GENERAL ELECTRIC
REVIEW

ELECTRICITY ON THE BALTIMORE AND OHIO

On another page of this issue we print an article by Mr. S. T. Dodd covering briefly the various types of electric locomotives used in the Baltimore and Ohio tunnel, and including a quite complete description of the latest type which has been installed during the present year.

A study of the electrification on the Baltimore and Ohio Railroad is in fact a review of the development of heavy electric traction in the United States, and to be properly understood the various steps must be considered in the light of contemporary history. The Baltimore belt line tunnel was designed to avoid the delays to traffic that were encountered at the city of Baltimore and was constructed at a time when electric traction had reached a state of development that made it possible to design the tunnel with the object in view of operating it electrically. As a consequence electric installation was not delayed, as it has been in other instances, by the conservatism and disinclination to make a change that is found in the case of an already established steam installation. The success in the preceding years of several more or less experimental heavy railway installations, had established the feasibility of heavy electric traction. The light high-speed railway motor of the eighties, with its double reduction high-speed gearing, had given place to the slow-speed multipolar iron clad motor of 1890, with its single reduction gearing. The success of this single reduction motor as compared with the double reduction type had naturally raised a number of very strong advocates for carrying the elimination of gears to its logical limit and producing a motor that should be absolutely free from gearing; their belief being that such a machine would be the ideal motor for heavy service. The adaptation of such a gearless motor to the speeds of the Baltimore and Ohio tunnel entailed some difficulties, such as the use of a large number of poles, a large diameter of driving wheels, and the connection of two motors permanently in series; but the work of a number of inventors and designers had proved the possibility of designing a gearless motor in spite of these difficulties and the six-pole gearless motor was therefore considered and adopted for this pioneer installation.

A different type of locomotive was selected for this second installation ten years later, as the locomotive was required wholly for freight service. Power economy combined with the high tractive effort required in freight service means slow speed, and economical motor design for a slow-speed locomotive means a geared motor. The decision as between geared and gearless motors for a locomotive of a certain speed seems to depend on principles of which the following is a general statement:

The peripheral armature speed of a well designed motor is fixed within fairly definite limits. When the normal linear speed of the locomotive is comparable with this peripheral armature speed it points to the conclusion that a motor can be economically designed with a speed of rotation approximating that of the axle, and indicates the possibility that a gearless design will be economical. As an illustration, the New York Central and the New York, New Haven and Hartford installations, where operating speeds of fifty to sixty miles per hour are required, are alike in one single feature, namely, the employment of gearless motors, thus indicating that for speeds of fifty to sixty miles per hour a gearless design is advisable.

When locomotive speeds and peripheral armature speeds are not comparable, as for example, in the case of a freight locomotive, we may conclude that an economical motor design requires a reduction of speed between the armature and axle, and this condition therefore indicates the necessity of a geared motor. These principles seem to have determined the design of the Baltimore and Ohio locomotives of 1903.

It is interesting to note that the new type of locomotive is also a geared design, although it is proposed for passenger as well as freight service and is designed for speeds approximately the same as those of the gearless locomotive of 1893. These facts seem to indicate that for the Baltimore and Ohio conditions of speed and train weight, the geared motor offers the most satisfactory solution.

Incidentally the improvement in mechanical design and workmanship is an important item in effecting this decision between geared and gearless motors. As an example the satisfactory installation of twin gearing may be noted. This makes possible the use of a high power geared motor where a gearless motor might have been more satisfactory if the choice had rested between the gearless motor upon one hand, and the ordinary type of single geared motor with overhung gearing upon the other.

The new locomotives embody a number of interesting features, the details of which are described in Mr. Dodd's article.

COMPENSATORS

Compensators—or auto-transformers as they are sometimes called—may, under certain conditions, be used to considerable advantage in place of transformers.

Their relative desirability depends upon a number of conditions, the size, cost and efficiency on the one hand, and absence of insulation between the load and the supply circuit on the other. If the difference in voltage between the two circuits is slight, the decrease in size, cost and losses due to the use of a compensator is great, and the absence of insulation usually of little importance. If, on the contrary, the difference in voltage is great, the size and therefore the cost and losses of the compensator approach those of a transformer capable of doing the same work, and the necessity of insulation between load and supply circuit assumes greater importance; so that a transformer would be more desirable.

In reaching a decision it is necessary to determine first the relative size of the compensator and the transformer which will have the required output. The method of rating compensators is therefore important.

The article by Mr. W. W. Lewis, which begins in this issue, treats of the advantage resulting from the use of compensators instead of transformers, and of the method of rating the former. This article is deserving of careful consideration because, while the method of rating compensators is very simple, it is not as well understood, perhaps, as it should be.

Many questions have arisen as to how a compensator which, for example, will transform 10 kv-a. from 100 up to 110 volts, can be rated 1.1 kv-a. The matter becomes clear when it is remembered that a 10 kv-a. transformer consists of 10 kv-a. of primary winding and 10 kv-a. of secondary winding interlinked by a magnetic circuit. In a transformer, there would, therefore, be a total of 20 kv-a. of winding for 10 kv-a. of output, and we may say that the rating of a transformer is equivalent to one-half of the total volt amperes of winding. The standard practice of rating compensators on the basis of one-half the total kv-a. of winding contained therein is, therefore, perfectly logical, and, since, the compensator mentioned above requires a total of 2.2 kv-a. of winding, it should be rated 1.1 kv-a. although its actual output would be 10 kv-a.

THE DEVELOPMENT OF PROTECTIVE DEVICES FOR HIGH TENSION CIRCUITS

The growing demand for electrical power, in many cases at places far remote from a point of economical generation, has resulted in the construction of long transmission lines and the transmission of energy at ever increasing voltages. The difficulties of utilizing large amounts of electrical power transmitted for long distances at high voltages would make such developments impracticable for commercial use had it not been for the design and introduction of reliable switching, measuring, and protective devices for safely and conveniently controlling this power.

A description of the appliances for accomplishing this purpose is of particular interest at this time, as they are being introduced extensively and have proved so successful that most transmission developments for some time to come may be expected to follow similar lines.

The article in this issue of the Review by Mr. P. G. Langley traces the development of the devices designed to protect electrical circuits and explains under what circumstances the apparatus now available should be used.

D. S. Morgan.

ELECTRIC LOCOMOTIVES FOR THE BALTIMORE AND OHIO RAILROAD COMPANY

By S. T. Dodd

The belt line of the Baltimore and Ohio Railroad is of interest to students of electrical development because the first electric locomotives ever used for heavy trunk line service were installed on this line.

In 1893, municipal requirements, as well as considerations of safety and convenience, demanded the use of some type of motive power other than steam locomotives for the operation of the tunnel through the city of Baltimore. As a consequence, a contract was entered into with the General Electric Company for supplying electric locomotives capable of handling passenger service.

It is difficult to appreciate today the courage that was required to make this decision at that period in the history of electric development. Only seven or eight years had elapsed since the electric railway motor had emerged from the experimental stage and had first been applied to the operation of actual street railway cars. The modern system of electric traction and modern types of electric motors and equipment were absolutely unknown. The decision, therefore, to use electric locomotives, and the construction of these locomotives themselves, mark an important epoch in the history of electricity.

The locomotives furnished for this first installation were of the gearless type, weighing ninety-six tons each. Each unit consisted of two four-wheel sections coupled permanently together, each section being equipped with two motors of the type known as the AXB70 and carrying a portion of the cab, mounted upon it. The characteristic feature of the motor was that it was gearless. It was built concentric with the axle and transmitted its power directly to the driving wheels. In this respect these original Baltimore and Ohio locomotives were prototypes of the heavy electric locomotives built since 1907 for passenger service on the roads entering New York City. In order to bring the locomotive speed down to tunnel requirements the motors were designed with six poles, and two motors were connected permanently in series.

It will be realized that a number of new problems presented themselves in this pioneer installation and that a number of new features had to be incorporated; but the success of the installation can be seen from the fact that the original locomotives are running today and doing satisfactory service in hauling passenger trains. The locomotives had a capacity of 28,000 pounds tractive effort at a speed of sixteen to twenty miles per hour, corresponding to approximately 1200 horse-power.

About ten years later, the extension of the service and its increased requirements demanded additional locomotives, and it was decided to adopt a type of locomotive particularly suitable for freight service.

The freight locomotives of 1903 are the heaviest electric locomotives in operation today. Each locomotive weighs 160 tons and consists of two 80-ton units coupled together and capable of being operated by one engineer. Each half unit is equipped with four motors geared to the axles. A geared drive was adopted in this case in order to obtain the heavy tractive effort and the slow speeds required for freight service. A complete 160 ton unit is capable of exerting a maximum tractive effort of 80,000 pounds at starting, and a tractive effort of 70,000 pounds at a speed of eight and one-half miles per hour, which corresponds to an output of 1600 horse-power. In daily service, one such locomotive takes trains weighing up to 1800 tons through the tunnel and over maximum grades as high as 1½ per cent. To compare the capacity of this locomotive with that of steam locomotives of standard type, it may be noted that, in the absence of the electric locomotive, three steam locomotives weighing with their tenders 370 tons are assigned to this duty and have difficulty in pulling trains of this weight over the track.

During the present year the service on the belt line has demanded a still further addition to the locomotive equipment and two additional locomotives have been put in service, which are illustrated and described in this article. The locomotives were designed and equipped by the General Electric Company, while the mechanical parts were furnished by the American Locomotive Company. A general view of the complete locomotive is shown in Fig. 1. This type of locomotive is similar to the type built by the same manufacturers for the Detroit River Tunnel Company, but differs from it in details and is the first of this design to be used on the Baltimore and Ohio. It is worthy of study as a good

Fig. 1. Latest Type of Baltimore and Ohio Locomotive

example of the latest type of electric locomotive for heavy service. The cab resembles in general the type which has been widely used for switching locomotives on interurban electric railroads and possesses many of the features of convenience which have contributed so largely to the success of this design. The trucks and running gear are of a heavy locomotive type suitable for the severe duty demanded in trunk line service. The running gear is articulated and consists of two four-wheeled trucks connected through a massive hinge which allows the two trucks to support and guide one another without interfering with the lateral flexibility required for taking curves with a long wheel-base. The framing is massive in appearance and the sections are heavier than actually required for mechanical strength on account of the necessity of obtaining ample weight for tractive effort. Side frames consist of steel castings, five inches thick, bolted together through steel end frames and bolster castings of a box girder pattern. Draft gear and buffers are carried on the outer end frames. Wheels are steel tired, fifty inches in diameter, with the motor gears mounted directly on extensions of the wheel hubs. Journal boxes are of cast steel, carried in pedestal jaws between shoes nine inches wide, and have journal bearings 7½ by 14 inches. The weight of the locomotive is carried on the boxes through semi-elliptic journal box springs equalized together so as to obtain the most uniform distribution of weight that is possible over groups of springs. It is well known that the advantage of

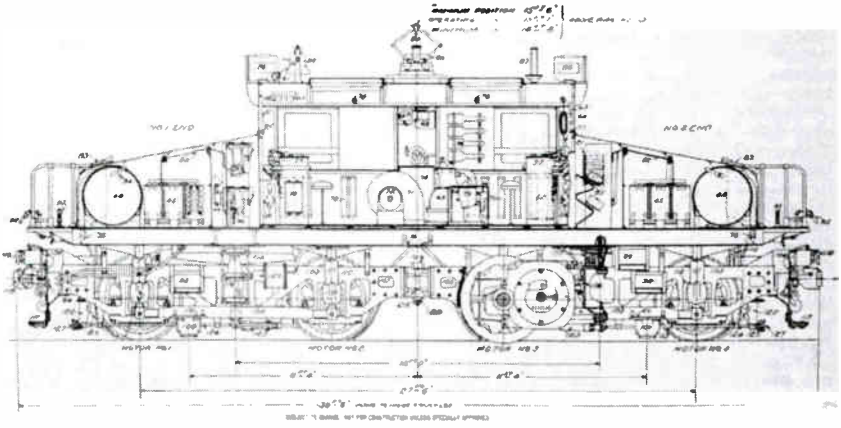

Fig. 2. Arrangement of Apparatus

this construction is that it concentrates the principal hauling and buffing strains in the trucks themselves and relieves the platform and cab of all stresses except those due to their own weight and that of the control and operating apparatus mounted on them.

The principle embodied in this type of locomotive construction is not new, but is one, the success of which has been demonstrated through its practical application to steam locomotives for a number of years. The Mallet compound locomotive, the heaviest type of freight steam locomotive in use, resembles the new Baltimore and Ohio electric type in that it has a wheel-base made in two halves and hinged together, taking the hauling stresses directly through this hinge. The remarkable success of this type of steam locomotive, its low flange wear, and its adoption by a number of important railroads for pusher service on their heaviest grade divisions, may be considered as proof of its suitability for heavy service.

The cab platform is 38 feet, 0 inches in length overall, and is carried upon side bearings on the two trucks and upon two center pins, one of which has a slight longitudinal sliding motion in order to accommodate the variation in center pin distance due to curving.

The platform is built up of 10 inch longitudinal sills 34 feet 1 inch in length and riveted to 10 inch ends sills. Body bolsters are built up of 1 inch by 12 inch plates to which are riveted the center pin castings referred to above. A cover plate below the two center sills forms, with the floor above, an enclosed air space which serves for delivering air to the motors from the blower located in the center of the main cab. The whole platform is braced and squared by heavy floor plates extending the whole width of the platform and rivetted to side sills and end sills.

The cab consists of a main operating section located in the center of the platform and sloping auxiliary end sections extending towards the ends of the locomotive. While the trucks and running gear of the locomotive transmit the principal mechanical stresses and are therefore of interest from the standpoint of mechanical design, the cab is of more interest from an electrical standpoint. Several interior illustrations are therefore presented, which show the detailed study that has been expended on the location and arrangement of apparatus and wiring.

Fig. 2 shows the arrangement of the principal pieces of apparatus. The auxiliary cabs are six feet in width and contain parts of the apparatus which are not subject to inspection and repairs. In the outer end of this cab is located the main air reservoir and sand boxes for sanding the leading wheels, and next to these, on the floor of the cab, are placed the rheostats. Perforated side sheets allow a circulation of air through and around these rheostats for ventilation, the upper part of the sheets being hinged and held with spring-locked buttons so as to permit convenient access for inspection of rheostats and wiring. The end cab is held to the platform and main cab by means of bolts, and for major repairs these can be removed and the end cab separated from the locomotive, thus giving access to all the apparatus contained in it.

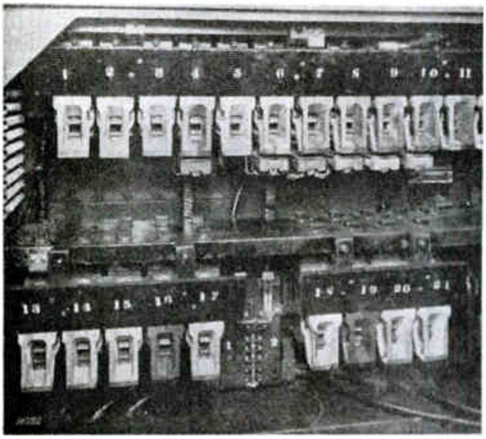

Fig. 3. Bank of Contactors

The contactors are located in the auxiliary cab but stand in a bank facing the main cab, from which access to them for cleaning and inspection can be obtained. Fig. 3 is a view of this bank of contactors, taken from the floor of the main cab. During operation these contactors are enclosed by asbestos-lined folding doors which shut them away from the main operating cab, as shown in several of the succeeding views.

The space on either side of the auxiliary cab is devoted to a platform running from the main cab to the ends of the locomotive, permitting on one side access from the main cab to the coupler, and on the other side an uninterrupted view for the operating engineer.

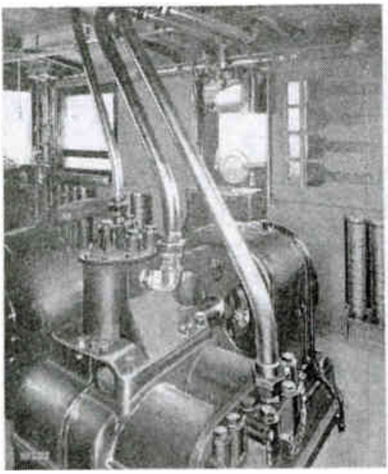

Fig. 4. Interior of Cab Showing Motor-Driven Air Compressor

Turning now to the main operating cab, it will be noted from the illustrations that apparatus is arranged and wired so as to offer a maximum of accessibility combined with a maximum economy of space. All wiring is in conduit, and the interior of the cab presents a neat and workmanlike appearance, even the bell and whistle ropes being drawn through pipes for protection and to conform in appearance with the rest of the piping and wiring. The central piece of apparatus in the cab is the air compressor. This is a CP26 compound compressor, motor-driven, with a capacity of 100 cubic feet piston displacement per minute when pumping against 130 lbs., reservoir pressure. Experience has demonstrated that the center of the main cab is the most desirable point for locating the compressor. Although it does not require an excessive amount of care, the various items which may require attention, such as valves, piston rings, brushes, etc., are naturally on different sides of the compressor. It must therefore be accessible from every side and consequently the center of the cab has been chosen for its location, rather than a less prominent place. Figs. 4 and 5 show the compressor and the piping leading to it. In passing from the low pressure to the high pressure cylinder, the air is carried through a two inch pipe to the roof of the cab and then through about 35 feet of pipe lying on the roof which provides a radiating surface to reduce the temperature of the air before it enters the high pressure cylinders. A similar length of radiating pipe is inserted between the high pressure cylinder and the main reservoir for the same purpose. The compressor is controlled by an electro-pneumatic governor mounted on the "A" side of the cab as shown in Fig. 4 and arranged for maintaining the reservoir pressure between the limits of 120 and 130 pounds.

Beside the compressor is placed a fan for forced ventilation of the motors, which delivers air into the enclosed space or distributing chamber between the center

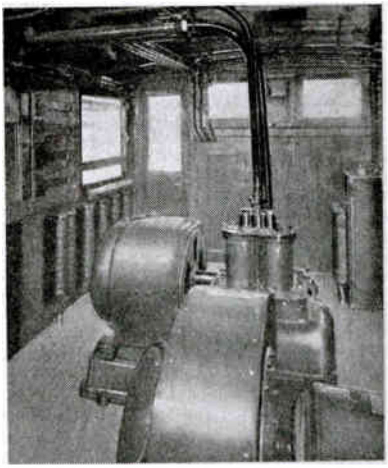

Fig. 5. Motor-Driven Air Compressor and Blower

channels, as above described. From this distributing chamber the air is carried through branch pipes to the motors.

