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GENERAL ELECTRIC REVIEW

VOL. XIII, No. 8

AUGUST, 1910

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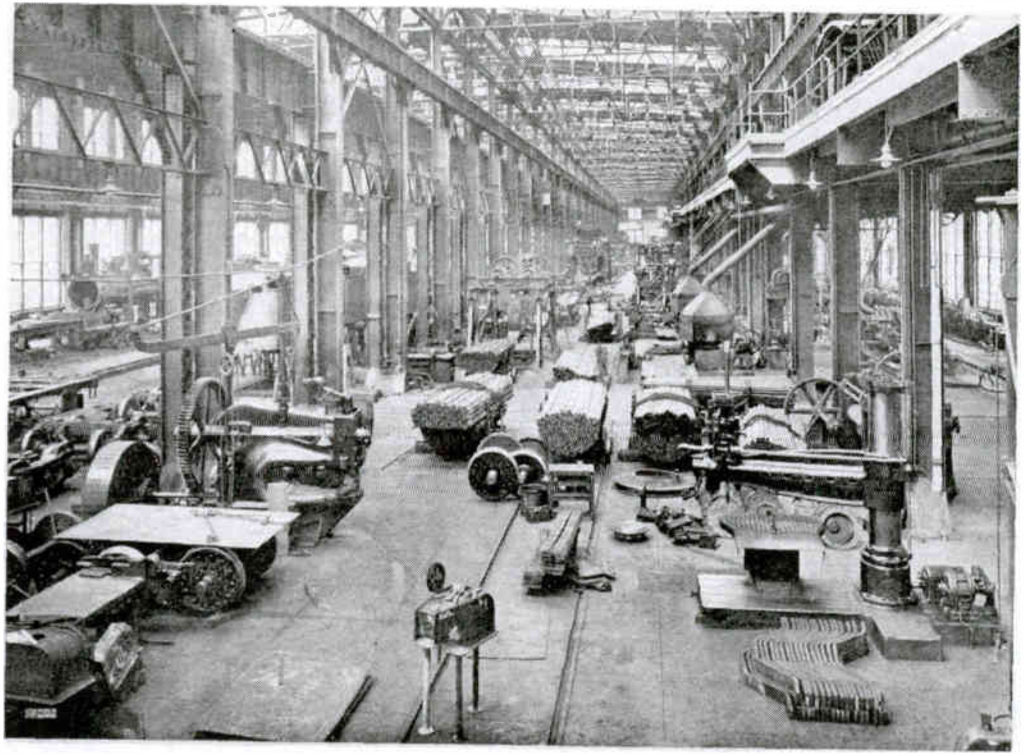

General View of Repair Shop of N. Y., N. H. & H. R. R., Readville, Mass.
(See page 367)

GENERAL ELECTRIC
REVIEW

LUMINESCENCE

The problem of artificial lighting has confronted mankind since the dawn of history; but, as in many other fields of endeavor, a greater advance has been made in the past century—and more particularly in the last 30 years—than in all the centuries that went before; the lamps of our forefathers in the 18th century being but little better than those used by the ancients, the main dependence for artificial light being placed upon candles.

The first real advances over the use of the candle were the introduction of illuminating gas, in the early years of the 19th century, and the replacement of sperm oil by kerosene which followed the discovery and development of the oil fields. The next epoch-making advance came with the utilization of electricity in the carbon arc light and the incandescent lamp.

Thus far the phenomenon of luminescence played no part in commercial lighting; the light both from the carbon arc and the incandescent lamp is due to temperature, the temperature of the upper electrode (mainly) and of the filament, respectively. Thus the light obtainable from these sources is limited by the temperatures available: *viz.*, the boiling point of carbon in the case of the arc—3750 deg. cent.; and about 1800 deg. cent. in the case of the carbon incandescent lamp, a higher temperature than this causing an excessive deterioration of the filament by evaporation. Were it possible to operate the filament at higher temperature switchout deterioration, the efficiency would be materially bettered, as that portion of the total radiation which is visible increases with the temperature. Along these lines there has been much research to obtain a material sufficiently refractory, and with a vapor tension low enough to withstand higher temperatures without evaporating. The "metallized" carbon filament, on account of its low vapor tension, was a long step in the right direction and reduced the power consumption to 2.3—2.6 watts per candle-power. Far superior, however, are the metals osmium, tantalum, and tungsten. With these metals, the operating temperature is limited by the melting point—not by evaporation as in the case of carbon. Of the three tungsten is the best, reducing as it does the power consumption to between 1 and 1.25 watts per candle-power. Happily, the available supply is practically unlimited.

While tunsgten is to-day the best material for the purpose, it is curious that Mendelejeff's periodic law indicates the existence of a metal, as yet unknown, of even higher melting point, which should therefore serve still better as a filament.

It has been suggested, however, that we may not have exhausted the possibilities of carbon, and that in some one of its allotropic forms, it may again take the lead as the most efficient filament.

As has been said, both the light from the carbon arc and from the incandescent lamp is due to and depends upon temperature, but the phenomena of luminescence—as explained by Dr. Steinmetz in his article on the subject in the present issue—do not follow the temperature law. Not only does the efficiency of light production fail to increase with the temperature, but sometimes quite the reverse. The author explains that the phenomenon consists essentially in setting the particles of the illuminating material in vibration under such conditions that they can vibrate at their natural frequency, thus producing characteristic radiations. When the selective radiations are within the range of the visible spectrum, a light of characteristic color results. The author shows that there are two convenient ways of obtaining these phenomena, *chemically* and *electrically*. The former method is used commercially in fireworks and signal sights, while the latter—which is by far the more important of the two—is exemplified in the Moore tube, the mercury arc and the flame arc lamps.

Electro-luminescence may be produced

in two ways, *i.e.*, by disruptive conduction and by continuous conduction. Disruptive conduction, of which the Geissler tube is an example, has been employed to very little extent commercially. A relatively high voltage is required at the terminals, and in order to obtain reasonable efficiency, the tube must be very long, so that the useful energy expended in the stream may be much greater than the energy lost at the terminals. For this reason, the tubes are essentially large units.

In the case of continuous conduction, in contradistinction to disruptive conduction, the current generates its own conducting vapor by evaporating the electrode material. Examples of this may be seen in the flame and luminous arc lamps. In the ordinary carbon arc lamp, the arc stream is almost non-luminous, practically all the light coming from the heat of the electrodes. In the flame and luminous arc lamps, on the contrary, it is the arc stream itself that is the source of light; this light being due to luminescence and the color depending upon the material of which the electrodes are composed. The efficiency of the light production therefore depends upon selecting materials for the electrodes such that a large proportion of the radiations will be in the visable spectrum. The best materials for this purpose are mercury, calcium and titanium. The first of these is used in the mercury arc, the last two in the flame and the luminous arc, respectively, *i.e.*, calcium giving a characteristic yellow-orange colored light of high efficiency, and titanium an exceedingly efficient white light.

To introduce the luminescent materials into the arc stream two methods are employed, *electro-conduction* and *heat evaporation*. In the former the luminescent material is placed in the negative electrode and itself forms the vapor that conducts the current. Lamps of this description are called "*luminous arcs*."

The lamps employing the method of heat evaporation are called "*flame arcs*;" in them the luminescent material does not engender the arc stream but is introduced into it by being vaporized by heat from one or both of the electrodes. An intensely hot arc is necessary in this case and the carbon arc is used, the calcium or other material being mixed with the hotter positive electrode, or sometimes with both electrodes.

Each of the above methods has its advantages and its disadvantages. In the case of electro-conduction, higher efficiencies may be obtained and, since the material forms the arc by electro-conduction and not by heat, the electrodes may be of any convenient size. The positive may therefore be permanent and the negative of such a size as to last for 100 or 200 hours.

On the other hand, the substances that can be used for electrodes are limited. Calcium can not be employed as no stable compound of calcium is known that forms a conducting vapor. When operating on the alternating current the choice of electrode material is even more limited, titanium carbide being the one titanium compound that seems to be satisfactory.

With the method of heat evaporation, however, the choice of luminescent materials is wide. The material need not be conducting, the carbon with which it is mixed furnishing the conducting vapor. Calcium compound may thus be used, as may a number of other substances that are not suitable for the luminous arc. The employment of carbon also insures a steady light, and, furthermore, renders the arc easily operative on the alternating current. On account, however, of the high temperature that must be maintained at the end of the electrodes, these must be small, and for this reason their life is short.

To summarize: of the three best materials for electro-luminescence, mercury is used in the mercury arc lamp, and the arc stream is supplied by electro-conduction from the negative; calcium is used in the flame arc and is invariably fed into the arc stream by heat evaporation from the positive electrode, or sometimes from both electrodes; titanium is usually employed in the luminous arc, and itself furnishes the arc stream from the negative electrode. It is also used in the flame arc lamp, when it is fed into the stream by heat evaporation.

By means of these materials efficiencies have been obtained far better than have ever been secured by temperature radiation. A specific consumption of 0.25 watts per candle-power is not uncommon with large flame arcs, and even better efficiencies have been noted. In fact there seems to be no limit to the possible efficiencies that may be reached through research in the field of luminescence.

POWER IN THE SILK MILL*

By Andrew Kidd, Jr.

Consulting Engineer

The object of this article is to endeavor, as far as possible, to point out to silk manufacturers and their operating superintendents the advancement that has been made in recent years in the driving of the different machines used in the silk industry.

It has been the privilege of the writer to follow closely the power requirements of silk mills for several years past, and, consequently, he has been brought in contact with all sorts of conditions.

The larger silk manufacturer is willing to spend judiciously far more money in proportion on his power equipment than the smaller manufacturer, if he estimates that his cost of production per yard will be correspondingly reduced or the quality of his product improved.

The cost of power in the average mill is probably less than 2½ per cent. of the finished product; therefore, a manufacturer can afford to allow an increase in the cost of his power if by so doing he can increase his production with practically the same operating expenses.

Many manufacturers rent their buildings with power. Those who generate their own power should investigate existing conditions from the coal to the finished product. It sometimes appears that a cheaper grade of coal is more advantageous than the higher grades, but this is not true except in very few cases. The cheaper grades of coal do not have the same number of heat units as the better grades, consequently, there is more firing, more ashes, more cleaning of boilers, etc., for the same amount of horse-power delivered.

In the older mills the boilers installed carry from 80 to 90 pounds pressure; in recent years the tendency among all textile manufacturers has been to install boilers for 125 to 150 pounds pressure.

In selecting an engine for motive power, the question is raised as to whether it shall be a Corliss, a high-speed type, or a steam turbine. If the plant is to be mechanically driven, the Corliss or high-speed type is applicable; but should electricity be under consideration as a means of distributing power, the steam turbine can be adapted under certain conditions. The high-speed engine, which is the cheapest in first cost, does not have the life of the Corliss or the steam turbine. The maintenance item on the high-speed engine is, consequently, more than on either of the others.

In many cases all exhaust steam from the engine can be used for process work or for heating the buildings in winter, and on units up to 150 horse-power it is a question whether or not a condenser system in connection with the engines will pay, if the exhaust steam can be used in any way. With an engine probably the condenser will not pay in any event, as the depreciation, interest on investment, and cost of power required to drive the auxiliaries relative to the condenser apparatus, will be a greater item than the amount of coal saved when running the plant non-condensing.

Every engine room should be equipped with a steam engine indicator, and cards taken at least once a week; or, what is much better, if the plant is equipped electrically, a recording wattmeter should be installed and readings taken every half day and averaged every week. The indicator cards will give a general idea as to power conditions in the mill. They will show, assuming that the mill is running under normal conditions when the cards are taken, whether or not the line shafting is still true and whether any abnormal conditions exist in the drive. The wattmeter readings will give the exact amount of power used in the mill, and these readings, together with the number of yards produced, furnish a very accurate record of the power requirements; in fact, in some large installations a wattmeter is placed in each department, so that an exact record may be kept of the power required to run that particular branch.

The mechanical system of driving is efficient if the mill is a one-story building of short length, and the power house placed in the center of the drive; but even in such cases, the many advantages of electric drive often call for its adoption. Where cross-belts, right-angle turns and the transmitting power from floor to floor and from building to building is considered, the efficiency of this plan is not comparable with that of the electric drive.

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* Reprinted from Silk.

