 75 tons per 24 hours.

The mill machinery is operated electrically, and water power, steam and oil engines are utilized for the generating of electric current. Two power stations supply current to the mill, both being located on Fox River, one in the mill itself and the other at Appleton, five miles up stream. The available head at Appleton is 16 feet and current from a 750 kw., 3-phase, 25 cycle, 6600 volt generator is transmitted to a substation at the mill, where it is stepped down by means of three 300 kw. transformers to 470 volts. At the mill a 700 foot crib dam has been constructed across the river and a head of 9 feet is available. The water wheel equipment here consists of nine vertical shaft reaction turbines. Five of these are geared to a common horizontal shaft, to which a 300 kw. generator is coupled. The remaining four turbines are connected in the same way to a second 350 kw. generator, but in addition to the waterwheel drive, this generator is also arranged for oil engine drive, the generator being located between the turbine-driven shaft and an oil engine and equipped with removable couplings on both ends of the shaft. In this way the oil engine can be readily used to operate the generator during periods of low water. In addition to these there is one 350 kw. generator mounted between two oil engines and direct driven by them, and one 175 kw., also oil engine-driven. The exciters are belt-connected and arranged for parallel operation. A steam engine is included in the equipment and is employed to drive a 360 kw. generator and exciter. It will be seen from this description that through the subdivision of the generating equipment, and the various prime movers available any possibility of interruption to the electric service is reduced to a minimum.



100 H.P., 1200 R.P.M. Induction Motor, Direct Connected to a 10 Inch, 2750 Gal. Centrifugal Pump
Finch, Pruyn & Company, Glens Falls, N. Y.



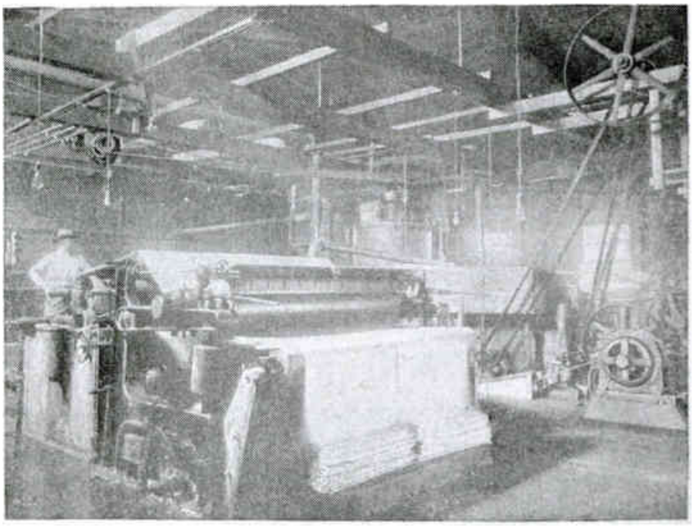
Double Impeller Stock Pump Driven by a 22 H.P., 1200 R.P.M. Motor. Finch, Pruyn & Company, Glens Falls, N. Y.

The first application of motor drive in this mill was made about six years ago and at the present time the motors in actual operation total fifty-five; provision has already been made, however, for additional installations. The application of motors to paper mill machinery in this plant exemplifies both the group and individual systems, as well as different methods of connecting the motors to the machinery, there being examples of direct connection, belt, and chain drive, and motors direct geared to the driving shafts.

In the bleach room eight agitators are driven in a group by one 60 h.p. motor.

In the beater room there are three Jordans driven by three 150 h.p. motors, as shown on first page of cover. These motors are equipped with the General Electric adjusting device which permits the motor to move on a sliding base with each change in the adjustment of the Jordan. The control panels for these motors are mounted in a small gallery so that the operator who manipulates them has an unobstructed view of the motors, while at the same time the panels occupy no useful floor space and are protected from accidental injury. There are three other Jordans in this room, which constitute an older equipment; they are driven from a countershaft, which is belted to a 300 h.p. motor mounted on the floor below, the controller being installed on the floor beside the Jordans. There are three other motor-driven Jordans, two of them being operated by a 250 h.p. motor while the third is provided with a 150 h.p. motor. These three machines are belt-driven and are not ordinarily used in production, being held as an emergency equipment in the event of injury to the other Jordans.

In the beater room a pair of beaters is driven by means of a 150 h.p. motor with the shaft extending on both ends and connected to the driving shafts of the beaters by chain belts, forming in this way a compact and highly efficient unit, as shown on page 440.



20 H.P. Induction Motor Driving Sulphite Machine and Flat Screen, and 15 H.P. Motor Mounted on Ceiling, Driving a Centrifugal Screen Through a Quarter-Turn Belt
Carolina Fibre Co., Hartsville, S. C.

Four other beaters are driven in a group by a 250 h.p. motor, belt connected.

In the washer room chain drive is used for one 40 h.p. and two 75 h.p. motors, operating three washers. There are also four screens and four deckers belt-driven in a group by means of a 75 h.p. motor.

In the size room the mixing outfit is driven by a 50 h.p. motor. Four paper dusters are driven by a 25 h.p. motor and a waste paper baler by a 2 h.p. motor, both motors driving through belts.

The pump equipment of the mill is practically all motor-driven. It comprises a hydraulic pump driven by a 50 h.p. motor, a pump for agitators and stock tanks by a 30 h.p. motor; two stock pumps and chests by a 15 h.p. and a 20 h.p. motor; the boiler house pump by a 15 h.p. motor, and boiler feed pump by a 30 h.p. motor, and two water pumps, one driven by a 35 h.p. and the other by a 75 h.p. motor. There is also an equipment utilizing a 15 h.p. motor to drive a water pump and air compressor, the latter supplying pressure for blowing out the water filters. All of these pumping sets employ belt drive. In addition to these there are three save-all pumps, to each of which a 10 h.p. motor is direct connected.

The constant speed ends of the three paper machines used in this mill are driven through chain belts by three 75 h.p. motors; the paper winder by a 20 h.p. motor, belt-connected, and the rewinder by a 7½ h.p. motor.

In the finishing room, ten motor-driven super-calendars are used, the ten motors being back geared to the super-calendar driving shaft. Four of these motors are of 75 h.p. capacity, five 50 h.p. and one 100 h.p. The threading-in rolls are individually driven by ten 15 h.p. motors, back geared to the driving shaft; and ten paper cutters and one trimmer are driven in a group, through belting, by a 30 h.p. motor.

The machine shop is equipped with a 15 h.p. motor driving the machinery through countershafting.

All the above motors are of the alternating current induction type and operate on 25 cycles, three-phase circuits.

In addition to the induction motor equipment, the finishing room is supplied with an overhead motor-driven traveling crane, for handling paper rolls of any weight up to two tons. This crane is operated by a direct current motor, and current is provided for it by means of a motor-generator set consisting of an induction motor direct coupled to a 220 volt d.c. generator.

Three systems of lighting are used in the mill, alternating current being used for incandescent lamps, while the motor-generator set referred to above supplies direct current for arc and mercury vapor lamps.

Dam, Power House and Grinder Station on the Penobscot River. Great Northern Paper Co., Dolby, Me.

Motor Distribution	No.	H.P.	Drive
8 Agitators	1	60	belt
3 Jordans	3	150	direct
2 Jordans	1	250	belt
3 Jordans	1	300	belt
1 Jordan	1	150	belt
2 beaters	1	150	chain
4 beaters	1	250	belt
2 washers	2	75	chain
1 washer	1	40	chain
4 screens and 4 deckers	1	75	belt
Size mixing outfit	1	50	belt
4 paper dusters	1	25	belt
Waste paper baler	1	2	belt
Hydraulic elevator pump	1	50	belt
Pump for agitators and stock tanks	1	30	belt
Stock pump and chest	1	15	belt
Stock pump and chest	1	20	belt
Boiler house pump	1	15	belt
Boiler feed pump	1	30	belt
Water pump	1	30	belt
Water pump	1	75	belt
3 paper machines constant speed end	3	75	chain
3 save-all pumps	3	10	direct
Water pump and air compressor	1	15	belt
Paper winder	1	20	belt
Paper winder	1	7½	belt
4 super-calendars	4	75	geared
5 super-calenders	5	50	geared
1 super-calender	1	100	geared
Threading-in rolls	10	15	geared
10 paper cutters and 1 trimmer	1	30	belt
Machine shop	1	15	belt

THE THREE-VOLTAGE RATING OF INCANDESCENT ELECTRIC LAMPS.

By F. W. Willcox

The three-voltage method of rating incandescent lamps, which was first adopted for the metallized filament, or Gem lamps, has now been applied to all types of regular incandescent lamps made in the standard commercial voltages of 100 to 125 volts. The Mazda, tungsten, tantalum, carbon and Gem lamps are now all rated on this basis.

A proper rating for incandescent lamps should provide for rating the lamps in total watts instead of by candle-power. The reasons for this are as follows:

First. The conventional candle-power rating, as employed for illuminants, has been a much abused and misused method of rating. As there are many different candle-power values (such as the horizontal, spherical, hemi-spherical, candle-power at different angles, etc.), candle-power, unless specifically defined, tends to become a misleading and meaningless basis for rating. Lamps are a current-consuming device and the logical rating for such devices is a total watt rating, since lighting and power are measured and sold almost entirely on a wattage basis. Candle-power values need not be abandoned, but can be used, when required, in a more definite way, properly defined and accurately stated for any given wattage of lamp.

Second. A desirable condition for the rating of an incandescent lamp is that the lamp should have its most exact measure

TABLE I—Life and Efficiency Ratings of Mazda Lamps at the Three Labeled Voltages.

Size of Lamp in Watts	TOP VOLTAGE		MIDDLE VOLTAGE		BOTTOM VOLTAGE	
	W.P.C.	Life in Hrs.	W.P.C.	Life in Hrs.	W.P.C.	Life in Hrs.
25	1.33	1000	1.39	1300	1.45	1700
Small bulb 40	1.25	1000	1.30	1300	1.35	1700
Large bulb 40	1.25	1000	1.30	1300	1.35	1700
60	1.20	1000	1.25	1300	1.30	1700
100	1.20	1000	1.25	1300	1.30	1700
150	1.20	1000	1.25	1300	1.30	1700
250	1.15	1000	1.20	1300	1.25	1700
400	1.15	1000	1.20	1300	1.25	1700
500	1.15	1000	1.20	1300	1.25	1700

TABLE II—Life and Efficiency Ratings of G. E. Tantalum, 100-125 Volts Lamps at the Three Voltages.

Size of Lamp in Watts	TOP VOLTAGE			MIDDLE VOLTAGE			BOTTOM VOLTAGE		
	Nominal W.P.C.	Actual W.P.C.	Life Hrs.	Nominal W.P.C.	Actual W.P.C.	Life Hrs.	Nominal W.P.C.	Actual W.P.C.	Life Hrs.
25	2.0	1.97	1000	2.1	2.06	1300	2.2	2.14	1700
40	1.8	1.79	800	1.9	1.87	1100	2.0	1.95	1500
50	1.8	1.79	800	1.9	1.87	1100	2.0	1.95	1500
80	1.8	1.79	600	1.9	1.87	800	2.0	1.95	1050

Note.—The above values are for direct current. On alternating current of 60 cycles and below, the lives are conservatively rated as 500 hours for the 25 watt lamp, and 600 hours for the 40, 50 and 80 watt lamps.

TABLE III—Life and Efficiency Ratings of GEM Lamps at Three Voltage.

Size of Lamp in Watts	TOP VOLTAGE		MIDDLE VOLTAGE		BOTTOM VOLTAGE	
	W.P.C.	Life in Hours	W.P.C.	Life in Hours	W.P.C.	Life in Hours
40	2.56	700	2.71	1000	2.89	1500
50	2.50	700	2.65	1000	2.83	1500
80	2.46	700	2.60	1000	2.78	1500
100	2.46	650	2.60	950	2.78	1400

TABLE IV—Ratings of Carbon Lamps, Single-Voltage and Three-Voltage Basis. 100 to 130 Volts. Standard Lighting Lamps. Regular Types.

Basis of Rating	Nominal Watts	Voltage	Actual Watts	Actual W.P.C.	Actual C.P.*	Spherical C.P.	Total Lumens	Lumens per Watt	Hours Useful Life	Style Bulb
Single Voltage	10	Single	10	5	2	1.7	21.3	2.13	2000	SS14
	20	Single	20	4.15	4.8	4.0	50.3	2.52	2000	SS14
	20	Single	20	4.15	4.8	4.0	50.3	2.52	2000	SS17
Three Voltage	25	Top	25	3.1	8.1	6.7	83.6	3.34	500	SS17
		Middle	24.1	3.31	7.3	6.0	75.4	3.13	725	SS17
		Bottom	23.2	3.52	6.6	5.4	68.3	2.94	1050	SS17
	30	Top	30	3.23	9.3	7.7	96.4	3.21	1050	SS17
		Middle	28.9	3.46	8.4	6.9	87.0	3.00	1500	SS17
		Bottom	27.8	3.69	7.5	6.2	77.7	2.81	2100	SS17
	50	Top	50.0	2.97	16.8	13.9	174.0	3.49	700	SS19
		Middle	48.2	3.18	15.2	12.5	158.0	3.26	1000	SS19
		Bottom	46.4	3.39	13.7	11.3	142.0	3.06	1500	SS19
	60	Top	60	2.97	20.0	16.5	208.0	3.49	700	SS19
		Middle	57.9	3.18	18.3	15.1	190.0	3.26	1000	SS19
		Bottom	55.7	3.39	16.4	13.5	170.0	3.06	1500	SS19
	100	Top	100	2.97	33.6	27.7	349.0	3.49	600	SS24
		Middle	96.4	3.18	30.5	25.2	316.0	3.26	850	SS24
		Bottom	92.9	3.39	27.4	22.6	284.0	3.06	1350	SS24
	120	Top	120.0	2.97	40.4	33.3	419.0	3.49	600	SS24
		Middle	115.8	3.18	36.6	30.2	379.0	3.26	850	SS24
		Bottom	111.4	3.39	32.8	27.1	340.0	3.06	1350	SS24

200 to 260 Volts

Basis of Rating	Nominal Watts	Voltage	Actual Watts	Actual W.P.C.	Actual C.P.*	Spherical C.P.	Total Lumens	Lumens per Watt	Hours Useful Life	Style Bulb
Single Voltage	35	Single	35	4.40	8.0	6.7	84.0	2.40	1000	PS19
	60	Single	60	3.69	16.3	13.6	171.0	2.84	750	PS21
	120	Single	120	3.69	32.5	27.3	341.0	2.84	750	SS24

* New International Candle-Power, by which a former 16 c.p. lamp now gives 16.26 c.p.

neither candle-power nor total watts, but watts per candle, which determines the temperature strain of the filament. The reason for this is that the watts per candle determines the degree of incandescence or temperature strain on the filament, and exact rating in this value will insure the most uniform service from the lamps.

All standard lighting lamps operating in multiple must be rated at an exact voltage (such as 110, 115 volts, etc.). It is a practical impossibility to manufacture all lamps, particularly those with metal filaments (such as the Mazda, tungsten, etc.) to either an exact total wattage or candle-power for any fixed voltage. It is possible, however, to so select the lamps, by allowing variations from the average value of total watts and candle-power, as to bring the lamp, at its rated voltage, to an exact watts per candle efficiency. This insures that each lamp is burned at a uniform degree of incandescence and, although the actual candle-power may vary somewhat, nevertheless the lamps will appear to the eye to be of uniform brilliancy and the variation in initial candle-power will not be as noticeable as under the old method of rating by candle-power with a varying efficiency. The filaments are also subjected to a uniform temperature strain, and this method of rating therefore insures a uniform lighting effect and a maximum of well maintained candle-power and life.