Against the side walls of the cab, as shown in Fig. 4, are mounted racks for paddles and flags, and electric coil heaters for maintaining the proper temperature of the cab.

Sand boxes for sanding the track in front of the rear truck of the locomotive are also placed in the middle of the side walls and are operated from the engineer's position simultaneously with the forward sand boxes in the auxiliary cabs.

Figs. 6 and 7 show the apparatus for direct control of the locomotive, located at the engineer's window. This is in duplicate at the opposite ends of the cab, and consists of the master controller, air brake valves, air gauges, and ammeters. The handles for bell and whistle ropes, the switches for headlights, and valves for sanders are also within convenient reach. Fig. 7 shows in detail the arrangement of this apparatus and also the uninterrupted view of track and right-of-way which is obtainable from the operator's seat.

It will be noted that one of the great advantages of this design of locomotive is that the engineer's window is about twelve feet back from the front end of the locomotive, an arrangement which affords a protection in case of collision and buffing accidents. In spite of this distance, the design of the sloping end cab and the open side platform in front of the engineer gives him a view which is practically as comprehensive as if he were located in the more dangerous situation at the front end of the locomotive.

The motor equipment consists of four GE209 motors. Each motor is furnished with twin gearing, a pinion being mounted on each end of the armature shaft and a corresponding gear on each driving wheel. Precautions are taken in the design and mounting of this gearing to ensure absolute alignment of the corresponding teeth of each pair of gears and pinions. With such precautions this type of gearing maintains accurately the alignment of armature shaft and axle, reduces the strains of gear teeth to a minimum, and has been demonstrated to give absolutely satisfactory results in service.

The motor is a 600 volt commutating pole machine, the equipment of four motors being capable of exerting a tractive effort up to the slipping point of the wheels of the locomotive which, at a coefficient of adhesion of 25 per cent, is equivalent to a tractive effort of 46,000 lbs. at a speed of fourteen miles per hour.

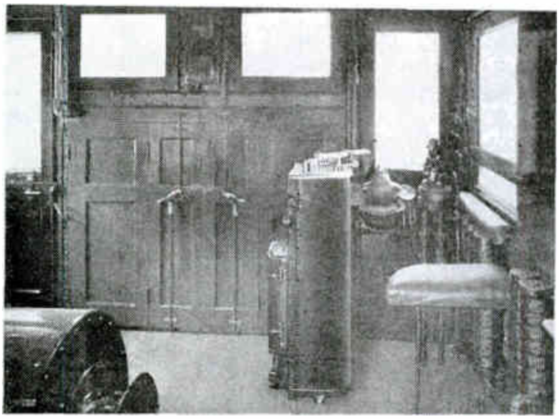

Fig. 6. Control Apparatus

To obtain some idea of the power of these new locomotives, they may be compared with the heaviest types of steam passenger locomotives. The new Baltimore and Ohio electric locomotives weigh ninety tons on drivers. The weight on drivers of the Pacific type of steam locomotives, which is the type used for heavy passenger service, very rarely exceeds seventy-five tons. A weight of ninety to one hundred tons on drivers is only obtained on freight locomotives of the Consolidation and Mikado types. The weight on drivers, which determines the maximum pulling power of the electric locomotives, is therefore comparable with the heaviest types of steam locomotives for freight service.

In the steam locomotive, however, on account of boiler limitations, it is impossible to carry the maximum tractive effort at speeds higher than eight or ten miles per hour, while the electric locomotive will

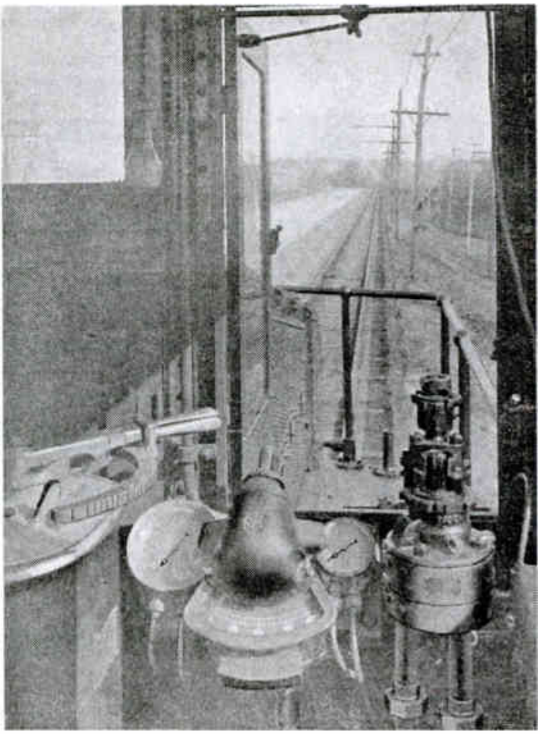

Fig. 7. Control Apparatus and View of Track from Engineer's Seat

develop its maximum tractive effort at a speed of fourteen miles per hour. This tractive effort of 46,000 pounds, at a speed of fourteen miles per hour, corresponds to an output of 1700 horse-power.

The electric locomotive, furthermore, is more flexible and has a greater power than indicated by these figures. By means of the multiple unit control, which is a feature of these locomotives, two of these 90-ton units can be coupled together and operated by one engineer in the forward cab. All the motors are controlled simultaneously by one operating handle, and therefore one engineer has under his control a maximum capacity of 3400 horse-power, or a maximum tractive effort of 90,000 pounds developed by one 180-ton locomotive.

It might be noted that 180 tons represents approximately the weight of a single large steam locomotive and its tender, and that in the steam locomotive only half this weight is on drivers, while in the electric locomotive the whole 180 tons is on drivers and is capable of being applied for developing tractive effort.

With a light passenger train, a single 90-ton electric locomotive will develop speeds of twenty-five to thirty-five miles per hour on the level. From the facts here cited, it is evident that the Baltimore and Ohio railroad has in its new locomotive an engine which is suitable for either freight or passenger service and is capable of handling the heaviest freight trains over the tunnel grades or the highest speed passenger trains at the greatest speed consistent with its tunnel service.

The following table gives the principal dimensions of the new locomotive:

Number of motors	4
Gear ratio	3.25
Number of driving wheels	8
Diameter of driving wheels	50 in.
Total wheel base	27 ft., 6 in.
Rigid wheel base	9 ft., 6 in.
Length inside knuckles	39 ft., 6 in.
Length of main cab	15 ft., 6 in.
Length of cab overall	33 ft., 6 in.
Total weight	184,000 lbs.
Tractive effort at 25 per cent co-eff.	46,000 lbs.
Speed at maximum tractive effort	14 m.p.h.

COMPENSATORS

Part I

By W. W. Lewis

The primary and secondary coils of a transformer may be connected in series between two supply mains and load taken from the secondary alone, or the primary alone may be placed across the supply mains and load taken from the primary and secondary in series. Such an arrangement of the transformer coils is commonly called a compensator, and the function of the arrangement is simply to boost or lower the supply voltage. When it is desired to effect only a slight change in voltage, when both voltages are low, or when it is permissible to have the secondary circuit directly connected to the primary, compensators may frequently be used to advantage. In such cases considerable economy will result, as compensators are usually smaller and more efficient than the corresponding transformers.

A simple example will serve to illustrate this. Fig. 1 shows diagrammatically the transformation of 100 kw. of power from 1000 to 500 volts by means of a 100 kw. transformer, and Fig. 2 by means of a compensator of one-half the capacity. Only a portion of the power output of the compensator is transformed from one coil to the other through the medium of the flux induced in the core. The remainder of the output is taken directly from the supply circuit by means of the series connection. While the output of the compensator in Fig. 2 is 100 kw., it is only necessary to transform one-half that amount and a 50 kw. compensator is sufficient. It is apparent that the total number of turns has been reduced one-third and that the ampere capacity of the secondary has been reduced one-half. The saving in space on account of the less amount of copper allows a corresponding saving in iron, and the net result is lower first cost, less copper and iron loss, less IR drop, and improved efficiency and regulation.

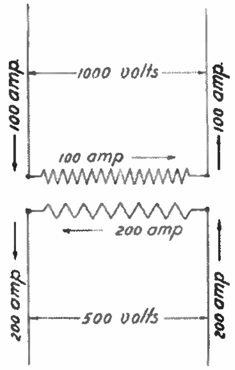

Fig. 1

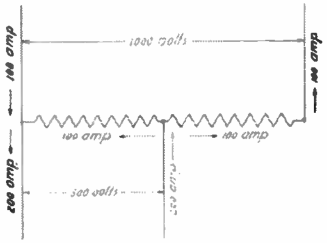

Fig. 2

Consider the general case of the transformation of a given amount of power ei (Figs. 3 and 4), neglecting losses and exciting currents. In Fig. 3 let

e = primary voltage
i = primary current
e_2 = secondary voltage
i_2 = secondary current
r = transformer rating

Then

$$ei = e_2 i_2 = r$$

But ei is evidently the rating of the primary coil and $e_2 i_2$ the rating of the secondary coil, so that the rating of the transformer is the same as the rating of either coil; or we may consider the transformer rating to be one-half the sum of the primary and secondary coil ratings, or

$$r = \frac{ei + e_2 i_2}{2}$$

Fig. 4 represents a compensator to transform the same power ei.

Let

e = impressed voltage
i = corresponding line current
e_2 = secondary voltage
i_2 = secondary current
r_1 = compensator rating

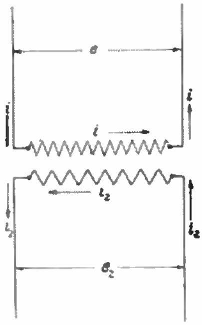

Fig. 3

In usual terms the primary of the compensator is the coil *ac* (Fig. 4), across which the high tension voltage is impressed, and the secondary the coil *ab*, from which the load is taken. In design, however, it is convenient to consider the winding as consisting of a secondary *ab* and a primary *bc*. The primary voltage is $(e-e_2)$ and the primary current is i.

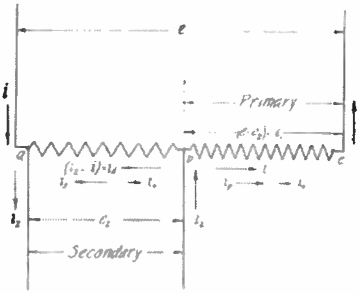

Fig. 4

The secondary winding *ab* is traversed by both the primary and secondary currents, and as these are practically opposite in phase, the resultant current carried by *ab* is (i_2-i). Then the rating of the primary coil is $(e-e_2)\,i$, and of the secondary coil $e_2\,(i_2-i)$. Obviously

$$(e-e_2)\,i = e_2\,(i_2-i) = r_1$$

Or, as before, we may consider the rating as one-half the sum of the primary and secondary coil ratings, or

$$r_1 = \frac{(e-e_2)\,i + e_2\,(i_2-i)}{2}$$

In general, we may say that the compensator rating is one-half the sum of the ratings of the individual sections of the winding. The advantage in this conception of the rating will become apparent later when the problem is complicated by taps. Now to transform the power ei, we have a compensator of rating $(e-e_2)\,i$, or a transformer rated ei; that is, the ratio of compensator rating to transformer is

$$\frac{(e-e_2)\,i}{ei} = \frac{(e-e_2)\times 100}{e} \text{ per cent}$$

Then if

$e_2 = 1/10\ e$, comp. will be rated 90 per cent of corresponding trans.
$1/4\ e$, comp. will be rated 75 per cent of corresponding trans.
$1/2\ e$, comp. will be rated 50 per cent of corresponding trans.
$3/4\ e$, comp. will be rated 25 per cent of corresponding trans.
$9/10\ e$, comp. will be rated 10 per cent of corresponding trans.
e, comp. will be rated 0 per cent of corresponding trans.

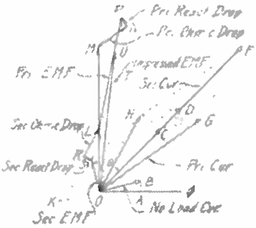

Fig. 5

From what has preceded it may be seen that the nearer the two voltages are alike, the smaller is the compensator that is necessary to transform a given amount of power. Since the primary and secondary windings are connected, the occurrence of a ground on the high voltage line will subject the insulation on the secondary to the strain of the high tension voltage. This prohibits the use of compensators when complete insulation between primary and secondary is necessary. For these reasons (with certain exceptions, such as in railway work) compensators should be used only when the actual difference between the impressed and delivered voltages is slight, or when both voltages are low.

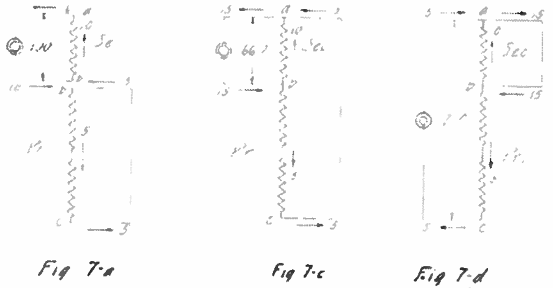

Fig 7-a Fig 7-c Fig 7-d

Fig. 7

The transformation by compensator may be represented vectorially as in Fig. 5. Using the same notation as in Fig. 4, Fig. 5 may be explained as follows:

At no load the only current flowing is the exciting current $OB = i_e$, composed of a wattless component OA and an energy component AB. OL and LM represent voltages equal and opposite to the secondary and primary induced voltages and in quadrature with the flux ϕ, and may be designated e'_2 and e'_1. Now load the secondary. The secondary current may be represented by $OD = i_p$. There is a corresponding current in the primary equal to i_p times the ratio of secondary to primary turns, which may be represented by $OC = i_p$. The total primary current is equal to $i_p + i_e$, represented by OG $(= i)$ in the parallelogram $OCGB$. The secondary line current is the sum of i_p and i_e, represented by the line OF $(= i_2)$.

The current in the secondary coil is equal to $(i_p - i_e) = (i_2 - i) = i_d$, represented by OH in parallelogram $OKHD$. The load current or secondary current, $i_2 = i_p + i_e$, may also be found by adding together the primary current i and the current in the secondary coil, i_d, or $OG + OH$ in the parallelogram $OFHG$. The secondary terminal e.m.f., $OS = e_2$, is found by subtracting from OL the secondary ohmic drop LR and the secondary reactive drop RS, parallel and perpendicular respectively to OH. The primary terminal voltage is found by adding to LM the primary ohmic drop MN and the primary reactive drop NP, parallel and perpendicular respectively to OG, which gives $LP = e_1$. The total impressed voltage, e, is the vector sum of LP and OS $(= OU)$ in the parallelogram $OSUT$. The power factor is represented by the cosine of the angle θ between the vectors OS and OC.

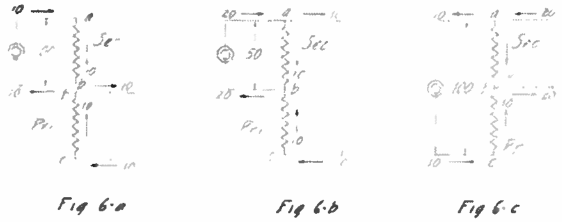

Fig 6-a Fig 6-b Fig 6-c

Fig. 6

As previously stated, in all matters of design the compensator is considered as consisting of two separate windings, a primary bc and a secondary ab (Fig. 4), and it is treated in the same manner as a transformer with similar windings. To illustrate, consider the case of compensator impedance and assume that all the impedance is due to reactance.

Fig. 6a shows a 1:1 transformer and Fig. 6b a 1:2 compensator having the same number of turns and carrying the same currents in the windings. To get an idea of the impedance of the transformer, short-circuit the primary windings and apply enough voltage to the secondary to force rated current through both windings. Assuming the normal voltage of the secondary to be 1000, if 100 volts are required to send rated current of 10 amperes through the windings, the reactance drop (neglecting drop due to ohmic resistance) is 10 per cent. With the compensator, however, only 50 volts are necessary to force the same current through the windings; i.e., the reactance drop is 5 per cent.

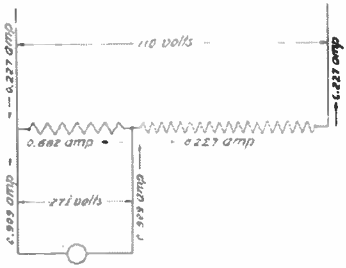

Fig. 8

This difference may be accounted for as follows: In the case of the transformer (Fig. 6a) the 10 amperes flowing through the primary winding produce a certain reactive drop, and an e.m.f. must be applied to the winding equal and opposite to this drop. This e.m.f., e, is induced by a flux produced by the secondary, which flux, being common to both windings, induces at the same time voltage across the secondary. Across the primary we then have an induced voltage e, neutralized by a reactive drop e, giving a resultant = O. Across the secondary we have the voltage e necessary to force 10 amperes through the leakage reactance of the secondary, and a voltage e induced by the flux required to energize the primary, a total of $2e (= 100$ volts). The voltage e necessary to send 10 amperes through either winding is 50.

In the case of the compensator the primary winding is connected directly across the generator and is in parallel with the secondary. Fifty volts is necessary to send 10 amperes through the secondary and the same 50 volts will send 10 amperes through the primary, since the windings are in parallel. The result is a reactance drop of 50 volts, or 5 per cent as against 10 per cent for the transformer. The generator volt-amperes are, however, in each case the same.

Let Fig. 6c represent the same compensator stepping down with a 2:1 ratio; the normal voltage of the total winding being 2000. To force 10 amperes through the primary bc we need as before 50 volts and also 50 volts to force 10 amperes through ab. As the secondary ab is short-circuited, the voltage applied to it by the generator is zero; therefore the 50 volts necessary to force current through ab are induced by the ampere-turns of bc. This, together with the 50 volts necessary to force 10 amperes through bc, gives 100 volts across bc and zero volts across ab. The reactance voltage is as before, $\frac{100}{2000} = 5$ per cent, the volt-amperes being the same as in Fig. 6a and Fig. 6b.