Fig. 1 shows an indicator card taken on an engine driving only the line shafting in a large silk mill, and Fig. 2 the card taken when the mill was in full operation. From these cards it will readily be seen that the amount of power necessary to turn all the line shafting, belts and loose pulleys is a large percentage of the total horse-power delivered by the engine when working under full load conditions.

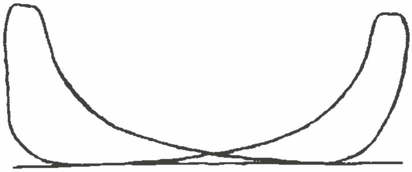


Fig. I.

Showing an Indicator Card Taken on an Engine Driving the Line Shafting Alone in a Large Silk Mill

Should the mill be one of fairly good size, the mechanical drive is not so efficient as the electric drive, since considerable line shafting and the large, heavy belts used for the main distribution of power are eliminated.

When considering the electric drive for a mill, the first point to be settled is the current to be used. The silk manufacturers and their operating superintendents are not always familiar with electrical subjects and are therefore not in a position to decide whether they should install alternating or direct current machines, and for their benefit I would like to point out the many advantages of the alternating current over the direct current for silk mill work, except silk printing, where the direct current is better suited

Direct current is equal in every respect to alternating current for lighting, but owing to the inherent characteristics of a direct current motor, it is not so suitable as the alternating current (known also as the induction) motor for power in the case of silk mills. The direct current motor, if allowed to run under load, will change its speed from 5 to 10 per cent. from 7:00 a.m. until 10:00 a.m.; that is, at 7:00 a.m the line shafting may be running at, say, 130 r.p.m., and if the speed of the motor is not regulated by the person in charge, at 10:00 a.m. the line shafting will be running at approximately 138 r.p.m.; consequently, the driven machines, whether they be throwing preparatory or looms, will have a corresponding increase in speed. If these machines will run satisfactorily at the higher speed, then while the motor is increasing in speed the manufacturer is losing an amount of production proportional to the difference between the speeds.

In mills having the direct current motor, a field rheostat is usually installed in the circuit, so that the speed of the motor can be regulated, thereby maintaining a constant speed on the line shaft. Regardless of the design or make of the direct current motor, this condition of speed change, due to the heat, is bound to exist, and necessitates manipulating a field rheostat to maintain an approximate constant speed. With the direct current motor the commutator and brushes must be inspected continually. After reasonable length of time, the commutator will necessitate truing up and the brushes are bound to wear out; thus the maintenance item should not be overlooked. Another feature is that the direct current motor should not be run at a load which exceeds its nameplate rating, as it is liable to spark and set fire to the lint and fly common in textile mills.

The alternating current motor does not have any of these features, as it is without commutator and brushes, and, with the exception of a slight variation due to changes in load, its speed does not change except with a change in the speed of the generator in the power house.

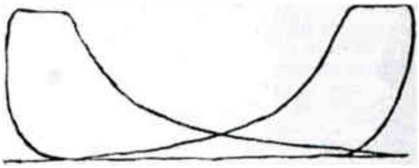


Fig. 2.

Showing an Indicator Card Taken When the Mill was in Full Operation

The remainder of this article will deal principally with the alternating current system, as it is without question the better suited for silk mills.

The switchboard of to-day is somewhat different from that built years ago. In the olden days any board equipped with a voltmeter, ammeter and main line switch was considered sufficient; to-day there is as much attention given to the switchboard as to either generators or motors.

When there is both a motor and a lighting circuit on the generator, there should be installed an ammeter in each phase of a two- or three-phase equipment, so as to be able to determine whether the generator is properly balanced. Any unbalancing is due to an uneven distribution of lamps on the different phases, for when the generator is delivering power for polyphase motors only, the current in each phase is the same.

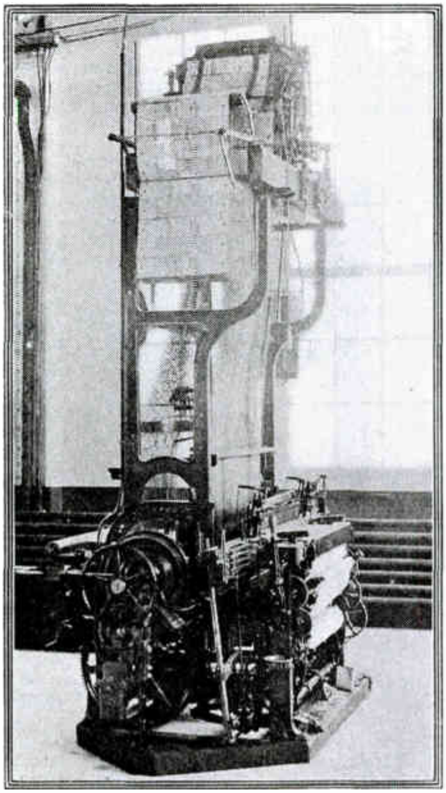
It is advisable to have a recording wattmeter on the board, or, if the plant is of sufficient size, a wattmeter can be placed in each circuit.

Knife switches with enclosed fuses are suitable for 220 volt power feeder circuits, but when 440 or 550 volts are used, these circuits should be controlled by oil switches having overload release. Knife switches on these higher voltages will hold an arc which not only burns the contact parts, but also mars the slate or marble board. This does not occur with oil switches, as the operating mechanism is usually the only part of the switch on the face of the board, while the switch itself is supported back of it. As the contact parts are immersed in oil, there is no injurious arcing, for when the circuit is broken the oil suppresses any arc which may occur; moreover, the oil switch is an important factor of safety to the operator.

The lighting circuit of 110 volts can be obtained by either balancer coils or transformers. Knife switches are suitable for the control of these lighting circuits.

A 220 volt circuit is suitable for most silk mills, but where the buildings are scattered and long circuits required, the voltage should be either 440 or 550. This reduces the size of wire necessary to transmit the same amount of horse-power. In choosing alternating current motors, the phase, frequency, efficiency, power factor and slip should be considered, and the most important of the last three items is the slip.

The grouping of machines under one motor is next to be considered. The motor should be placed as near to the center of the power load as possible; right-angle turns in the drives being avoided, and also belts from one floor to another. Motors from 15 to 25 horse-power in capacity are best suited for either a throwing or weaving mill; for when the motors are larger a large part of the flexibility of electric drive is lost, and with the squirrel cage rotor type of motor which is commonly used the starting current is relatively large. The current when starting under load amounts to between three and four times the normal running current, so that, should a large motor be thrown on a generator of limited capacity at a time when other motors and lights were in operation, this excessive current would mean a sudden overload on the


Individual Motor Drive Applied to Jaquard Loom

generator, which would show up principally in a dip or flicker of the lights.

High speed motors should be installed whenever possible, as the power factor and efficiency of these motors is better than that of the slow speed motors.

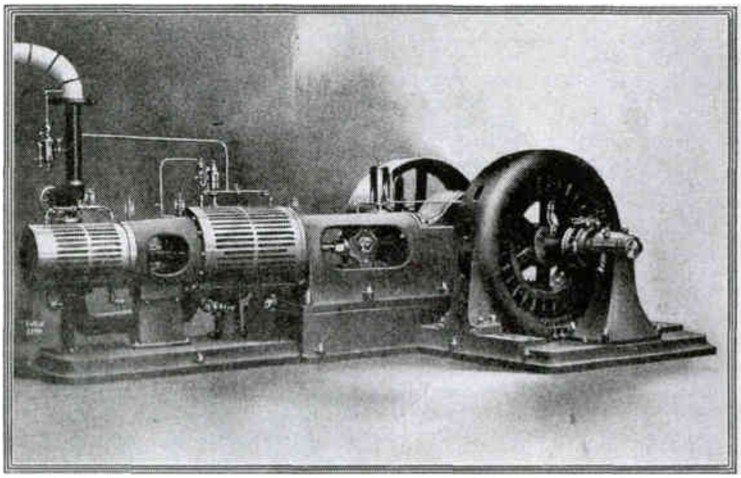
The slip of an induction motor is the difference in speed caused by a difference in load and, in the writer's opinion, it is far more important than efficiency. A motor with 4 per cent. slip and 87 per cent. efficiency is preferable to a motor with 6 per cent. slip and 89 per cent. efficiency, especially in the weave shed, where the load on the motor may vary from 40 to 100 per cent.

The group system is the most used, but the individual system for looms is coming into popular favor, as some of the largest silk manufacturers have adopted it and have pronounced it a decided success.

This individual system has not the same advantages for throwing machines or preparatory machines, such as warpers, winders, quillers, etc., that it has for looms, as the load factor on the former machines should be about 100 per cent. The preparatory machines take very little power—winders and quillers about ⅜ horse-power each. The driving of these two machines calls for a constant load, but when we take the warping machines, the conditions are entirely different, especially when beaming is in progress.

During the process of warping the power required is approximately ¼ horse-power. When the operation of beaming starts the power required is approximately ½ horse-power, and this increases as the roll becomes larger in diameter and more weights are added, until the warp is about beamed, when the motor is called upon to give about 1¼ horse-power. This will cover about all warpers that are beaming less than 20,000 ends, and with a length of warp of approximately 450 yards.

On one occasion the writer installed the individual drive on some warpers and a ¾ horse-power motor was used, this motor being capable of delivering for very short periods



105 K.W., 60-Cycle, 3-Phase Generator Direct Connected to Tandem Compound High Speed Engine

of time, up to 1½ horse-power. It was found later that the operator could not put the required tension on the warp, and that when this was attempted the motor was stalled. The motor was tested out and it was found that the power taken when stalled was between 1¾ and 1⅞ horse-power.

On further investigation, it was found that the warp consisted of 40,000 ends and extra-heavy weights were used. This condition is the exception rather than the rule. A 1½ horse-power motor was then installed and tested under similar conditions as before, when it was found that the maximum power required was 2¾ horse-power.

The warping operation lasts from four to six days, which, as explained, requires ¼ horse-power, and the beaming lasts from 2½ to 4 hours and requires from 1¼ to 2¾ horse-power. The load is very intermittent while beaming, as the operator is required to stop very frequently to tie threads, etc. It is evident that the individual system for these machines entails a comparatively greater outlay of money than that required by the group system. It is seldom that out of ten warpers there are more than three beaming at once, and the overload capacity of the large motor in the group system would easily take care of this heavy power condition, giving the group system a far higher efficiency and the circuit a better power factor.

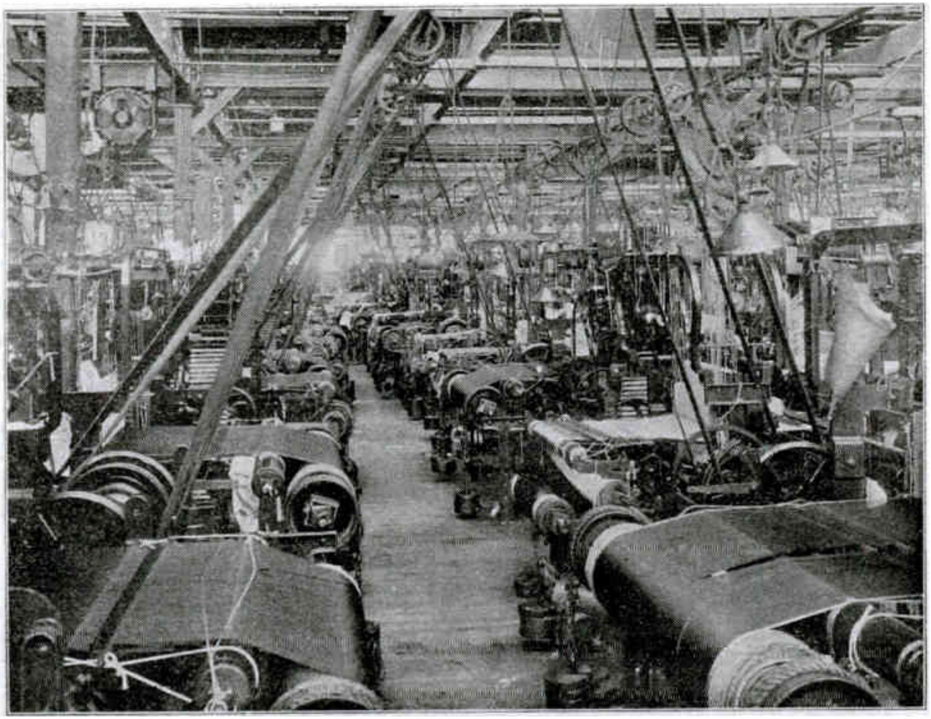
The efficiency of the mill is *no more* with the individual system than with the group system, and, when purchasing motors for the individual drive of looms, one should not be led to believe that it is. The efficiency of a 20 horse-power motor, used in the group system, is approximately 88 per cent., while the efficiency of a ½ horse-power motor, used in the individual system, is approximately 70 per cent. It can readily be understood that this loss is equal to, or greater than, the loss of a belt transmission from the motor to the line shaft and from the line shaft to the loom. However, there are points more vital than efficiency to be considered, first among which is the increased production, then low maintenance cost, absence of oil and dirt overhead, absence of belts, better light (both natural and artificial), and the convenience of placing machines in any position without regard to line shaft.