The total watts assigned to any lamp will represent the average value, but the variation necessary to give an exact watts per candle rating will not amount to enough to disturb conditions.

Third. A proper rating for incandescent lamps should further provide a flexible method which would permit of using the lamps at several different efficiencies in order to adapt them to varying conditions of voltage regulation and power costs.

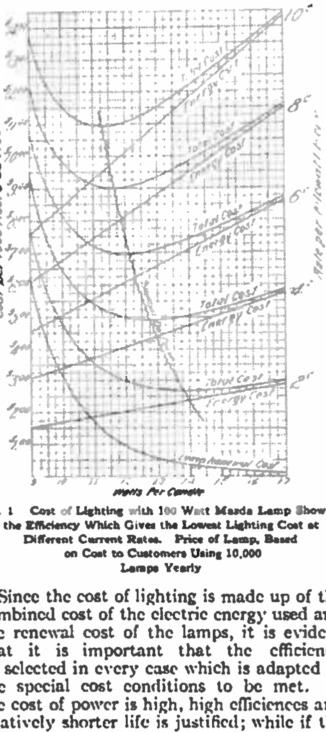


Fig. 1 Cost of Lighting with 100 Watt Mazda Lamp Showing the Efficiency Which Gives the Lowest Lighting Cost at Different Current Rates. Price of Lamp, Based on Cost to Customers Using 10,000 Lamps Yearly

Since the cost of lighting is made up of the combined cost of the electric energy used and the renewal cost of the lamps, it is evident that it is important that the efficiency be selected in every case which is adapted to the special cost conditions to be met. If the cost of power is high, high efficiences and relatively shorter life is justified; while if the cost of power is low, lower efficiencies and correspondingly longer lamp life is desirable. Moreover, an efficiency which will give satisfactory life on a circuit when the voltage is uniform and does not rise more than two or three volts above normal, would not give satisfactory life when the voltage rises four or five volts above normal. It is therefore desirable that lamps be available in different efficiencies to meet different service conditions. This means that either a large line of lamps be provided at different efficiencies or that each lamp be so rated that it can be used at several different efficiencies.

The former method is objectionable in that it makes it necessary for manufacturers, dealers, central stations and others to carry a large and complicated stock of lamps if they are to meet all service conditions so as to obtain the most economical lighting. Thus, in the past, the same lamp in a number of sizes appears under several different ratings. For example, a carbon lamp which at given voltage is a 24 candle-power, 3.1 watts per candle lamp, becomes at 4 volts lower a 20 candle-power, 3.5 watts per candle lamp, and at 4 volts lower still a 16 candle-power 4 watts per candle lamp. For each rating there was a different label with a different voltage marked on it. Evidently, it would be much simpler to mark these three voltages on one label and use this same label on each of the lamps so that any one of them could be used at any of the three efficiencies. This is the plan followed under the three-voltage method of rating.

120 Volt
Top Voltage

120 Volt
Middle Voltage

120 Volt
Bottom Voltage

Three-Voltage Rating

Under the three-voltage plan each lamp has a label bearing three voltages, for example,
120, 122 or 124
118, 120 or 122
116, 118 or 120
as shown by the sample labels illustrated herewith. In all cases these voltages vary by steps of 2 volts. They are known as the "top," "middle" and "bottom," or "first (V-1)," "second (V-2)" and "third (V-3)." In the first of the sample labels shown, 120 volts is "top" voltage, in the second, 120 volts is "middle" voltage and in the third, 120 volts is "bottom" voltage.

The three-voltage rating permits any lamp to be operated at any one of three different efficiencies and enables the consumer to select lamps of the particular efficiency that will give him the lowest total cost including energy consumed and lamp renewals combined. If for example the regulation of the circuit is originally such as to require that the lamps be operated at an efficiency corresponding to that obtained at "bottom" voltage, and is later improved by the installation of more copper or regulating devices, the customer can readily improve his efficiency by ordering the same lamps at "middle" voltage or "top" voltage, depending upon the extent of the improvement in regulation. In the same way any change in power cost could be met with a similar change in lamp efficiency, which would enable the consumer to keep his total lighting cost, including power and renewals, to the lowest possible figures.

Determination of the Proper Efficiency at which a Lamp Should be Used

The proper efficiency at which a lamp should be used is determined by the lamp renewal cost, which is fixed by the price and life of the lamp. The minimum practical limits of life are generally considered to be about 400 to 500 hours; above this value the life will be varied to suit the conditions of current and lamp cost. For any given efficiency the life will be affected by the voltage regulation; it is therefore the actual life obtained in service that is the determining factor.

Assuming the voltage to be constant, the lives of the various lamps at the different efficiencies are as given in Tables I, II, III and IV. Under the proper conditions of voltage regulation, the most desirable efficiency is that which will give a life not less than the practical limit before stated, and which will give the consumer the lowest total cost for lighting service, including power cost and lamp renewal cost.

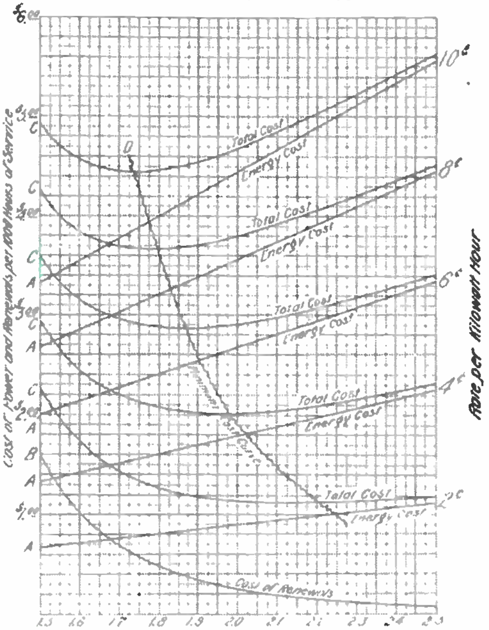


Fig. 2. Cost of Lighting with 40 Watt Tantalum Lamp, Showing the Efficiency Which Gives the Lowest Lighting Costs at Different Current Rates Prices of Lamp, Based on Cost to Customers Using 10,000 Lamps Yearly

At the ordinary rates for current, the cost of the power consumed by a lamp is equal to many times the cost of the lamp itself. Therefore, if the lamp is burned at too low an efficiency, the cost of energy consumed will increase at a much faster rate than the cost of renewals will decrease. As the cost of lighting is made up of the sum of these two factors (energy cost and lamp renewals), a balance should be struck between efficiency and life which will make the combined cost of energy and renewals a minimum. Where the cost of energy is high, the lamp should be operated at a relatively high efficiency. In this case its life will be shorter and the renewal cost will be increased, but the energy consumption for a given amount of light will be decreased. On the other hand, where the cost of energy is low the lamps may be operated at a lower efficiency, thus decreasing the renewal cost and increasing the consumption of energy. It is apparent, therefore, that for every energy rate there is a corresponding lamp efficiency which will give the lowest total lighting cost, including energy and renewal cost. In the following pages we will determine this efficiency for one size of each of the various lamps (Mazda, tantalum, Gem and carbon).

Mazda

Table I gives the life and efficiency ratings of Mazda lamps at the three labeled voltages. The top voltage gives the highest efficiency and lowest current cost, and the greatest brilliancy and volume of light, with the excellent life of 1000 hours—a year's service for the average consumer. At the lower voltages (middle and bottom), the lamps operate at lower efficiency with longer life, but with reduced brilliancy and volume of light.

The efficiency established for the Mazda lamp at top voltage, as given in the table, has been carefully determined as that efficiency which will give the lowest cost of lighting service, including energy and renewals, to the consumer paying rates of 8 cents per kilowatt-hour and over. The top voltage rating is therefore the one that should be used by the average central station customer.

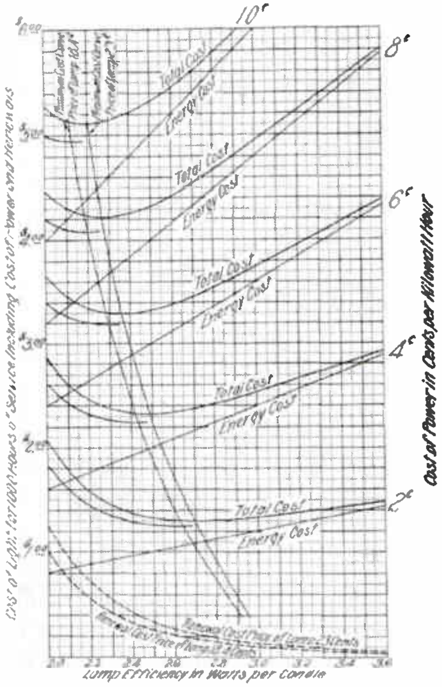


Fig. 3. Cost of Lighting with 50 Watt Gem Lamp, etc. Price of Lamp 18.4 and 23 Cents.

The diagram of Fig. 1 shows graphically the cost of lighting with the 100 watt Mazda lamp at different power rates and efficiencies. One curve shows how the cost of lamp renewals varies with the efficiency at which the lamp is operated; another set shows how the energy cost varies with the efficiency of the lamp. Combining the two curves, we get curves which show how the total cost of lighting (energy and renewals) varies with the efficiency of the lamp. These curves are shown in the diagram for energy rates of 2c., 4c., 6c., 8c. and 10c. per kilowatt-hour. The efficiency at the lowest point of the curve is the one at which the lamp should be worked in order to get the lowest total cost of lighting at the rate represented in the curve. The curve connecting the minimum points of all of the total cost curves for the lamp gives the efficiencies to obtain minimum costs, and is known as the minimum cost curve.

From these curves, the efficiencies that will give the lowest lighting cost can be readily determined. For example, suppose the energy cost is 8c. per kilowatt-hour. Referring to the curve, we find that the lowest total cost for light with the 100 watt Mazda lamp is obtained at an efficiency of about 1.17 watts per candle. From Table I it is seen that the nearest efficiency is 1.2 which is obtained at the top voltage rating, with a life of 1000 hours. In like manner, at 4c. per kilowatt-hour we find that the lowest total cost is obtained at an efficiency of 1.27 watts per candle. The table shows that the nearest efficiency to this is 1.25 which is given at the middle voltage rating, with a life of 1300 hours.

The curve shows that at the 8c. rate, the lowest cost of 1000 hours' service is about $9.00—equivalent to 9c. per kilowatt-hour. Therefore, the cost of lamp renewals is only about 1c. per kilowatt-hour—a very small item compared to the 8c. per kilowatt-hour energy cost. It is therefore shown to be poor economy to operate lamps at low efficiency in order to lengthen their lives, except where the energy cost is very low.

Tantalum

Table II gives the life and efficiency ratings of the tantalum lamps at the three rated voltages. These efficiencies and lives have, like the Mazda lamps, been determined so that the top voltage gives the average consumer the most economical lighting service.

As shown, the efficiencies of the 40 and 50 watt lamps (which are the best and most widely used sizes) have been increased to 1.8 watts per candle at top voltage and the old standard efficiency of 2 watts per candle is given at the bottom voltage, with a life of 1500 hours. The 25 watt lamp gives a life of 1000 hours at top voltage, 2 watts per candle efficiency, and a life of 1700 hours at bottom voltage, 2.2 watts per candle efficiency.

The values taken are those obtained on direct current, the life being somewhat shorter on alternating current. The life for alternating current given in the note is very conservative, as the 40 and 50 watt lamps will considerably exceed 600 hours in the average case. Tests have shown that the average breaking life of the 40 watt tantalum lamp at 2 watts per candle on 60 cycle current, is 1000 hours. In general, however, the bottom voltage rating should be used on alternating circuits of 60 cycles or lower. The top voltage is desirable on direct current service for the consumer paying rates of 8c. per kilowatt-hour and above for current.

This is shown graphically for the 40 watt lamp by the cost curves in Fig. 2, which are similar to those given for the Mazda lamp in Fig. 1.

Gem

The three-voltage method of rating was first adopted for the Gem lamp, and the excellent results obtained from the system with these lamps led to its adoption for the other types.

The life and efficiency ratings of these lamps at the three rated voltages are as given in Table III.

The minimum cost curves for the 50 watt Gem lamp at two different lamp prices, 18.4 and 23 cents, are given in Fig. 3.

Carbon

The Carbon lamps were the latest type to which the three-voltage method of rating was applied, this method having just recently been adopted for these lamps.

This rating is used for those sizes of the regular 100 to 130 volt types which were formerly supplied and used at several different efficiencies. This includes the 25, 30, 50, 60, 100 and 120 watt sizes of the regular types and the 30, 60 and 120 watt sizes of the round bulb and tubular types.

The 200 volt lamps, and lamps below 8 candle-power in the 100 volt types, are still rated at one voltage only, by what is known as the "single-voltage rating," as distinguished from the three-voltage rating. However, these lamps are also now rated for size in watts instead of candle-power.

Table IV gives a list of the standard carbon lamps as now rated, and also the lives and efficiencies at the different ratings (single, or top, middle and bottom).

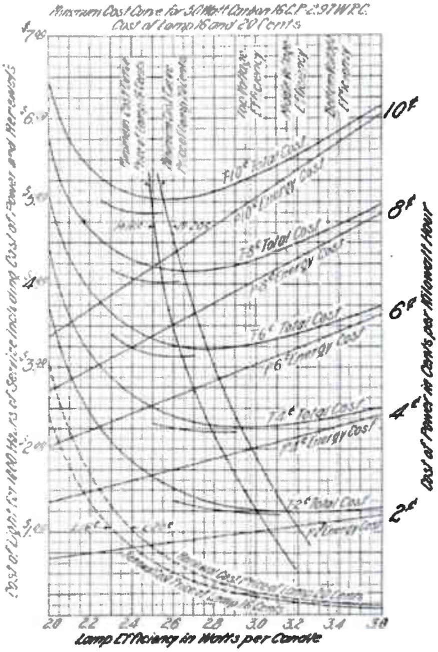


Fig. 4. Cost of Lighting with 50 Watt Carbon Lamp, Showing the Efficiency Which Gives the Lowest Lighting Cost at Different Current Rates. Price of Lamp, 16 and 20 Cents

Fig. 4 shows minimum cost curves for the 50 watt carbon lamp at two prices per lamp, 16 and 20 cents. As shown by the curve, the minimum cost of lighting with the 50 watt lamp at 20 cents, will be obtained by using top voltages for all power rates of 4 cents per kilowatt-hour and over. At rates of 2 cents per kilowatt-hour, the lowest cost is obtained by using middle voltage and it is only when the rates are lower than 2 cents per kilowatt-hour that bottom voltage should be used.

At a lower price the lamp should be operated at a still higher efficiency. This is shown by a comparison of the 20 cents per lamp curve with the 16 cents per lamp curve.

The new method is not a radical departure from the old, and with the exception of a few sizes, any customer can obtain exactly the same lamp he is now using, under the new rating.

NOTES ON ELECTRIC LIGHTING *

PART I

By Caryl D. Haskins

Manager Lighting Department, General Electric Company

Yesterday we gave preliminary consideration to lighting undertakings; the underlying conditions which make them possible, wise or unwise business propositions, their relations to the community, etc.. etc. Today we shall go into more specific engineering questions.