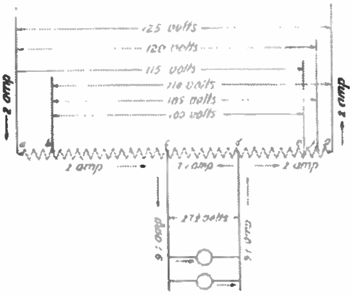

Fig. 9. Single Circuit, 250 Watt House Compensator

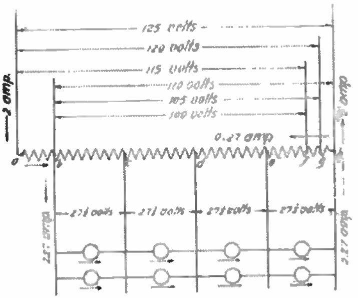

Fig. 10. Four Circuit, 250 Watt House Compensator

For a ratio of transformation of say 1:3, we find by the same reasoning a compensator reactance drop of 6¾ per cent as against 10 per cent for a transformer with corresponding windings and currents, as represented in Fig.

7. In general, if the ratio of transformation of a compensator is $m:n$, the reactive drop will be $\frac{n-m}{n}$ of the drop required for a transformer with the same windings and current capacity.

The General Electric Company manufactures special and standard compensators for various uses, and the most important of these will now be taken up in more or less detail and an attempt made to explain their connections and the manner of calculating their rating.

House Compensators

These are for the operation of low voltage tungsten lamps in multiple, one compensator taking care of a whole house. Compensators for 250 and 500 watts output are built for operation on 100–125 volts, with one and four secondary circuits, and a similar line of compensators for operation on 200–250 volts. A 1100 watt, eight-circuit compensator for 200–250 volts is also built. Four taps are brought out of the primary to take care of variations in primary voltage. These compensators are classified as follows: LC 60–0.216–100/105/110/115/120/125–27½ volts. Figs. 9 and 10 show the connections for 250-watt house compensators of one and four circuits respectively. The manner of figuring the kilowatt rating of these will be explained in detail. In Fig. 9, with 250 watts input and 125 volts impressed, 2 amperes will flow in the primary line; at the same time 9.1 amperes at 27½ volts will be drawn from the secondary. Then 2 amperes will flow in the sections *ac* and *dg*, and (9.1 − 2) = 7.1 amperes in the section *cd*.

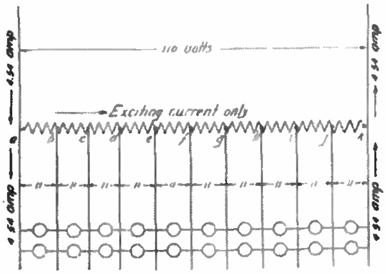

Fig. 11. 500 Watt Sign Compensator

The following tabulation shows the conditions with various impressed voltages:

Impressed Volts	Section	Amperes	Volts
125	*ac*+*dg* *cd*	2.00 7.10	97½ 27½
120	*ac*+*df* *cd*	2.08 7.02	92½ 27½
115	*ac*+*de* *cd*	2.17 6.93	87½ 27½
110	*bc*+*dg* *cd*	2.27 6.83	82½ 27½
105	*bc*+*df* *cd*	2.38 6.72	77½ 27½
100	*bc*+*de* *cd*	2.50 6.60	72½ 27½

An inspection of this tabulation will show the maximum current carried by each section under any condition, and it is evident that such maximum current must be provided for in winding the compensator. The maximum current in each section times the respective voltage gives the following:

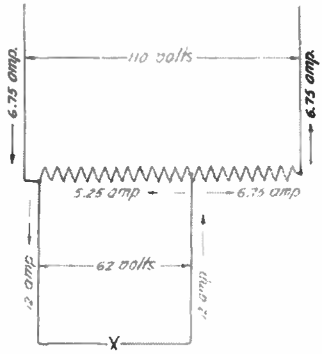

Fig. 12 Multiple Flame Arc Compensator

Section	Current	Volts	Watts
ab	2.17	15	32.6
bc+*de*	2.50	72½	181.3
ef	2.38	5	11.9
fg	2.27	5	11.4
cd	7.10	27½	195.2
			432.4

The rating of a compensator for the above service is $\frac{432.4}{2}$ equals 0.216 kw. As the current values (except in section *cd*) are nearly alike, the primary section, *ac*+*dg*, would be wound throughout for 2.5 amperes and the secondary section, *cd*, for 7.1 amperes.

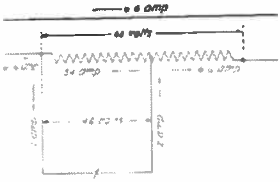

Fig. 13. Series Flame Arc Compensators

The problem presented in Fig. 10 is very similar to that of Fig. 9, with the further complication that from one to four circuits may be in use at one time, the output at any time being proportional to the number of circuits in use. An investigation shows the following maximum conditions for each section:

Section	Amperes	Volts	Watts
ab	2.17	15	32.55
bi	1.87	100	187.00
ik	2.27	10	22.70
			242.25

This gives a rating of $\frac{242.25}{2} = 0.121$ kw., or about 56 per cent of the rating of the one circuit compensator with the same output.

It is evident that the rating thus obtained gives no indication of the output or performance of the compensator. It does, however, afford a basis of comparison as to size, cost and losses with a transformer of similar rating or another compensator.

Sign Compensators

As indicated by the name, these compensators are for use in supplying power to signs lighted by low candle-power, low voltage tungsten lamps. Three sizes are made at the present time, all ten circuit secondary, 60 cycles, suitable for operating at 50 to 140 cycles and 100 to 130 volts.

Let Fig. 11 represent a sign lighting compensator, 500 watts output, 110 volts impressed, with the secondary divided into ten circuits of 11 volts each and each circuit good for 50 watts output. The following table is the calculation of the rating.

No. Circuits Loaded	Total Watts Output	Pri. Cur.	Cur. in Loaded Sec.	VOLTAGES	
				Pri.	Sec.
1	50	.454	4.09	99	11
2	100	.91	3.63	88	22
3	150	1.36	3.18	77	33
4	200	1.82	2.72	66	44
5	250	2.27	2.27	55	55
6	300	2.72	1.82	44	66
7	350	3.18	1.36	33	77
8	400	3.64	0.90	22	88
9	450	4.09	0.45	11	99

By inspection it will be seen that the maximum current flowing in the loaded secondary coil at any time is 4.09 amperes with one circuit loaded, and in the primary coil 4.09 amperes with nine circuits loaded. When all ten circuits are loaded, we have the condition shown in Fig. 11, viz., 4.54 amperes in both primary and secondary lines and exciting current only in the coils. As the single loaded circuit might be any one of the ten, all the coils must be designed to carry the maximum current of 4.09 amperes. The rating of the compensator will then be:

$$\frac{(4.09\times 99)+(4.09\times 11)}{2} = \frac{450}{2} = 0.225 \text{ kw.}$$

Arc Lamp Compensators

Various compensators are manufactured for the different kinds of arc lamps. Those for flame arc lamps will be considered as typical. They are of two styles, one for series and one for multiple operation. The

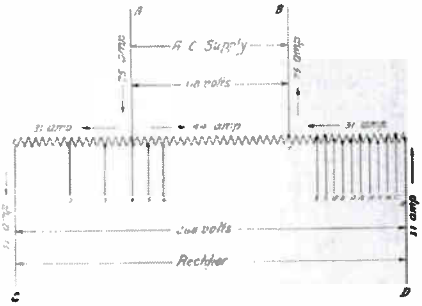

Fig. 14. Mercury Arc Rectifier Compensator

multiple compensators are for operation on 110, 220, 440 and 550 volt mains, all giving 12 amperes, 62 volts on the secondary. The series compensators are for operation on 6.6 and 7.5 ampere constant current circuits, giving 12 amperes, 48 volts on the secondary. Figs. 12 and 13 give the connections. The calculation of the rating is evident.

Mercury Arc Rectifier Compensators

The purpose of these is to step up the alternating current supply voltage to a voltage suitable for the rectifier. Fig. 14 shows a compensator RRC–60–5.5–330/110, designed for regulating the voltage and current of rectifiers operating at 50 amperes, 120 volts direct current. With 110 volts impressed, a range of voltage from 120 to 340 may be obtained in various steps. Rough regulation is secured by means of one blade of a double-handled dial switch, which allows line *A* to be shifted to any part of the winding from tap 1 to 6, line *B* being fixed to tap 7. Fine regulation is secured by shifting line *D* from tap 8 to 18 by means of the other blade of the dial switch, line *C* being fixed to tap 1. The rating of this particular compensator is figured roughly on the basis of 8.3 kw. output at 330 volts.

Starting Compensators

Standard starting compensators are made for two-phase and three-phase, Form K, squirrel-cage induction motors, with voltages of 110, 220, 440, 550 and 2200 and frequencies of 25, 40 and 60 cycles, in sizes from 5 to 200 h.p. The use of starting compensators greatly reduces the starting torque but prevents a large rush of current, which would cause disturbances on other parts of the power system. For motors smaller than 5 kw. no starting compensators are used. The compensators for motors of from 5 to 18 h.p. are provided with 40, 60 and 80 per cent starting taps and designed for respective line currents of 16, 36 and 65 per cent of the starting current that the motor would require without compensator. For larger motors taps are provided for potentials of 40, 58, 70 and 85 per cent of the line voltage, and for respective currents equal to 16, 34, 50 and 72 per cent of the current required to start without compensator. The proper starting voltage is found by trial and permanent connection made to that tap. The compensators are rated arbitrarily: thus CR152 for use with induction motor IQ8 poles, 15 h.p., 900 r.p.m., 110 volts, Form K.

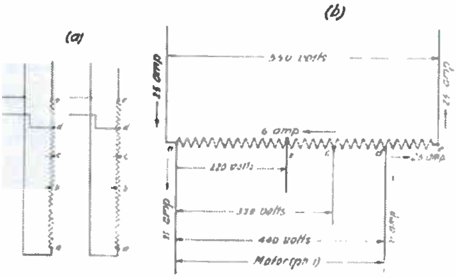

Fig. 15. Starting Compensator for 7½ H.P. Form K Induction Motor

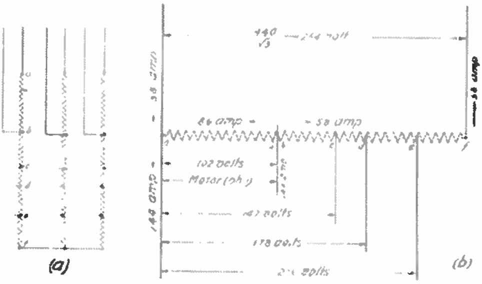

Fig. 16. Starting Compensator for 50 H.P. Form K Induction Motor

In designing these compensators the motor efficiency is assumed to be about 75 per cent, and the starting current without the compensator about 5½× (full load current). The calculations are then made, using the proportions of currents mentioned above for different taps. This would give a compensator designed for continuous load. As starting compensators are only intended for one minute service, the current density in the coils is greatly increased above the usual densities; in other words a greatly reduced size of copper is provided, and the size of the compensators is correspondingly reduced.

Figs. 15 and 16 show compensators for two- and three-phase motors respectively, and the following tables will make clear the calculation.

CR131 starting compensator for 110–550–720–440 volt motor.

Tap	Tap Volt in Per Cent	Tap Volt Motor	Tap Volt Per Leg	Starting Current	Current Primary	Current Loaded Coil
1	40	176	102	141	58	86
2	58	255	147	210	122	88
3	70	308	178	257	180	77
4	85	374	216	304	259	45

Conditions to be provided for:

Section	Maximum Current	Voltage	Actual Design Amp. 1 Min.
ab	86	102	88
bc	88	45	88
cd	122	31	180
de	180	38	180
ef	259	38	259

For starting synchronous motors and rotary converters special compensators are built. Automatic starting compensators do not differ from the above as far as the compensator feature is concerned.

(To be Continued)

THE PROMISE OF ELECTRIFIED AGRICULTURE*

By Edmund P. Edwards

The central station industry of the United States is today devoting its entire energy, with relatively few exceptions, to serving the needs of our urban population. This is the field which has offered the greatest return for the least investment of time and capital, in that the communities served occupy a restricted area and represent concentrated wealth.

The term "has offered" is used advisedly if the data of eminent statisticians is to be relied upon and their prophesies given weight, for this data shows that a new era has dawned in this country and that in the last few years an unparalled economic revolution has started and is gaining tremendous impetus. For want of a better name we may call this revolution "scientific agriculture."

Electricity is destined to play one of the most important parts, if not *the* most important part, in this movement, and I venture to predict that the time is not far distant when station operators will consider the agricultural field as equaling in fertility the present limited "served areas."

Europe has been forced to a realization of this and is far ahead of America today in the development of agriculture and the application of electricity to its needs. This realization has been forced upon Europe because of the necessity for intensive farming. Results have been achieved more quickly and with less expenditure of effort because of the relative denseness of the population as compared with that of America, and because the average area of the European farm is much smaller than the average area of the American farm.

As an instance of German development, we are told that in 1902, thirty-five towns near Hanover having a total population of thirty-five thousand including outlying districts were using about two thousand horsepower in motors for agricultural purposes.

The same necessity for intensive farming is rapidly approaching in this country as is evidenced in many ways, notably the falling off in our export of food stuffs.

Our principal product is corn, of which we exported 10.3 per cent in 1900. This dropped to 1.41 per cent in 1909 in the face of an increase in production equaling 32 per cent. Exports of wheat amounted to 34 per cent in 1900 and to 17.19 per cent in 1909 in the face of an increase in production equaling 41 per cent.

Shall we wait until we are a debtor instead of a creditor nation before we take steps to apply a remedy which is in our own hands and which has been successfully applied by European countries? The solution of this problem must be undertaken intelligently and it can only be solved by a close and systematic study of conditions as they exist today and the results of this study applied to local conditions as the needs of each separate community dictate.

It is the purpose of this paper to present the problem as a whole for the consideration of those best qualified to attack it along

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* Paper read at the Twenty-sixth Annual Meeting of the Association of Edison Illuminating Companies, Thousand Islands, N. Y., September 6, 7 and 8, 1910.

broad lines. No endeavor will be made here to deal in great detail with the innumerable ramifications of the subject. If the possibilities as a whole, which I believe to exist, are made apparent to the readers of this paper, my immediate purpose is served and it only remains for those who are guiding the central station industry to work out in detail each individual problem or prospect looking to the utilization of electricity, for if we stop with a general treatment of the subject but little benefit will accrue. While the farmer of today is immeasurably better equipped to study the problem of agriculture from a scientific standpoint, he is not so much interested in the general phase of the situation as should be the vender of electricity and the manufacturer of agricultural implements and machinery. Furthermore, the farmer has very little time to devote to the abstract problem. Consequently it develops upon the manufacturer and the central station industry to propagate data in its simplest and most attractive form, setting forth clearly to the farmer the advantages that will be derived by him from the installation of labor saving electrically-operated devices.

Certainly the best way to launch such a campaign will be through the co-operation of the operating companies and the manufacturers, using a competent personnel thoroughly trained to point out the mutual advantage that can be derived by the farmer, the central station operator, and the manufacturer.

General Statistics

The land area of the United States comprises 1,903,461,760 acres. Of this area 44.1 per cent is devoted to farming. The total population in 1909 was estimated to be 88,262,446. Of this population about 62,000,000, or 70 per cent live in the rural districts. The remaining 26,000,000 constitutes our urban population. As of today, then, our central stations are serving only 30 per cent of our population. There are approximately 7100 public service corporations distributing electricity today, having a total installed capacity of approximately 5,000,000 kilowatts or a per capita installation of .19 kilowatts per urban inhabitant.

Let us assume that our efforts result in the installation of 0.1 kw. per capita in the rural districts, only one-nineteenth of that devoted to the needs of urban communities. This would mean an increase of approximately 620,000 kw. or 12.4 per cent.

If we can reach but a small percentage of the rural population the outlet for current and electrical apparatus will be enormously increased. Is this increase worth going after? Can it be accomplished? The following figures indicate that it is worth while and can be accomplished.

The wealth production of farms in 1899 was $4,717,000,000. In 1909 it was $8,760,000,000. An increase of 87 per cent in ten years as against an increase in population of 20 per cent. By far the greatest increase has been made in the last three years, which goes to show the strides that agriculture is making. Contrast these figures with the combined production of gold and silver, amounting in 1909 to $127,242,300 which is only 5.35 per cent of the combined value of the corn and wheat crop for that year.

Again, of the total of 29,073,233 people engaged in gainful pursuits in 1900, 10,381,765 were engaged in agriculture and kindred occupations. Still there is a continual complaint because of the shortage in agricultural labor.

The number of horses and mules in the United States in 1910 is estimated at 29,163,000, 89 per cent of these being utilized in agriculture. Is it not reasonable to assume that many of them can be superseded or their efforts augmented by mechanical contrivances? The increase in value of mules and horses warrants the belief that it is possible to do both.

The man with a single plow twelve inches wide must walk 5,280 miles in turning the sod of a field one mile square and three horses are usually required. This plowing must be done in a limited time. Let us assume ninety days.

As the average amount that can be plowed in one day by one man is about two acres, it would require 105 horses and 35 men to plow that one square mile.

In 1900 there were 838,591,744 acres in farms. To plow this land it would therefore require approximately 4,650,000 men and 13,850,000 horses, and this covers only one operation. Add to this the operations of discing, harrowing, seeding and cultivating and some realization will be had of the possibilities presented for the application of mechanical devices and power to operate them. This problem has already been attacked by the manufacturers of steam and gasolene traction engines and great progress has been made. European countries, however, recognize the simplicity and economic value of electricity as applied to plowing and they have developed electric plows which are thoroughly commercial.

Is not all this a clear indication that electrical energy is utilized in our rural districts to a much smaller extent than in our urban districts, whereas the need for electrification is as great if not greater?

Irrigation

Irrigation is destined to become one of the most important, if not the most important, economic factor of this country. Water, where and when you want it, will act as a governor regulating the stability of the national machine.

Elections, the value of securities, and in fact nearly every thing of importance, hinges on the condition of crops. This in turn hinges largely on weather conditions and the natural supply of water. Uniformity in the production of crops is therefore basically necessary and irrigation will help to bring this about.