The individual drive facilitates the easy changing of the speed of looms to suit different classes of silk. These changes are made by using different pinions on the motor, one pinion tooth making a variation of approximately 7 picks on the loom.

The horse-power of the motors used on looms differs materially and depends on the width of the loom, number of picks per minute, class of goods, and whether or not the motor starts and stops with the loom. The practice most commonly followed is to start and stop the motor with the loom. With this method there is an element of flexibility, usually a slip gear, installed in the drive, and the throwing of the shipper handle operates an oil switch which starts and stops the motor; in fact, the operation for the weaver is exactly the same as when the tight and loose pulley or friction pulley is used. There are many equipments installed where the friction pulley is retained and the shipper handle mechanism connected in such a way that the oil switch is thrown just a trifle sooner than the friction clutch, the theory being that the motor has a chance to accelerate at least part way before the load is thrown on. Should the oil switch be thrown in with no element of flexibility in the drive (either a slip gear or a friction pulley), considerable damage would result to the warp, which would show up principally in broken threads, owing to the fact that the motor would start the loom too suddenly.

The motor used on the individual drive must have sufficient capacity to start the loom quickly and make a good, clean pick, throwing the shuttle full across the loom; also to force the filling thread back against the weave, so that there will be no marks in the cloth. If the motor is too small it will pick up too slowly, and the above difficulty will become evident. If the motor is of too large capacity, the starting of the loom can be regulated by the tension on the slip gear or the friction clutch.

On looms from 27 in. to 36 in., a ⅜ horse-power motor should be used, and from 36 in. to 60 in., a ½ horse-power motor. On box looms a ¾ horse-power motor should be used, as the mechanism of this loom is heavy and the loom usually wide, even though the speed rarely exceeds 110 picks per minute. It takes almost as much power to run these looms up to speed without a warp as it does to run them when the weaving is in progress. Velvet and plush looms are heavier, and a one horse-power motor is usually installed.



Weave Shed Under Group Drive. Motor Suspended From Ceiling

Regarding narrow fabric looms, the operation of this loom is somewhat different from that of the broad looms. Under this class of fabrics would be placed silk ribbons, hatbands and elastic goods. The element of flexibility is not provided with these looms, as the mechanism does not require it. The quicker the loom can start and get in full operation the less liability there is of having a mark in the weave.

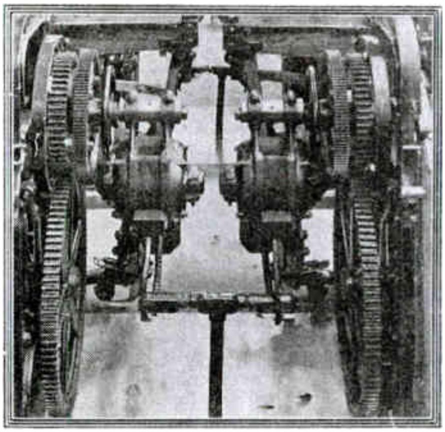
On the silk ribbon and hatband looms the motor is geared direct to the loom, and is started and stopped by means of an oil switch. The size of the motor on ribbon looms varies from ¼ to ½ horse-power, depending on the number of shuttles. Hatband looms run with approximately the same power requirements but the elastic looms take considerably more power and are usually run at a higher speed. The tension of the elastic calls for considerable power, and in some cases the number of picks per minute on these looms is as high as 155. The ordinary elastic loom requires about a ¾ horse-power motor.

On the elastic looms the motor is kept running, and the loom is started and stopped by means of a friction pulley. The starting torque required of the motor to get these looms in operation is so high that it would be practically impossible to start and stop the motor with the loom unless an exceptionally large motor was furnished, which would have poor efficiency and also low power factor; besides, the first cost would be exceedingly high, and the advantages to be gained would not compensate for the difference.

The wiring for the individual drive should be so arranged that there will not be more than ten motors on one circuit. Each motor is protected with its own set of fuses, and can thereby be cut out of the circuit should change be necessary.

In choosing a generator to supply current to these individual motors, particular attention should be paid to the power factor of the circuit, which is, normally, around 55 per cent. This low power factor does not necessitate the burning of any more coal, but does call for a larger generator than would be necessary for a motor load having a power factor of 85 per cent.; and, unless the generator is designed to take care of this condition, it will become overheated.

In the beginning of this article it was stated that the direct current is best suited for silk printing machines. This is true, because a great variation of speed is required. The alternating current two or three-phase motor cannot be adapted efficiently to meet this requirement.



Method of Mounting Motor to Loom

Among those in charge of silk printing establishments, there are a few who realize the many advantages of the electric drive or printing machines. There are two methods of driving these machines: one by armature and field control, and the other by the Ward-Leonard system.

The armature and field control method is the cheaper to install, as the speed variation necessary is obtained by resistance inserted in armature and field circuits, and only one generator for the total number of printing machines is essential. The speed is controlled by the ordinary type of rheostat placed on the frame of the machine, easily accessible to the operator.

The Ward-Leonard system is a method of motor control in which the speed variation is obtained by changing the strength of the generator field, which causes the voltage of the circuit to vary accordingly. The speed of a direct current motor will vary directly and almost in proportion to the voltage across its terminals. This system of driving necessitates a separate generator for each motor, which makes it decidedly more expensive to install, but it has advantages over the armature and field control system, and the most important one is the speed regulation, for, by the Ward-Leonard system, the finest increments of speed change can be obtained. The controller can be placed on the machine in a manner similar to that followed for the armature-field control system, or it can be placed on the ceiling or wall near the printing machine and a push-button block mounted on the machine.

This push-button block has four buttons—accelerating, decelerating, stop and lock. By pushing the accelerating button the motor will start and accelerate in speed until the button is released, when it will run at a constant speed. Should the operator find his speed excessive, by pushing the decelerating button the speed is gradually lowered, and when released the motor will run at constant speed, as in the case of accelerating.

By pushing the stop button the circuit is entirely broken and the machine brought to rest.

There are two push-button blocks, usually about 4 in. by 6 in. each, mounted one in front and the other at the back of the printing machine. Should the operator at either the front or back of the machine desire to work around its moving parts, he may push the lock button, which prevents the motor from being started until the button is released, thereby preventing a possible accident to himself.

With the Ward-Leonard system a switchboard with removable plugs should be provided, so that any motor can be operated by any generator to best suit the working conditions of the whole department. The motor is usually mounted on the ceiling and belted to the printing machine. No definite statement can be made regarding the power necessary to drive these printing machines, as it may vary from 3 horse-power to 15 horse-power, depending on the number of color rolls used and the degree of tightness at which these rolls are set. The most suitable voltage for this work is 220 volt direct.

The electric drive of printing machines gives better speed regulation, saves space, improves the quality of, and turns out less damaged goods, since the machine can be stopped in less time than with engine drive.

There is just one more important factor in the power of silk mills to which the writer desires to call attention, and that is the advantages of the central station supply. By central station is meant the local light and power company. A silk mill, or, in fact, any mill, is a very desirable load for a central station, and in some localities central stations quote very low prices for power, as this service loads up their generating apparatus at a time when it would be otherwise running light. Most central stations can afford to sell power cheap during the ordinary working hours of a silk mill, as their operating expenses are approximately the same, with or without this load.

In comparing cost of power from central station against that of the isolated plant, it must be borne in mind that the central station delivers power right to the motors, which is different from indicated horse-power of the engine in the isolated plant, as all losses in engine and principal belt drives in the mechanically driven mill, and all losses in the engine and generator in the electric isolated plant, are eliminated.

The advantages of a central station supply may be summarized as follows:

Reduction in initial expenditures, or an equivalent increase in productive machinery.

Greater security of supply, due to the extra spare units which are invariably installed in a central station.

Freedom from the fluctuations of the coal market.

Privilege of operating any particular department without running the entire line shafting in the mechanically driven mill, and the power-house equipment in the electrically driven mill.

The writer has endeavored to treat the power question of silk mills in a general way, without going into details, but he would be glad to furnish any reader with detailed information, as he has records from actual tests taken on most of the different machines used in this industry.

THE ELECTRIFICATION OF THE CASCADE TUNNEL OF THE GREAT NORTHERN RAILWAY COMPANY

By W. I. Slichter

The Great Northern Railway Company has adopted electric traction on a section of its main line which includes the tunnel through the summit of the Cascade mountains. This tunnel has become the limiting feature of the railway's capacity for through traffic, owing to the difficulty of handling the heavy trains on the steep grade through it.

As these conditions are common to most of our trunk lines, and the electric installation has successfully overcome them, the Great Northern's electric system is of interest as an object lesson, to show the ability of electric traction to increase the capacity of sections of railroads where, owing to certain physical conditions, operation with steam locomotives has reached its limit.

The conditions which prevailed previous to the electrification were as follows:

The heavy freight trains, coming from the western terminus, on reaching the steep grades of the mountain section, required the service of from two to four of the heaviest locomotives, and even these could not haul the trains faster than about seven or eight miles per hour.

When the tunnel itself was reached the operation became still more difficult; the grade was steep; the smoke and steam from the locomotives coated the rails with a damp greasy soot which caused the wheels to slip; and the locomotives filled the tunnel with the noxious gases of combustion which would nearly suffocate the train crews and made the operation positively dangerous.

It was attempted to mitigate these conditions by using special locomotives and specially selected coal for the tunnel; but even then the conditions were far from satisfactory, and the capacity of the whole road was limited to the ability to get the trains over this short section.

To meet this condition of affairs it was proposed to haul the trains through the tunnel by electric locomotives, as this would completely eliminate the delays due to the bad atmospheric condition in the tunnel, while in addition, a further gain would be made owing to the greater power of the electric locomotives, which would be able to haul the trains at double the speed of the steam locomotives.

The Cascade tunnel is 104 miles east of Seattle on the main line of the Great Northern Railway. From Seattle eastward the line is practically level for forty miles; for the next forty miles to Skykomish the ruling grade is one per cent. From Skykomish to the tunnel there is a practically continuous grade of 2 per cent. and a ruling grade of 2.2 per cent. From the tunnel eastward for about thirty miles there is an average of 1.7 per cent. down grade.

Power House and Tower

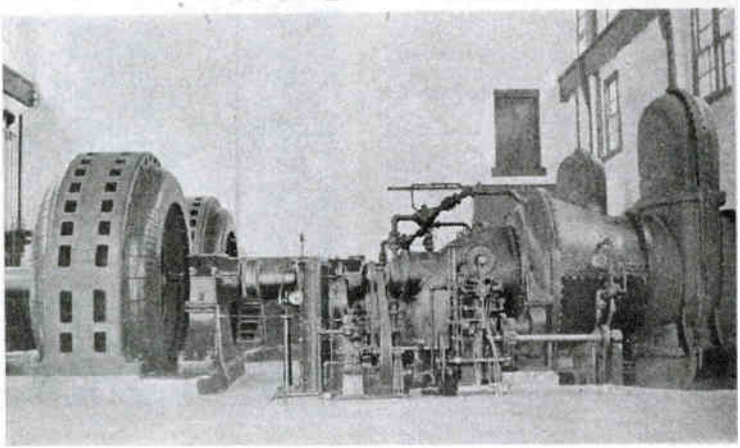
The tunnel itself is about 14,000 ft. long, perfectly straight, and has a uniform grade of 1.7 per cent. In the yards at each end of the tunnel there are grades of 2 and 2.2 per cent. on which all the trains must be started.

In the preliminary study of the proposition the project of equipping the whole section, from Skykomish to Leavenworth, 57 miles, including the worst grades, was kept in mind, as it is considered probable that this extension will be made in the near future. For the present, only the tunnel and its approaches are equipped, involving about

21,000 ft. of the right of way and about six miles of single track, including sidings.

The territory through which the railway passes includes many water falls suitable for power development, and a number of these are controlled by the railway company. This in itself naturally makes the adoption of electric traction attractive.