The central power station for the generation of electric energy may, of course, be anything from a small 50 kw. equipment up to one of those enormous aggregations of many thousands of kilowatts, which characterize Chicago, New York, Boston, and other very large cities; aggregations so large that they stand by themselves as special problems involving serious individual studies.

For the backbone of today's talk, after thinking the matter over rather carefully, I have selected the conditions commonly surrounding plants ranging from a minimum of 300 to a maximum of say, 1000 kw., or from about 400 to 1300 h.p.; an average undertaking, such as one would contemplate for a town of from 10,000 to 20,000 people. I shall occasionally deviate, in connection with special issues, to considerations pertaining to very large concentrations of power; but we shall, except where stated otherwise, regard the subject under discussion as a unit plant of this general capacity.

In dealing with a problem of this kind, the engineer's first decision of course, must relate to the selection of his prime mover and its physical connection to the generating apparatus. In central station practice, we find three general classes of prime movers:

1st. The steam engine
2nd. The internal combustion engine
3rd. Water power.

With water powers the question is largely one of location. Unfortunately, water head and flow can not be found everywhere. Commonly one thinks of water power as without cost *save only the cost of development*. Largely, this is true, but not seldom, when ill considered, this cost has proved too much. There have been a very considerable number of unsuccessful water power generating plants in the history of the lighting industry of this country, due to a number of causes. Where such plants have been unsuccessful, however, the cause of failure can generally be traced back largely to poor (too sanguine) initial engineering. Excessive cost of development means bad engineering, and it has not seldom been preceded by a low initial estimate. History tells us also of unwise judgment and over-hopeful estimates as to the probable damage to the works from floods and ice; unwise and carelessly made surveys as to the condition of streams in drought periods, the latter resulting in an inadequacy of water in dry summers, and the former in excessive water during flood periods, with the consequent destruction of property, such as dams, tail races and gates.

It is safe to say, that most unsuccessful water power plants have failed because of an

---

*The article is the first of a series to appear in the REVIEW, comprising the notes of a course of extemporaneous lectures delivered before the engineering students of the Rensselaer Polytechnic Institute, Troy, N. Y. The series begins with the author's second lecture, the first lecture having been devoted to topics not essential to the course from an engineering standpoint insufficient water supply. A very high percentage of the early intermediate size, low head, water power undertakings in the eastern states, which started out with brilliant prospects, today have stand-by steam plants as large as their water power development. But bear in mind this does not mean that they are failures by any means.

To civil engineers the development of water power is, of course, of peculiar interest, but it can be no more dealt with generically than can the matter of bridge construction. I shall, therefore, pass it by with the excuse that it is a special study too big and vital to form a part of this lecture. I can not refrain, however, from a few more generalities. Water power developments of low head, such as usually characterize those in the eastern states region, require more careful investigation and involve more unfavorable possibilities and variables, and, in short, constitute a much more indefinite problem than do any plants using steam power. A high proportion of the successful water power plants for lighting and power purposes in this country, are in our western states, where high heads, in rather close proximity to large towns, are far more common.

A high head proposition for electric purposes generally involves a comparatively low cost of development. This must not be misunderstood to mean that low-head propositions are inherently bad, but rather that they are, as a rule, more difficult problems to solve and are more costly.

The price of coal has a very important relation to water power development; often it is the controlling consideration. Every additional dollar per annum for fuel to obtain a given power, obviously justifies an expenditure of from $10.00 to $15.00 for additional development in connection with a water power, providing always that the engineering premises for the development are sound.

I have known few better examples of wise development of small water powers for the generation of electrical energy than that of a certain plant in the Hawaiian Islands. The conditions are unusual. The value of the crops in some portions of the islands exceed one thousand dollars per acre, but the success of these crops is dependent in a very large measure upon irrigation. On the west side of one of the islands which has a mountain backbone, sugar grows very luxuriantly, but a great lack of rainfall prevails upon the other side of the range. It was found that sugar would grow quite as well on the eastern side as upon the other if the land could be properly irrigated. A civil and electrical engineer found that rainfall and springs were plentiful to the very summit of the west side. He drove two shafts into the mountain from the east about four-fifths of the way to the summit, and water was encountered plentifully as soon as the shafts were well into the mountain. A heavy flow was speedily secured at a point giving 800 foot head, and the cost was estimated and proved to be low. With this water the engineer drove his electrical generating apparatus, and after doing its work, the water was taken to irrigation ditches and used to wet the crops close in to the east side of the mountains, while the power generated was used to drive a large number of pumps at numerous remote points in the dry belt. This undertaking would probably not have been justified save for the high cost of coal and other fuel equivalents ($10 to $12 per ton).

The internal combustion engine was our second alternative prime mover. For central power station use, the internal combustion engine is comparatively new. No one who has studied the question doubts the enormous promise of this prime mover. It has already been developed to a highly efficient status for relatively small capacities. The preponderance of evidence seems to indicate, however, that the larger units are as yet somewhat unreliable, occupy a large amount of floor area, and are of disproportionally great weight and high cost. They have not yet reached wide use for electric lighting purposes, but they promise much in conjunction with gas producer development. We shall not pursue this subject, because, frankly, I am not well versed in it, and there is not time, anyway, to go into it in greater detail. By the natural process of logical or arbitrary elimination, this leaves us *steam*.

Under the general classification "Steam," we have three alternatives:

(1) The reciprocating engine, belt or rope connected to the generator.

(2) The reciprocating engine, direct connected to the generator flexibly or rigidly.

(3) The turbine, direct connected to the generator, and constituting a unit piece of apparatus with it.

The decision as to which one of these alternatives shall be adopted is the first concrete problem to settle before going forward with the steam generating station.

In considering these things, we have to measure reliability, floor space, weight, efficiency, first cost and maintenance. Efficiency has been placed low in the list, not because it does not belong high, but because it is so largely dependent upon physical conditions. Efficiency and first cost fluctuate in first importance, one up and the other down, as the cost of fuel and labor is high or low and the cost of money is high or low. Efficiency literally and relatively varies with the cost of fuel and water for the boilers, and the availability and temperature of the condensing water.

In reliability, the direct connected engine and the turbine set are probably on a substantially equal basis, with a slight advantage, if any, in favor of the turbine. Either alternative has a material advantage over the belted or rope drive sets as to reliability.

In considering floor space, we must give attention to the cost of the building as well as the land area required, which stated plainly means the cost of real estate. This is of prime importance in large cities where the price of real estate is high. It is not of course, so serious a problem in smaller towns. We must also consider the cost of labor necessary to transport and install the apparatus.

The three alternatives rank thus in regard to floor area:

Belted or rope drive sets . .	100% floor space
Direct connected or reciprocating engines	57.5% floor space
Turbo-generators . . .	20% floor space

In the matter of weight we have to consider freight charges, ease of handling, cost of foundations and the cost of the permanent cranes of the station. The relative weights are about as follows:

Direct connected sets . . .	100% weight
Belted or rope drive sets inclusive of engine and generator . . .	90% weight
Turbo-generators	50% weight

You will note that the belt or rope drive sets occupy a somewhat intermediate position. This, however, is exceedingly variable, so much so as to make it quite possible that in some instance they would occupy a higher place as to weight than the direct connected sets.

The speed of the belted generator is, of course, higher in substantially every case than the speed of the direct connected sets.

In the matter of reliability the turbine is the equal of the other alternatives, or better.

In the matter of weight the turbine is materially preferable.

In the matter of floor space the turbine is greatly preferable.

In the matter of first cost, belted sets are generally cheapest, turbo-generator sets intermediate, direct connected sets, except when of very high speed with reduced reliability, most expensive.

These statements and figures are all based on averages and vary materially in individual cases.

Efficiency, as I have already said, is in a considerable measure a question of fuel, condensing water, the temperature of that water, its value, availability, etc. Turbines are at their greatest advantage at very high vacuums. Under all conditions of continued use, the advantage lies with the turbo-generator, but reciprocating engines vary widely. Well built turbines, properly used, give efficiencies better than reciprocating engines under all conditions of sustained service, and these economies increase rapidly as the size of the turbine is increased. Belted sets may be safely eliminated from consideration under the conditions that we are discussing; they should be considered only in connection with very small projects. Let us remember, however, that nearly one-half of the central stations in this country are belted, a condition which must change sooner or later—three thousand problems for the engineer of tomorrow.

How many units should an average central station contain? Under average conditions up to 1000 kw. total, three units of equal rating are preferable. The "valley" to normal load will be taken care of by one unit, the normal to "average peak" load by two units, and all abnormal peaks (as during the night before Christmas), by three units. This installation, in the average plant, permits of the reservation of one unit as a "standby," for use only when abnormal peaks exist, or when repairs to other units become necessary. Under these conditions it is possible to avoid running the generators at low efficiency, that is, at a low proportion of the full load.

The decision as to whether alternating current or direct current shall bo generated in a station must now be reached. The conditions governing this decision are dependent upon the amount of energy to be distributed, the relative reliability of the apparatus (a.c. or d.c.), the relative cost of operating, and the first cost of installation. Where power is to be distributed over large areas, this becomes a question of potential rather than direct current versus alternating current; but it is after all reduced to a question of the character of current, because only very low potentials are feasible in direct current multiple distribution. This is due to two reasons: First, incandescent lamps are only made in low voltages (220 volts maximum); and, second, because commutation becomes difficult at high voltages. We may safely assume that where the area over which we are to distribute exceeds, say, 2000 feet maximum radius, it is practically necessary to resort to voltages in excess of those that are feasible for the direct current service of incandescent lamps.

The first cost of a complete system depends very largely upon the cost of feeder copper, and as this varies inversely as the square of the voltage at which power is transmitted, the higher potentials (which means alternating current) are generally imposed upon the central station as an unavoidable condition. We must remember that there is always one factor in favor of the direct current service; i.e., copper depreciates less rapidly than apparatus, and the investment in copper, while initially high, is more permanent than the investment in apparatus under most conditions.

In the matter of reliability of operation, both as to generating and subsidiary apparatus, alternating current has some advantage, largely because of freedom from commutation and its difficulties. The great recommendation for alternating current, aside from the economical distribution of power, is its flexibility, enabling us to do a large number of things at all sorts of voltages. Let us then, decide to use alternating current in our plant:

The next question is one of frequency. We have three common frequencies in the United States and several others which are not uncommon, as for example, 40 cycles, the frequency in use here in Troy. Nevertheless, 40 cycles is not a common frequency throughout the United States. Our common frequencies are 25, 60 and 125 cycles. The latter is the commonest frequency of early apparatus. It is made for light weight transformers and light apparatus. In the early days of the art, when high frequencies were not at a disadvantage, this frequency was widely used—today, a system having a frequency of 125 cycles is generally considered obsolete, for reasons presently to be explained.

Sixty cycles is now the common frequency for lighting undertakings. It is low enough to make synchronizing easy, and is highly satisfactory for induction and synchronous motors. It is not too high to prevent the use of rotary converters and is amply high to give good light through incandescent filaments without noticeable flicker.

Twenty-five cycles is the preferred frequency for long distance transmission systems as well as for railway generating systems. It is peculiarly well adapted to the operation of rotary converters. Twenty-five cycles may well be considered the power distribution frequency and 60 cycles the lighting frequency. For lighting purposes, it has been contended by some authorities that with 25 cycles there is a certain flicker, which, while not observable, is alleged to be fatiguing to the eye. From a practical standpoint perhaps the most important consideration in connection with this question, *is the frequency of electric plants in nearby towns*. An engineer who is building a new plant in the United States today is undoubtedly building it within striking distance of some other plant or plants, generally within reach of a half-dozen other plants. The value of his property is destined to be materially greater if his frequency is the same as his neighbor's. Sooner or later central stations will be tied together for mutual support; the smaller ones will disappear as generating units and the larger ones will assume the load. When this occurs, the wisdom of the adoption of a standard frequency will be apparent; the smaller concern can then buy its power from the larger without changing its subsidiary apparatus. The plant with a special frequency is obviously at a greater disadvantage when it becomes an economic measure for it to purchase current from a neighbor.

Let us assume, that our plant will be a 60 cycle one, and that our voltage will be 2300. This is the commonest standard voltage for lighting projects and is sufficiently high for reasonably economical distribution over areas not exceeding two to five miles radius. The determining of the operating voltage is a purely physical question, dependent upon data as to area, density, and distribution of load.

(To be continued)

SOME NOTES ON THE BEHAVIOR OF D.C. MACHINES*

(With Special Reference to Interpole Machines)

BY P. Q. R.

Shunt Field Faults

In the case of a generator which is required to be self-exciting there is only one correct connection of shunt field terminals to the armature busbars. If the machine be run with correct rotation and does not build up, then probably the shunt field is wrongly connected, and should be reversed. Cases often occur, however, where the field is correctly connected (especially when the machine is being run up for the first time), and some half an hour will elapse before the machine commences to build up; or a machine may build up with the wrong polarity to be put on the station busbars. The remedy then is not in reversing the field connections (if this were done the machine would no longer build up), but in reversing the residual magnetism in the pole pieces by separately exciting the field from some external source for a short time. With a motor there can not be an incorrect shunt field connection, because it is always excited direct from the line. The actual connection determines the direction of rotation.

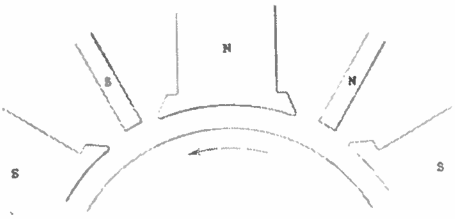


Fig. 1 Polarity of Interpoles in the Case of a Generator

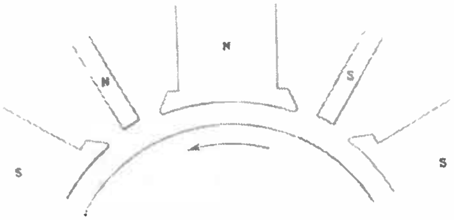


Fig. 2. Polarity of Interpoles in the Case of a Motor

Series Field of Compound-Wound Machines

A generator running at constant speed will have its volts increased as load increases when the series field is correctly connected, and to obtain any degree of compounding it is usual to insert a low resistance or diverter in parallel with it, which can be adjusted for any value of voltage desired. In this way drop in engine speed can be compensated for between no load and full load as well as compounding, and there is no drawback to the use of a diverter, as is the case with interpoles.

With a motor a diverter in the series field is rarely, if ever, used; the drop in speed due to the series turns can be foretold accurately enough, and there is always an allowance of 5 per cent above or below rated speed with any direct current machine. It is of the greatest importance, however, to be certain that the series field is right way when starting up for the first time, especially in a variable speed interpole machine. It would be safe in either case to run the machine light first of all. Load should then be put on very gradually, and if the speed tends to rise appreciably, it is almost certain that the series field is reversed and bucks the shunt field; and in that case the machine should be at once shut down. The shunt field of a variable speed interpole machine is extremely weak when on top speed, and the series field, if reversed, is sufficient to wipe it out altogether, with the result that the machine would either race to destruction or arc over between the brush studs, thus blowing its own circuit breaker and possibly shutting off the supply.

It is a common error also to suppose that the series field of a motor is wound to buck the shunt field, thus slightly weakening the shunt field on full load and keeping the speed constant at all loads. These differentially wound machines are rarely, if ever, to be found; the variation of 3 or 4 per cent in speed between no load and full load of a good shunt motor is quite near enough a constant for all commercial purposes, and, moreover, it appears to be forgotten that any machine must necessarily be some 3 or 4 per cent higher in speed when hot than when cold, due

---

* Reprinted from Electrical Engineering, London.

to increase of shunt field resistance and consequent weakening of field current.