The development of irrigation in this country in the past few years has made great strides. It has increased land value enormously. It should prove one of the greatest sources of revenue to the central station when applied to truck gardens alone. The character of the load is ideal, coming as it does in the summer months and at the time of low peak.

The combined population of Greater New York, Chicago, Philadelphia and Boston is over 9,500,000 and these cities cover an area of six hundred and ninety square miles. They are all surrounded by truck gardens. Assuming that the central station reaches out for a radius of ten miles, the territory covered will comprise 704,800 acres. Assuming that six thousand gallons of water per acre per day is required for irrigation, a load approximately one and one-fourth million kilowatt hours per day of twenty-four hours will result. Assume that this load lasts for thirty days, totaling approximately 40,000,000 kilowatt hours, at 10 cents per kilowatt hour; this will yield a revenue of $4,000,000. Discount this as liberally as you please, the proposition is still immensely attractive. Certain central stations have already made extensive inroads into this practically undeveloped field. Others are slowly following their example.

NOTABLE INSTALLATIONS

The activities of the Mount Whitney Power & Electric Co. in Tulare and Kern Counties, Calif., are particularly worthy of note and are dealt with in great detail by Mr. John C. Hayes in a paper read before the American Institute of Electrical Engineers, April, 1910. Surface water versus pumped water, rates, cost, etc. are discussed.

This company at the present time is irrigating about 18,000 acres using a connected load for this purpose of nearly 4000 kilowatts out of a total capacity of about 6000 kilowatts.

The Rochester Railway & Light Company has also done much in this field, having installed sixteen pumping plants on farms adjacent to Rochester.

The North Shore Electric Co., of Chicago, is inaugurating a similar campaign.

Electric Stimulation of Vegetable Growth

It is surprising to note the number of experiments that have been made, the calibre of the men conducting them, and the results which have been obtained along the line of electric stimulation of plant life. Among these men are Prof. Lemstrom of Helsingfors University, Finland; Sir Oliver Lodge, England; Prof. Daniel Berthelot, France; Ex. Judge T. H. Williams of Brooklyn, and Warren H. Rawson of Boston.

The European practice most in vogue is electrostatic in nature. A network of wire is supported over the fields at a height of from fifteen to seventeen feet. A rectified current having a potential of 100,000 volts is used. The net work is positively charged and the negative conductor grounded.

In Sir Oliver Lodge's experiments a two horse-power oil engine was used, the primary current being furnished by a three ampere, 220 volt generator stepped up through an induction coil. Nineteen and one-half acres were treated in this manner for ninety days, current being actually used for three hundred and twenty-two hours during the early summer months and in the early morning hours. It was shown that both the quality and the quantity of the yield was materially bettered through this treatment and the growth greatly accelerated, wheat showing an increase in quantity of 45 per cent, corn 35 to 40 per cent, potatoes 20 per cent, beets 26 per cent, strawberries 50 per cent to 128 per cent, and barley 39 per cent. Practically the same results were noted on a twenty-four acre field in Germany.

The theory is advanced that the flow of sap is stimulated and the nitrogen of the air freed and made available as a fertilizing agent.

It is impossible to predicate the extent to which such methods of cultivation may be utilized, but possibilities seem to exist, for we are told by the Department of Agriculture that 6394 tests on corn, 3227 tests on wheat, and 1483 tests on oats, show an average dollars and cents loss relative to the increase in yield where chemical fertilizers are used.

This does not mean, of course, that the use of chemical fertilizers for grain crops is ill advised or unnecessary. On the contrary their use is essential in order to replenish an exhausted soil.

Lodge's experiments show that it cost approximately $2.00 per acre (operating cost) to achieve the results noted. The average cost per acre where commercial fertilizers are used is $7.14 per acre.

If it were possible to apply this system to any appreciable part of our grain area, it can readily be seen that the food problem would be largely solved for some time to come. Even if it is not possible to reach out into our corn fields, it may not only be possible but practical to stimulate the growth of our truck products.

The lead of Europe is being followed to some extent in this country and the results obtained abroad have been duplicated here. Judge Williams has a farm at East Northport, L. I., where the Lodge system is used. Mr. Rawson has a farm at Arlington, Mass., where the electrostatic method is being tried out. In the very near future we will know more about this subject and be in a better position to determine whether or not these principles can be utilized to practical advantage.

Other methods have been used for the stimulation of plant life by electricity, such as the electrolytic effect of buried plates connected by copper conductors and electrically charged, the utilization of atmospheric electricity, etc.

Electric Appliances on the Farm

Many electrically-operated machines and devices are now on the market. The list is being added to rapidly. The following tabulation will give some idea of the development along these lines:

DEVICE	HORSE-POWER REQUIRED
Cream separator	½ to 4
Milking machine	3 to 5
Grindstone	½
Bottle washer	½
Water pump	1 to 10
Shredder	10 to 15
Silage grinder	10 to 20
Feed grinder	5 to 10
Threshing	10 to 20
Wood saw	3 to 5
Corn sheller	1 to 4
Hay press	4 to 25
Refrigerating	½ to 25

Taking the lower capacity we get a total of 50 h.p. installed. Suppose that each of the 5,737,372 farms had a connected load of 50 h.p. The manufacturer would be called upon to furnish 286,869,600 h.p. in motors with a corresponding capacity in generators, and the central station operator would find an inexhaustible outlet for power.

Heating and cooking devices, fans, etc., which we may term luxuries, would follow the installation of what we may call economic necessities.

Many farms throughout the country are today installing electrically-operated machines. The number of farms so electrified, are of course, a negligible percentage of the total, but there is a healthy if gradual increase going on.

Hearts' Delight farm at West Chasey, N. Y., operated by Mr. M. H. Miner, is a striking example of what can be accomplished through the use of electrical devices and machinery. This farm has been fully written up of late and it is unnecessary to give a detailed account of the installation.

There are many similar installations operating on a small scale and the avidity with which the press of the country seeks and disseminates information bearing on these installations is a very good indication of the interest that the community at large takes in the subject. Scarcely a day passes when no mention is made in the papers of the country of electrical applications on the farm. This newspaper campaign will serve a valuable purpose in preparing the ground for a more analytical and practical treatment of the subject.

In conclusion, it must be borne in mind that the figures used in this paper are only intended to be illustrative. They are not intended as an accurate guide to what we may expect from the promise of electrified agriculture.

BEECHNUT PACKING COMPANY

By W. D. Bearce

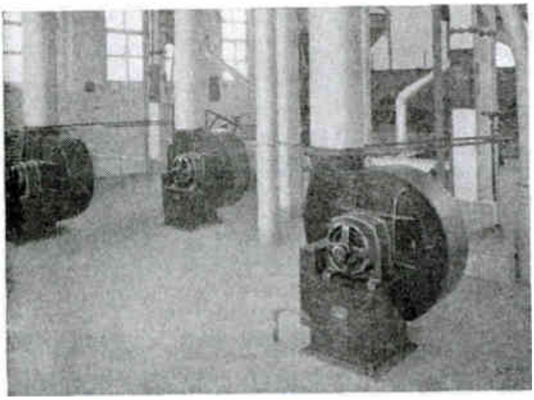

Fig. 1. Top Floor of Peanut Butter Factory Showing Three Motor-Driven Blowers

Recent pure food agitation with the resulting legislation has been particularly effective in securing the use of clean materials and methods for canning and preserving the many food products which are every year turned out by our canning factories. Probably no one thing could induce a greater increase in the consumption of canned meats, fruits, vegetables, etc., than the conviction by the consumer that absolutely sanitary methods and pure materials are being used in the handling and preparation of the raw materials. Following this line of argument, the Beechnut Packing Company with their modern plant at Canajoharie, N. Y., are endeavoring to impress the consumer with the unquestionable superiority of their methods and for this reason the factory throughout the year is open for inspection to all visitors.

One of the most important factors in the maintenance of hygienic surroundings, as is well exemplified in this factory, is the use of individual motor drive wherever possible. While in this particular case the primary consideration in the installation of motor drive is the feature of cleanliness, further advantages are also gained, such as economy of power, increased production, etc.

Located on the Erie canal some forty miles east of Utica, the factory is in the midst of a fertile farming country; furthermore, in this section of New York state, hydro-electric power is comparatively cheap and plentiful, and no generating plant need be maintained. The power for this factory is purchased from the Montgomery Light & Power Company, a local distributing agent, at 2300 volts, 60 cycles. It is generated at the East Creek power station eleven miles distant, whence it is transmitted to Canajoharie at 15,000 volts and stepped down at the local substation. The East Creek power station has a rated capacity of 1000 kw.; this is now being added to by a new station of 6000 kw. capacity located at Tribes Hill, about three miles from the present plant.

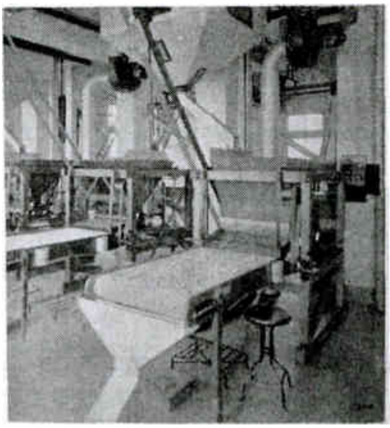

Fig. 2. Hoppers for Cooling Roasted Peanuts

A day load of this character is particularly desirable for a central station, and it is therefore possible to offer hydro-electric power at a rate below the cost of steam power. In the event of breakdown, the factory can make use of its own generating plant, which has a rated capacity of 80 kw. However, as the average load at the factory is about 200 horse-power, this plant can supply only about one-half the power required.

The several illustrations accompanying this article show the variety of operations which employ electric drive to advantage. The two larger departments, the peanut butter factory and the sliced meat department, are unusually good examples of the improved conditions attending the use of individual drive.

A short description of the methods employed in handling the materials will enable the reader to more easily understand the work which is required of these motors.

Three floors are devoted to the manufacture of peanut butter. On the top floor (Fig. 1) raw shelled peanuts are received in 250 pound bags and stored until used. On this floor also are located the peanut roasters and three blower motors, the latter forming part of the blower system. The peanuts are first placed in the motor-driven roasters and after being properly cooked are taken out into large hoppers to cool. (Fig. 2). From these hoppers, which are three in number, they pass to the next floor by gravity and are delivered to the so-called blanching machines, which remove the brown skin from the peanut and split it in halves. The process also breaks out the germ or heart, which part is afterwards discarded.

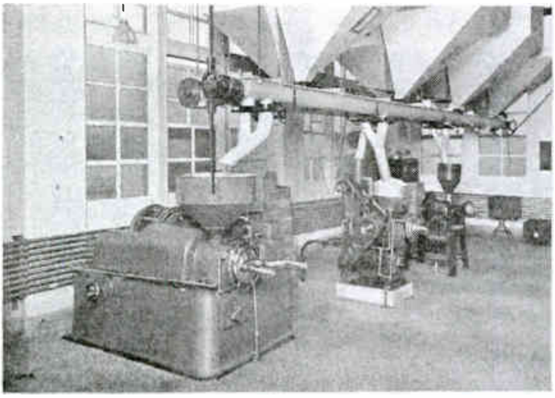

Fig. 3. Motor-Driven Peanut Butter Machines

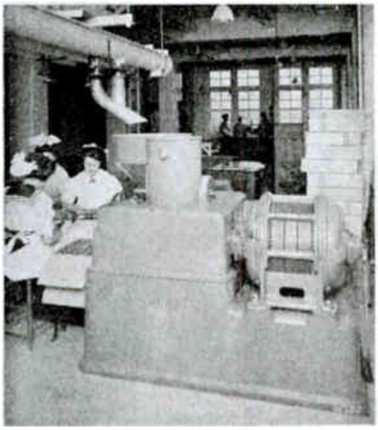

Fig. 4. Filling Glasses with Peanut Butter

From the blanching machines the peanuts pass through a winnowing process to the floor below, during which the brown skins, germs, and any other foreign matter is blown out. On this floor they pass through a further cleaning process and are again raised to the top floor by an air blast of just sufficient force to lift one-half of the peanut. In this way any stones or heavy material which may have escaped the winnowing process is taken out. Returning to the third floor, the peanuts are dropped onto the moving belt of the sorting machines, where the operatives sort out any defective peanuts or foreign material. The product is now ready for the peanut butter machines and drops into the hoppers on the second floor. (Fig. 3).

On this floor are located three peanut butter machines, each direct connected to a Form K induction motor. The largest machine, which is driven by a 15 h.p. motor, has a capacity of five tons per day. The two smaller machines are driven by 3 h.p. motors and have a capacity of about 1500 pounds per day. It is interesting to note that two varieties of peanuts are used, the so-called Virginia peanut and the Spanish peanut. By mixing these in proper quantities the required amount of oil is obtained from the latter variety. In the illustration (Fig. 4) the operatives may be seen filling the glasses directly from the spouts, at a rate of fifty-eight per minute. In this department it is evident that belts, shafting and shaft hangers would afford opportunities for the accumulation of dirt and dust, whereas by the use of the direct connected motor, the room can be kept clean and sanitary.

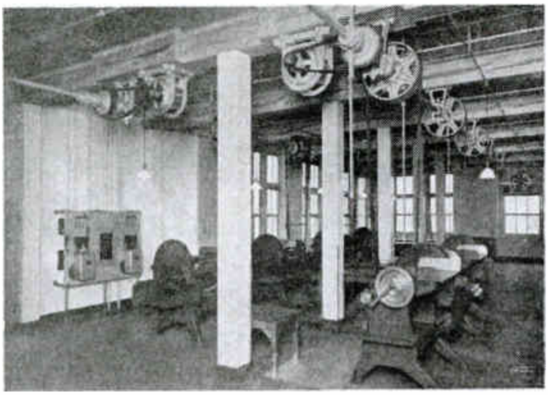

Fig. 5. Machines for Slicing Bacon and Dried Beef. Operated from Line Shaft

The White Packing-Room

The white packing-room, so called on account of its white enameled finish, is used entirely for preparing and packing the sliced dried beef and sliced bacon. Special machinery, the cutting knives of which revolve at 500 revolutions per minute, is employed for slicing the meats. Fig. 5 shows a corner of this room in which two 10 h.p. motors, suspended from the ceiling, are used to drive the several slicing machines. It will be noted that the machine on the extreme left is equipped for individual drive. This equipment is more clearly shown in Fig. 6. The two motors now used for driving the line shaft are soon to be replaced by individual motors mounted on each machine. A considerable saving can be effected in this way, as on many occasions either the raw material is not promptly delivered or else the sliced meat is not required for packing and only two or possibly three of the machines need be operated. In Fig. 5 the starting apparatus for each motor consisting of switches and compensators mounted on standard panel, may also be seen.

In another part of this room the glass jars are thoroughly wiped out by motor-driven cleaners similar to the one shown in Fig. 7. A ½ h.p. motor carries the two wipers while a 2 h.p. motor collects all dust and carries it from the room. Several of these outfits are being set up to replace belt-driven machines.

Among the many other purposes for which electrical energy is employed, is the driving of ventilating fans, vacuum pumps, labelling machines, belt conveyors and elevators. The conveyors are driven by an induction motor and raise the empty jars to

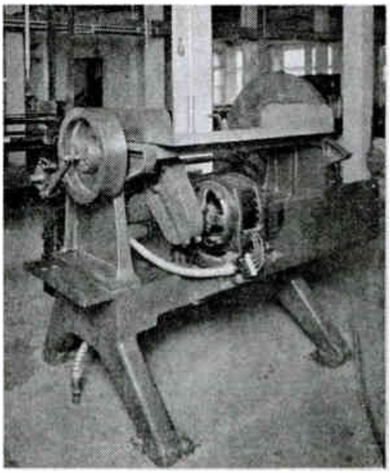

Fig. 6. Slicing Machine Individually Driven by Small Induction Motor

the fourth floor, the force of gravity carrying the boxes down the inclined rolls (Fig. 8).

In the bean department, which is located on the third floor of the main building, the machinery is driven by a 10 h.p. motor, chain belted to the line shaft. The machinery in this department consists of sorting machines similar to those used in the peanut department, and filling and sealing machines.

The cap-room, so called, is on the first floor adjoining the boiler room. In this department the metal covers are punched out and shaped in large punch presses. The rubber washers are cut on special machines, and threads are pressed into the screw top covers. Several special grinders are also required for sharpening the knives of the slicing machines. This entire room is operated by the 10 h.p. motor shown in Fig. 9.

The power, as before mentioned, is supplied at 2300 volts, 2-phase, 60 cycles. From this potential it is stepped down to 220 volts for driving the motors. In order to supply the incandescent lamps with 110 volts, a neutral wire is tapped in on the transformer winding and the various circuits are balanced on the two phases. Almost all the incandescent lamps, which are well shown in several of the illustrations, are tungsten, using Holophane reflectors. There are in all one hundred and sixty 100 watt lamps and fifty 60 watt lamps of this type.

The total number of motors in actual service is eighty-three, totaling 250 h.p.

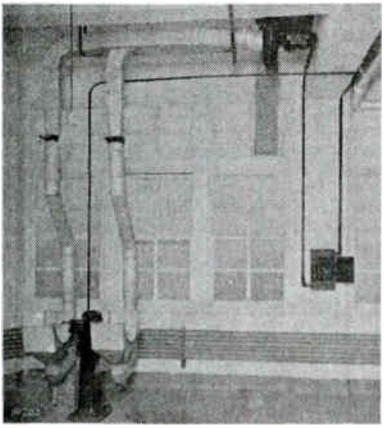

Fig. 7. Motor-Operated Cleaners for Glass Jars

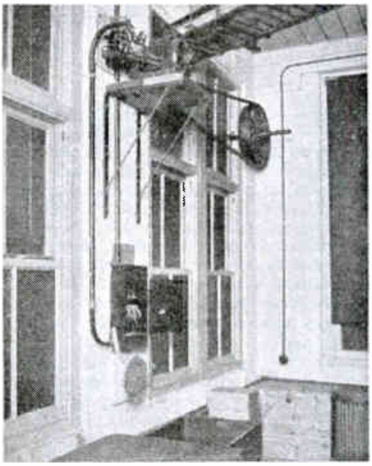

Fig. 8. Induction Motor for Operating Conveyor; Rolls for Carrying Boxes by Gravity From Fourth Floor

Current at 220 volts is supplied from six 25 kw. General Electric transformers. During the past year this plant turned out 7,500,000 packages of product and employed about 350 persons.