The main features of the scheme of electrification are a hydro-electric power house at Leavenworth, operating under a head of 180 ft., having a present capacity of 5000 kw. and an ultimate capacity of 7500; a three-phase 33,000-volt transmission line, 30 miles in length; a step-down transformer substation at Cascade; a three-phase distributing system operating at 6600 volts, and four three-phase electric locomotives. The following description of the system is taken largely from a paper on "The Electric System of the Great Northern Railway" read before the A.I.E.E. by Dr. Cary T. Hutchinson.



Water Turbine and Generator Units in Power House

Power House

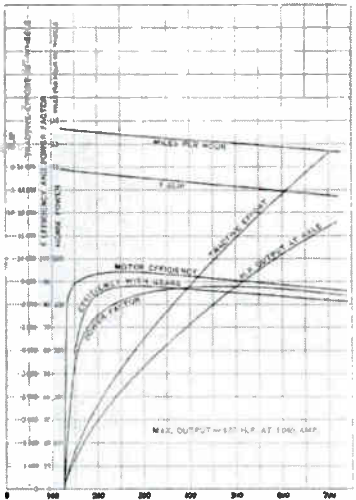
The power house at present contains two 4000 h.p. water wheels built by the Platt Iron Works of Dayton, Ohio, which operate at a head of 180 ft. Each water wheel is directly connected to a General Electric alternating current 2500 kw., 6600 volt, three-phase, 25 cycle generator running at 375 r.p.m. These generators are designed to operate at 80 per cent. power factor and, in conjunction with a voltage regulator, to give a constant voltage with a great variation in load and power factor. This combination has worked so well that it has fallen to the lot of the regulator to take care of the drop in speed of the water wheels. It has proved itself capable of maintaining normal voltage at the terminals of the generator when the speed of the water wheel has dropped to 80 per cent. of normal, and when full load is drawn from the generator at a power factor of approximately 80 per cent.

There are two 125-kw. exciters, each driven by its own water wheel, the current in the fields of these exciters being controlled by the voltage regulator. One exciter is of sufficient capacity to supply the excitation for both generators, leaving the other exciter as a reserve and to supply the auxiliary power of the station.

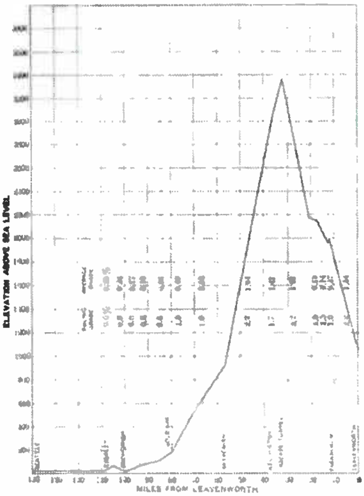
The power station is situated on the right of way about 30 miles east of the tunnel. The railway at this point is not equipped for electric operation, although it is intended to be so equipped later. For the present, all the power is transformed from 6600 to 33,000 volts by a bank of four water cooled, 25 cycle, 830 kw., 6600/33000 volt transformers, three of which are used in normal operation, the fourth being maintained as a spare. These transformers and the high tension switching apparatus are contained in a special room of the power station, separated from the main generating room by a fireproof wall.

The cables from the generators are run in conduits beneath the floor from the generators to the switchboard. From the step-up transformers there are two three-phase outgoing lines which are protected by electrolytic cell lightning arresters placed on the end wall of the building.

The power station also contains two water rheostats intended to absorb the energy which is generated by the locomotives when descending grades at times when there is no demand upon the system. These water rheostats consist of two concrete tanks in each of which three tubular electrodes are suspended in such a manner that they may be raised and lowered automatically in accordance with the load to properly regulate the system. These water rheostats are controlled by a centrifugal governor, driven from the main shaft of the generators, which causes the electrodes to be lowered into the water box whenever the speed of the generators increases above the normal value due to the generators acting as synchronous motors when the locomotives are regenerating. This governor is designed with a positive action so that there is no tendency of the system to hunt, due to the water rheostat overshooting its position.



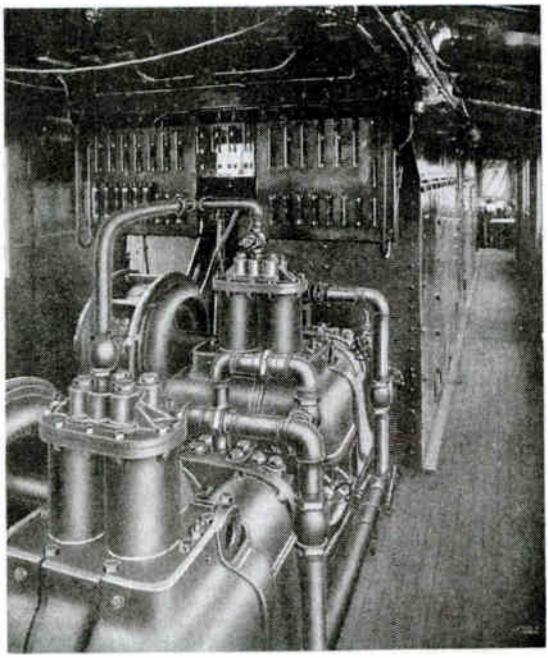
Characteristic Curves of Great Northern Three Phase, 475 H.P. 25-Cycle, 500-Volt Motor. Gear Ratio 4.26; 60 In. Wheels



Profile of Great Northern Railway—Leavenworth to Seattle

Transmission Line

The transmission line is 30 miles in length and consists of two circuits, each including three No. 2 B.&S. stranded hard-drawn copper wires. Each circuit is in a vertical plane at one side of the pole, thus permitting the use of short cross-arms. Provision has been made for a ground wire to be strung at the top of the pole which, however, has not yet been installed. A telephone line is carried on the same poles. The transmission line is not transposed but the telephone line is transposed at every fifth pole. The poles are 40 ft. long, placed 6 or 7 ft. in the ground, the tops being from 10 in. to 12 in. in diameter. The line is divided into three sections by two out-of-door switches, each near a station and under the supervision of a station agent.



Interior of Locomotive

Sub-Station

The sub-station is at Cascade, practically at the east portal of the tunnel. This sub-station contains four single-phase transformers similar to those in the power house; three of these are connected in a bank, the fourth serving as a spare. These transformers reduce the voltage from 33,000 to 6600 volts, three-phase, in which form power is fed to the distributing system. The low pressure bus-bars at the sub-station are connected directly to the line at Cascade and there is also a feeder running from the sub-station through the tunnel to the extreme end of the Wellington yard.

Distribution System

Power is distributed by means of two overhead wires and the track, the latter serving as the conductor for the third phase. The outside overhead construction consists of bracket or cross-catenary, depending upon the number of tracks, but in the tunnel the wires are supported at intervals of 50 ft. by means of clamps attached by swiveled connection to a stud, which is in turn swiveled to the middle point of a turnbuckle. The two eyes of the latter each connect, by means of strand wire, to a link and a petticoat strain insulator arranged in series, the two petticoat insulators being secured to the roof of the tunnel by means of two expansion bolts. Anchors and side braces for the wires in the tunnel are located at intervals of 3000 ft.

In the tunnel the wires are 17 ft. 4 in. above the top of the rail. They are spaced 8 ft. apart to permit the trainmen to operate the hand brakes, or to walk on the tops of the freight cars. In the open the wires are 24 ft. above the top of the rail, are 5 ft. apart, and are supported at intervals of 100 ft. At anchorages and switching points heavy steel bridges are used. Lightning arresters are connected to the trolley wires at several points in the system.

On account of the variation in the spacing of the trolleys, current is collected by the ordinary swiveling trolley pole and wheel instead of a bow collector.

Where wires of opposite phase cross at turnouts they are insulated from each other by an insulated crossing, which is built up of four wooden insulators, each about 5 ft. in length and radiating from a central crossing pan.

Locomotives

Each of the four locomotives has a total weight of 230,000 lb., all on drivers, and has two trucks connected by a coupling, each truck having two driving axles. A three-phase motor is connected by twin gears to each axle. The two trucks are coupled together in such a manner that each tends to guide the other around the curves. They also tend to support each other vertically and are somewhat similar in mechanical design to the Mallet type of steam locomotive. One truck is side equalized while the other contains a three-point suspension. The springs are thereby equalized in groups and the groups are so arranged as to eliminate all skew or twisting stresses in the truck frame.

The wheels are 60 in. in diameter with removable steel tires 3½ in. thick. The wheel centers are steel castings. The gears are shrunk on an extension of the wheel hub, thus eliminating the torsional stresses from the locomotive axles. The motors are connected through gears at both ends, that is, they are twin-geared to the driving wheels, thus having the advantage of maintaining accurate alignment between the axle and armature shafts.

The cab, which is made of No. 10 steel plate, extends the entire length of the platform. The greater part of the control apparatus is placed in a separate compartment 60 in. wide and 22 ft. long, located in the middle of the cab and enclosed by steel partitions extending directly up to the monitor roof. This leaves two open operating spaces at the ends of the locomotive, connected by two side aisles 30 in. in width. This center compartment is divided into three parts by steel plate partitions; the middle part containing the high tension apparatus including the switchboard, and the end parts, which are duplicates, each containing one transformer and the contactors for two of the motors. The rheostats are placed in the monitor at the top of the cab. The air for ventilation, after passing through the transformers, cools the rheostats and then escapes to the atmosphere.

The motors, of which there are four per locomotive, are of the three-phase induction type designed for operation at 25 cycles and wound for a primary voltage of 500. They are similar in their construction to standard stationary type induction motors, but are adapted in the details of their design to traction purposes. The rotors, or secondaries, are wound with definite poles and the terminals are carried to collector rings, by means of which the starting resistance is connected into the circuit. The ratings of the motors are given in the table of data following, and the power factor and efficiency are shown in the characteristic curves. Each motor can exert a maximum tractive effort of 19,000 lb. at rated voltage, and the transformer which reduces the line voltage from 6000 to 500 is provided with a 625-volt tap to which the motors may be connected in case the line drop becomes excessive.

The control system of each motor is separate; the circuits branch from the transformer, two motors being fed from each transformer. The speed and tractive effort of the motors are controlled by varying the resistance in their secondaries. There are 13 steps in the resistance and these are obtained with 9 contactors by a scheme of dividing the resistances into two or three groups, each having its contactor. These groups are brought into different combinations so that each group is used repeatedly, sometimes in series and sometimes in multiple with the others, and is not merely employed for one step. The control is designed to allow of a train being accelerated at an average tractive effort of 37,500 lb. without exceeding a maximum of 41,000 lb. or falling below a minimum of 35,000 lb. The application of the power is continuous throughout the whole range of the controller.

No provision is made for connection in concatenation or changeable pole connection to permit of running at fractional speeds without resistances, but the resistances are so proportioned that the locomotive can run for 15 minutes at full rated tractive effort without overheating the resistances. The first step on the control gives a tractive effort of 10,000 lb. at standstill, and the second step 20,000 lb.

A separate and independent set of resistances is provided for the secondary of each motor to avoid the tendency of the motors to exchange current and "buck," which would occur if the driving wheels were not of exactly the same diameter and one set of resistances was used for all the motors.

The principal data of the locomotive are given in the following table:

Great Northern Locomotive Data

Total weight	230000 lb.
Weight on drivers	230000 lb.
Number of driving axles . .	4
Number of other axles . . .	0
Diameter of wheels . . .	60 in.
Gear ratio	4.26
Number of motors	4

Output of motor for one hour (nominal)	400 h.p.
Output of motor for one hour (test)	505 h.p.
Rise in temperature	75 deg.
Output of motor for three hours (nominal)	250 h.p.
Output of motor for three hours (test)	397 h.p.
Rise in temperature	75 deg.
Forced ventilation (cu. ft. per min.)	1500
Number of poles on motors	8
Frequency	25 cycles
Synchronous speed of motors	375 r.p.m.
Voltage between terminals	500
Synchronous speed of locomotive	15.7 m.p.h.
Number of transformers	2
High potential voltage of transformers	6000
Rating of transformers (3 hours)	400 kv-a.
Forced ventilation (cu. ft. per min.)	1500
Number of step in control	13
Method of control.	Resistance in Secondary
Continuous rating locomotive, lb. tractive effort	25000
Accelerating rating locomotive, lb. tractive effort	38000
Momentary rating locomotive, lb. tractive effort	56000
Maximum rating locomotive, lb. tractive effort	72000
Length overall locomotive	44 ft. 2 in.
Total wheel base	31 ft. 9 in.
Rigid weel base	11 ft. 0 in.