Interpoles

The object of commutating poles or interpoles is to neutralize the armature reaction at all loads, and thus leave the flux from the shunt poles undisturbed as much as possible; this will then allow of good commutation with a fixed brush position at all current values.

In practice the whole of the line current is carried round these poles, and the turns are sufficient to produce from 1 to 1.5 times the reactive ampere turns on the armature, according to the air gap. The exact proportioning of these parts is very important, for if badly designed the commutation might be even worse than if commutating poles had not been supplied. These poles have their winding always put directly in series with the armature of the machine, and after the connections have once been correctly made, they will be correct under whatever conditions the machine is to work, *whether motor or generator, or for either direction of rotation*, because for any reversal of current in the armature there will be a corresponding change of current and reversal of polarity in the interpoles. The correct connection is that which produces the polarity shown in Fig. 1 for a generator and Fig. 2 for a motor. The polarity is opposite in the two cases because the reversal of the armature current reverses the polarity of the interpoles.

Cases occur in which the ampere turns on the commutating poles have too high a value; then, instead of rewinding new spools, the device of inserting a low-resistance in parallel with the interpole winding is resorted to, and by correctly adjusting this resistance the proper percentage of the total current is diverted through it, thus reducing the ampere turns on the interpoles to the correct value.

This, however, is not to be recommended, especially in cases where the load is fluctuating, because the turns on the interpoles, being wound on an iron core, possess a large amount of self-induction which resists a rapid increase of current round the poles. When load then varies with a corresponding change in current, during the change the self-induction of the interpoles prevents a rapid change of current round them, and for the moment a greater percentage than normal passes through the low non-inductive resistance in parallel with them. The interpoles do not therefore at all times correctly compensate the current values of the armatures, which results in sparking at the brushes. The difficulty could only be overcome by winding the low resistance mentioned above around an iron core, which should have approximately the same self-induction as the interpoles; the current would then be correctly proportioned between them for all changes in value.

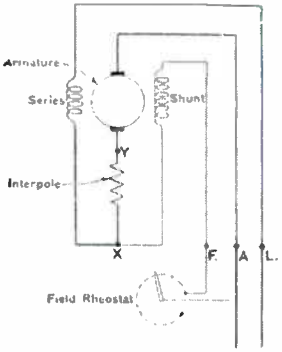


Fig. 3. Diagram of Connections for Compounded Interpole Machine

Fig. 3 shows the usual connections of interpole machines; X, F, A, L representing the terminals on the connection board of the machine. X serves as a terminal for the equalizer bar, if one is required, in the case of a generator running in parallel with others. F is the extremity of the shunt field, which is usually connected to the rheostat in the field circuit on the switchboard before being joined to the other side of the line. A and L are the armature and line main terminals coupled to the main switches. In the case of a motor the starting rheostat would be inserted between A and the main switch. The point Y is the connection of the interpole winding to one of the armature brushes; this is not brought out to the terminal board. If, therefore, the interpoles were of wrong polarity and required reversing (which would be easily detected on starting up the machine by the violent sparking when the brushes were in correct position), the connections could not be got at and the only way to overcome the difficulty would be to rock the brush gear one pole-pitch forward, thus reversing the armature relative to the interpoles.

In the case of a generator, this reversal of the armature would necessitate a reversal back again of the interpoles and armature *together* by interchanging X and A on the terminal board, thus making the relation between the armature and the shunt and series fields the same as before, and allowing the machine to build up. With a motor this reversal of the armature would reverse the rotation; and to bring back the rotation to the original, interpoles and armature together are reversed by interchanging X and A.

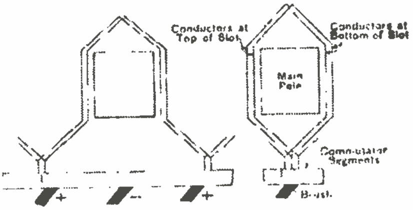


Fig. 4. Series-Wound Armature

Fig. 4a. Parallel-Wound Armature

Before considering the behaviour of these types of machines, it must be thoroughly understood at the commencement that brush position is the one all-important factor in successful operation The commutating zone of a compole machine is very accurately defined, and the smallest alteration of brush position very greatly alters the characteristics of the machines.

The electrical neutral must in the first place be arrived at. Perhaps the best method is to find the brush position on which the machines will run at the same speed as a motor in both directions of rotation for the same applied voltage. Circumstances will not allow of this always, so the following mechanical method is more common and can be relied upon to have sufficient accuracy. By reference to Fig. 4 for a series wound armature, and 4a for a parallel wound armature, the whole thing is made simple. Any armature coil is selected, and the armature is moved round until the slots in which the coil is wound are symmetrical with respect to the pole tips of a shunt pole. The commutator segments to which the conductors in this coil are connected are traced out and the brushes are moved to lie symmetrically with respect to these. This brush position can be confidently assumed to be very near indeed to the electrical neutral.

The actual influence which interpoles have with different brush positions is very well illustrated in the following example: The machine under test was a 500 kw., 500 volt, 1,000 ampere generator, with interpoles but no series field. It was desired to run the machine on dead short-circuit with 1,000 amperes flowing. The only resistance then in circuit was that of the armature and interpoles, and it was found that with brushes on the electrical neutral the residual magnetism in the shunt poles was just sufficient to produce a voltage which caused 980 amperes to flow through the armature. When three segments forward lead were given to the brushes, the 980 amperes above were reduced to 40 amperes.

Very often in practice, on the other hand, backward lead is purposely given to the brushes of an interpole generator when commutation will allow it; because then the interpoles are helping the shunt poles, and less shunt field current is required for any given voltage. Again, with a motor, where commutation will allow it, quite an appreciable alteration in speed can be obtained by alteration in brush position; but interpoles are not supplied very often except with variable speed motors, the regulation of which is obtained by means of resistance in the shunt field. Brush position is then very important, since other difficulties arise on high speeds which definitely fix the position of the brush gear; but these considerations will be dealt with later.

The difficulties in interpole generators are not very great. Sparkless commutation can be obtained with the brushes varying as much as two or three commutator segments; the only item which determines a fixed brush position is when the machine is required to have a certain degree of compounding. The distance of the brushes from the electrical neutral materially affects the amount of shunt field current for a given voltage, hence it will be at once seen that there is only one brush position at which the compounding at all loads will be that desired.

With interpole motors the case is different. It might be that the motor is required to be reversible; this at once determines that the brushes must be on the electrical neutral. It might be that it must run at greatly different speeds, the extreme values of which could have a ratio of 5:1; or the speed on no load must be higher than that at full load, or *vice versa*. For all these cases the interpoles require great accuracy in design to secure

---

* Not the case with General Electric Machines. See Editorial.

good results. The iron forming the pole-core should not be more than half saturated when full load current is flowing so that the flux produced is in direct proportion up to considerable overload of the current, and thus fully neutralizes the armature reactions at all loads

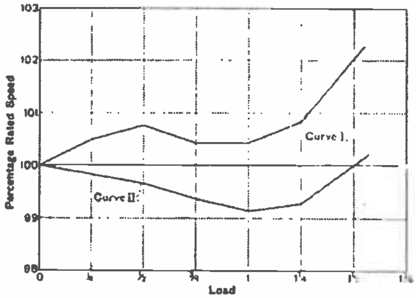


Fig. 5. Speed Characteristics of Interpole Motor
(I) Brushes in Neutral Position
(II) Brushes Given Half a Segment Forward Lead

*If possible, an interpole motor is run with its brushes on the neutral, but in many cases when the machine has become hot there might be a slight tendency for it to surge on full load, or, if not on full load, perhaps on 50 per cent overload. Besides this, the influence of the interpoles on the main field is such that the speed on full load and overload might be even higher than on no load.

Any tendency for the speed to rise on load should be remedied, because on some overload or other the machine is almost sure to surge considerably, and in the event of a heavy overload for a short period at any time it will be damaged, due to the extremely heavy surging current values or to its racing to a dangerously high speed. The only remedy for this difficulty is to give the brushes, say, half a segment forward lead (but this, of course, can not be done when the machine is reversible). The interpoles ought to allow of this and still give sparkless commutation if well designed. The additive action of the interpoles to the shunt field then keeps down the speed and at the same time keeps the field strong enough to prevent surging. Perhaps even in this case, if the speed at full load was lower than on no load, on 25 per cent overload the speed might still be higher than on full load. The machine has not necessarily a drooping characteristic at all loads; hence it is worth while to insure that the speed on 50 per cent overload is going to be very little higher, if at all, than on no load. The speed characteristic of an interpole motor of 500 volts 40 h.p., 800 r.p.m. is shown in Fig. 5. Curve I shows the speed with brushes on neutral position, Curve II with the brushes given half a segment forward lead. A good machine would usually allow of one segment forward lead being given to the brushes before sparking commences.

*A much simpler way out of the above difficulty is to supply a series winding, so that as load comes on the machine the series turns help the shunt field and keep down the speed and at the same time the machine is perfectly stable. This is done in every case with a reversible motor, in which the brushes must necessarily be fixed on the neutral. In the latter case the shunt field and series field are in permanent connection to the supply line through the main switches, of course, and the interpoles and armature together are brought out to the reversing controller. With variable speed motors the value of the shunt field current on the highest speed is very small, and in many cases in which a series winding is employed as well, the machine would safely run on top speed without any shunt field at all.

When a series winding is not employed the safety of the machine depends on this small value of shunt field current.

The connecting cables from the various terminals of the machine are often threaded in any manner through the frame between the spools, when really this simple thing is a very important consideration. These cables carry the full load current of the machine, and, lying as they do adjacent to a shunt spool, they are equivalent to half a turn practically round the spool. The influence of that number of ampere turns on the shunt spool when it is itself very weak is very considerable, and the result is that brushes collecting from conductors under its influence spark quite appreciably when all others are perfectly sparkless; there might be increase or decrease of shunt field strength, but certainly there is bad commutation. Cables of this sort should always pass between the spools in pairs, in which current passes in opposite directions.

In conclusion, a word might be said about the heating of such machines. In the first place the size for a given output has been reduced to a minimum and the space available

---

* Not the case with General Electric Machines. See Editorial.

is so well utilized that ventilation suffers considerably. It is safe to say that a machine whose output is limited by temperature will operate practically sparklessly at 25 per cent overload and, take 50 per cent overload for short periods without undue sparking. In many cases, too, the output can be considerably increased by the addition of a small fan on the armature shaft to aid ventilation, and by so doing the advantage of decrease in cost for a given output far outweighs any small loss in efficiency. In fact, cases often occur where, after the addition of a small fan, the efficiency is actually increased, due to the greatly reduced copper losses in the machine at the lower temperature

---

COMMERCIAL ELECTRICAL TESTING

Part XII

By E. F. Collins

TRANSFORMERS—Cont'd.

Core Loss and Exciting Current

When a transformer is connected to a source of alternating current, a loss of energy takes place in the iron, owing to cyclic reversals of the magnetic flux. This loss of energy is known as the core loss; its value depending on the wave form of the impressed e.m.f., a peaked wave giving a somewhat lower core loss than a flat wave. It is not uncommon to find alternators giving such a peaked wave form that the core loss obtained on transformers excited by them is 5 to 10 per cent less than that obtained on the same transformers when excited from generators giving a true sine wave. On the other hand some generators give a very flat wave form, so that the core loss is greater than that obtained when sine wave is used. The core loss test is similar to the impedance test, except that voltage is applied to one winding, the other being left open circuited. Voltage should always be applied to the low potential winding in order to avoid placing meters in high potential circuits. Core loss should always be taken from a sine wave alternator and transformer connections made so that the alternator is operated at normal excitation when normal potential reading of core loss is taken.

To make this test, estimate the capacity of the meters required, connect the ammeter in circuit and take a preliminary reading of exciting current to show what meter capacity is required. Be sure to place the high tension leads so that no one can come in contact with them and that there is no danger of short circuit. The instruments should be so placed that they have no influence upon one another, and are not affected by any stray field.

A core loss curve should be taken, starting at 50 per cent of rated potential and increasing the voltage to 25 per cent above normal. To do this, hold the frequency constant and vary the voltage, taking simultaneous readings of the excitation amperes and watts core loss. Do not plot the curve as each reading is taken, but as soon as all are finished. If the curve is not smooth, repeat the test. The curve will be more satisfactory if meters can be so selected that no change in them is necessary throughout the curve. Record all meter numbers, their constants and date of calibration, temperature of iron, and numbers and ratios of potential transformers or of multipliers. Wherever possible, use the wattmeter without a potential transformer or multiplier, by connecting the transformer for the lowest potential, as this will give more reliable results.

When the normal voltage of both windings is above 5000 volts it is often more satisfactory to take core loss indirectly; that is, to read input into the secondary of a transformer used to step up to the voltage of the transformer in test. This step-up transformer should have its ratio, resistance and core loss carefully measured.

Connect the primary of the step-up transformer to the secondary of the transformer in test, putting a low reading ammeter in circuit to read the exciting current. Read volts, watts and amperes in the secondary of the step-up transformer as usual. In calculating the actual core loss, subtract the C^2R and core loss of the step-up transformer from the total wattmeter reading. While this method has its disadvantages, it is almost as accurate as that of using a potential transformer of large ratio and a current transformer and is certainly much safer. Connections for this test are shown in Fig. 48.

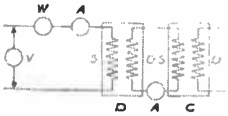


Fig. 48

Connections for Core Loss Test

Parallel Run

The discussion of the parallel test is given here rather than under the heading of "ratio" or "polarity," because the heat run is the next test, and excitation voltage must therefore be provided.

Having previously tested the ratio and polarity on one of the transformers of the group, the parallel run can be made and the polarity of the others checked with the one tested; also the ratio of the remaining transformers. If the transformers differ in ratio by one-tenth of 1 per cent, the fact will be shown in the parallel run, because the test is made at the full potential of the transformer. If a transformer is one turn out, a difference of voltage between the two transformers of from 15 to 40 volts will be shown, depending upon the size of the transformer. This potential gives quite a spark and the exact amount of voltage difference may be determined by connecting a voltmeter between the two transformers.

The connections for the parallel run are shown in Fig. 49, No. 2 being the standard transformer—the one on which polarity and ratio have been taken. Only two transformers must be connected at the same time, for if voltage is on the entire set, there is more danger of some one coming in contact with the primary leads. Connect two of the transformers as shown in Fig. 49, making one side of the primary connections permanent, and arranging the other side so that the circuit may be completed with a small fuse wire of not over 3 amperes capacity. One end of this fuse wire should be carefully fastened to one end of a clean dry stick about two feet long. Close the secondary switches and by touching the frame of one of the transformers with the fuse wire, determine whether voltage is on the transformer; a small spark indicates that the transformer is excited. Now excite the alternator, gradually bringing it up to normal potential. As soon as field is applied to the alternator, the man handling the fuse wire should begin tapping its loose end on the primary terminal of the other transformer; if no spark is seen the transformers will operate in parallel. If a small spark appears, connect a voltmeter in series and read the difference of voltage with normal potential on the transformers. If this voltage is more than one-fourth of 1 per cent of the rated voltage of the transformer, the wrong coil should be located and corrected. Instead of reading the voltage, the exchange current may be read by connecting an ammeter in the circuit instead of the voltmeter. This current should not exceed 5 per cent of the normal current. Continue the parallel tests as above, until all the transformers have been run in parallel with the one selected as standard.