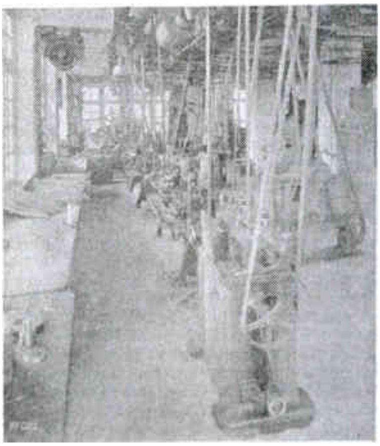

Fig. 9. Special Grinders for Sharpening Knives of Slicing Machines. Group Driven From 10 H.P. Motor

INSTALLATION OF LOW PRESSURE TURBINE, BETTENDORF AXLE COMPANY, DAVENPORT, IOWA.

By P. Bendixen, Master Mechanic

About two years ago the Bettendorf Axle Company, of Davenport, Iowa, were considering an addition to their electrical equipment due to the growth of the plant, and made a thorough investigation of the various prime movers suitable for the purpose. Taking into consideration the heating of the shops in winter and the fact that the old power plant was running non-condensing, all factors pointed to the low pressure or exhaust turbine as the most suitable power unit to install, from the standpoint of reliability, simplicity, economy and maintenance.

The power equipment at that time consisted of two 100 kw. direct connected high speed tandem compound engine-driven units, a number of hydraulic pumps, and an air compressor exhausting into one header, making an ideal arrangement for connection to an exhaust turbine. Having made a study of various turbine plants, the company decided to install a 500 kw. horizontal Curtis turbine. This turbine was put in operation in September, 1909, and has been in service for about fourteen hours per day since. It supplies all electrical power required by the plant, which at present amounts to 250 kw. average load; this power being used mostly for the operation of cranes, the lighting of shops, and for lifting magnets. When machinery now under construction is completed and installed, the load will be increased to about double. The main steam supply is derived from the exhaust of the hydraulic pumps, but, owing to the fact that these pumps are subject to interrupted service due to breakdowns on the system, other means of supplying steam had to be provided and a connection was therefore made from the exhaust header to the high pressure steam pipe through a 4 inch by 8 inch Foster pressure-reducing valve. By means of this connection the required amount of steam to keep the turbine in operation is secured. This arrangement works very satisfactorily, as the valve operates within a range of one-half pound drop in pressure. The average back pressure is about three pounds, and to take care of an excessive back pressure, the exhaust header is provided with a 12 inch relief valve set to operate at five pounds pressure. All steam to the turbine passes through an 18 inch two stage separator, which separates all oil and moisture from the steam. A 3150 foot Worthington condenser is installed, the condensed steam being returned to the boiler feed water heater.

While no figures are available to substantiate a statement as to the exact performance of the turbine, it is thought possible, when running with 28 inch vacuum, to recover 75 per cent of the energy delivered to the pumps, compressors, and reciprocating engines. In cool weather it has been possible to run for weeks with a vacuum of from 29 to 29½ inches, this, of course, making quite a difference in the steam consumption. In order to maintain a good vacuum, it has been found necessary to pipe the steam seal in which the carbon packing rings are located with high pressure steam to insure against any leakage of air around the shaft. The amount of steam required for this purpose can best be found by experiment, and when once adjusted requires very little attention.

Before putting the turbine in service it was run for a few days under various loads, the generator being loaded on a water box. It was found that sufficient exhaust steam was available to furnish 425 kw. continuously, and as much as 575 kw. for short periods. Six boilers of about 120 h.p. each were in service at that time. The results of the test would indicate that 75 to 80 per cent of the energy delivered to the engines and auxiliaries was recovered.

The governing of the turbine is very good, as with a load fluctuation of about 500 amperes the variation in potential does not exceed two or three volts. The lighting load consists of enclosed arc, flame arc, mercury vapor and incandescent lamps, all of which show up very much better when operated by the turbine than when the engine-driven units carry the load. This improved performance is owing to the better regulation of the turbine.

In operating the turbine, a practice is made of drawing a few buckets of oil from the tank every two weeks and adding the same amount of fresh oil; this seems to keep the oil in good condition. No trouble has been experienced in keeping the bearings cool, this being accomplished by means of circulating water. In order to maintain a uniform flow, the water is taken direct from the mains and passed through a reducing valve which takes care of any fluctuation in pressure in the main supply.

The emergency governor is tested regularly once a week; it has never failed to respond to increase in speed, invariably tripping the stop valve on the turbine.

It is found that the attention required by a turbine generator of the size here installed is not as much as that demanded by one of the engine-driven units. Good results are got without the use of a receiver generator between the units and the turbine, as the reducing valve makes up for any deficiency in the steam supply, which might be due, as stated before, to the stoppage of one of the engines or pumps. With this arrangement a sufficient supply of steam (direct from the boilers if necessary), is always assured, thus making the installation fully as reliable as the high pressure engine or turbine, and much more economical than either of these when running non-condensing.

The longest continuous run so far made with this turbine has been five days and nights. No shut-downs, due to trouble of any kind with the turbine, have occurred since the turbine was first put in operation, and this company can conscientiously recommend the installation of a low pressure turbine in any place where a sufficient supply of exhaust steam is available for its operation.

THE DEVELOPMENT OF PROTECTIVE DEVICES FOR HIGH TENSION CIRCUITS

By P. G. Langley

The past decade has witnessed a growth of electrical development which far surpasses the progress made in any other industrial line. It was shown at an early date that the simplest, safest, most efficient, and therefore the cheapest method of utilizing power, was to be found in the use of electricity as the converting agent.

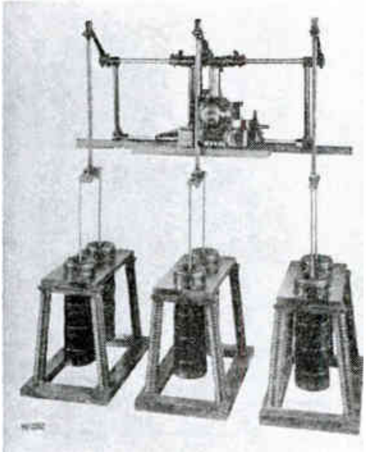

Fig. 1. 60,000 Volt High Capacity Oil Switch

Electricity is most economically generated near a natural source of power, whether of water, gas or coal origin. This fact has led to the development of many power possibilities, some of them remote from localities where there was a demand for power. Those close to centers of demand were first developed, and as the distances over which power was to be transmitted were small, few serious difficulties were encountered in the early days. As the nearer sources of energy were gradually developed and the demand for power increased, the utilization of the more remote powers was undertaken. Then arose engineering problems which forced the development of apparatus capable of handling the high voltages necessary for economical transmission over long distances. One of the first important steps toward high voltage transmission was made about eight years ago by the Washington Water Power Company. This company, in order to supply power to the mines of Washington and Idaho over transmission lines about one hundred and fifty long miles, decided to use 60,000 volts. This development proved so successful that it was speedily followed by others, and by rapid rises in voltage, until 110,000 volts is now not unusual and a rise to 140,000 volts has been proposed.

To meet these conditions of operation it has been necessary to develop switching, measuring, and protective equipments along radically new lines. High voltage developments are necessarily expensive, and to effect economy, large powers must be employed; so that in addition to taking care of high potential strains, it has been necessary to produce equipments capable of withstanding the explosive effect of interrupting the flow of large amounts of energy.

Fig. 2. Expulsion Type Combined Fuse and Disconnecting Switch

The first high voltage switches were designed along the lines of the then existing switches for lower voltages, the spacing and insulation being increased in proportion to the voltage. These switches (Fig. 1) consisted of contacts working in separate enclosing chambers, partly filled with oil, in which the arc was finally broken. For each live wire two breaks in series and consequently two chambers were employed, each pair of chambers being installed in an isolating, fireproof compartment. The chambers were later improved by the addition of baffle plates and expansion compartments, which prevented disruption of the oil, splashing of oil out of the pots, and allowed space for the safe expansion of gases formed by arcs.

To increase the rupturing power, these switches are provided with explosion chambers surrounding the contacts, these chambers confining the oil and forcing it at high pressure between the contacts at the point where the arc is ruptured. The explosion chambers are entirely submerged in a larger volume of oil and any oil forced out by the expansion of gases is immediately and automatically replaced. These switches are usually electrically operated and located at some distance from the point of control, but they have also been designed for hand operation. They are limited to systems of not over 60,000 volts.

Such switches are suitable for large power installations and are expensive. To meet the condition where a small amount of power was to be tapped from a transmission line some simpler protective device had to be provided. This problem was solved by the introduction of the expulsion type fuse (Fig. 2.)

This fuse, which is mounted in a suitable holder that acts as a disconnecting switch for the circuit, allows of opening the charging current of a line or the magnetizing current of a transformer. When this is done the fuse holder is disconnected from the circuit so that a fuse can be easily and safely removed or replaced.

These fuses under proper conditions furnish excellent protection for lines and apparatus, since, due to their property of generating a high pressure at the rupturing point of the fuse, and their quick action, the circuit is opened with little if any more disturbance than when an oil switch is used.

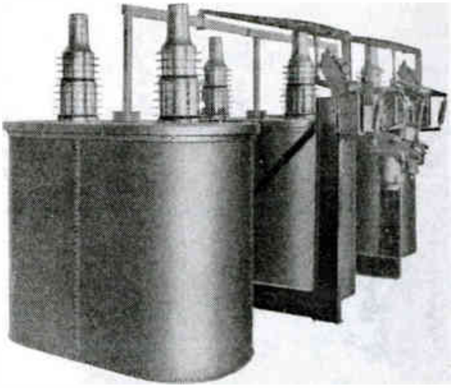

Fig. 3. Moderate Capacity High Voltage Oil Switch

There are a number of engineering features which should be carefully considered before deciding upon the use of fuses. Fuses should not be used:

1. When the current to be ruptured exceeds the rating of the fuse, or when the capacity of the system exceeds the rupturing capacity of the fuse.
2. Where the arc formed by the blowing fuse is objectionable.
3. Where short interruptions of service, due to the time necessary to replace fuses, is an objection.
4. Where overloads or short circuits are frequent, and circuits should be opened selectively after a time limit. In such cases, oil switches should be recommended.

To meet the demand for a reliable oil switch of moderate capacity that could be installed at a less cost than the larger switch a new type has been designed. In this switch each pole, which consists of two breaks in series, is assembled in a separate iron tank of large dimensions. The three poles necessary for a three-phase circuit are operated as a unit by one mechanism, either by means of a hand-operated lever, by air, or by solenoids electrically operated from the control board. (Fig. 3.)

Fig. 4. High Capacity High Voltage Oil Switch

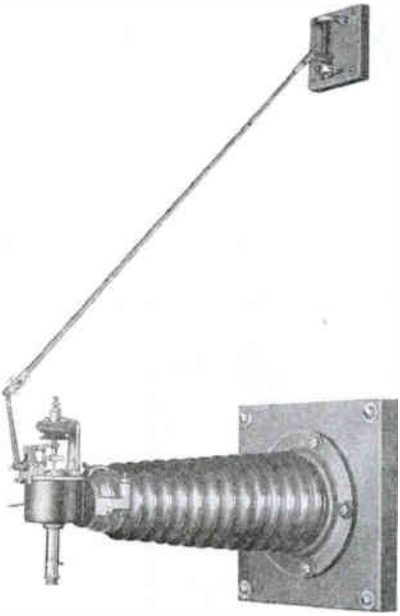

Fig. 5. High Voltage Series Relay

This switch does not require isolating cells for the oil tanks, these being simply set up on the station floor. The spacing of contacts and size of tanks are varied according to voltage, the limit of which is 110,000 volts.

High capacity oil switches which are capable of handling the largest powers yet developed, at any voltage considered up to the present time, have been designed along the lines of the one last mentioned. In order to provide the necessary insulation between live parts, spacings and break distances have been increased. The oil tanks are larger and contain a greater volume of oil. (Fig. 4.)

These switches, being top connected, admit of a very simple and flexible station layout. Since all wiring is overhead, station buildings do not require basements, and therefore can be constructed more cheaply than when bottom connected switches are used. The absence of cell work and barriers, also tends to greatly reduce the cost of installation.

In order to provide automatic protection for apparatus under abnormal conditions of overload or short circuit, two schemes are now in general use. The first and oldest employs series transformers, the primaries of which are connected in the high voltage circuit to be protected. The secondary winding, suitably insulated from the primary, is connected either direct or through suitable relays to the coil that acts upon the tripping mechanism of the switch controlling the circuit. The second uses relays, thoroughly insulated from the ground, the solenoids of which are connected directly in the main circuit. These relays operate the tripping mechanism of the switch either direct by means of insulating rods, or by means of an auxiliary source of power and a trip coil on the switch mechanism. They are designed only as single-pole units, one of which is connected in each live wire, and are not suitable for conditions which require the bringing together of two high voltage circuits in one unit.

Fig. 6. High Voltage Series Transformer

Where wattmeters or watthour meters are required, series transformers are necessary and can be used to operate protective devices in addition to carrying the instrument load.

Fig. 7. Series Ammeter for High Voltage Circuit

By mounting a standard ammeter on a suitable insulator to prevent leakage to ground, a very satisfactory indicating device has been developed for use on high voltage circuits (Fig. 7). These instruments are connected directly in the main circuits and should be so mounted that accidental contact with them by the station attendant is impossible. These instruments are used in those installations which lend themselves to the use of series relays, and together they form a very compact and cheap equipment.

Disconnecting switches of various forms are in general use on high voltage circuits. These, as a rule, are not intended to open a power circuit, but can be depended upon to open the magnetizing current of a transformer

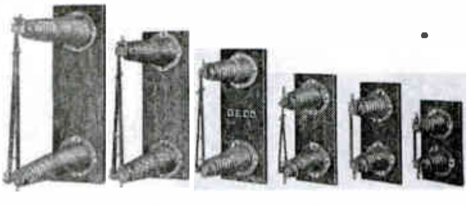

Fig. 8. Knife Blade Disconnecting Switch

or the charging current of a line. The well known knife-blade type is widely used, the spacing and break distances being in proportion to the voltage. These switches are invaluable for isolating stations or apparatus at times when it is necessary to make repairs or do other work which would otherwise require shutting down the entire system.

Fig. 9. High Voltage Outdoor Disc Switch

Switches capable of opening a moderate amount of power have been perfected for outdoor use (Fig. 9). These are mounted on poles or tower structures and may be operated from the ground by means of suitable mechanism. The final breaking of the arc is accomplished on metal horns which, bending upward and outward, allow the arc to follow its natural course upward and to rupture itself at the ends of the horns.

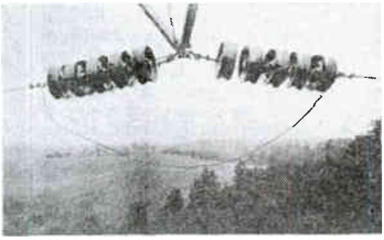

Fig. 10. High Voltage Strain Insulator

The most difficult problem in high voltage development has been to produce suitable insulation for the lines on which the success of any power transmission scheme depends. Exposed to all weather conditions, traversing long stretches of exposed country, and compelled to make numerous bends and to follow the natural grades, it has been necessary to produce insulators to meet any and all service conditions.

With the old style pin insulator construction, line voltages were limited to about 60,000 volts, owing to the great weight of the insulators for higher voltages and the great cost of towers, which had to be erected at close intervals.

Higher voltage transmission has been made possible by the introduction of a comparatively new insulator, known as the link type (Figs. 10 and 11). These are made in two forms, one called the suspension type and the other the strain type. Each complete insulator consists of a number of porcelain units joined together by suitable links, the number of units in series being varied in proportion to the line voltage. By the use of these insulators it has been possible to greatly increase the distances between supports, and to reduce the cost of lines to a practical basis.

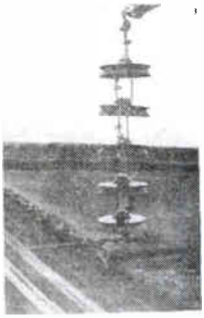

Fig. 11. High Voltage Suspension Insulator

THE CURTIS TURBINE*

PART II

BY CHARLES B. BURLEIGH

Referring again to the 25 kilowatt turbine, we will now take up the consideration of the buckets and wheels, but we must first determine our bucket speed and wheel diameter. It should be clearly understood, however, that the values deduced and given in this article are simply to exemplify the interrelation of the steam velocity, bucket speed, wheel diameter, etc., and are not intended to be taken as the actual values that exist in these turbines. In our example, our steam conditions are fixed by an expansion from 150 pounds gauge (the pressure that we have assumed) to atmospheric pressure, resulting in a steam velocity of 2950 feet per second. To be safe let us allow 10 per cent velocity loss and select 2655 feet per second as the available velocity.

We can not select a single wheel, as it would necessitate a wheel velocity of $\frac{2655}{2} = 1327$ feet per second, and a two wheel abstraction would require a wheel velocity of $\frac{2655}{4} = 664$ feet per second. This latter would do, but we feel that a machine of somewhat less diameter and slower shaft speed would be more practical. Let us therefore try a three-wheel type, which will give us $\frac{2655}{6} = 442.5$ feet per second as bucket speed.

This is a very desirable peripheral speed and one that is well within the limit of safety.

Now let us see how we may best utilize this 442.5 feet per second bucket speed, which represents the speed of our wheel peripheries to which the buckets are secured, the wheels being securely keyed to the shaft upon which we must rely for our results.

It will at once become evident that the speed of this shaft will be wholly dependent on the radius of the circle through which the buckets move at the foregoing specified speed. To obtain a desirable shaft speed, therefore, we must determine on a proper wheel diameter.

In arriving at a decision regarding these features of design, we have considerable latitude as there are two variables, our wheel diameter and our rotative speed. We can therefore take advantage of this fact by selecting a rotative speed which permits of the most satisfactory design of generator.

On carefully considering the 25 kilowatt generator we find that a shaft speed of 3600 revolutions per minute readily lends itself to the best design.

Now let us consider the effect of a shaft speed of 3600 revolutions and a bucket speed of 442.5 feet per second on our wheel diameter.