Distribution of Weight

2	Trucks	81,500 lb.
1	Cab	30,000 lb.
44	Motors	48,800 lb.
8	Gears and gear cases	11,000 lb.
2	Transformers	20,800 lb.
2	Air compressors	5,800 lb.
1	Blower	1,300 lb.
40	Rheostats	10,200 lb.
56	Contactors	3,200 lb.
	Miscellaneous	17,400 lb.
	Total	230,000 lb.

That is,

Total weight per axle	57,500 lb.
Dead weight per axle	18,500 lb.

Operation

The original problem was to provide equipment to handle a train having a total weight of 2000 tons, excluding the electric locomotives, over the mountain division from Leavenworth to Skykomish, a distance of 57 miles. The system was to be first tried out at the Cascade Tunnel.

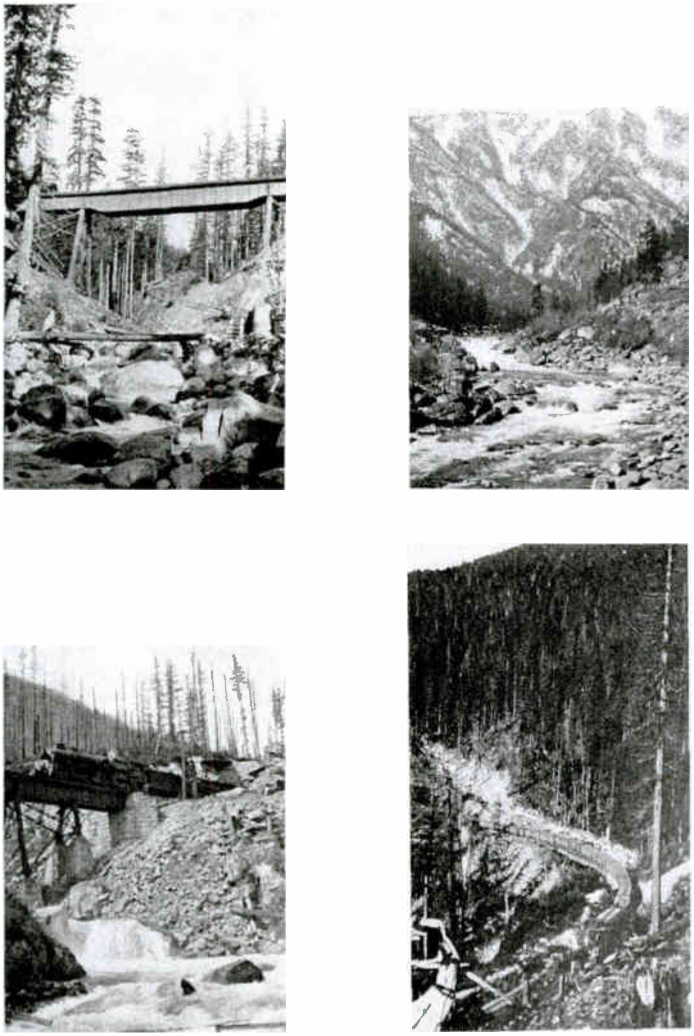
The tractive effort required to accelerate a train having a total weight of 2500 tons on a 2.2 per cent. grade, using 6 lb. per ton for train resistance and 10 lb. per ton for acceleration, making a total of 60 lb. per ton, is 150,000 lb.; this would require four locomotives of a tractive effort of 37,500 lb. each. The railway company's engineers limited the weight on a driving axle to 50,000 lb.; therefore, four driving axles per locomotive are needed, giving a coefficient of adhesion of about 19 per cent. This is a measure of the maximum power required. The locomotive, therefore, was designed to give a continuous tractive effort of approximately 25,000 lb., and it was expected that four of them would be used with a train of maximum weight. However, the locomotive as built greatly exceeds this specification.

The specification of the motor required an output of 250 h.p. continuously for three hours, with 75 deg. C. temperature elevation, when supplied with not more than 2000 cu. ft. of air per minute. The test results of the motor show a continuous output of 375 h.p. at 500 volts with 1500 cu. ft. of air, and 400 h.p. at 625 volts, with the same amount of air; the one-hour rating of the motor at 500 volts with 1500 cu. ft. of air per minute is 475 h.p.; the ratio of continuous output to the hour-rating with 1500 cu. ft. of air is therefore 79 per cent. The continuous output at 500 volts corresponds to a tractive effort of 9350 lb. per motor, and the one-hour output to a tractive effort of 11,900 lb. per motor. The locomotive, therefore, will give 37,400 lb. tractive effort in continuous duty, or 47,600 lb. tractive effort for one hour. The characteristic curves of the motor at 500 volts are shown in cut on page 351.

The locomotives have shown themselves capable of hauling 885 tons trailing load each, if the power requirements are continuous; but, as there are necessarily stops, their actual rating is somewhat greater than this.

The locomotive has been tested to a maximum tractive effort of nearly 80,000 lb., corresponding to a coefficient of adhesion of nearly 35 per cent.; with 60,000 lb., or 29 per cent., each locomotive can accelerate the train of 885 tons trailing on a 2.2 per cent. grade, using 60 lb. per ton as the total tractive effort; or, in other words, the train that a locomotive can haul, as determined by the average duty and safe heating limits, is just about equal to the train that it can accelerate on the maximum grade; that is, the average capacity of the locomotive and its maximum capacity are in the same proportion as the average duty and maximum duty.

The electric service was started on July 10, 1909, although one or two trains had been handled previously. From that time until August 11, practically the entire eastbound service of the company has been handled by electric locomotives.



Scenes Along the Great Northern Railway

During this period of 33 days there were 212 train movements of which trains 82 were freight, 98 passenger and 32 special. In each case the steam locomotive was hauled through with the train. The tonnage handled was as follows:

Freight tonnage	171,000 tons
Passenger tonnage	88,500 tons
Special tonnage	15,500 tons
Total	275,000 tons

This is an average of 8350 tons per day, all eastbound.

The average freight train weight was as follows:

Cars	1480 tons
One Mallet locomotive	250 tons
Three electric locomotives . . .	345 tons
Total train weight	2075 tons

The maximum weight of cars was 1600 tons; the minimum, 1200 tons.

The representative passenger train handled is made up as follows:

Coaches	426 tons
One steam locomotive	250 tons
Two electric locomotives . . .	230 tons
Total train weight	906 tons

The maximum passenger train was about 125 tons greater.

It was found that the frictional resistance of the Mallet locomotives which were hauled through with the trains was about 47 lb. per ton, so that the work performed by the electric locomotives is considerably greater than is shown by the actual weights of the trains.

Using 20,000 lb. as the pull required for a Mallet locomotive on the 1.7 per cent. grade, the total tractive effort for the average freight train is:

Cars	1480 tons × 40 = 59,200 lb.
One Mallet . .	250 tons × 80 = 20,000 lb.
Three electrics . .	345 tons × 40 = 13,800 lb.
	93,000 lb.

This is equivalent to 31,000 lb. for each locomotive.

Regeneration

A number of tests were made to determine the power returned when regenerating. A representative test on a ten car passenger train weighing 950 tons gave 597 kw., showing that one ton descending the 1.7 per cent. grade at 15 m.p.h. will deliver 0.67 kw. to the system.

Efficiency

The losses in the system when delivering 4000 kw., equivalent to supplying four locomotives, at the west end of the Wellington yard are:

	Kw.	Per Cent.
Power house	4740	100
Sub-station	4250	89.8
Trolley wheel of locomotive	4000	84.5
Driving axles	3320	70

At the average load the efficiency is higher.

General

In the paper above referred to, Dr. Hutchinson assigned the following reasons for the choice of the three-phase system as compared with the direct current or single-phase systems:

1. The three-phase motor and control are distinguished by the greatest electrical and mechanical simplicity; the motors will stand any amount of abuse and rough use.

2. Greater continuous output within a given space than can be obtained with any other form of motor.

3. Uniform torque. This is an advantage over the single-phase system.

4. Possibility of using 25 cycles. The single-phase system would probably have involved a lower frequency.

5. Regeneration on down grades. This is accomplished in the three-phase system with no additional complication or apparatus on the locomotive.

All of the electrical apparatus in the power house and sub-stations, together with the locomotives, was supplied and manufactured by the General Electric Company.

COMMERCIAL ELECTRICAL TESTING

PART X

BY E. F. COLLINS

Double Pitot Tube, or Government Method of Testing

This test is made in accordance with Government specifications* issued by the Navy Department under the cognizance of the Bureau of Construction and Repair.

Use of Air Table

When making a fan test the temperature of the air near the fan should be taken by two Fahrenheit thermometers, one hanging free in the air and the other with the bulb wrapped in thin cloth, this cloth being saturated by having its lower end placed in a small receptacle filled with water. The water must be at the maximum temperature which it will naturally attain in the room. Corrected barometer reading must also be recorded on the test sheet.

The method of finding the weight of air from the air tables (mentioned in the specifications) is as follows: On the page containing the dry bulb reading, as given by the test sheet, is noted the corresponding barometer reading. In the column under the dry bulb temperature and opposite the barometer reading, the corresponding weight of air is given. The weight of air found in the table must then be corrected to correspond with the corrected barometer reading found in test; this correction being found in the second line from the top of the page. Correction must also be made for the difference between the wet and dry bulb temperatures by adding to the weight of air already obtained the number corresponding to the numerical difference between the wet and dry bulb reading, found in the third sub-division under dry bulb temperature. The numerical differences are tabulated in the second sub-division of the column.

Example:

Given barometer reading 30.15 in.
Dry bulb reading 67° F.
Wet bulb reading 59° F.

Under the column showing the dry bulb temperature of 67° and opposite the barometer reading of 30.1, the weight of air is given as 0.07517. The addition for each 0.01 of an inch of barometer is given as 2.6 in the second line from the top of the page. Multiplying this by 5; *i. e.*, by the excess of the corrected barometer reading over that selected in the table, the result is 13, which number must be added to the weight of air previously found. The wet bulb depression is the difference between 67° and 59°; *viz.*, 8°. The number opposite 8 is 23, which must also be added, making the total weight of air 0.07553. All pressure readings should be corrected for standard air (see page 359) by multiplying the actual pressure obtained by the ratio of the weight of standard air to the weight of air at the time of test. The readings of horsepower input to the fan should also be multiplied by this ratio.

Pressure and Horse-Power Curves by Double Tube Method

A pressure curve may be taken by the double tube method as follows:

The opening at the outer end of the discharge pipe should be closed and pressure and power readings taken. Under this condition the static and impact pressures should be exactly the same, since no air passes through the fan. Readings should then be taken as the opening is increased by equal increments from closed to wide open, the opening being measured each time. The speed of the fan should be held constant throughout the test, and the air readings and electrical input readings taken simultaneously.

It will be noted that in a test which is made with a pipe on the discharge side of the fan, the reading of the impact tube is always greater than the static reading. If the pipe is on the suction side, the opposite will be true; the difference between the two readings being the velocity head. The Pitot tube should point against the stream of air in both cases.

If readings are taken by means of a U tube, the readings of both sides of the tube should be recorded. It should always be stated whether the readings were taken by the U tube or by a manometer; if by a manometer, the manometer constant should be recorded and should always be used in working up the test.

Calculation of Fan Tests by the Double Tube Method

A fan test of this kind should be worked up in the following form:

Fan Rating
Motor Rating
Double Tube Test, Taken at R.P.M.

No.	h''	h'	h	"f"	V	Q	h'' + "f"	h' + "f"	Air H.P.	Fan H.P.	Ef.
1											
2											
3											
4											

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*General Specifications—Appendix 8. Instructions for Calculating and Testing Ventilation Systems.

Wet bulb..°F.
Dry bulb..°F.

$$``f" = \frac{L \times h'''}{D \times 39}$$

Effective area of pipe..........sq. ft.
Barometer..in.
Wt. of air..lb.
Effective area of pipe = ...sq. ft.

The first column gives the number of the reading.

The second and third show the impact and static readings taken from the test sheet and corrected for standard air.

The fourth column shows the velocity head or the difference between h' and h''.