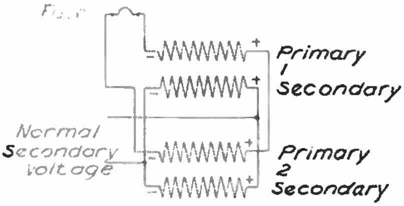


Fig. 49

Connections for Parallel Run

If the transformer has two circuits that may be operated either in series or parallel, the parallel test should be made by connecting together the corresponding ends of these coils on one side, completing the circuit by means of fuse wire and applying full potential to the other winding of the transformer. It is just as essential that the coils of a transformer operate satisfactorily in multiple as that two transformers so operate.

Normal Load Heat Run

The heat test may be conducted in several ways, all of which are designed to approximate as nearly as possible the operating conditions of the transformers. A run with actual load might be made by using water rheostats, but as this would be very expensive, some form of motor-generator method should be used. Fig. 50 shows the connections for testing two transformers by the motor-generator method. The secondaries of both transformers are connected in multiple and then connected to an alternator which supplies the core loss and exciting current. The primaries are connected in series, opposing each other; if the transformers have the same ratio, the voltage from *A* to *B* will be zero.

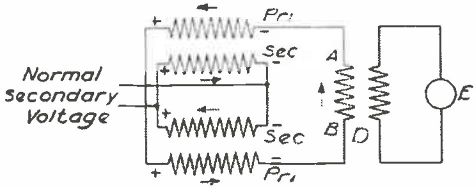


Fig. 50
Connections for Heat Run

The secondary of an auxiliary transformer *D* is connected in series with the primaries of the transformers in test. Alternator *E* connected to the primary of transformer *D* supplies the copper losses. The same method may be used for any even number of transformers, but it is not advisable to run more than six at one time. Fig. 51 shows connections for the heat run on three transformers, the primaries and secondaries of which are connected in delta. Across one corner of the delta, impedance voltage is impressed for the three transformers connected in series. The current circulates within the delta and is entirely independent of the secondary voltage.

The two methods outlined above require only sufficient power to supply the losses.

In arranging for the heat run, see that the alternators and transformers are of sufficient capacity to carry the load; the current necessary to supply the iron losses being equal to the sum of the exciting currents of the transformers. If the transformers have several secondary coils, connect them in series so that when the heat run is completed no time will be lost in making connections for measuring hot resistance. The alternator supplying the core loss should operate at normal excitation; the voltage required to supply the load current being equal to the impedance voltages of the transformers. If there is more than one primary, arrange to run them in series if possible. If the transformer is to have a 50 per cent overload test, add 50 per cent to the voltage already obtained.

Shop transformers should always be interposed between the primaries of the transformers in test and the alternators to prevent the breaking down of the armature and to avoid high potentials on the switchboards. "Step" the voltage either down or up, or down and up again, depending upon circumstances; but always have transformers between the alternator and the primaries of the transformers in test. Having made connections, place a man on guard to prevent any one coming in contact with the wiring; then see whether the proper load and overload can be obtained. There should be some resistance left in the field of the alternator so that as the alternator fields and the winding of the transformers heat up, the load can be kept normal.

Place spirit thermometers in the top of each transformer to read the temperature of the air escaping from the coils. Two thermometers should be used for the primary and two for the secondary windings, placing them about one inch above and just over the ducts between the coils. Also, place two thermometers on the core to read the temperature of the iron, one near the top and one near the bottom, and two thermometers to read the temperature of the air escaping from the iron. The transformers can now be loaded. With the alternator running at proper speed, the total exciting current of the transformers should be read and the secondary voltage can be checked.

Air blast transformers are usually run at full load for 30 minutes without air, in order to heat them up and thus shorten the heat run. Some transformers can not be operated for more than 20 minutes without air and they must be carefully watched to see that they do not get too hot. After the air blast is put on, it is usually necessary to keep the iron damper closed for some time to allow the core to heat up, as the copper heats much faster than the iron. The amount and pressure of air required depends on the guarantees as to temperature and to some extent on the voltage of the transformers. The large amount of insulation on the coils of high voltage transformers tends to retard radiation.

If transformers are guaranteed for a maximum temperature rise of 40° C. at normal load, and 55° C. rise after a 25 per cent overload for two hours, the air should be adjusted to give about 35° rise on the copper and 40° rise on the iron. If the iron seems too hot, increase the air pressure, partially closing the top damper; if the copper is too hot, increase the pressure and partially close the lower damper.

If the transformers are guaranteed for a maximum rise of 35° C. at normal load and 55° rise after 50 per cent overload for two hours, the air should be adjusted to give about 30° rise on the copper and 35° rise on the iron. These adjustments should be carefully made during the first hours of the heat run.

When properly adjusted the transformers should run about four hours at a practically constant temperature. Place the thermometers for measuring the room temperature near the intake of the blower so as to get the temperature of air delivered to the transformers. Read all thermometers and take the resistance on one winding of each transformer every hour. Iron temperatures may be read while the transformers are under load, since the frames are grounded. If primary leads are brought out at the top of the machine, the voltage should be cut off when taking other readings; if, however, the transformers are bottom connected, the temperatures may be read while the machines are under load. If it can be avoided, do not change the position of thermometers when taking readings.

When ready to measure resistances, shut down the blower, take off the load and measure the resistances as rapidly as possible, so as not to allow the transformers to cool off. One minute per transformers should be ample time for these readings. The rise by resistance is calculated as follows:

t = Cold temperature of coil.
T = Hot temperature of coil.
R_t = Cold resistance of coil.
R_r = Hot resistance of coil.

$$T = (238+t)\frac{R_r}{R_t} - 238.$$

$T - t$ = Rise in degrees C.

During the heat run a careful inspection should be made for loose laminations. If any transformers are found that rattle or buzz, due to loose iron, they should be plainly tagged and a chalk mark made on the core as near as possible to the point at which buzzing was heard. The heat run and other tests should now be finished, except the double and high potential tests, which must always be taken after all repairs are made.

It sometimes happens that the iron casings are loose, causing them to rattle. Tighten up all the screws, and if this does not stop the noise, strips of felt must be placed between the sheet iron casing and the cast iron corner castings, cap and base. If this defect is discovered during the first part of the heat run, it should be repaired before the heat run is continued; if not, repairs will be made directly the heat run is finished. After such repairs, always apply full voltage at normal frequency to see if the trouble has been remedied. If a motor-generator method can not be used, the copper and iron heat runs may be taken separately.

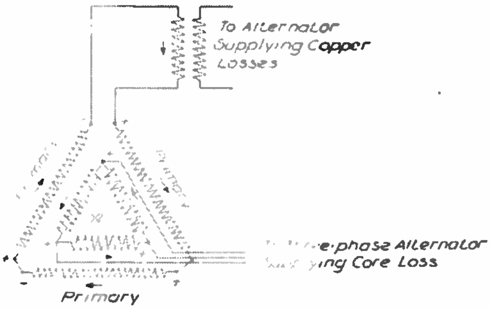


Fig. 51
Connections for Heat Run

To make a short circuit heat run, short circuit the secondary windings and apply normal current to the primary. When this test is finished and the hot resistances taken, open-circuit the primary, arranging the primary leads so that there is no danger of any one being injured, and apply normal voltage at proper frequency to the secondary until the iron temperatures are constant. Finish up the tests as if the heat run were taken by the motor-generator method. The same amount of air will be required and the heating will be practically the same as though both iron and copper were loaded at the same time.

At the end of the heat run measure all resistances carefully and read the thermometers. The same care should be used as when taking cold resistances, and if any set of readings indicates a doubtful increase of resistance, the readings should be checked, using a different set of meters. If the work is properly conducted, ten minutes is ample time to take a complete set of resistance readings on four transformers. A careful inspection of all soldered joints should be made to see that there is no undue heating.

When no overload is specified, the transformers must be run for 20 minutes at 50 per cent overload current to test soldered joints. This test follows that of hot resistance.

Overload Heat Runs

This test is ordinarily limited to two hours and is taken as a continuation of the normal load heat run. Engineering instructions should always specify the overload tests required.

Transformers are sometimes designed to run continuously at overloads, or may be guaranteed to operate at a certain kilowatt output at some power factor less than unity. Overload heat runs should be very carefully watched, particularly those of short duration. Special attention should be given to the length of the run, as the temperatures often rise very rapidly. At the finish of the heat run, record all temperatures and measure all resistances. The same air pressure should be used for the overload as for the normal load.

Insulation Test—Double Potential Test

In this test, as well as in the core loss and impedance test, the alternator supplying the voltage should be operated at as near normal voltage as possible, so as to avoid distortion of the wave form. Double potential is applied to test the insulation between turns and between sections of the coils. Since it is impossible to obtain double voltage on a transformer at normal frequency, due to high density in the iron, the frequency must be increased. Apply twice the normal voltage for one minute, followed by one and one-half times normal voltage for five minutes. The last test is taken in order to discover any short circuits that might develop during the double potential test, and yet not become apparent in the short time that the double potential is applied. The primary bushings should be cleaned before the test and the transformer guarded to prevent accidents from the high voltage circuits. Any buzzing or leakage of current should be noted.

In applying and taking off the high potential, vary the alternator field gradually; that is, do not open the field switch with a jerk, for if this is done trouble is very likely to occur. As soon as this test is taken, make the proper comments on the test sheet.

In case a transformer breaks down, the defective coil should be located and plainly marked. Then, in disassembling the machine, the coil can be easily found and the cause of the defect ascertained, thus preventing a repetition of the breakdown.

Air Readings

The method at present used is to read the velocity of the air through a standard orifice by means of an air meter. Knowing the velocity and the area of the orifice, the cubic feet per minute can be easily calculated. A large box with an opening in the bottom should be held against the transformer, using a small piece of felt as packing and being careful to allow no air to escape. The size of the orifice should be noted, and the time that the air meter is allowed to run. Always record the reading in cubic feet per minute. The air readings are to be taken with the dampers in the same position that they occupied during the heat run, and at the same air pressure.

High Potential Test

The application of a high potential to the insulation of a transformer is the *only* method for determining whether the dielectric strength is sufficient for continuous operation. Mechanical examination amounts to little and measurement of insulation resistance is equally valueless, since insulation may show high resistance when measured by a voltmeter with low voltage, but offer comparatively little resistance to the passage of a high tension current.

The insulation test which should be applied to the windings of a transformer depends upon the voltage for which the transformer is designed. The voltage to be applied should always be obtained from standing instructions, or from engineering notices. In testing between the primary and the core or the secondary, the secondary should be grounded for the following reasons: In testing between one winding and the core, a potential strain is induced between the core and the other winding which may be much greater than the strain to which the insulation is subjected under normal operation, and therefore greater than it is designed to withstand. In testing between the primary and the core, the induced potential between the secondary and core may be several thousand volts, and the secondary may thus be broken down by an insulation test applied to the primary under conditions which would not exist in normal operation. During the test, all primary leads, as well as all secondary leads, must be connected together. If only one terminal of the transformer winding is connected to the high potential transformer, the potential strain may vary throughout the winding, and at some point may even be greater than at the terminal of which the voltage is applied. Under such conditions, the reading of the electrostatic voltmeter or the arcing across the spark gap affords no indication of the insulation strain. Indications which are best learned by experience reveal the character of the insulation under test.

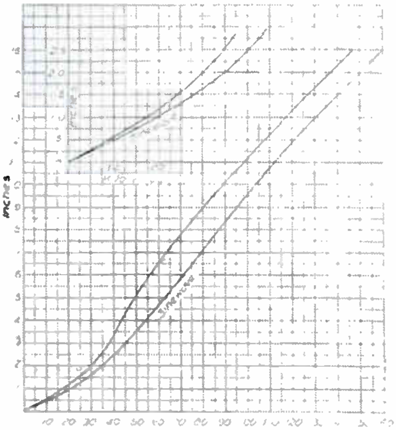


Fig. 52
Curve of Arc Distances

The charging current of a transformer varies with its size and design. The current may be measured by means of an ammeter, placed in the low potential circuit of the testing transformer. It will increase as the voltage applied to the insulation is increased. Inability to obtain the desired potential across the insulation may be due to large electrostatic capacity, or to the inability of the high potential transformer to supply a large capacity current at the voltage desired. A breakdown in the insulation will result in a drop in voltage indicated by the electrostatic voltmeter. An excessive charging current will flow and the insulation will burn if the discharge is continued for any length of time.

For any test above 10,000 volts always use a spark gap, setting it according to the sine wave curve of arcing distances (Fig. 52). Use a new set of needles each time. Connect both ends of the primary winding to one terminal of the high potential transformer and ground both ends of the secondary to the core and frame, connecting the other terminal of the high potential transformer to the frame. Set the spark gap for the voltage to be applied and connect in the proper electrostatic voltmeter. Be sure that everything is clear, then apply the voltage, bringing it up gradually until the gap arcs over. Then decrease the voltage until the arcing ceases and again bring it up just to the arcing point, holding this voltage for one minute before gradually taking it off. A note of the charging current should be made on the record sheet.

When a transformer breaks down, the defective coil should be located by making it "smoke up." In doing this, burn only enough to show the coil. If much damage is done by smoking it may be impossible to discover the cause of the break-down.

(To be continued)

THE STEAM TURBINE

PART II

By Dr. Ernst J. Berg

The first turbine of the impulse type had but a single wheel, and while this design has been used extensively, its principal drawback lies in the fact that its efficient speeds are far higher than can be used to advantage without the introduction of gearing.

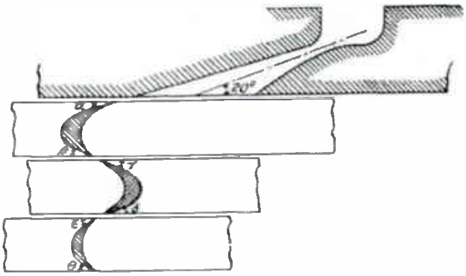


Fig. 1

To convince you of the correctness of this statement, we will proceed to determine the relations between steam velocity and available energy.

We have obviously,

$$\tfrac{1}{2} Mv^2 = \text{available energy};$$

thus $v^2 = \dfrac{2 \times \text{available energy};}{M}$

or since the mass $M = \dfrac{W}{g} = \dfrac{\text{weight}}{\text{acceleration}},$

we get, if the available energy per pound of steam is given:

$$v^2 = 2 \times 32.2 \times \text{available energy},$$

or $v = 8\sqrt{\text{available energy}}.$

We have shown before that if saturated steam is expanded from 175 lbs. to 28 in. vacuum, the available energy per pound of steam is 253,000 ft. lbs.; thus, the velocity of the steam as it enters the condenser would be,

$$v = 8\sqrt{253{,}000} = 4020 \text{ feet per second}$$

If the steam were expanded to atmospheric pressure only (when the available energy is 139,500).

the velocity would be $v = 8\sqrt{139{,}500} = 2990.$

Thus in the first case the steam velocity is about twice as great as that of a modern rifle ball; in the latter case, fifty per cent greater.

If the buckets revolve at one-half the velocity of the steam, the relative velocity of the steam in the buckets is one-half the absolute steam speed. Since, however, the bucket is moving at one-half of the original steam speed, it follows that with a relative velocity of one-half and a bucket velocity of one-half, the absolute velocity of the steam as it leaves the bucket is zero; thus all velocity has been converted to mechanical work.

Since it is a little difficult to see just why the bucket velocity should be one-half of the steam velocity, it may be well to also explain it in another way.