A disc one foot in diameter revolving at a speed of 3600 revolutions per minute will have a circumferential speed of $3600 \times 3.1416 = 11309.76$ feet per minute.

The diameter of the wheel, to the periphery of which the buckets are to be secured, must bear the same ratio to one foot that 11309.76 feet bear to $442.5 \times 60 = 26550$ feet (our bucket speed per minute) or $\frac{26550}{11309.76} = 2.347$ feet = 28 inches as the diameter of our wheels including our buckets.

In arriving at our bucket speed we determined to adopt the three-wheel design. We can, however, modify this decision somewhat with decided advantage to our design.

Instead of using three separate and distinct wheels we may secure three rows of buckets to the periphery of one wheel, so arranging them that the steam will pass through and actuate the three rows in the same manner as though each row was supported by its own individual wheel; by so doing we are enabled to reduce the weight of the rotor and produce one which can not under any conditions distort or run out of alignment, and at the same time reduce the steam friction losses to a minimum as well as economize length parallel to the shaft.

The buckets should be the next item for our consideration.

At one time the Curtis turbine buckets were cut by special machinery, in some cases from the periphery of the wheel of steel casting, in others in the outer circumference of a ring of steel casting the outer diameter of which corresponded to the diameter of the wheel to which it was ultimately to be secured.

Some eight or more years of experience however, has developed the fact that under certain wet steam conditions, slight steam wear has become apparent; it was therefore decided some years ago to use compositions

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* The calculations in this article are theoretical and disregard friction, losses due to angle of nozzles, etc., etc.—*Editor.*

for all buckets. The buckets are dovetailed in corresponding slots machined into the peripheries of the steel wheel or wheels, the other ends of the buckets being secured to a shrouding by riveting over bosses which are provided on the ends of the buckets.

This results in a bucket construction practically impervious to the action of any quality of steam and one well insured against mechanical injury. Its staunch characteristics are evidenced by the satisfactory operation of over two million horse-power capacity of these machines in commercial service, their installation extending over a period of some eight years.

A row of intermediate or redirecting buckets secured to the shell of the machine is installed between each two rows of moving buckets. These intermediates are exact counterparts of the moving buckets, but their curvature is in the opposite direction from that of the moving buckets.

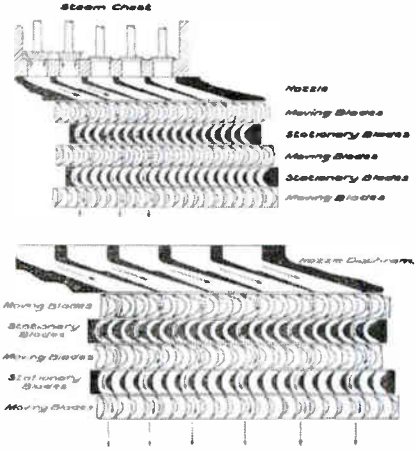
Like the moving buckets, these intermediates are securely shrouded, and as their only province is to redirect the steam delivered to them by the preceding row of moving buckets and deliver it in its original direction to the succeeding row of moving buckets, they only extend around that part of the periphery of the machine covered by the steam belt, which, as previously stated in the machine under discussion, is only about one-sixth of its periphery; the remainder of the periphery is left entirely open.

The following diagram will enable me to call to your notice perhaps more clearly some of the characteristics in connection with the bucket shape and the steam action on them.

At the upper left-hand corner several expanding nozzles are represented, designed to deliver the steam to the buckets, expanding it in its passage through the nozzle from 150 pounds to atmospheric pressure, thereby imparting to it the stated available velocity of 2655 feet per second.

It will be noticed that the angle of delivery or direction given by the nozzle to the steam, corresponds closely to the arc of the buckets, the first row of which the steam will easily enter without shock, excessive friction or sharp angular deflection.

In the case of the machine under consideration, the steam, on entering this row of buckets at a speed of 2655 feet per second, will give up energy to the buckets and lose velocity equal to twice the bucket velocity (twice 442.5 feet per second), actuating the buckets toward the right in proportion to the energy imparted. The steam following the path provided by the curvature of the buckets will leave them in the reverse direction at a speed of 2655 minus twice the bucket speed or 2655 − 885 = 1770 feet per second.



Arrangement of Expanding Nozzles and Movable and Stationary Buckets

The steam is next delivered to the first row of intermediates or redirecting buckets, secured to the shell of the machine and incapable of motion, and following the path provided by the curvature of these intermediates, is delivered to the second set of moving buckets with its original direction restored and without diminution of its velocity of 1770 feet per second.

You will notice that here again the direction given the steam by the intermediates permits of its easy unobstructed entrance to the moving buckets; these being secured to the same wheel as the first set must of necessity move at the same speed (442.5 feet). Here again the steam gives up energy to this row of buckets in proportion to twice the bucket velocity and leaves them at a speed of 1770 minus 885, or 885 feet per second. This second row of moving buckets delivers the steam to the second row of intermediates, which in turn delivers it to the third and last row of moving buckets at a speed of 885 feet per second. These buckets moving at the same speed as the others (442.5 feet or one-half the speed of the steam) abstract the remainder of the steam's velocity. Thus the steam has given up all its energy to the moving member.

One or two features of bucket design may be of interest. You will notice that the path provided for the steam is a gradual curve, presenting no sharp or sudden changes of direction, and that the path gradually increases in area as the velocity is being abstracted from the steam in its travel.

You will also notice that viewed in cross sections the distance between the center of the buckets is less than between the tips. The reason for this is that with steam traveling at a high velocity, on making the turn at the bucket center, it would be subjected to a compression, which, if this area were equal at all points, would result in effecting a partial vacuum on the front center of each bucket. As a result, eddy currents would develop in the steam and a portion would change its direction of flow, be drawn into this vacuum and run back into the incoming jet, thus impairing the efficiency. Thus, while the expansion of the steam is in no way dependent on the area between buckets (for which reason inequalities at this point are of less vital importance than in other types of turbines), it is still a matter worthy of very careful design to porportion this area exactly in accordance with the compression and still not contract the area to the extent of introducing friction, which would be so objectionable.

The short staunch bucket design with all buckets positively secured and prevented from changing position with relation to each other, is a prominent factor in the success of these machines.

It will be noticed by reference to the diagram, that since the finished buckets are narrower than the supporting material and the shrouding, they are absolutely protected from coming in contact with anything other than the actuating medium.

A description of the shell of this machine I have purposely left for the last, as in the single stage machine at least, this portion would be entirely unnecessary but for three comparatively unimportant functions:

1st. It serves as a convenient support for the intermediates and steam chest.

2d. It confines the exhaust steam and enables us to dispose of it conveniently.

3d. It prevents, to a certain extent, heat radiation and keeps drafts of air from distortint the steam flow through the buckets.

If it were not for these three relatively unimportant duties it might be omitted entirely, since the steam is expanded to atmospheric pressure before being delivered to the interior of the machine, and atmospheric pressure prevails throughout every part of the machine enclosed by the shell, the same pressure would exist if the shell were not present. I mention this to show more clearly that there is no necessity for packed joints or fine clearances in any direction in order to maintain designed efficiency.

This condition exists of course only in the Curtis turbine of the single pressure step or stage, non-condensing type, and would not apply to a multi-stage or single-stage condensing unit. The shell, therefore, of the unit under consideration is a simple cast iron casing designed to be easy of access and to conveniently and rigidly support the steam chest and intermediates to which they are securely bolted.

The foregoing, while referring more specifically to the twenty-five kilowatt horizontal non-condensing unit, is substantially descriptive—with the modifications with regard to pressure stages and velocity stages of the entire line of both horizontal and vertical turbines of the Curtis type.

While the efficiency was an item of extreme importance in the design of the Curtis turbine, reliability and simplicity were of paramount importance.

The appreciation of the limitations of the gas engine, the steam engine and the reaction turbine resulted in the development of a steam turbine with characteristics closely resembling the hydraulic turbine. This steam turbine is as simple and reliable as the hydraulic turbine, more efficient than the steam engine, and compares very favorably with the gas engine in this particular when all items which represent the expense of operation are considered.

The simplicity of the Curtis turbine is beyond dispute, as in this particular it is almost identical with the hydraulic turbine, which previous to the development of this type of steam turbine, stood alone as the simplest power producing prime mover.

As compared with the reciprocating steam or the explosive type of engine, the omission of cylinders, pistons, piston-rods, wrist-pins, cross-heads, guides, connecting-rods, cranks and crank-pins, as well as flywheels, offer sufficient excuse for the existence of the steam turbine; to say nothing of the fine adjustments necessary, due to the fact that, with the exception of the flywheel, sliding metallic contact exists between these parts during operation.

So much for the simplicity of the turbine. As regards its efficiency, it is superior to the reciprocating engine, especially after a period of service, for unlike the engine, which loses efficiency after service, the turbine does not deteriorate in this respect, even after long continued operation; a fact which is substantiated by the statement of Professor N. C. Carpenter, Professor of Steam Engineering, Cornell University, in his discussion of Mr. Orrok's paper (mentioned below). Professor Carpenter said that upon testing a 75 kw. Curtis turbine that had been in service some 7000 hours, the results were not materially different from those obtained on a new machine of the same capacity and design.

For an extended discussion of the relative efficiencies of the turbine and reciprocating engines, the reader is referred to the article by Mr. Richard H. Rice, which appeared in the April, 1909, issue of the REVIEW. A comparison of the efficiencies of the small Curtis turbine and turbines of other types is to be found in the paper by Mr. George A. Orrok, which appeared in the "Tansactions of the American Society of Mechanical Engineers," May, 1909. The deduction to be drawn from the paper of this unprejudiced author, is that the Curtis turbine, in point of efficiency, is so superior as to be in a class by itself.

COMMERCIAL ELECTRICAL TESTING

PART XIV

BY E. F. COLLINS

TRANSFORMERS—(Cont'd)

Efficiency Tests

The efficiency of a transformer is the ratio of its net power output to its gross power input, the output being delivered to a non-inductive circuit. The power input includes the output together with the losses, which are as follows: (1) The core loss, which is determined by the core loss test at rated frequency and voltage, and (2) the I^2R loss of the primary and the secondary calculated from their resistances. As the losses in the transformer are affected by temperature and the wave form of the e.m.f., the efficiency can be accurately specified only by reference to some definite temperature, such as 25° C., and by stating whether the e.m.f. wave is sinusoidal or otherwise. The formula for efficiency may be written:

Per cent efficiency

$$= \frac{\text{output}}{\text{output} + \text{core loss} + I^2R \text{ loss}}$$

Regulation Tests

In transformers the regulation is the ratio of the rise of secondary terminal voltage from full load to no load (at constant primary impressed terminal voltage) to the secondary full load voltage. Regulation may be determined by loading the transformers and observing the rise in secondary voltage when the load is thrown off. This method is not satisfactory on account of the expense of making the test and the small difference between no load and full load secondary voltages. Much greater reliance can be placed on results calculated from separate measurements of reactance drop, resistance and magnetizing current, than on actual measurement of regulation. The following method is used by the General Electric Company:

Let IR = total resistance drop in the transformer expressed in per cent of rated secondary voltage.

IX = reactance drop similarly expressed.

P = proportion of energy current in load, or the power factor of the load. Non-inductive load, $P = 1$.

W = wattless factor of primary current. (With non-inductive load, W = magnetizing current expressed as a decimal fraction of full load current; with inductive load, W = wattless component of load plus magnetizing current.)

Secondary full load voltage = 100 per cent.

Secondary no load voltage = E.

For non-inductive load

$$E = \sqrt{(100 + IR + W\,IX)^2 + (IX)^2}$$

For inductive load

$$E = \sqrt{(100 + PIR + QIX)^2 + (PIX - QIR)^2}$$

In each of these equations, the last expression within brackets represents the drop "in quadrature."

The reactance drop expressed in per cent

$$IX = \sqrt{(\text{per cent impedance drop})^2 - (IR)^2}$$

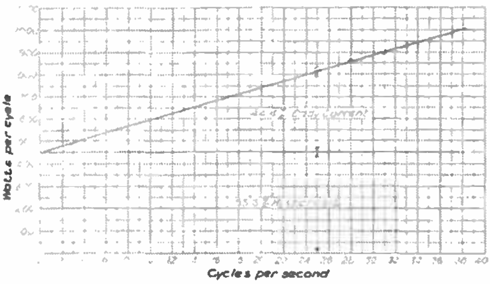


Fig. 63. Seperation Curve

The magnetizing current

$$= \sqrt{(\text{exciting current})^2 - \left(\frac{\text{core loss}}{\text{voltage}}\right)^2}$$

Special Engineering Tests

The separation of the core loss from copper loss may be considered as a special test on constant potential transformers. The core loss of a transformer consists of hysteresis and eddy current losses. The hysteresis loss is that due to cyclic reversals of the magnetism of the core, its value depending on the quality of the iron, and in a given transformer varies directly as the frequency and as the 1.6 power of the magnetic density. Eddy current loss is due to electric currents flowing in the iron, and varies with the conductivity of the iron, the thickness of the laminations, and the square of the frequency.

The method for separating the losses is as follows: Since the hysteresis loss varies directly as the frequency and the eddy current loss as the square of the frequency, by maintaining a given density in the core and varying the frequency, data can be obtained from which a separation curve can be plotted. The voltage to be applied varies directly with the frequency at which it is applied; thus 100 volts at 60 cycles becomes 200 volts at 120 cycles. Plotting watts per cycle as ordinates and cycles per second as abscissæ, curves similar to those shown in Fig. 63 are obtained. At least four points should be taken to determine the curve. By comparing the losses at normal frequency and density, the quality of the iron and the insulation between laminations can be deduced.

The eddy current loss in the copper conductors of a transformer may be separated from the ohmic loss in the following manner: The ohmic loss is independent of frequency, while the eddy current loss varies with the square of the frequency. Hold the current constant and take readings of watts, volts and speed while varying the frequency. Plot watts loss as ordinates and cycles per second as abscissæ, and project the curve back to the zero line. At zero frequency, the total loss will represent the true ohmic loss or I^2R. (See Fig. 64.)

In very exceptional cases, short circuit tests are taken on transformers to determine their behavior in case they are accidentally short circuited in service. This test is obtained by connecting one winding of the transformer to the power source, which should be of four or five times the capacity of the transformer, and short circuiting the other windings. The tendency of the ends of the coils to flare out due to the excessive magnetic repulsion is the important point in this test. The test should be short, as the current is from 15 to 30 times normal.

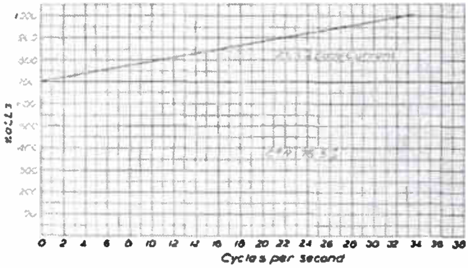


Fig. 64. Separation Curve

SERIES TRANSFORMERS

Series transformers designed to supply current for operating meters and relays are generally tested in groups of ten to twenty at a time. The tests made are: Cold resistance on the secondary winding (one out of every five), polarity, ratio, heat run and insulation. To test the insulation between layers, the transformers are run for one minute at full load primary current with the secondary open. The primary and secondary windings must be carefully distinguished. In series transformers the winding that is to be connected in series with the circuit is called the primary, and the primary leads are nearly always brought out through much larger bushings than the secondary leads.

Cold Resistance

When several transformers are tested at the same time, a measurement of cold resistance on the secondaries need only be taken on about one-fifth of the transformers in the group. The primary resistance is too low to be measured accurately, and this test is usually omitted. The same precautions must be observed on these transformers as on large transformers.

Polarity

Polarity should be carefully taken. If the polarity is not correct, trouble will be experienced in making connections for polyphase meter circuits.

Ratio

Instead of actually determining the ratio, the transformers are checked with a standard. The one selected as standard must be sent to the standardizing laboratory to be carefully checked for ratio at proper load and frequency. Having selected one of the group as a standard, connect the primaries of all the transformers in series. Short circuit all the secondaries as shown in Fig. 65; then connect the ammeter to the secondaries of the standard and check the transformer. This connection must be made with lamp cord or other suitable wire, and must be sufficiently long to allow the ammeter to be at least ten feet from the primary circuit in order to avoid the effects of stray field. Check the reading of the ammeter connected to the standard by means of another ammeter, bring the current up to normal and note the reading of the check ammeter. Now transfer the ammeter on the standard to another transformer and bring the current up to the reading previously noted or the check ammeter. When correct, read the ammeter on the transformer in test; if this reading agrees with the reading when the ammeter was on the standard the ratio is correct. Proceed in this manner until all the transformers have been checked with the standard.

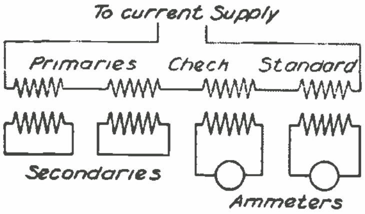


Fig. 65. Connections for Ratio in Series Transformer

New check readings are often necessary, due to unequal heating of meters and lines. Ratios should check within one per cent. Keep all secondaries short circuited except those to which the meters are connected. A few transformers of this type are built with two sets of windings; these should be tested as though they were two separate transformers.

Heat Run

On a new design of transformer a heat run should be made at normal primary current with the secondary short circuited until constant temperature is reached. Temperature rise by resistance should be taken hourly on one transformer out of every five, and thermometer temperatures on each one. When constant temperatures are reached, the transformer should run for two hours at the thirty minute load, which will be found stamped on the name plate. On transformers that are duplicates of some that have been previously built, a two hour heat run at the thirty minute load is sufficient. Measure hot resistances on one out of five and take thermometer temperatures on all. They should then be run for one minute at the thirty minute load with the secondary open to test the insulation between turns and between layers. This corresponds to the double potential test on other transformers.

The high potential test may be taken on several transformers at the same time. See that all secondaries and cases are properly connected together. Series transformers used in connection with potential regulators have the same characteristics as constant potential transformers and are tested as such.