The fifth column is friction, which must be calculated from the velocity head by the formula $``f" = \frac{L \times h'''}{D \times 47}$; where "$f$" is the friction loss in inches of water, L the length of pipe between the fan and the Pitot tube, D the diameter of the pipe, if round, or the average of the width and depth, if square or nearly square. L and D must always be of the same denomination. The friction loss should be added to both the static and impact readings before the curves are plotted, but it does not affect volume.

The sixth column gives the air velocity and may be obtained from the formula

$$V = 1097\sqrt{\frac{h'''}{w}}$$

The volume must be given in the seventh column. It is obtained by multiplying the velocities given in the sixth column by the effective area of the pipe; *i.e.*, 0.01.

The horse-power in the air can be calculated from the formulæ:

$$\text{Air horse-power} = \frac{P \times Q}{33000} \text{ or } \frac{p \times Q}{3367} \text{ or } \frac{h \times Q}{6346}$$

The horse-power input to the fan is the horse-power output of the motor.

Unless instructions are issued to the contrary, all fan tests for government work should be plotted with pounds per square foot, horse-power input to fan, and efficiency, as ordinates; and volume in cubic feet per minute as abscissæ. Both static and impact pressure should be plotted.

Cone Method of Test

In the cone method of test an adapter is used, where necessary, to change the fan outlet from rectangular to circular, a cone being placed on the circular end. This cone is made up of sections about one foot in length, the sides of which slope about two inches to the foot. Readings are taken by a single Pitot tube, the open end of which is held flush with the opening in the cone and pointed against the stream of air. Pressure is registered as before by a manometer or U tube. The readings are taken, one at the top, one at the bottom, and one at each side of the cone, at a distance from the edge of the pipe of about ⅛ of the diameter of the opening. A reading is also taken in the center of the cone opening. The average of these five readings represents the impact pressure produced by the fan, and is taken as the velocity head. The velocity may be obtained from the formula given for the double tube test.

The static pressure may be obtained as follows: Divide the volume as figured for each opening by the area of the fan outlet, thus obtaining the outlet velocity V_1. The corresponding velocity head can then be obtained from the formula. The velocity head subtracted from the impact pressure gives the static pressure, which should be plotted as well as the impact pressure.

These tests should be plotted with pressures in inches of water, horse-power input to the fan, and efficiencies, as ordinates; and volumes as abscissæ.

The following form should be used for tabulating the results of calculations:

Fan Rating
Motor Rating
Cone Test taken at R.P.M.

No.	h'''	V	A	Q	V_1	h''	h'	Air H.P.	Fan H.P.	
1										
2										
3										

Wet bulb..°F.
Dry bulb..°F.
Barometer..in.
Wt. of air..lb.

After the curves are plotted, the efficiency as given by the calculations should be checked with the efficiency obtained from the curves. This will correct any discrepancy between the efficiencies as obtained from the curve and as calculated.

The Box Method

The fan is arranged to discharge directly into a box of sufficient capacity to reduce the air velocity to a minimum. Cones similar to those used in the cone test are attched to an opening in the side of the box at right angles to the opening into which the fan discharges. Readings are taken in the same manner as in the previous test, and a record is also made of the box pressure by a U tube connected to a pipe inserted through a hole in the side of the box. This end of the pipe should be flush with the inside of the box to avoid eddy currents. The pressure shown by this pipe will be somewhat higher than that registered at the end of the cone, and both pressures should be corrected for standard air and plotted on the final curve sheet.

The volume must be calculated as in the cone test, but the pressure obtained in the box is taken as the static pressure produced by the fan, since the velocity head is lost in the box. To obtain the impact pressure, the volume obtained should be divided by the area of the opening of the fan, and the corresponding velocity head figured from the formula. This velocity head should be added to the static pressure shown by the cone readings. For transformer ventilation it is customary to calculate the pressure in ounces, measured at the cone opening.

The following form should be used in tabulating the calculations:

Fan Rating
Motor Rating
Box Test taken at R.P.M.

No.	h'	p	V	V_e	Q	V_e	h'''	h''	Air H.P.	Fan H.P.	Eff.
1											
2											
3											
4											

Wet bulb.....................................°F.
Dry bulb.....................................°F.
Barometer.....................................in.
Wt. of air.....................................lb.

Air horsepower should be calculated from the static pressure and the efficiency obtained will be the static efficiency.

Formulae for Blower Tests

H = Head of air in feet.
h = Head of water in inches shown by manometer.
h' = Static head; h'' = impact head; $h''' = h'' - h'$ – velocity head.

Weight of water = 62.4 lbs. per cu. ft. at 62° F.

Weight of column of water 1 ft. sq., 1 in. high, 5.20 lbs. at 62° F.

Weight of cu. ft. of air at 30 in. Bar., 70° F., 70 per cent. humidity = .07465 lb.
This is taken as "Standard Air."

Weight of air under other conditions, neglecting humidity =

$$\frac{.07403 \times B \times 530}{30(460+t^{\circ})} \text{ for Fahrenheit,}$$

or

$$\frac{.07465 \times B \times 294.1}{30(273+t^{\circ})} \text{ for centigrade.}$$

V = Velocity of air in feet per minute.
v = Velocity of air in feet per second.
Q = Volume in cubic feet per minute.
P = Pressure of air in lbs. per sq. ft.
p = Pressure of air in ounces per sq. in. $= \frac{h}{1.732} = .577\ h$.
"f" = Loss of head in inches due to friction in pipes $= \frac{L \times h'''}{D \times 47}$
L = Length of pipe between the fan and the Pitot tube.
D = Diameter of pipe, if it is round; or = the average of the width and depth, if it is square or nearly square.
$P = 5.20 \times h = 9\ p$.
A = Area of pipe in sq. ft. A_e = Effective area of pipe $= A \times K$.
$H = 5.20 \times \frac{h}{w} = 69.73 \times h$ for standard air.

$$v = \sqrt{2gH'''} = 8.02\sqrt{H'''} = 8.02\sqrt{\frac{5.2 \times h'''}{w}} = 18.28\sqrt{\frac{h'''}{w}}$$

$$V = 481.2\sqrt{H'''} = 1097\sqrt{\frac{h'''}{w}} = 4015\sqrt{h'''} \text{ for Std. Air.}$$

$$Vol. = 1097\sqrt{\frac{h'''}{w}} \times KA$$

$$= 3654 \times A\sqrt{h'''} \text{ for } K = .91:$$

$$= 3774 \times A\sqrt{h'''} \text{ for } K = .94:$$

for Std. Air.

K = .94 for the Cone Method.
K = .91 for double Pitot tube or Navy method.

For a given opening pressure varies as the square of the speed of the blower.

Volume varies as the square root of the pressure, hence, directly as the speed.

Air horsepower varies as the cube of the speed.

$$\text{Eff.} = \text{Efficiency} = \frac{\text{Air Horsepower}}{\text{Fan Horsepower}}$$

APPLIANCES FOR ELECTRICAL MEASUREMENTS*

Part I

By C. D. Haskins

Manager Lighting Department, General Electric Company

All military operations of the future and all peace service of the army must deal with electrical questions in a very comprehensive way, and in a rapidly increasing ratio from now onward.

Not less than one officer in seven in the regular establishment, and, perhaps, we may predict not less than one officer in fifteen of the entire commissioned force on a war basis, must have a reasonably complete working knowledge of applied electrical engineering under future conditions of the service.

This statement applies particularly to the Corps of Engineers, to the Signal Corps and to the Artillery Corps, and to less degree to the cavalry, infantry and other field services, inasmuch as all of these arms must come into contact constantly or intermittently with the operation of electrical appliances.

The quartermaster's department and regimental quartermasters will, at some very early date, be constrained to equip themselves with a working knowledge of electrical engineering, and it is with the positive conviction of these necessities, and with a knowledge of their acceptance by the great military nations of Europe, that the following notes have been prepared.

It has been my valued privilege to present at various post-graduate schools of the service a number of lectures devoted to what might be termed "military electrical engineering," and since the more practical considerations surrounding electrical measurements are amongst the more important functions of adequate equipment in electrical engineering necessary to the military electrical engineer, my notes on this occasion are to be devoted to a consideration of the more useful and essential facts in relation to the common appliances for electrical measurements.

In laying this material before you I realize that it is not a topic pertaining particularly to the Signal Corps, but no officer of the Signal Corps who is engaged in devoting his attention to the electrical branch can properly conduct his work without a thorough comprehension of the governing considerations in connection with measuring appliances, and I conceive, therefore, that a proper treatment of this subject must necessarily be useful.

In the consideration of this subject, it is by no means my intention to deal with the highly sensitive devices which are found in the electrical laboratory. Military electrical engineering can have little connection with or occasion to deal with such instruments. They constitute a highly specialized study, and are well dealt with in the text books of the art.

There are, however, three general classes of electrical measuring devices with which the electrical engineer officer of every branch of the service should be intimately familiar, since they fill an important part in the execution of all electrical work with which the military profession is likely to bring its members in contact. These three groups are:

Switchboard instruments
Portable testing instruments
Recording and integrating meters.

Two of these groups are, of course, confined to what might be termed fixed installations, while the group of portable testing instruments is equally important to the fixed or mobile equipment.

Switchboard Instruments

With a continuous current system the two essential instruments are the ampere meter (ammeter) and the volt meter (voltmeter).

In the earliest days of the electric lighting art an incandescent lamp commonly served the purpose of the voltmeter, and the practiced eye was expected to determine, from the brilliancy of the lamp, the correct or incorrect voltage of the system; in short the lamp itself was utilized as a crude voltmeter.

Since the good or poor service of an electric lighting system is entirely dependent upon the maintenance of a reasonably uniform voltage, the voltmeter is obviously of paramount importance, and, during the early history of the art, a very great amount of attention was devoted to the design of structures for the accurate and reliable indication of voltage.

It is interesting to note in connection with the electrical measuring device art, especially in the field of switchboard and recording instruments, that probably no class of mechanical or electro-mechanical

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* Paper read before The Army Signal School, Fort Leavenworth, Kan.

devices have been worked out along so many entirely different lines of underlying physical principles as have these.

The problem in indicating instruments (in which class we must place, of course, all switchboard instruments and all portable testing instruments) is to devise a structure which shall indicate upon a scale the current, voltage, or other electrical value under measurement, in its appropriate unit, with the greatest promptness and accuracy, under all the ordinary conditions of use.

The motion of indication must be accomplished with the minimum amount of power waste consistent with positiveness and reliability, and the structure must be such as to be as nearly as possible independent of all external influences.

Following the use of the pilot lamp in its function of voltmeter, we find in the early records of the art a general use of thermal instruments; structures dependent upon the expansion and contraction of metal with variations of temperature, the familiar Cardew voltmeter of the text books being a type of this class.

The position of the needle in such an instrument was determined by the amount of current passing through a controlling wire, the temperature of that wire varying with the amount of current passing through it, and the length of the wire with the temperature.

Such instruments are now relatively rare in the art. They are substantially never used in connection with continuous current systems, but are still used at times in connection with alternating current measurements, because of the fact that they are entirely independent of frequency, and may be used indifferently upon systems of varying frequency.

Thermal instruments are likely to be of especial importance in the future to the Signal Corps, since they constitute the one group of indicating devices for potential measurement which may be regarded as independent of frequency changes, and since the work of the Signal Corps in the future must be closely interwoven with the application of alternating currents of greatly varying frequencies, these instruments are likely to become vitally important in connection with this work as the art progresses.

In considering voltmeters for the switchboard, the practical engineer of today should give due regard to the consideration of accuracy. In writing specifications it is customary to specify that switchboard voltmeters shall be accurate through the upper half of the scale within 75 per cent.

I wish to place emphasis upon the limitation of this demand to the upper portion of the scale, and to emphasize the fact that no indicating instrument should be relied upon in switchboard practice at values below one-third scale. The active forces of coercion and control are so relatively minute in relation to the variables of friction and external influences at the low values as to destroy the reliability of the indications.

It has been customary at times, in writing specifications fixing the accuracy of voltmeters to be used on continuous current service, to limit the amount of energy to be expended in actuating the structure. Such specifications are of doubtful advisability and menace the permanency of accuracy, since the actuating forces are small at best, and it is highly desirable in all measuring structures that constant forces should be large in relation to the variable forces.

It is consequently desirable that the coercive forces shall be relatively high, and that the restraining forces against which such coercive forces are balanced shall also be relatively high.

It is probably safe to indicate a current of ten to fifteen milli-amperes as about the correct value at full scale of a voltmeter destined for use on continuous current.