If the buckets stand still, then the steam, entering at say 2000 ft. per sec., would recoil with a speed of 2000 ft.; if the buckets move at a speed of 500 ft. per sec., the steam would hit the bucket at 1500 ft. It would recoil from the buckets at that speed but, since during the recoil the buckets are moving at the rate of 500 ft., the remaining velocity would be only 1000 ft. per second.

If the bucket speed had been 1000 ft., the entire velocity would evidently have been converted into mechanical energy. In a turbine, however, the steam does not enter in a direct line with the direction of the motion but, for reasons of construction, there is a certain angular difference. The angle between the nozzle and the bucket is usually 20°.

The "entrance" angles, $\alpha\beta\gamma$, (Fig. 1,) depend upon the relation between steam speed and bucket speed, the higher the bucket speed in relation to the steam speed, the blunter the angle should be in order that the steam may enter without shock—and at the same time not hit the back of the bucket. For this reason, we notice that in the second wheel of a two-wheel combination, where there is little difference between the steam speed and the bucket speed, the entrance angle is much larger than in the first wheel, where there is a great difference between the velocities.

The "leaving" angles, δ, ϵ, θ, depend upon the opinion of the designer; the smaller these are, the more the energy that can be abstracted, but the higher the buckets will be to pass a given amount of steam. The rotation loss is therefore greater, which fact is evident, since with small angles the steam path is greatly restricted, as may be seen from the figure below.

Through very careful construction the single stage turbine has been operated at bucket speeds as high as 1,400 feet per second (turbines of other designs do not, as a rule, go to higher speeds than 500 feet). It is of interest to all what efficiency could be expected at that speed.

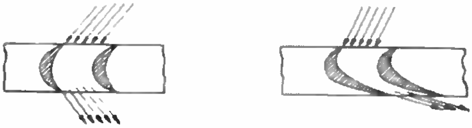


Fig 2

Assuming, then, a speed of 1,400 feet, a nozzle loss of 5 per cent in energy, a loss in the wheel of 10 per cent of the velocity, a nozzle angle of 20°, and a leaving angle of the bucket of 30°, we get the diagrams of Fig. 3, which represent the steam and wheel velocities when the steam enters and leaves the bucket.

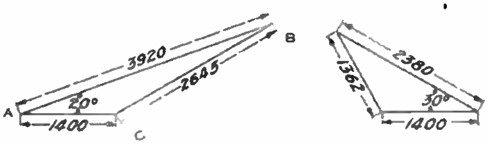


Fig. 3

A-B is the velocity of the steam as it leaves the nozzle. It is,

$$v = 8\sqrt{0.95 \times 253,000} = 3,920 \text{ feet.}$$

A-C is the bucket speed = 1,400 feet.

B-C is therefore the relative velocity of the steam as it enters the wheel and is equal to 2,645 feet. The relative velocity of the steam as it leaves the bucket is, according to the loss assumption, 2,380 feet; therefore the velocity of the steam as it is rejected into space is 1,362 feet.

Under these assumptions, we have:

The loss in the nozzle = 0.05 × 253,000 = 12,650 foot lbs.;

loss in the wheel $\frac{1}{2}mv^2 - \frac{1}{2}mv_1^2 =$

$$\frac{2645^2 - 2380^2}{64} = 20,600 \text{ ft. lbs.}$$

and the rejected energy, $\frac{1}{2}mv_2^2 = \frac{1362^2}{64} =$ 28,800,

making a total loss of 62,050 foot lbs. Therefore the bucket efficiency corresponding to indicated efficiency with engines is:

$$\frac{190,950}{253,000} = 75.5 \text{ per cent.}$$

To overcome the difficulties connected with high rotational and linear speed, such as are necessary for good economy in the single stage turbine, Curtis introduced the multi-stage type and the use of two or more wheels in each stage. This type can most readily be understood by considering each complete turbine as made up of a number of smaller turbines placed in series. The pressure distribution is governed by the size of the exhaust opening in each section, which opening, as a rule, forms the nozzles for the next section.

Depending upon the pressure in each stage, the work per stage varies. With the same work per stage, in a five-stage turbine operated with initially dry saturated steam at 175 lbs. abs. pressure and 28 in. vacuum, the available energy of each stage should be:

$$\frac{253,000}{5} = 50,600 \text{ foot lbs. per lb.}$$

The shell pressures corresponding to this available energy are 75 lbs., 30 lbs., 11 lbs., 3.8 lbs., and 1 lb. abs. for the first, second, third, fourth and fifth stages respectively.

Thus, for instance, in the nozzles leading to the first stage the steam is expanded from the initial pressure of 175 lbs. abs. to 75 lbs. abs. Neglecting any losses in the nozzles, the steam velocity (which obviously is the same in all stages) as it leaves the nozzle is then:

$8\sqrt{50,600} = 1,800$ feet per second.

Two wheels running at 450 ft. per second would thus abstract all the energy in the steam.

The size of the nozzles and the expansion ratio is governed by the flow of steam through orifices. As long as the pressure at the nozzle end is less than 8 per cent of the initial pressure and the steam is dry and saturated,

Napier's law, $F = p_1\frac{a_1}{70}$

or Grashof's law, $F = \frac{p_1^{.97} a_1}{60}$, gives results which closely agree with observed values.

Of the two laws, Grashof's seems preferable, at least at low pressures, when Napier's law gives values of flow somewhat smaller than those actually obtained. For instance, the two laws agree within about 2 per cent for pressure ranges from 80 to 200 lbs., but with a pressure of 15 lbs., Napier's law gives values about 7 per cent low and at 5 lbs. 11 per cent low.

Napier's law has the great advantage of simplicity and is therefore preferable if a constant is applied, which depends upon the initial pressure.

$$F = p_1\frac{a_1\,k}{70}$$

Where:

F = flow of saturated steam in lbs. per second.
p_1 = initial pressure in lbs. abs.
a_1 = throat area in square inches.
k = constant = 0.995 for $p_1 = 200$ lbs. abs.
= 1. for $p_1 = 175$ lbs. abs.
= 1.01 for $p_1 = 120$ lbs. abs.
= 1.02 for $p_1 = 85$ lbs. abs.
= 1.03 for $p_1 = 62$ lbs. abs.
= 1.04 for $p_1 = 47$ lbs. abs.
= 1.06 for $p_1 = 25$ lbs. abs.
= 1.08 for $p_1 = 13$ lbs. abs.
= 1.12 for $p_1 = 3.5$ lbs. abs.

The flow with superheated steam is reduced 6.5 per cent for each 100° Fah. Thus the equation becomes:

$$F = p_1\frac{a_1\,k}{70}(1 - .00065\,t_1)$$

where t_1 is the number of degrees superheat.

With moist steam the flow is increased approximately inversely as the square root of the quantity x.

Therefore the general equation of steam flow when $p_2 = 58 p_1$, whether the steam is superheated, saturated, dry or moist, can be expressed by:

$$F = p_1\frac{a_1 k\,(1 - .00065\,t_1)}{70\sqrt{x}}$$

Example:

Initial pressure, $p_1 = 100$ lbs. abs.
Final pressure, $p_2 = 50$ lbs. abs.
Superheat, $t_1 = 100°$ F.
Area, $a_1 = 1$ square inch.

We have then: $k = 1.015$, and $x = 1$.

Thus: $F = \frac{100 \times 1 \times 1.015 \times 0.935}{70} =$ 1.35 lbs. per sec.

and with steam of 3 per cent moisture the flow would have been:

$$F = \frac{100 \times 1 \times 1.015}{70\sqrt{.97}} = 1.48 \text{ lbs. per sec.}$$

When the difference of pressure is less, that is, when $p_2 > 0.58\,p_1$, the flow through a given orifice is less than that given above and changes with the shape of the nozzle.

Grashof gives the following formula for saturated steam:

$$F = \frac{p_1^{0.97} \times a_1 k_0}{60}$$

Where $k_0 = 1$ for $\frac{p_2}{p_1} = 0.58$
$= 0.9$ for $\frac{p_2}{p_1} = 0.76$
$= 0.8$ for $\frac{p_2}{p_1} = 0.83$
$= 0.7$ for $\frac{p_2}{p_1} = 0.88$
$= 0.6$ for $\frac{p_2}{p_1} = 0.915$
$= 0.5$ for $\frac{p_2}{p_1} = 0.945$
$= 0.4$ for $\frac{p_2}{p_1} = 0.955$
$= 0.3$ for $\frac{p_2}{p_1} = 0.985$

This formula has been verified by Gutermuth when a non-expanding nozzle was used; however, with a nozzle having expansion he found the flow to be somewhat greater.

Having determined the volume of the steam from the tables and its velocities in the various paths, we can readily proportion the actual dimensions of the buckets.

The nozzle throat area, that is, the smallest area of the nozzle, is found from the equation of the flow of steam.

The largest area of the nozzle, or what is equivalent, the expansion ratio, is also determined from the same equations, taking account, of course, of the fact that a considerable part of the steam is often converted to water by the expansion in the nozzle, and therefore the area is less than would be the case if the exhaust were dry.

The relation between bucket efficiency and bucket speed can best be shown by Fig. 4, where the bucket efficiency is plotted against the ratio of bucket speed to theoretical steam speed.

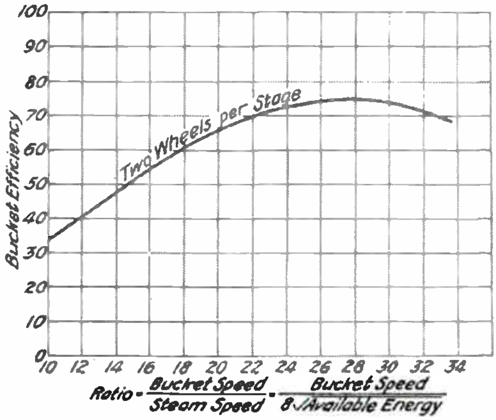


Fig. 4

It may seem strange that with a two wheel combination the maximum efficiency is reached when the speed of the buckets is 28 per cent of the steam speed, since even if there were no losses in velocity or energy, all speed could be abstracted by a two-wheel combination at a bucket speed only 25 per cent of the steam speed. This would be the case if the action were purely of the impulse type, but as the buckets have to be constructed, there is some slight expansion in the steam while passing from the nozzle through the turbine, this expansion resulting in a velocity in the second wheel which is greater than should be expected from the pure impulse type.

Referring now to Fig. 4 if there were no rotation losses, the maximum efficiency of the turbine could be expected to be 75 per cent and the efficiency of the complete unit, including generator, say 72 per cent.

This figure has not, however, been reached at the present time. A combined efficiency of 68 per cent is as high as can be claimed by any manufacturer.

The rotation loss is often of considerable magnitude.

This loss is proportional to the third power of the linear speed, that is, the bucket speed. It is practically proportional to the square of the diameter and directly proportional to the absolute pressure.

As rotation loss formulæ are very different with different types of turbines and arrangements of buckets and diaphragms, no general equation can be given, but different constructions demand different constants.

For a two wheel combination a fair approximation can be obtained as follows:

$$KW = 0.0003\ p\left(\frac{u}{100}\right)^3 D^2$$

Where KW = kilowatt loss,
p = absolute pressure in the stage,
u = bucket speed feet per second,
D = diameter at bucket in feet.

As an instance, the rotation loss in the second stage of the five-stage turbine discussed, which runs at 750 kw. and has a bucket speed of 465 ft. is:

$$KW = 0.003 \times 30 \times 4.65^3 \times 11.8^2 = 125 \text{ kw.}$$

The total rotation loss in the entire turbine will be about 500 kw., or 3.5 per cent of the output of a 14,000 kw. turbine.

To conclude, it is hoped that this lecture gives the necessary information for the understanding of the action of steam in turbines. Of course, important features enter in the design, which can not be explained briefly or by equations, such as practical clearances around wheels, effect of highly polished nozzles and wheels, etc. These details must be studied experimentally, not only with each type of turbine, but with different sizes of each type.

INSULATION AGAINST ELECTRICAL IMPULSE FORCES

By Dr. C. P. Steinmetz

In the insulation of electric circuits for medium and high voltages a safety factor of 4 is used. That is, while normally the rated voltage comes across two insulations, the apparatus is tested with double voltage across single insulation. Experience has shown this is sufficiently high for standing indefinitely the voltages constantly existing in the circuit. Nevertheless break downs of the insulation occur, and will take place with increasing frequency, by transient voltages—that is, by electric impulse forces of indefinite voltage—and no safety factor of insulation that is permissible with a reasonable size of apparatus, can completely guard against such electric impulse forces.

The conditions are somewhat similar to those met in the mechanical strength. Stationary structures, intended to carry constant mechanical loads, may be designed rigidly with a chosen safety factor. Structures, however, which are exposed to mechanical impulse forces, the impact of moving masses, could not be safely designed in this manner. For instance, an automobile tested by loading it at standstill with three or four times the weight it is intended to carry, would not offer any certainty of standing the shocks met in operation, since the force exerted by a moving mass is indefinite; that is, depends on the rapidity of stoppage of the motion, and the rigidity of the structure. Thus an instantaneous stoppage of the motion, with a perfectly rigid mass, would give an infinite force, and where motion has to be stopped or changed suddenly, something must give; that is, the impact force must be taken up by elastic or unelastic deformation. Thus in the automobile, tires, springs, and the entire structure take up the impact force by their elasticity, while the friction clutch represents an instance of inelastic absorption of the impulse force resulting from the difference in speed of motor and car.

In electric circuits impulse forces of indefinite voltage may occur, even under apparently normal conditions of operation, due to the kinetic and potential electric energy of the system (the magnetic and electrostatic energy); and in large medium voltage systems such electric impulses have commonly been observed reaching intensities corresponding to a constant voltage striking distance of two or more times the circuit voltage.

Just as in a mechanical structure impact forces appear at the points where sudden changes of speed occur, so in the electric circuit impulse forces reach their greatest intensity at the points where the circuit constants abruptly change. Such points are the terminals of reactances, of transformers, and other inductive devices, and these are the danger points at which indefinite and sometimes more or less unlimited voltages may be expected, and should be guarded against.

Characteristic of an impulse force (as the mechanical force when suddenly stopping a motion, or the voltage when suddenly destroying electric inertia) is that the energy is limited but not the intensity or voltage. The latter is theoretically unlimited, and is higher the more rigid the mechanical structure, or the more perfect the electrical insulation. Fortunately, just as a mechanical structure can momentarily stand forces far beyond those which when permanently applied would result in a break down, so also electrical insulation can momentarily stand voltages very much higher than it can stand permanently.

For instance, a quarter inch air gap between needle points, which breaks down at 5000 volts permanently applied, may momentarily stand over 100,000 volts; oil and solid insulations show the effect of the time of application still more markedly.*

While the voltage of electric impact forces may be extremely high, their disruptive effect may, and in all probability usually is relatively low, due to their limited energy and therefore limited duration.

The energy which may appear in the impulse force depends on the stored electric energy of the system, and thus approximately on the size of the system and on the availability of this energy, that is, the (relative) resistance of the circuits. The larger the system and the lower the resistance of the circuits, the greater is the energy which may appear in these impact forces, and the greater therefore their disruptive effect. Relative to the normal insulation of the system, the disruptive effect of electric impulse forces is probably greatest in the large medium-voltage systems.

---

* Some data on the behavior of air and oil when subjected to momentary voltages are given in a paper on the "Disruptive Strength of Air and Oil with Transient Voltages", published in the Proceedings of the A.I.E.E.