(To be Continued)

NOTES ON ELECTRIC LIGHTING

PART III

BY CARYL D. HASKINS

MANAGER LIGHTING DEPARTMENT, GENERAL ELECTRIC COMPANY

We have now reached the third stage in our electric lighting problem—we must distribute our product. Not many years ago the distribution of electric current was the simplest, least technical, and least considered branch of the work of the central station engineer. This is no longer true. The problems of distribution—the opportunities for saving or loss in a good or bad system and the possibilities of increased dividends by a betterment of distribution—have been sharply accentuated.

The problems involved in distribution are many and, as a class, belong in a large measure to those which are often best solved by men who have come up from the bottom. The direct current system of distribution was, of course, the earliest phase of the situation and the simplest. Superficially, direct current distribution involved no technical questions; it was the lineman's problem. Soon, however, direct current practice tended toward underground work and became less simple.

Direct current service went underground first because it was early found to be suited to dense territories only—territories which did not lend themselves well to overhead wiring. To be sure, ten years ago many if not all large cities had a very high percentage of overhead wiring, but fire safety and estheticism speedily combined to put the wires under the surface. Incidentally, the telephone and telegraph wires were forced underground at about the same time.

The national decision that dense city wiring had to go underground brought the engineer face to face with new and serious wiring problems—mechanical as well as electrical problems, very difficult to solve in the light of the then existing knowledge. Much of the early history of underground practice was a history of mishaps, but rapid improvement in the art and a close study of its difficulties by a large number of men, many of whom made a specialty of this particular phase of the situation, largely overcame many of the problems. This underground work developed a new class of electrical engineers—engineers who of necessity possessed a precise knowledge of advanced chemistry.

The Edison three-wire system is the basis of all important current distributions for lighting, but long before this system was introduced, the so-called "Edison ring" system had been developed. The "ring" system effected no material saving in copper, but made a decided improvement in regulation. This was, perhaps, the earliest and simplest form of the multiple feeder system, in which the current might feed in either direction, according to the character of the load. The Edison three-wire system was the first to go underground in long sections, and the first satisfactory form of underground conductor was the so-called "Edison tube;" probably you are all familiar with it. It consisted of iron pipe within which the conductors were placed, solidly surrounded by a non-conducting compound. This compound changed with the advance of the art, but the construction used was too satisfactory to be speedily altered. The joining of the pipe was naturally a difficult matter and in the earlier days the joints were liable to failure and breakdown—a difficulty which yielded only to improvements resulting from experience.

One of the greatest difficulties in early underground work, a difficulty which occurred on lighting systems but to an even greater extent on railway circuits, was that of electrolysis. Dealing as we were in the earlier days with direct current, the grounding of circuits and the consequent tendency of current to go "crosslots" caused deterioration and ultimate breaking up of gas and water pipes by electric decomposition. This was at one time a very serious and alarming situation in many of our larger cities. Today we are practically free from this difficulty as a result of better insulation and construction. I specifically remember in one of our larger cities, not so very many years ago, a difference of potential of fifteen volts between gas and water pipes in the same cellar, a phenomenon of "homeless" current. I recall also an instance of a dishonest but ingenious person who operated a fractional horse-power motor between water and gas pipes. Some one paid for the current he used, but it was not he.

As I have already stated, the greater part of the troubles caused by electrolysis was due, not to electric lighting service, but rather to street railway service; in fact, it was owing to poor bonding of the rails, in consequence of which the rail current, with no low resistance return path, split up into devious crosslot paths through pipes and water.

Good modern practice tends toward underground service for both direct current and alternating current, through lead covered cable. This is the standard construction today for underground work. There is little need of going into the construction of lead covered cable; you are all familiar with it and know its many advantages. It stands well against disintegration, it is proof against constant immersion in water, and a tight "wiped" joint is easily and quickly made. Remember that the Romans could wipe a joint quite as well as we do today. For all these reasons and many more, leaded cables stand out practically ideal for most if not all underground service. Great lengths of leaded cable are today put down in open trenches, it being only necessary to place it far enough underground to insure adequate mechanical protection. The wiring in Central Park, New York City, which was very nearly completed when winter set in last year and to which approximately 1500 street lamps had been connected, is all underground, the cable being simply laid in trenches and given no further protection than the soil above it.

For street work, conduit has numerous advantages. With this construction it is customary to put down enough ducts to care for the requirements of years to come; the conductors being drawn in as more circuits are needed. In working with lead covered cable, it is feasible and usual today to trench and lay sufficient cable to take care of present needs, but repeated trenching for cable additions is both costly and inexpedient. Cable laying through manholes and conduit has been brought to a highly perfected state and a gang of five or six men will lay a surprising amount of cable in one day. As you probably know, the work has been commonly done by means of a drawing-in wire laid with the conduit. Lately there is a tendency to do away with this wire and most of the cable laying in certain large cities is done by sending a weasel (with a string) through the conduits after an imaginary rat. This is good practice; one may even say good engineering.

In the earlier days lines were run out, each independent of the other. In some of the larger cities we used to hear of the "Front street line," the "Smith street line," the "Market street line," etc. Each was entirely independent; today both alternating and direct current systems commonly have all lines and feeders tied together. They are, however, sectionalized and can be broken apart whenever occasion demands it. The average modern system stands as one big meshwork, with the net result that regulation is easy as compared with the early practice of separate lines, each with its separate load conditions.

Before going further, I have one more word to say about electrolysis. Electrolysis, quite aside from the waste of current, is very destructive of underground piping, with the result that this property of gas and water companies was, at some points in some cities, seriously impaired in a brief time. Serious accidents, directly attributable to electrolysis of gas and water pipes, occurred on several occasions. I recall one very serious accident in one of our large cities some years ago where electrolysis opened a gas pipe and a heavy leak followed. The leaking gas had pocketed in a large recess in some structural work and was ignited by a spark. A terrific explosion resulted; two street cars were blown up and five or six people killed or injured. Electrolysis is, in fact, replete with danger if proper engineering steps are lacking to safeguard against it.

Alternating as well as direct current lines must, of course, go underground in the very dense sections of large cities, for exactly the same reasons as those already given. In some cases even the transformers for stepping the voltage down to the requirements of house to house service are likewise placed underground in manholes. This practice is likely to grow more common with city growth. It is already common practice among the lighting systems of Europe, and is rapidly becoming so in the United States.

Alternating current is generally distributed on secondary circuits at about the same potential as direct current, and the wiring in dense districts is also tied together in a meshwork. It is common practice to bank transformers at the most efficient center of distribution, according to the distribution of the load. In good practice, the operating company of alternating current meshworks maintains curve drawing meters on the system, for the purpose of keeping a record of the voltage fluctuations under various conditions of load. The distribution of transformers and the arrangement of the secondary meshwork can and should be accurately determined from these records, and altered from time to time to suit the progressive change of conditions.

Recording voltmeters distributed over the secondary system indicate just what the voltage fluctuations are, and the transformers can be moved from center to center to maintain a balanced condition for the average load.

It must be borne in mind that long distance alternating current lines, and even short distance overhead lines, are liable to much disarrangement due to lightning discharges and other static disturbances. No such difficulty obtains, to any appreciable degree at least, in underground service. Where underground and overhead alternating current lines are in series with each other, this difficulty does occur and is probably somewhat accentuated. Where underground cable is brought into a central power station, as is common in large towns, the static charge, due either to the static induction of the system itself or to occasional static charges from atmospherical disturbances, makes necessary the installation of devices for the protection of apparatus and appliances within the power house. Today, almost all incoming cables in power houses are provided with "bell ends" on the lead jacket to safeguard both the cable itself and the station equipment from static discharge which otherwise might establish, and indeed often has established a breakdown "short" on the system.

Probably ninety-five per cent of the wiring that is employed in this country today for lighting and power purposes transmits energy in the form of alternating current. This alternating current line work varies all the way from lines of two or three No. 6 wires in the extreme rural districts, to the cables borne on the enormous steel tower constructions of the great long distance transmissions. The rural lines interest because it is through such lines that we are to take light and power to those 45,000,000 people already referred to.

The cost of these lines is an important controlling factor in the extension problem and varies enormously in different sections of the country and under different physical conditions. I know of lines—well built lines, thirty foot poles (perhaps a little too short), forty-five poles to the mile (which is fair rural spacing)—where the construction has been carried out, exclusive of the wiring, for $450 to $500 per mile. Such lines carry relatively low alternating current potentials, up to say 6600 volts. Above 6600 volts the cost goes up rather rapidly because of the cost of insulation. There exist, however, other somewhat similar lines carrying no more energy, but built in outlying territories under entirely different conditions at very a much higher cost; a cost which would be prohibitive for other than the suburban sections of large cities. In our larger cities, the cost of such work is probably about $1500 to $1800 per mile. There can be no doubt, of course, that from a purely engineering standpoint these "near city" lines are very much better constructed than the rural lines just referred to, but beyond a certain point it is a difficult matter to improve construction at a justifiable cost: a betterment of one per cent, for instance, beyond a certain stage, can not be obtained except at an increased cost of a much higher ratio.

Experience counts for much in line work. For example, no one can learn anything about setting poles from text books; in fact, one does not begin to learn very much about it by doing the work for six months or so. Many poles are today set in concrete, and in many soils this is not only good but economical practice. For example, with concrete the average hole does not have to be dug so deep, yet the pole is firmer. It may be pertinent to here give you a little "wrinkle" which has come to my notice in connection with pole setting in concrete. Instead of using broken stone, use cinders from the power station. This does not make as good a concrete for ordinary purposes, but for pole setting it is better, for, without other sacrifice, it has the advantage of materially lessening the labor and reducing the time necessary to break the poles out when this becomes necessary.

For the sake of estimate making, it may be assumed that the average cost of construction of alternating current lines in this country today, that is, lines of three wires, is probably about $750 to $800 per mile.

One of the most difficult problems for the electrical engineer to solve in connection with central station practice, is to determine what will be the cost, in relation to derivable revenue, of running an extension from the end of this sysem to some small community desiring service. There are a dozen or more such communities within twenty miles of most electrically served towns today crying for electric service, but the cost of running lines to them is high, and is commonly regarded as larger than the returns will warrant. This is one of the detail studies of the electric lighting industry which has as yet been gravely neglected. The engineers of the Pacific coast, however, are doing all sorts of things along this line; things which few eastern engineers would think of attempting. I know of one engineer of high standing in the far West who is operating a very large system and who has some hundreds of miles of power transmission under his supervision. I asked this engineer to how small a community he would go from his main line over a distance of say two miles. His answer was startling. He said, "It doesn't have to be a community; I never let any farmer within two miles escape me." His power is water-power, and he has more power than he needs for the present. He has capacity to spare, and it is his doctrine, probably a sound one, that his system can afford to take individual losses for the sake of upbuilding the system as a whole; in short, this man believes in the saying that, "where the wires go the load will grow," and it must be said that the history of his system justifies his faith.

(To be continued)

THE UNION BAG AND PAPER COMPANY, HUDSON FALLS, N.Y.

By John Liston

The group of paper mills operated by this company constitutes an important factor in the paper industry of the United States, as they have a combined production of 370 tons of paper per twenty-four hours. There are eight mills in the group, distributed as follows: One at Hadley, N. Y., three at Ballston Spa, N. Y., and four on the banks of the Hudson River, at Hudson Falls, N. Y., the location of the latter group being indicated by the accompanying chart.

The mills at Hudson Falls produce bags and Manila paper, and use both ground wood and sulphite, the total production of this group amounting to approximately 265 tons of finished paper per twenty-four hours.

In addition to the pulp and mill buildings the company operates a paper bag factory at Hudson Falls, which consumes practically the entire product of the mills.

The main forest preserves are located in Canada and in the Adirondacks, the wood being shipped from Canada by boat through Lake Champlain to Whitehall, from which point it is carried by rail to the wood yards at Hudson Falls. The timber from the Adirondack preserves is floated down stream to a saw mill located about 100 yards north of pulp mill No. 2, as shown in the chart.

The present company was organized in 1899, and thereafter acquired the various mill buildings which constitute the present Hudson Falls group. The machinery in these buildings was originally driven by water power supplemented by steam engines, but at present the water power is used largely for the generation of electric current, 74 motors having an aggregate horse-power of 4000 being employed for driving practically all the auxiliary machinery. The grinders,

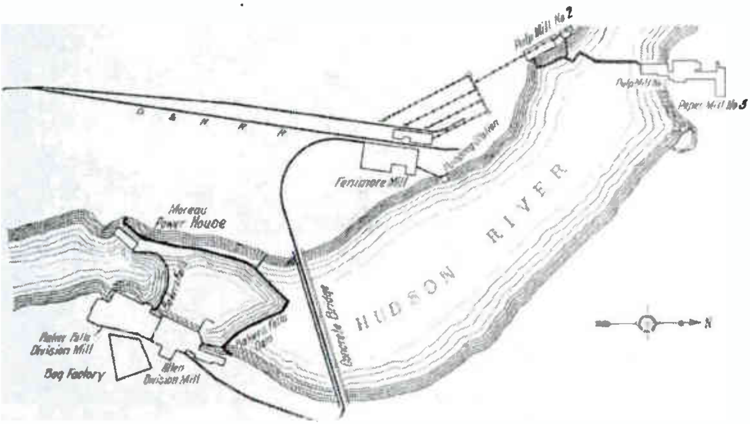


Fig. 1. Map Showing Arrangement of Buildings of Union Bag and Paper Company

however, are waterwheel-driven and one of the paper machines is driven by a steam engines, while others utilize motor drive.

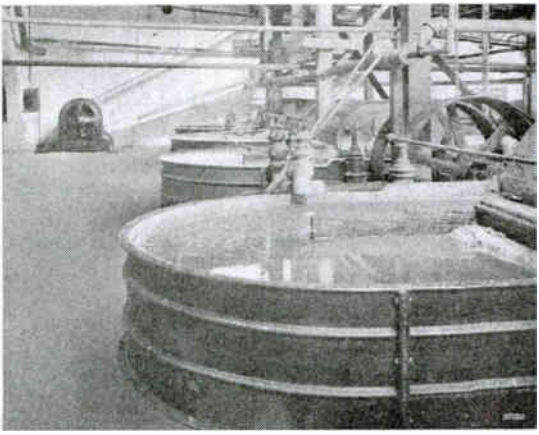


Fig. 2. 175 H.P. Induction Motor in Beater Room Allen Division Mill

At this point the Hudson River affords excellent water power facilities, as there is available at Bakers Falls an effective head of 58 feet, and in 1901 the first hydro-electric development was undertaken. This comprised an equipment of three 750 kw., 6600 volt, three-phase, 40 cycle generators connected to three 1200 h.p. Morgan & Smith double runner water turbines (Fig. 3). The exciters are direct connected. The effective head was obtained by means of a horse-shoe shaped crib dam thrown across the river just above Bakers Falls.

As the demands of the electric service increased it was decided to construct a second power station, which was erected on the opposite bank of the river and is known as the Moreau Station. A concrete canal was extended from the crib dam already referred to, and provision was made for the installation of five 2000 kw. generators, with separate penstocks for the operation of two exciters. The effective head in this station is also fifty-eight feet.

At the present time a single 2000 kw., 6600 volt, three-phase, 40 cycle generator direct connected to a double runner Hercules turbine, has been installed; a 150 kw., 125 volt exciter being separately driven by an 18 inch single runner turbine. This generator unit is shown on page 530. The available water at this point is ordinarily sufficient to supply the power demands of the plant, but in order to insure uninterrupted electric service in the event of low water or injury to any of the units in the hydro-electric station an auxiliary generator outfit has been installed in the Fenimore mill. This reserve equipment (Fig. 4) consists of a 1000 kw., 550 volt, three-phase, 40 cycle generator direct driven by a Hamilton-Corliss engine and provided with a belt connected exciter. An air blast

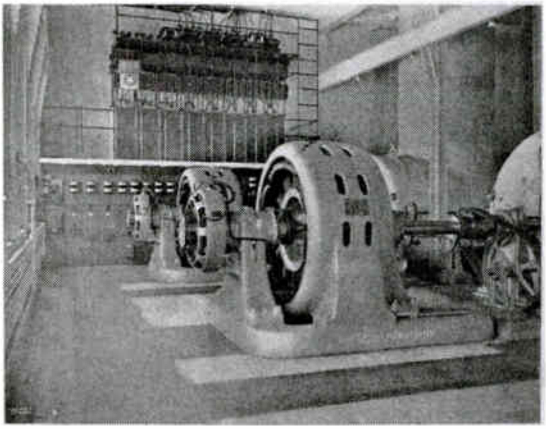


Fig. 3. Two of the Three 750 Kw. Waterwheel-Driven Generators in the Bakers Falls Power House

transformer of 1100 kw. capacity is used to step up the potential to 6600 volts, so that the current from the Fenimore power station may be switched onto the mill bus-bars and the reserve generator operated in multiple with either hydro-electric plant. The generators and exciters in all three power stations are of General Electric manufacture, and the type of air blast transformer installed in both the Fenimore and Bakers Falls power station is shown in Fig. 5. It consists of a three-phase Type AB transformer mounted over an air chamber, to which pressure is supplied by means of duplicate rotary blowers direct driven by 2 h.p. motors, one blower being held as a reserve.

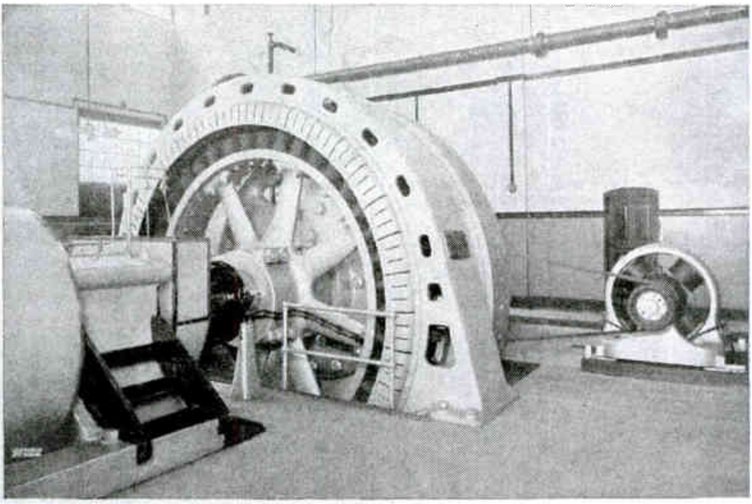


Fig. 4. 1000 Kw. 550 Volt Three-Phase 40 Cycle Engine-Driven Generator with Belted Exciter, Fenimore Mill

The extent to which electric drive is employed in these mills is indicated by the following description:

All the motors used to operate the machinery of the sawmill, paper mills and bag factory operate on 550 volt, three-phase, 40 cycle circuits, the General Electric induction motor having been adopted as a standard throughout.