Having given due consideration to the forces which make for accuracy, it is next necessary to determine, in connection with switchboard voltmeters, those characteristics which make for freedom of sensitiveness to external influences.

Under conditions of continuous current service, the commonest disturbing influence is that of stray fields, which, of course, includes the earth's field and fields induced by neighboring conductors.

The thermal instruments, commonly known as "hot wire" instruments, above referred to, are, of course, free from such disturbances, but such structures have today largely given place to magnetic mechanisms of which the D'Arsonval and the Thomson structures are typical.

The D'Arsonval structure consists of a magnetic mechanism of constant magnetic flux, and of a movable coil so situated in the field of that structure as to take a position in the field in opposition to the torsion of a spring, the position being determined by the amount of current passing through the movable coil.

It is obvious that such a structure is in some measure susceptible to variation by the modification of the field flux, due to external causes.

The density of the field in such an instrument is generally so considerable as to be unaffected by the earth's field within practical limits, but so great is the value of projected fields from heavy bus-bars or other heavy conductors that at times they have an appreciable bearing upon the accuracy of the instrument, by increasing or decreasing the gross flux of the coercive field.

This is a matter which should be considered with care in providing switchboard instruments for most systems. There are three remedies: First, to make the permanent point of use of the instrument so remote from external influences as to minimize the influence of stray fields; second, by shielding the instrument with an iron casing of such a character and in such a manner as to short circuit the lines of force projected by the stray field through a path external to the instrument itself; or third, by resorting to instruments of astatic construction.

Astatic instruments are, for all practical purposes, independent of stray fields, since their coercive and restraining forces are equally and oppositely influenced by varying and irrevelant external magnetic influences.

Astatic instruments are, generally speaking, of somewhat greater first cost than otherwise equally accurate instruments in which this feature is not embodied, but it is probably desirable in most cases to specify an astatic instrument where the conditions of service demand the use of switchboard instruments in close juxtaposition to conductors or in the presence of considerable masses of structural iron and steel work.

If astatic instruments are not utilized it is customary to determine by actual test the general sensitiveness of the instrument in use to projected fields.

Closely correlated to error incident to projected fields is the not altogether uncommon phenomena of permanent derangement due to heavy projected fields, caused by the permanent change of flux in the permanent magnet used in these instruments. Radical examples of such derangement are relatively common.

It will be readily appreciated that any structure of this character dependent upon a permanent magnet must in some measure be subject to loss of accuracy by exposure to a field external to itself.

Modern instruments have been so highly perfected that the external field must be of high value in relation to the flux of the instrument itself to have a permanent effect; nevertheless such high value is met with in switchboards carrying very heavy currents, and freedom from its effect can be insured only by highly developed shielding or by the utilization of electro-magnetic elements; when, of course, it is necessary to resort to a structure in which the coercive and restraining forces both vary with fluctuations in field strength.

Voltmeters of the electro-magnetic type are used in the art from time to time in forms which involve less costly and complex structures than those here dealt with. For example: structures utilizing a simple solenoid and iron core, the pull of the solenoid acting against the force of gravity or a spring; or structures involving the use of a fixed coil and a movable magnetic vane or arm, acting against the force of gravity or a spring; or, in some cases, structures involving the use of one fixed and one movable coil, without the use of magnetic material.

Solenoid and coil instruments and coil and vane instruments are obviously far more susceptible to error due to external influences, especially stray fields, than are instruments with a substantially closed magnetic circuit; but, because of their simple structure and low first cost, they are much used for rough measurements such as the measurements of voltage across batteries, etc., or in connection with small electric lighting or power systems, where high accuracy is not required of the switchboard instruments.

All commercial voltmeters for use on continuous current are subject to slight temperature errors. This is due to the fact that their indications are dependent upon the amount of current passing through a fixed resistance.

Numerous alloys or combinations of pure metals and alloys have been resorted to to minimize this error, and indeed it is theoretically possible to substantially eliminate it; but in ordinary practice variations in room temperature do cause a variation in the resistance of the voltmeter circuit, and consequently a variation in the accuracy of the indications of the instrument. Good modern practice prescribes that the accuracy of the instrument shall not vary more than .02 per cent. degree centigrade, normal accuracy generally being fixed at 25 per cent. centigrade in commercial calibration.

The second important instrument in connection with continuous current switchboards is the ammeter.

Elementally the mechanical structures employed for ammeters parallel those employed for voltmeters. A voltmeter is indeed an ammeter measuring the amount of current passing through a fixed resistance.

In direct current switchboard practice, it was customary, in the early days, to take the entire current to be measured through the instrument; but such practice was both costly and cumbersome, and presented no advantages adequate to justify the continuance of the practice.

In all ordinary switchboard practice today it is usual to measure the drop of potential across a fixed resistance; that is, the modern ammeter is connected in shunt to a resistance and consequently the commonly used modern switchboard ampere meter is in reality a voltmeter and subject to all the conditions and limitations laid down in connection with voltmeters.

No more common error has characterized the recent art than the misdirected effort to cut down the resistance of the shunt (and consequently the loss) to so low a point as to reduce the coercive force in the instrument to a value materially below that necessary to secure positive and permanently accurate operation.

It is safe and conservative, in connection with modern practice, to call for the use of ammeter shunts for direct current service h ving a drop of 60 milli-volts at their rated capacity.

As voltmeters vary with fluctuations of temperature, so also do ammeters, for obviously not only does the resistance of the circuit of the ammeter itself change with temperature, but also that of the shunt, and in the case of the shunt this change is accentuated by the fact that the shunt is itself heated by the current passing through it; but the utilization of special alloys has largely obviated this difficulty.

Great attention has been given both to the determinating of the proper compromise as between the proper drop and coercive force of the instrument on the one side, and a safe limitation of resistance to the point where excessive heating is not involved on the other. Much thought, too, has been given to the design of shunts in relation to the provision of ample radiating surface.

It is ordinarily conservative to specify that the variation in accuracy in a shunt type ammeter of the kind commonly used on switchboards shall not exceed 0.15 per cent. per degree centigrade in room temperature. It should be borne in mind that the accuracy of the shunt ammeter is absolutely at the mercy of the character of the connections between the shunt and the main circuit and the shunt and the instrument.

If the connections between the shunt and the main circuit are imperfect, then the resistance of these connections will cause excessive heating of the shunt, with a consequent increase in resistance and false indications of the ammeter. This point is to be carefully watched in all installations, and in writing specifications it is desirable to carefully cover this point.

Again, if the connections between the instrument and the shunt are imperfect, the resistance of the instrument circuit is greater than that contemplated, and since the total resistance of an ordinary ammeter such as is commonly used in switchboard practice is only about 20 ohms, the resistance of a bad contact may change the total resistance of the instrument circuit by a high percentage, and give a series of false indications which may be well nigh disastrous. Circuits have been overloaded and generally destroyed by such defects.

Poorly drawn specifications frequently seek to achieve economy by utilizing a single ammeter for the measurement of current values upon several circuits, this being accomplished by the use of a similar shunt in each of the circuits to be measured, successively connecting the ammeter to No. 1, No. 2 and No. 3 shunt by switching or plugging.

This practice is exceedingly bad because of the variation in the contact resistance of the various switches and the error incident thereto.

Specifications calling for such arrangement should be condemned since they sacrifice accuracy to a dangerous degree in an endeavor to secure an economy which is in reality trivial. It is far better to be without an ammeter on a circuit than to attempt to measure under conditions involving so high a degree of unreliability.

It is desirable to make it clear that the objection to switching or "plugging over" a single ammeter onto two or more circuits is broadly pertinent only to ammeters used in connection with shunts, or, to state the case more literally, to voltmeters (for that is what such ammeters are) in which the needle, when at the highest point of the scale, is actuated by, let us say, 15 milli-amperes at 0.06 volts across the two terminals.

With the exception of integrating and recording instruments, the ammeter and the voltmeter comprise substantially all the instruments commonly used on continuous current circuits.

In the field of alternating current switchboard measuring appliances we find a very much larger field of conditions to be dealt with, and we must give consideration to all of the following mechanisms: the voltmeter, the ammeter, the indicating wattmeter, the polyphase indicating wattmeter, the synchronism indicator, the frequency indicator and the power factor indicator.

The alternating current voltmeter in ordinary practice today takes two forms: a structure having a fixed coil and a free coil, moving in relation to one another and against the restraining force of a spring or of gravity; or a fixed coil and a moveable magnetic vane, also moving against the restraining force of a spring or gravity.

The type of instrument in which the moving vane is utilized is capable of somewhat less precise accuracy than that involving the fixed and movable coils. It is, however, satisfactory for general voltage determination, and is the form commonly used.

The higher grade alternating current voltmeters, and indeed ammeters and other instruments of their general structure and characteristics, are very commonly made in such physical form as to permit of the use of a vertical pivot.

This structure is resorted to primarily because moving coil instruments of types in which no highly concentrated magnetic field is used have a high ratio of weight of moving element to torque, and by the use of the vertical pivot or step bearing the ratio of torque to friction is improved in the ratio of about two to one, as compared with similar mechanisms utilizing horizontal bearings.

We may compare this modification to a top revolving upon a vertical bearing, as compared with the same top spinning between horizontal bearings of highly perfected construction.

Instruments with vertical pivots must obviously, for the sake of convenience, have horizontal scales, which, however, chance to coincide with convenient arrangement. The most commonly used instruments in alternating current service are known as horizontal edgewise instruments.

Alternating current voltmeters are generally required to indicate at the generating plant the secondary voltage of the system, and they are consequently not ordinarily connected directly and physically to the generating circuit or feeder, but to the secondary of a transformer, the primary of which is connected to the generating circuit and the ratio of which is similar to that of the transformers in use on the circuit outside.

This statement applies, of course, only to systems where distribution is accomplished through step-down transformers, which method is, however, substantially universal.

The principal purpose of this so-called step-down transformer is, of course, to secure a voltage corresponding with that of the applied system, but incidentally it should be noted that with rare exceptions no instruments whatever should be connected directly and physically to the circuit when that circuit is of high potential. There are exceptions to this rule, but above 2300 volts it should be carefully observed, even on small systems, for in small structures like instruments it is difficult to provide insulation which will insure permanent isolation of the electrical parts of the instruments from the circuit, and obviously a ground on an instrument might be fatal to human life.

For high grade alternating current practice it is entirely proper to specify an accuracy between one-half scale and full scale within one per cent. of actual.

Alternating current voltmeters are subject, as are direct current voltmeters, to changes in room temperature, and in addition they are subject to other conditions of a more elusive character. Thus in some types a very noticeable error may be introduced by the use of the same instrument on circuits deriving their energy from machines giving different wave forms, and the same is true of changes in frequency. These deviations, however, if pursued, would carry the subject into a highly specialized branch of study.

Alternating current ammeters have, in a large measure, the same physical characteristics of mechanical construction as have voltmeters. They are commonly used, however, not in connection with shunts but in connection with so-called series or current transformers, that is, transformers, the secondary current of which varies in direct ratio to the variations in the current of the primary.

Such transformers are in reality step-up transformers with a very small number of turns in the primary (sometimes only a fraction of one turn) and a relatively large number of turns in the secondary. These devices obviously serve the same economic purpose in connection with alternating current as do the shunts in direct current service. The same kind of care must be exercised in making connections to them as to shunts. This is particularly true with the primary or high current connections, but not so radically true with the secondary or low current connections.

Current transformers are generally manufactured commercially for use interchangeably with ammeters of appropriate capacity and suitable type. They are not as a rule accurately reliable through a range exceeding ten to one, and it is preferable to so arrange the system as to rely upon them only through a range of five to one.

It is good practice to specify that the ratio error of current transformers shall not vary more than 1½ per cent. with a change in secondary load from one-tenth to normal full load. This latter stipulation is pertinent to the utilization of the same current transformer for the excitation of the actuating coils of several instruments, as for example, the current coil of a voltmeter, the current coil of an ammeter and the current coil of an integrating meter, all in the same circuit.

It is customary at times to specify the net accuracy of the ammeter and the current transformer, considered as a unit, in which case a variation of 2 per cent. from zero at all points between one-half scale and full scale is permissible.

Whilst the ammeter and the voltmeter may be regarded as the fundamental indicating instruments for all systems, and the only really necessary ones for continuous current service, the use of alternating current has rendered it desirable, and even necessary, to place upon most, if not all, switchboards, a number of other indicators reading in other units.