As the economic area of electric supply is approximately proportional to the square of the voltage, the size of the system and therefore the disruptive effect of the impulse forces appearing in the system, increases approximately with the square of the voltage; while the voltage for which the system is insulated increases only in proportion to the operating voltage (and at low voltages is still higher). Thus in an 11,000 volt underground distribution system the relative disruptive effect of electric impulses compared with the insulation of the system, is very much greater than in a 2300 volt primary distribution system, due to the much larger size of the former and therefore greater energy of the impulses, and also the relatively lower resistance of the cables, compared with the 2300 volt distribution circuits. When we come to very high voltage (60,000 or 100,000), we find that at present the sizes (kw. capacities) of such systems are not larger, but usually smaller than the largest 11,000 volt distributions, the percentage resistance is usually much higher, and the normal insulation of the circuits so much higher that electric impulse forces again offer relatively less danger of disruption.

Thus it seems to follow that the necessity of guarding the danger points of the system, i.e., the terminals of inductive devices, against unlimited voltages of limited energy, is at present greatest in the medium voltage high power systems, the large central station distributions, and next to these in other high power low resistance systems.

An increase of the safety factor of insulation at the danger points of such systems, where impulse forces of relatively high energy may be expected, increases the protection but relatively, since the impulse voltage is theoretically unlimited, and very soon the practical limits of economic insulation are reached. Furthermore, with the increase of insulation (of "electric rigidity") the voltage of the impulse force may be increased, and thus somewhat its disruptive effect.

It appears that in protecting systems against electric impulses we should give up the conception of a definite safety factor of insulation against steady voltage and endeavor so to design the apparatus and the entire system that no voltage of limited energy, no matter how high, can cause any damage. Damage to apparatus and harm to the system is usually done by the main current following a transient discharge, but probably never by the transient discharge itself, that is, the energy of the impulse. Thus, if the apparatus can be designed so that the energy of the impulse can be by passed or dissipated by a momentary high voltage, without any possibility of a discharge to ground followed by a short circuit occurring, the apparatus should be safe.

The energy of an impulse may be reflected or by passed by capacity (the aluminum cell works largely in this manner); or it may be dissipated and the voltage of the impulse thereby kept down by electric deformation in the dielectric (the insulation absorbing energy by what may be called dielectric hysteresis) by glow discharge, corona, brush discharge, streamers or spark discharges from the terminals at which the impact occurs, or by leakage. The terminals of reactive devices should therefore be so arranged, that no limited power spark discharge from them can reach the ground and thereby cause short circuit; but it may be advantageous to make such arrangement that the discharge may reach some high resistance conductor, as wood, concrete, etc., which separates it from ground, as hereby the energy of the impulse could be destroyed without the danger of a short circuiting arc following.

Thus the problem of protection against electric impulse forces seems largely to be one of the design of apparatus, and therefore does not yet allow of a general solution, but requires each problem to be taken up individually by choosing such a design that a static spark from the terminals of the apparatus can not cause a short circuit.

In the design of reactive devices for high power medium voltage systems, the protection against electric impulse forces is a far more important and serious problem than the insulation against the normal circuit voltage or against the internal voltages originating in the apparatus.

DEVELOPMENT OF ELECTRICAL DRIVE IN THE MILLS OF THE PROXIMITY MANUFACTURING CO., GREENSBORO, N. C.

By John P. Judge

The Proximity Manufacturing Company of Greensboro, N. C., operates two large cotton mills for the manufacture of indigo blue denims.

Caesar Cone, President Proximity Manufacturing Co.

The company was organized in 1895 by Messrs. Moses H. and Caesar Cone, and associates. The Proximity mill was erected and started in 1895, its equipment including 20,000 spindles and 1000 looms. A double spinning shift was instituted, and the looms were operated only in the day time. According to the custom at that time, the power house closely adjoined the mill, a 750 h.p. Corliss engine being belted directly to the head shaft in the spinning room and separately belted to jack shafts between engine room and weave shed.

As the business of the concern increased, additions to the equipment were made until it was found that the engine was carrying about 20 per cent overload and to get satisfactory draft a fan had to be installed in the stacks. In 1900 the owners determined that better results could be got by restoring the engine to its rated load, and after a thorough investigation, decided to install a separate engine with generator to drive the weave room. This was the first step taken by the company towards its present extensive system of electric drive. The equipment consisted of a 250 kw., 100 r.p.m., 600 volt, three-phase, 40 cycle generator direct coupled to a Corliss engine, the set being erected in the power house alongside of the first engine. Three 100 h.p. motors were installed in the basement of the weave room, each motor being belted to four shafts. Two of these motors are shown on Fig. 1. In ten years continuous service the total expense chargeable to these motors has not exceeded $100.00. The only change made in this motor equipment was that automatic oil switches were substituted for the air brake switches and fuses originally installed.

Before this installation was made, careful readings were taken on the engine to determine the amount of power used in the weave room. Similar readings were taken after the motors were installed (the number of looms having been increased 10 per cent during the

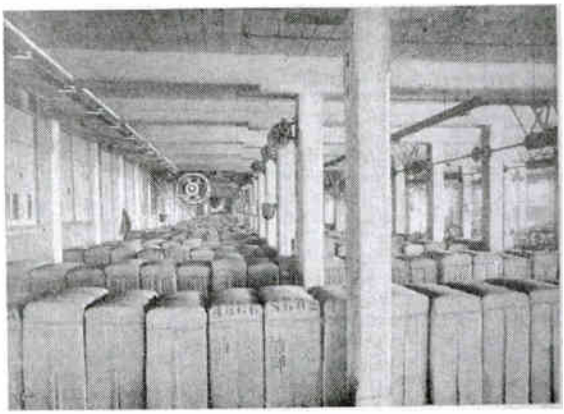


Fig. 1. View in Basement Showing Motors for Operating Machines in Weave Room Located on Floor Above. Proximity Mill

meantime), which showed that almost exactly the same amount of power was required as before, but with an increased production of 15 per cent; it having been found possible to operate the looms faster with the motor drive. It was also found that for the same total output formerly carried on one engine, the two engines consumed less steam and required less coal, and incidentally the fan was not required in the stack.

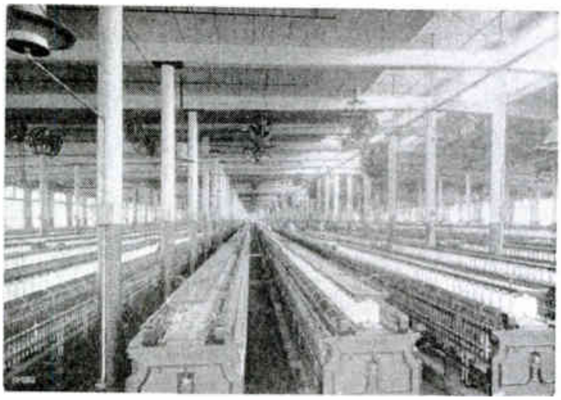


Fig. 3. Second Story of Spinning Building Containing 60,000 Spindles Operated by Seven 200 H.P. Motors Mounted on Ceiling. White Oak Mills

In 1902 the owners decided to build a larger mill about two miles from Proximity; this mill now being known as the White Oak mill. The site is an ideal one, being well elevated and surrounded by a thick growth of pine and oak. A considerable tract of woodland is set aside as a park for the benefit of the operatives.

This mill has 60,000 spindles and 2000 looms, with the necessary preparatory machinery and dye house. The main buildings comprise a two story picker building, 312 ft. by 78 ft.; a two story spinning building, 750 ft. by 155 ft.; a weave shed, 904 ft. by 180 ft.; a dye house, 312 ft. by 105 ft.; and a power house, 264 ft. by 136 ft., with two radial brick stacks 170 ft. high, one with a 12 ft. flue and one with a 9½ ft. flue.

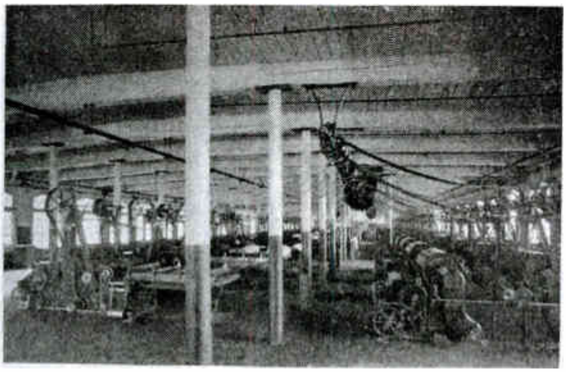
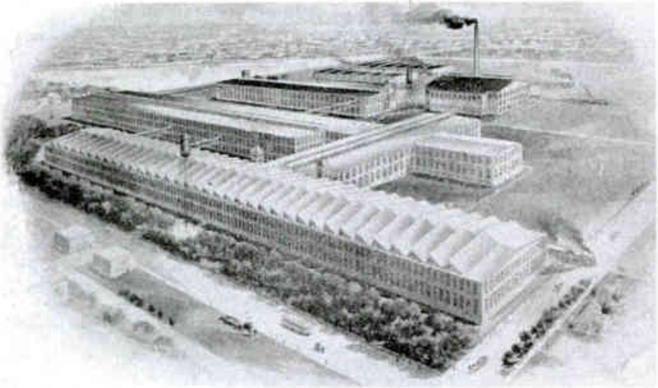


Fig. 2. Second Story of Picker Building Showing 200 H.P. Motors Suspended from Ceiling Rafters. White Oak Mills

The owners' experience at the Proximity mill had convinced them of the advantages of electric drive, and the White Oak mill was therefore laid out for that system of power distribution. The power house was placed to the west of the other buildings, as the land slopes in that direction, giving good facilities for the delivery of coal to the boilers and for handling the condensing water. One-half of the building is devoted to the boiler room, which contains 26 Heine water tube boilers, 16 of 200 h.p. and 10 of 250 h.p. each. The other half of the building, which is separated from the boiler room by a fire wall, is the engine and generator room, with a considerable offset for the switchboard. Two generating units were installed when the mill was built, each unit consisting of a 1250 kw., 600 volt, three-phase, 40 cycle generator direct coupled to a 2000 h.p. Corliss engine operating



White Oak Mills, Proximity Manufacturing Company

at 75 r.p.m. At the same time, there was also installed one motor-driven and one steam-driven exciter, each of 50 kw. and each capable of exciting the two generators. All feeds are carried in an underground tunnel from the switchboard to the several buildings.

Fig. 2 is a view in the second story of the picker building. The two motors shown are each of 200 h.p., 480 r.p.m., and are directly connected to the line shaft by two flexible couplings. In the first story there are three motors totalling 200 h.p., which operate the openers, etc. The first story of the spinning building contains two motors of 200 h.p. each, which operate the cards, drawing frames, slubbers and speeders. The second story contains spinning frames aggregating 60,000 spindles, together with warpers, etc., all of which are driven by four motors, each of 200 h.p., mounted on the ceiling and belted to countershafts as shown in Fig 3.

The looms in the weave shed are driven from below, the motors and shafting being located in the basement. In this building there are four motors, each of 150 h.p., 600 r.p.m., belted to four shafts. Fig. 5 shows some of

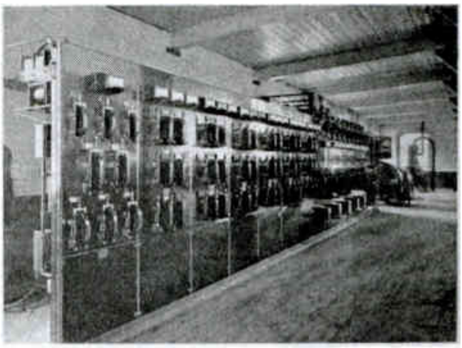


Fig. 4. Switchboard and Exciter in Power House, White Oak Mills

the motors in basement of weave room. It will be noted that this building is equipped in precisely the same manner that the weave room at Proximity was equipped five years before—good evidence that the owners were well satisfied with their first experience.

The dye house of this mill is unusually large and admirably appointed. The dyeing machinery is operated by one motor, which is of 100 h.p., a similar motor being used for driving the slashers in another section of this building. This mill is operated single shift.

In 1907 it was decided to enlarge the power house at White Oak and drive the Proximity mill therefrom, abandoning the mechanical drive, which had been retained there, except for the weave room. At the same time it was concluded to abandon night work at Proximity. This necessitated doubling the capacity of the yarn-making machinery at that mill; a new two story building 430 ft. by 130 ft. being erected for the purpose. A new dye house was also constructed and other improvements made, bringing the equipment of this mill up to 45,000 spindles and 1500 looms.

In the power house at White Oak there were added two 1500 kw., 600 volt, 40 cycle, three-phase generators, each coupled to a 2250 h.p. Corliss engine. The four units are shown on page 434, and the switchboard in Fig. 4. This view also shows the motor-driven and steam-driven exciters. When this last enlargement was made, a motor-driven exciter of 125 kw. capacity was installed.

Fig. 5. Ground Floor of Weave Room Showing 150 H.P. Motors Operating Machinery on Floor Above

To transmit the required power to Proximity, it was necessary to step up the voltage at White Oak and to step it down at Proximity. Consequently, three single-phase, 40 cycle, 1000 kw., 600/15,000 volt water cooled transformers were installed in a brick building just outside of the switchboard room at White Oak, and a steel tower line was carried to Proximity.

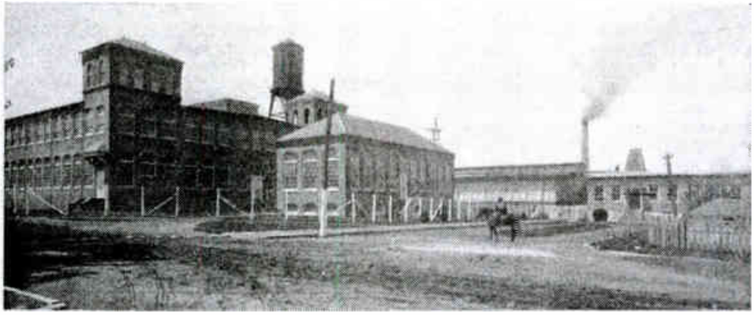


Fig. 6. Office and Substation, Proximity Mill

A substation for transformers and switchboard was also erected at Proximity; this building, which is 75 ft. by 30 ft., being shown in the foreground in Fig. 6. One end of this building is partitioned off by a heavy brick wall, and in the section so enclosed are placed three 40 cycle, 1000 kw., 15,000/600 volt, single-phase transformers and the lightning arresters, the transformers being located on a level with the ground. This section is full height of the building, giving ample room for high voltage connections. Fig. 7 shows the main section of this building. Besides the switchboard, a 250 kw. rotary converter is installed, which furnishes current for the direct current arc lamps, formerly served by a separate engine-driven generator. The handle of the 15000 volt automatic oil switch controlling the primary of the transformers is also shown at the end of the switchboard, the switch being located in the transformer section.

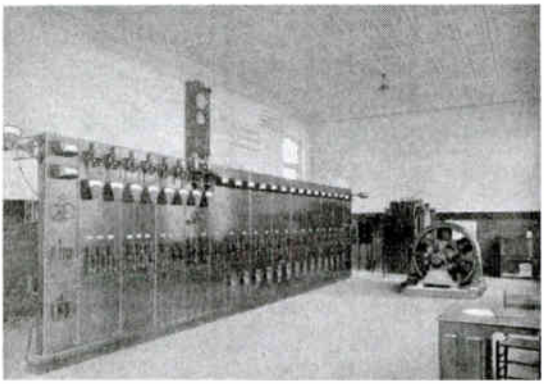


Fig. 7. Substation at Proximity

Switchboards in Power House

The switchboards are of black enameled slate, and are of standard General Electric design; each generator panel equipment including a Thomson recording wattmeter, as does also the panel controlling the line to Proximity mill. On each feeder panel is an indicating wattmeter, and at the end of the board is a generator voltage regulator. These meters are read daily and a careful log is kept, by means of which the engineers are enabled to check the power output against coal consumption and also against the production of the mills. Very interesting and useful data is thus secured.