In the saw mill, which is located some distance up stream from the mill buildings, all the machinery, consisting of two 65 inch circular saws, an air compressor for the log kickers, and a chain log conveyor, is driven in a group by a 100 h.p. motor. Current for these motors is transmitted to the saw mill at 6600 volts, and stepped down through transformers to the motor voltage.

Connecting the saw mill with pulp mill No. 2 are two wood conveyors, each of which has two branches driven by a 50 h.p. motor. The wood conveyor system is clearly indicated in the chart of Fig. 1, and for the various sections two 50 h.p., one 75 h.p. and one 20 h.p. motors are used.

When wood is received by rail it is rapidly unloaded into hoppers at the foot of the wood piles, and piled by means of extendable "butterfly" conveyors. These conveyors were especially designed by the engineers of the Union Bag & Paper Company and are motor-operated. They consist of a chain conveyor which starts from the hoppers already referred to and piles the wood rapidly as it is unloaded from the cars. Two of these equipments are used, both being operated by 15 h.p. motors inclosed in a small house at the top of the conveyors. When the wood pile has reached a height which limits the further operation of the conveyor, the

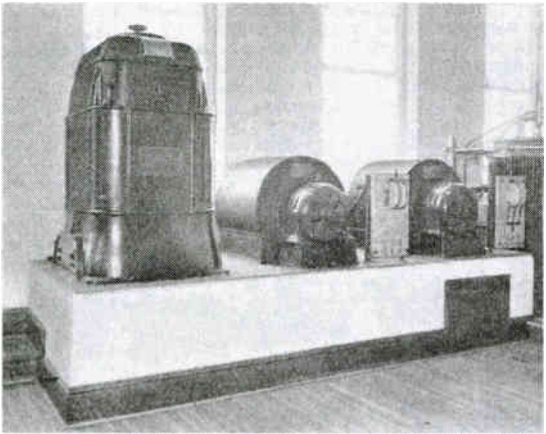


Fig. 5. 300 Kw. 6600/2300 Volt Air Blast Transformer with Duplicate Blower Outfit, Bakers Falls Power House

motor house is moved to the highest point on the pile and the conveyor lengthened by the addition of a sufficient number of chain links to give the required extension. By means of these butterfly conveyors the cars can be unloaded and the wood piled with a minimum of manual labor, and the wood pile carried to a much greater height than would ordinarily be economical. Both conveyors are provided with flaming arc lamps, so that operations can be carried on with equal efficiency day or night.

For conveying the wood from the piles to the wood room a motor-driven portable unloading conveyor is used, consisting of a 15 h.p., 1200 r.p.m. motor installed on a small truck running on rails set parallel to the wood piles. The conveyor can thus take wood rapidly from any section of the pile and transfer it to the main conveyor, which carries it to the wood room of the mills.

The main grinder stations at Hudson Falls consist of two pulp mills located at the ends of a dam which gives an effective head of twelve feet. Pulp mill No. 1 is located on the east bank of the river and is provided with four grinders, each being driven by a 56 inch vertical waterwheel. Water power is also used for the operation of the screen room and wet machines. The product of this mill goes directly to an adjacent paper mill (No. 5), in which a 66 inch waterwheel is used for driving four beaters. A 112 inch paper machine, steam engine-driven, is also located here.

Pulp mill No. 2 is located on the west bank of the river and is provided with eight grinders, each driven by a 56 inch vertical waterwheel, while an additional wheel of 48 in. diameter is used for the operation of five wet machines.

Immediately south of pulp mill No. 2 is located the Fenimore mill, which produce all the sulphite required for the group of mills

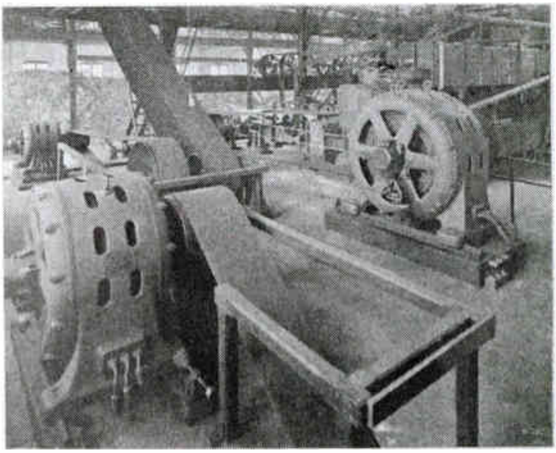


Fig. 6. 250 H.P. Motor Driving Eleven Centrifugal Screens, 75 H.P. Motor Driving Six Wet Presses and 150 H.P. Motor Driving Two 16 in. Centrifugal Stock Pumps, Fenimore Mill

at Hudson Falls. In the wood room a 200 h.p. motor drives two chippers, twelve barkers and a shavings conveyor, while a 150 h.p. motor, located in the basement, drives a splitter, shaving screen and a conveyor for carrying the shavings to the boiler house.

The conveyor for carrying the chips to the charging floor of the digester house is operated by a 30 h.p. motor, which also drives the exhaust fan for the digester house. Four digesters, 15 ft. by 49 ft., are used and for this reason a small passenger elevator is installed, being operated by a 5 h.p. motor.

The manufacture of acid is carried on in a separate tower constructed of brick; the electrical equipment consisting of a 10 h.p. elevator for conveying raw material to the charging floors, a 10 h.p. motor driving a draft fan for the sulphite burners, and two 15 h.p. motors which are direct connected to centrifugal acid pumps.

Water for the various processes in this mill is supplied by a pumping station located at the river's edge, as indicated in Fig. 1, and containing four triplex pumps and one 6 in. centrifugal pump, all driven by a 150 h.p. motor.

In the sulphite mill eleven screens are driven in a group by a 250 h.p. motor, while a 75 h.p. motor operates eight wet presses and a 150 h.p. motor two 16 inch centrifugal stock pumps, as shown in Fig. 6. These three motors are installed in a compact group, each one provided with a separate controlling panel. The stock is conveyed from the blow pits to the stock tank by means of a pump driven by a 85 h.p. motor.

Between the mill buildings and river bank two artesian wells have been sunk for auxiliary water supply, the air compressor and pumps for these wells being driven by a 40 h.p. motor.

The boiler equipment of this plant, in addition to furnishing steam for the digesters, is used for the operation of the reserve 1000 kw. steam generating outfit already referred to. Motor drive has been adopted for the boiler house, and a coal and an ash conveyor are each driven by a 10 h.p. motor. In the machine shop a 50 h.p. motor drives the entire equipment through shafting.

In order to facilitate the delivery of sulphite to other mills of the group, an industrial electric railway has been provided, crossing the river on a concrete arch bridge which, at the time of its construction in 1907, was the largest bridge of its type in the world. The motor cars for this railway consist of two street railway outfits which have been converted for the service. They operate on a 500 volt direct current circuit, current for which is supplied by a motor-generator set consisting of a 60 h.p. motor belt connected to a 400 kw. direct current generator, the set being located in the wood room of the Allen Division mills on the east bank of the river.

The group of mill buildings known as the Allen Division was originally designed for waterwheel and steam drive, and water power is still used for operating the grinders and screens in the Allen pulp mill. One 54 inch waterwheel, which formerly operated three Jordans, is now held in reserve, having been replaced by a 200 h.p. motor. The six paper machines included in the mill equipment are all motor-driven, three of them by a 250 h.p. motor and the remaining three by a 175 h.p. motor. This latter equipment replaces two steam engines which are now held as a reserve. One of these small paper machines is run at constant speed throughout, while the speed variation at the finishing end of the other two is obtained by means of a cone speed changing device on one, and a Reeves drive on the other.

In an electrically-operated mill it is possible to eliminate all mechanical means of securing the required variation at the finishing end of a paper machine, either by providing a motor-generator set and operating the finishing end by a direct current motor, or by adopting the type of variable speed induction motor which has been developed by the General Electric Company for this class of work.

In the beater room one 1200 lb. and three 850 lb. beaters and two mixers are group-driven by a 175 h.p. motor, while a 30 h.p. motor drives the elevator and cutting room machinery. A 17 h.p. motor is used for driving some minor special machines.

The last group of paper mills is known as the Bakers Falls division and is located immediately south of the Allen division; and, like the former, was originally steam- and waterwheel-driven. Some of the buildings in this group are very old, but electric drive has been as successfully adopted in their case as in the newer mills.

In the beater room a group of seven beaters and one Jordan is driven by a 250 h.p. motor, while a second group of four beaters and one Jordan is driven by 175 h.p. motor; this latter equipment being shown in

Fig. 2. Still a third group consisting of three beaters and one Jordan is driven by two 100 h.p. motors mounted side by side and belt connected to a common driving shaft. There is also a 30 h.p. motor used to drive a broke mixer.

All the paper machines in this division are motor-driven at constant speed. There are three 68 inch paper machines, driven respectively by two 50 h.p and one 60 h.p. motor, and two 59 inch paper machines, one driven by a 60 h.p. motor and the other by an 85 h.p. motor.

In the boiler house of the Bakers Falls division a 20 h.p. motor operates a draft fan and feed water pump, while various water pumps are driven by a 100 h.p. motor. The machine shop is group-driven by a 40 h.p. motor.

To the east of the Allen and Bakers Falls mills there is located the bag factory of the company, which utilizes a large percentage of the product of the mills in the manufacture of paper bags. This factory is equipped throughout with motor drive, current being taken from the circuits which serve the paper mills. The group systems of motor drive has been adopted for automatic bag machines, printing presses, embossing machines, cutters and finishing room machinery.

The entire electrical equipment at Hudson Falls is a good example of the adaptability of motor drive for mills which were originally designed for mechanical drive, and it

Fig. 7. General View of Bag Factory, Allen Division and Bakers Falls Paper Mills

ALLEN DIVISION MILLS

H.P.	R P M	Service	Location
60	800	Motor-generator set for industrial railway	Wood Room
10	1200	Elevator	Store Room
30	800	6½ in. x 8 in. Gould triplex water pump	
200	480	Two Jordans	
250	480	Three paper machines (44 in., 64 in., 66 in.)	
175	600	Three paper machines, three 6 in. centrifugal pumps, three 7 in. x 10 in. triplex stock pumps, one 12 in. x 10 in. vacuum pump, one 12 in. x 12 in. duplex vacuum pump, three screens, three agitators	
175	600	One 1200 lb. beater, three 830 lb. beaters, two mixers . . .	
1	1600	Forge blower	Machine Shop
30	800	One roll grinder, one rewinder, two paper cutters, one fan, two size mixers	Cutter Room

BAKERS FALLS DIVISION MILLS

H.P.	R.P.M.	[illegible]	Service
50	800	One paper machine (size 88 in.)	No. 1 Mill
30	800	Stock pumps for machine, chest, screens and agitators, two stock chests, machine striper, rewinder and beader in finishing room, elevator	
30	800	Broke mixer	
*100	400	Three beaters, one Jordan, one stock pump, 6 in. x 10 in. triplex, one stock pump, 7 in. x 8 in. trip, one agitator (twin)	No. 3 Mill
100	600	One 3 in. centrifugal water pump, one 8 in. centrifugal water pump one 6 in. centrifugal water pump, one 7 in. x 7 in. triplex pump for bag factory water supply	No. 3 Mill
175	600	Four 800 lb. beaters, one Jordan, two 7 in. x 8 in. triplex stock pumps one agitator	
85	800	One paper machine, 68 in., two 12 in. x 12 in. suction pumps, one 6 in. centrifugal water pump	
10	1200	Exhaust fans	No. 3 Mill
60	800	One paper machine, two 7 in. x 8 in. trip, stock pumps, two agitators	No. 2 Mill
60	800	One paper machine, 59 in.	No. 3 Mill
250	480	Seven beaters, one Jordon, two 7 in. x 8 in. triplex stock pumps one agitator, one 4 in. x 6 in. triplex pump	No. 2 Mill
*3	800	Blowers for air blast transformers	Power House
5	1200	Coal conveyor	Boiler House
20	800	Draft fan and boiler feed pump	Boiler House
40	800	Machine shop	
17	1200	Miscellaneous small machinery	No. 1 Mill

FENIMORE MILL

*10	1200	Coal conveyor	Boiler House
5	1200	Ash conveyor	Boiler House
*2	800	Blower for air blast transformers	Engine Room
12	1200	Centrifugal pump	Engine Room
150	600	Three 10 in. x 12 in. triplex double acting pumps—Two 12 in. and one 10 in. centrifugal pumps, and one cylinder water screen	Pump House
150	600	14 Barkers, one splitter and one shaving conveyor	Wood Room
200	480	Two clippers, one chip screen, one chip conveyor to chip screen, chip conveyor under re-chipper	Wood Room
		One crusher, one splitter, one worm conveyor	
5	1200	Elevator (passenger)	Digester Room
30	800	Chip elevator and exhaust fan	Digester Room
10	1200	Elevator	Acid Tower
*15	1200	Acid pumps	Acid Tower
10	1200	Draft fan for tubes and sulphur burners	Acid Tower
85	800	10 in. centrifugal blow pit pump and one 48 in. exhaust fan	Press Room
250	480	Twelve centrifugal screens and four flat screens	Press Room
150	600	Two 16 in stock pumps, press room screen, knot grinder, 6 in. centrifugal pump (from Jordon to stock chest) 5 in. centrifugal tailings pump, and 8 in. centrifugal water pump	Press Room
75	800	Eight wet machines, agitator in concrete tank, two knotter screens and one stock thickener	Press Room
50	480	One 8 in. x 8 in. triplex vacuum pump, one 18 in. x 18 in. Gould single acting pump, one 4 in. centrifugal pump stock (from screens to wet machines), 5 in. centrifugal pump (hot water from tanks to blow pits) and repair shop	Press Room
50	800	One 10 in. centrifugal white water pump from wet machine to screens	Press Room
10	1200	Machine rewinder, elevator and ventilating fan, calendar reel winder	Machine Room

* Two motors.

also indicates the flexibility of the system and ease with which additional electrical equipment may be provided for by means of auxiliary generating stations. As in other paper mills which were originally designed for steam and waterwheel drive and which later adopted electric drive, the initial electrical installation in this mill has been followed by a rapid extension of motor drive, as the benefits of the new system were demonstrated in actual service. From the foregoing description it will be seen that, except for the grinders, a very large percentage of all the machinery is electrically-operated, and present plans for the extension of the electrical equipment indicate the satisfactory service which the induction motor renders under the severe demands of paper mill work.

Realizing that the induction motor can be applied with entire success to the operation of grinders, the Union Bag and Paper Company are at present equipping a grinding station with induction motor drive near their Canadian forest reserve. Twelve hundred h.p. motors will be used for each pair of grinders, the grinder shafts being coupled direct to either end of the motor shaft.

The hydro-electric plants at Hudson Falls not only supply ample power for the electrical equipment of the mills, but furnish current to the towns of Hudson Falls and Fort Edward, and also transmit current at 22,000 volts to the Mechanicville substation of the Hudson Valley Railroad.

Illumination for the mill and factory buildings is provided by means of incandescent lamps and a limited number of arc lamps; flaming arc lamps being used for outside night work, while for the bag factory, with its high ceilings, forty enclosed arc lamps are employed.

NOTES

The twenty-sixth annual meeting of the Association of Edison Illuminating Companies was held at "The Frontenac," Thousand Islands, N. Y., last September, 6th to 8th. The convention was largely attended, and a great many valuable and interesting papers were read and discussed. At its conclusion the President, Mr. Thomas E. Murray, was re-elected for another term, as were also all the other officers of the Association. The meeting was brought to a pleasing finale with a banquet on the evening of September 8th, at which Mr. and Mrs. Thomas A. Edison were the guests of honor.

Charles P. Steinmetz and Thomas A. Edison

Dr. C. P. Steinmetz was one of the delegates appointed to represent the General Electric Company, and we are able to reproduce an interesting "snap-shot," taken during the convention, of these two "Masters of Science," Thomas Alva Edison, who initiated the era of dynamic electricity for incandescent lighting and power in 1880, and Charles Proteus Steinmetz, who has devoted his profound knowledge of mathematics to the solution of the many intricate problems involved in alternating current phenomena and their practical application to commercial uses.

* * * *

During the month of October the following student engineers entered the Testing Department of the General Electric Company:

Billingsley, D. W., Mississippi A. & M. College
Bressler, R. A., Swarthmore College
Burleson, C. A., Sheffield Scientific School
Canfield, R. B., Sheffield Scientific School
Carpenter, C. T., University of Utah
Clemson, W. E., Columbia University
Coffin, L. F., Swathmore College
Collins, E. B., Worcester Polytechnic Institute
Cummings, H. L., Jr., University of Utah
Ehrlich, L. B., Alabama Polytechnic Institute
Fagley, G. H., Bucknell College
Faulkner, J. C., Alabama Polytechnic Institute
Gebhardt, E. F., Jr., University of Vermont
Kenyon, R. E., Oklahoma A. & M. College
McSpaden, L., University of California
Mohus, C. E., Alabama Polytechnic Institute
Montgomery, W. McV., Virginia Polytechnic Institute
Moyer, L. M., University of Washington
Murphy, W. P., Pennsylvania State College
Musser, H. P., Virginia Polytechnic Institute
Parker, A. A., Lehigh University
Parsons, L. W., Pennsylvania State College
Pine, P. P., University of Colorado
Schweckert, T. C., University of Virginia
Shelton, E. K., University of Washington
Shiels, R. T., A. & M. College of Texas
Sonntag, A. H., University of Illinois
Stang, P. A., Syracuse University
Summer, W. C., Pennsylvania State College
Swenson, I., Pratt Institute
Tait, W. J., University of Montana
Tull, I. N., N. C. College of A. & M. A.
Wathen, T. N., University of Texas
Watson, W. C., Worcester Polytechnic Institute
White, E. O., University of California
Williams, W. G., University of Oregon
Wise, E. M., Jr., University of Texas
Zimmerman, H. R., Oregon Agricultural School