The electrical equipment is all of General Electric manufacture, and includes:

Two 64 pole, 1250 kw., 75 r.p.m., 600 volt generators.

Two 64 pole, 1500 kw., 75 r.p.m., 600 volt generators.

One 48 pole, 250 kw., 100 r.p.m., 600 volt generators.

One 50 kw., 125 volt marine set (exciter).

One 50 kw., 125 volt motor-driven generator set (exciter).

One 125 kw., 125 volt motor-driven generator set (exciter).

One 15 kw., 125 volt motor-driven generator set (exciter).

Six 40 cycle, 100 kw., 15,000/600 volt water cooled transformers.

One 6 pole, 250 kw., 230 volt, 3-wire rotary converter.

819 arc lamps.

and the following standard 40 cycle, Form "L" (wound rotor), 550 volt motors:

Ten 200 h.p.
Nine 175 h.p.
Three 150 h.p.
Four 125 h.p.
Five 100 h.p.
Two 75 h.p.
One 60 h.p.
One 50 h.p.

These mills are probably the largest consumers of cotton in the South, using approximately 60,000 bales per annum.

All mechanical and electrical problems are under the supervision of the General Superintendent, Mr. R. G. Campbell, and his assistants, Messrs. U. S. Greer, steam engineer, and W. J. Dorworth, electrical engineer.

CURVES OF REACTIVE POWER

By V. Karapetoff

Professor Electrical Engineering, Cornell University

Overexcited synchronous machines are frequently used for raising the power factor of a load, in order to reduce the line current and consequently the size of generators and transmission lines; by so doing the voltage regulation and the efficiency of the whole plant are improved. In some cases it is advisable to run overexcited synchronous machines without any load connected to them, simply to supply the magnetizing current for other apparatus fed from the same line; in this case these machines are called synchronous condensers.

From the curves on the attached curve-sheet the necessary size of a synchronous condenser, or the reactive kilovolt-amperes which must be supplied by a synchronous machine in order to correct the power factor from a given value to another given value, can be determined.

Example:

A power house supplies a load of 7500 kw. at a power factor of 80 per cent lagging. How many reactive (wattless) kilovolt-amperes must be furnished by a synchronous condenser in order to raise the power factor to 90 per cent leading?

Solution:

Select the curve (Fig. 3) which crosses the axis of abscissae at 80 and follow it beyond the bend. To the abscissa of 90 per cent the corresponding ordinate is 1230 kv.-a. (per 1000 kw.); hence the required size of the synchronous condenser is 1230×7.5=9225 kv-a.

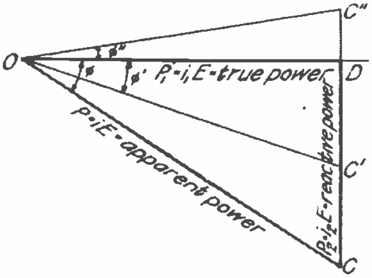


Fig. # 2.

In the same example, in order to raise the power factor to unity, 750×7.5=5625 kv-a. are necessary. To raise the power factor to 95 per cent lagging, only 420×7.5=3000 kv-a. are required. The curves show that to correct the last few per cent of power factor require the most reactive power. This follows from the fact that the cosine of an angle varies very slowly with small angles; a power factor of 95 per cent implying a phase displacement between the voltage and the current of over 18 degrees.

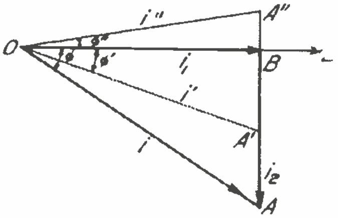


Fig. # 1.

Having determined the required reactive power from the curves, the rating of a synchronous motor is obtained by combining vectorially (at right angles) the useful power and the reactive power (Fig. 2). Thus, if the input into the motor must be, say, 5000 kw., and besides this, the motor has to supply 3000 kv-a. for compensating low power factor, the motor is rated at

$$\sqrt{5000^2+3000^2}=5830 \text{ Kv-a.}$$

at a power factor of $\frac{5000}{5830}=86$ per cent leading.

The curves were calculated and plotted as follows: In Fig. 1, let $OA (=i)$ represent the vector of the total current before the corrective reactive power is applied. Let i_1 be the energy component of the current and i_2 the wattless component; ϕ is then the angle of phase displacement between the current and the voltage. Multiplying all the three sides of the triangle by the line voltage

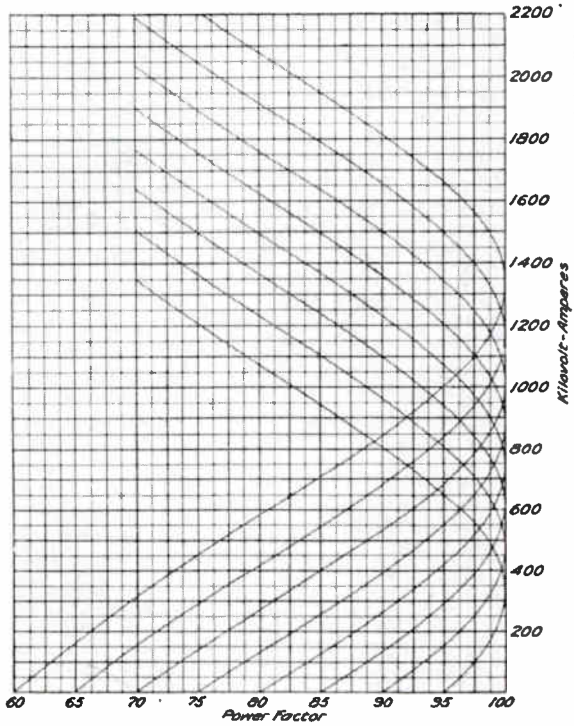


Fig. 3

E, the triangle of power (Fig. 2) is obtained. It is understood, of course, that the vectors of the currents are multiplied by the *numerical value* of the voltage, and *not* by the vector of the voltage. In Fig. 2 the hypothenuse represents the apparent power, the horizontal side the true power, and the vertical side the reactive power. If I is in amperes and E in kilovolts, P and P_2 are in kilovolt-amperes, and P_1 is in kilowatts. From Fig. 2 we have:

$$P_2 = P_1 \tan \phi;$$

or, the reactive power per 1000 kw. of true power

$$P_2 = 1000 \tan \phi \qquad (1)$$

Let now a leading wattless current AA^1 be taken by a synchronous motor or condenser. The generator current is then reduced to OA^1, and the reactive power supplied by the generator to $DC^1 = P^1_2$.

The new phase angle is ϕ^1, and we have:

$$P_2^1 = 1000 \tan \phi^1 \qquad (2)$$

The reactive power taken by the synchronous motor is obtained by subtracting *eq.* (2) from eq. (1), or

$$CC^1 = \Delta P_2 = 1000(\tan \phi - \tan \phi^1) \qquad (3)$$

This is the formula used in calculating the curves of reactive power. If the reactive power taken by the synchronous motor or by a condenser is so large that the generator current OA'' leads the voltage, formula (3) becomes

$$\Delta P_2 = 1000(\tan \phi + \tan \phi'') \qquad (4)$$

In other words ϕ' in formula (3) must in this case be considered negative.

The following table shows the method of obtaining a few points on the curve corresponding to the initial power factor of $\cos \phi = 80$ per cent lagging. For this power factor the angle $\phi = 36°$ $30'$; $\tan \phi = .740$.

These values of P_2 are plotted against the corresponding values of $\cos \phi'$ as abscissae.

	LAGGING			LEADING	
$\cos \phi' =$	0.90	0.95	1.00	0.83	0.75
$\phi' =$	25° 50′	18° 10′	0°	−31° 50′	−41° 20′
$\tan \phi' =$	.484	.328	0	−.621	−.880
$\Delta P_2 =$	205	421	749	1370	1629

The other curves are obtained in a similar manner, beginning with different values of the initial power factor $\cos \phi$.

MOTOR OPERATED BOAT HAUL AND FERRY

By W. D. Bearce

Coincident with the increasing tendency to install electric drive for all industrial purposes, there is an equal tendency to make use of electricity for all sorts of labor saving devices. While the electrical operation of a boat haul, an example of which is here illustrated, is not an uncommon application of electric power, its employment for the propulsion of a ferry boat is rather a novel feature.

The boat house of the Edison Club, Schenectady, N. Y., is located on an arm of the Mohawk river, opposite a large island upon which the club has obtained ground for tennis courts, a baseball diamond, etc. The use of any kind of bridge is impractical on account of high water and ice in the spring; for the same reason the boat house had to be placed about 25 feet above and 50 feet back from the river at its normal water level. As may be seen from the illustrations, all the auxiliary apparatus is simple in construction, being of the home-made variety.

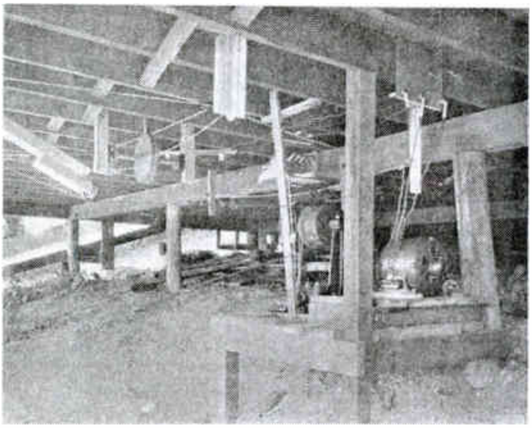


Fig. 2. Arrangement for Operating Ferry Boat

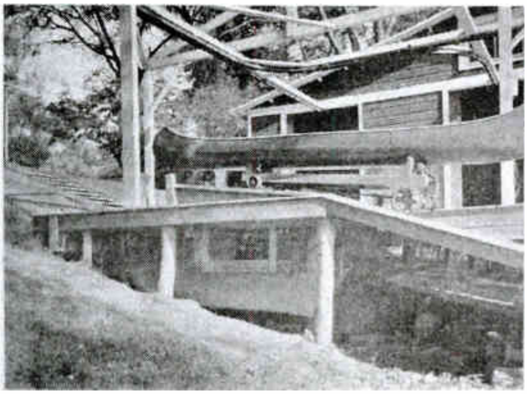


Fig. 1. Mechanism of Motor-Operated Boat Haul

Three-phase current was available from local power mains; a two horse-power motor was therefore belted up to a suitable drum for operating the boat haul. This apparatus is supported from the under side of the platform as shown in Fig. 1; this arrangement allowing a rope to pass from the drum up through the platform to the car. An improvised brake, shown in the extreme left of the figure, is mounted on the shaft with the drum and equipped with a solenoid and plunger for releasing.

The movement of the car is controlled by a three-pole double-throw switch so connected that when thrown down, current is sent through the solenoid, releasing the brake and allowing the car and its load to descend by gravity. By opening the switch the brake is operated and the car brought to a stop. Throwing the switch up connects both solenoid and motor to the supply mains, thereby revolving the drum in the opposite direction.

For supplying motive power to the ferry-boat operating between the main land and the island, another 2 h.p. induction motor was adapted to the frame of an old suction pump, the pistons being replaced by a drum. Back gearing reduces the speed to a low value and the driving rope, through suitable pulleys, takes half a turn on the drum. The slack rope is taken up by a comparatively heavy idler, shown at the left of the picture.

When an extra strain is exerted, as at starting or in case of any obstruction, the taut rope lifts the idler, thus allowing the drum to slip under the rope. A single rope carrying balanced weights at each end, operates a double throw reversing switch which can be operated from either side, or from the boat. Stop blocks on this rope automatically bring the ferry to a stop at either landing.

NOTE

In preparing copy for Fig. 11 of Mr. Baum's article on Fire Damp Apparatus, appearing on page 406 of the September issue of the Review, data which is essential to an understanding of the diagram was omitted. For the sake of clearness, we republish the diagram, together with the necessary key.

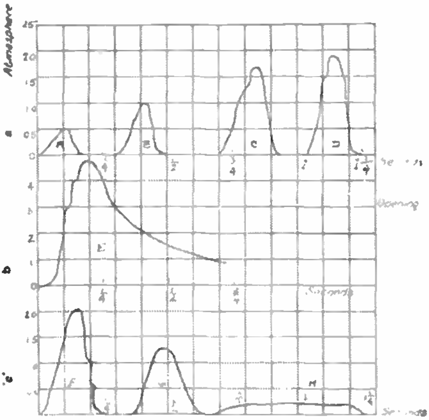


Fig. 11, a and b. Pressure Corresponding to Various Cross Sections of Openings for Rich Mixture and Same Position of the Ignition Point. c, Pressure Corresponding to Distance of Ignition Point from Opening for Same Mixture and Size of Opening

A, opening, 2.72 sq. in.
B, opening, 2.23 sq. in.
C, opening, 1.24 sq. in.
D, opening, 1.02 sq. in.
E, opening, 0.28 sq. in.
F, ignition in back.
G, ignition in center.
H, ignition in front.

OBITUARY

Mr. Theodore P. Bailey, Assistant Manager of the Philadelphia Office of the General Electric Company, died at his home in Mt. Airy, Philadelphia, on Saturday, August 20th, as the result of a delayed operation for appendicitis.

Mr. Bailey was born in Covington, Ky., August 17, 1856, and was educated in the public schools of Princeton, Ill. Completing his school course, he engaged in newspaper work in the latter town and later took up the study of stenography, securing a position as court stenographer, first at Morris, Ill., and then at Joliet, Ill. While engaged in this work, Mr. Bailey made a study of law and in 1881 was admitted to the bar at Ottawa, Ill. In the following year he moved to Chicago and entered the employ of the Thorn Wire Hedge Company, at the head of which was General A. K. Stiles. General Stiles and Norman T. Gassette were the original promotors of the Van De Poele Electric Company, and in 1883, through the influence of the former, Mr. Bailey became associated with this concern, and from that time on devoted his attention to electrical matters.

In 1885 he accepted a position with the Chicago office of the Thomson-Houston Electric Company, acting as Western representative of that concern and, after its merger with the General Electric Company, continued in charge of the street railway work of the Chicago office, later becoming assistant manager of the office.

In 1905 he resigned his position with the General Electric Company to enter the railway contracting business as Vice-President and General Manager of the L. E. Myers Company, of Chicago. He remained with this concern until 1907, when he accepted a position with the automobile department of the St. Louis Car Company. In the fall of 1908 he again entered the employ of the General Electric Company, as assistant manager of the Philadelphia office.

Mr. Bailey was one of the first men to introduce electric railways in the West, and for many years was one of the most widely known men in the street railway circles of that section. Among the principal installations in which he was interested were those at Des Moines, Iowa; Omaha, Nebr.; Topeka, Kans.; Ottawa, Ill.; St. Louis, Mo.; Kansas City, Mo.; Minneapolis, Minn.

At the time of his death Mr. Bailey was a member of the Chicago Automobile Club, Chicago Athletic Club, White Marsh Country Club, and an associate member of the American Institute of Electrical Engineers.