First among such instruments we must consider the indicating wattmeter.

Alternating current systems operating at unity power factor are practically never found in modern practice. Any distribution system serving devices involving iron in their circuit, such as transformers, arc lamps, fan or other motors and the like, is subject to phase displacement between the current and potential waves, and, as a consequence, the product of volts and amperes is not a true measure of the power output of the system, since the measured amperes and the measured volts are not concurrent.

It is therefore necessary to provide an instrument which will indicate the true watts upon the circuit. This instrument is the indicating wattmeter.

Physically, such instruments, whilst capable of being made in numerous forms, are substantially never found today save in one general form, namely, a moving coil rigidly attached to the indicating mechanism, excited through a fixed resistance across the system, and responding to fluctuations of potential; and a fixed coil, creating the field in which the potential coil moves, varying in its strength with fluctuations in current.

The mechanical combination of these elements may be greatly varied, but the resultant phenomena of torque and motion varying with the voltage multiplied by the current must be always the same.

In modern practice the potential coil of such instruments is usually attached to the secondary of a potential transformer, as in a voltmeter (indeed, the moving coil is essentially a voltmeter) whilst the fixed current coil is attached to the secondary of the current transformer, as in the case of an ammeter.

Two-phase and three-phase indicating wattmeters are commonly manufactured for such systems, and, whilst necessitating greater complexity of construction, involve similar principles. Such instruments are generally known by the name of polyphase wattmeters. There is another form of indicating wattmeter perhaps less commonly used, which involves the use of no moving wire, but the motion of which is dependent upon the torque produced by the induction of foucault currents in a disk by a mechanism whose inductive effect is dependent upon the watts in the system. Such a disk armature has a turning torque dependent upon the watts, and tends to turn against the restraining force of a spring. This mechanism is a modification of the familiar integrating induction type recording wattmeter, which will be dealt with later.

Whilst it is possible to determine the power factor of the system or the wattless component by comparing the volt-amperes (voltmeter, ammeter) with the true' watts as shown by the wattmeter, it is common and good practice to place power factor indicators upon each outgoing line or at least upon those involving the larger power loads, which are, of course, the larger inductive loads.

The purpose of this instrument is to show from week to week, rather than from moment to moment, the condition of the circuit, indicating when the inductive load of that particular circuit has been run up too high for economy, and pointing to the desirability of the correction of this condition, as by the introduction of synchronous motors or rotary condensers, or by the re-arrangement of the circuits. The power factor indicator is to be regarded as a technical luxury rather than a necessity.

This is also true of the frequency indicator, the function of which is to indicate upon a scale, as its name indicates, the frequency or alternations upon the system. This instrument serves to constantly inform the operator of the speed accuracy of his apparatus, as the efficiency and good behavior of most of the apparatus on the system is in some measure dependent upon the maintenance of proper frequency.

It would be undesirable to leave the subject of switchboard instruments without making some reference to electrostatic voltmeters, which are quite commonly used, especially in connection with high potential systems, where for various reasons it may be undesirable to introduce potential transformers between the system and the measuring device.

Electrostatic voltmeters actuate the needle in its movement across the scale by the electrostatic attraction or repulsion of one or more fixed vanes upon one or more movable vanes attached to the spindle and needle.

Numerous variations of construction may be and are resorted to in connection with such mechanisms, and these variations will be dealt with in another portion of this paper.

The principle of the electrostatic voltmeter is utilized in operating so-called ground detectors—instruments whose function it is to show upon a scale the presence of and to measure the resistance of a ground on a circuit or system, as well as to indicate the wire upon which the ground is present.

A common way of accomplishing this upon a single-phase system, for example, is to attach each of two fixed vanes or sectors to each of the two outgoing wires and a third fixed vane or sector to earth. A movable vane or vanes attached to the needle will, with no ground on the system, stand at such a position as to hold the needle in the center of the scale, but, should a ground occur upon either leg of the line, then the permanently grounded sector and the temporarily grounded sector will become essentially one, and the movable vane will take a position calculated to bridge through the shortest path between the ungrounded sector, and the grounded section of the system.

Before leaving switchboard instruments, a moment of consideration must be given the question of damping.

Substantially all indicating mechanisms have a most trying tendency when under rapid fluctuations of load to vibrate with such violence and for so considerable a time as to render any reliable readings substantially impossible.

If the moving element is light and of small inertia this motion is of small amplitude and of high frequency, resulting in vibrations of the needle which result in little more than a blur of the needle, whilst if the moving element be of relatively high inertia the motion is of large amplitude, longer period and at least equally difficult to interpolate.

Three common means have been resorted to for correcting this difficulty. In the early days of the art perhaps the most common means and certainly the simplest was to attach an air vane or an air dashpot of some form to the moving element. This served reasonably well in the days of small coercive forces, and vibrations of relatively large magnitude, but it was obviously inadequate for certain classes of instruments, which led to the introduction of fluid dashpots, one form of which consisted in attaching to the moving element a disk shaped hollow cylinder containing some viscous fluid as, for example, glycerine.

Such construction was open to objection, first because of excessive weight of moving element, and second because of the tendency of the fluid to cling to the interior of the moving cylinder and throw the mechanism out of balance.

In modern practice where a strong and relatively dense magnetic field constitutes a portion of the structure, it is easy to place a disk or cup or other similar element in this field, attached to the moving spindle in such a way that the motion of the spindle moves this foucault element through the field, resulting in the induction of foucault currents therein, thus damping the motion admirably, and rendering the instrument, in the phraseology of the art, "dead beat."

Where concentrated magnetic fields are not available, through the inherent principles of the instrument, the air vane is maintained as the preferable method, and has been developed to a high degree of perfection.

(To be Continued)

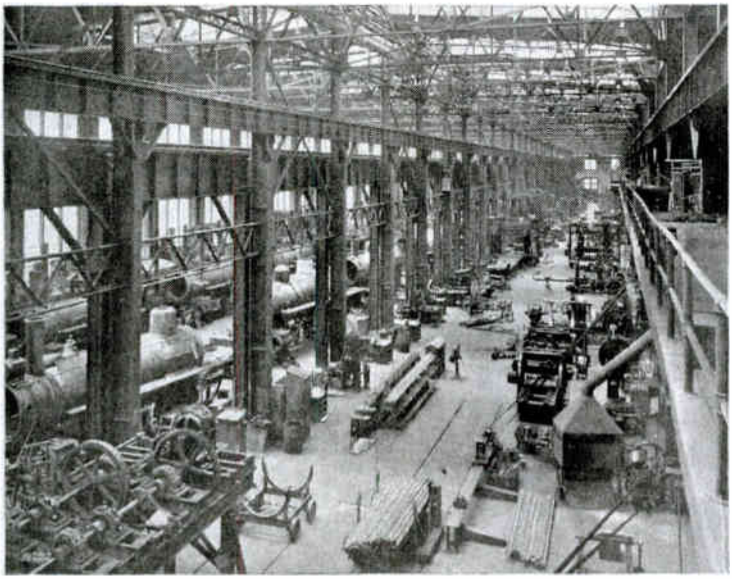
READVILLE REPAIR SHOP OF THE N. Y., N. H. and H. R. R.

By A. I. Totten

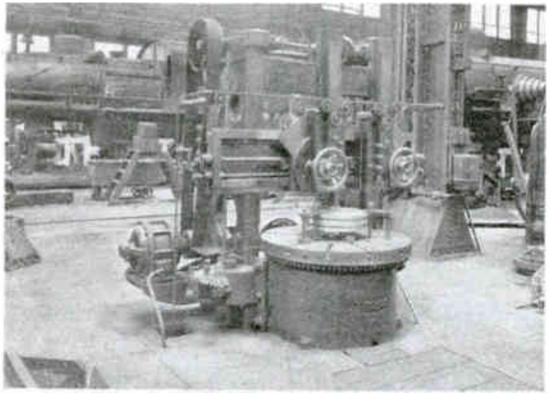
The main building of the Readville Shops of the New York, New Haven and Hartford Railroad is 904 ft. 6 in. long by 150 ft. wide and comprises a machine shop, an erecting shop, a boiler shop, and a tank shop. This building is of brick and concrete construction, with structural steel frame, and has a roof covered with 5-ply asphalt and gravel. A great deal of attention was paid to the construction of the concrete floor, which is laid in squares with strips of tar paper separating the various sections.

The erecting shop occupies half the width of the building and two-thirds of its length; it is built on what is known as a longitudinal design, will house 36 locomotives, and can make heavy repairs to 45 locomotives per month. The three longitudinal tracks are spaced on 23 ft. centers, the two outside tracks being used for engine repairs and the middle track for stripping and erecting, also for the storage of driving wheels during the period that the engines are in the shop. Stripping and erecting pits 150 ft. long are located under the center track at each end of the erecting shop, and between the central and outside tracks are storage pits which extend the full length of this shop. These pits are covered with 4 in. by 12 in. yellow pine plank, every tenth plank being provided with heavy malleable iron handles to facilitate its removal.

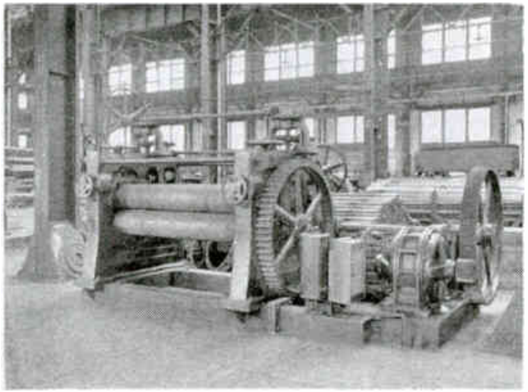
At the end of the erecting shop and occupying about 300 ft. of the total length of the building, is the boiler shop. These two shops are served by two 60 ton and two 20 ton cranes, the former being used for handling locomotives and the latter for handling boilers and the lighter work in connection with stripping, erecting, and transferring the various parts. These cranes, as well as all other cranes in the shops, are operated by



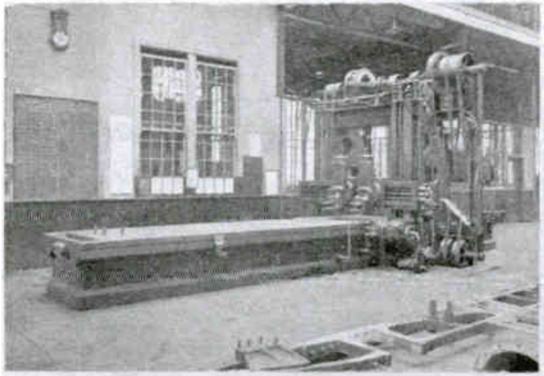
Portion of Machine Shop on the Right; Erecting Shop on the Left



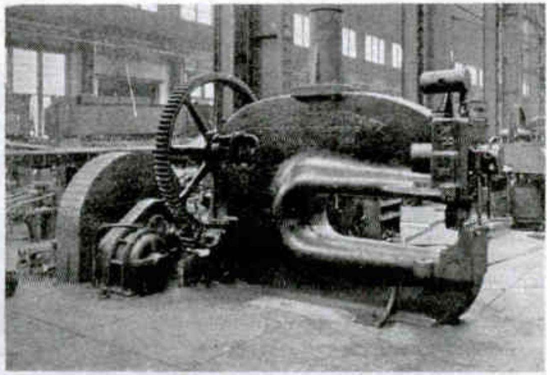
51 In. Boring Mill Driven by 3½ H.P., 1750 R.P.M., 550 Volt, Form K Induction Motor



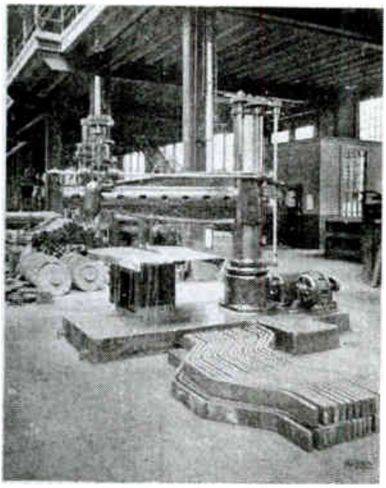
Straightening Roll Driven by 10 H.P., 450 R.P.M., 550 Volt, Form M Induction Motor



5 Ft. x 20 Ft. Planer Direct Connected to 35 H.P., 750 R.P.M., 550 Volt, Form K Induction Motor



Shear Driven by 10 H.P., 750 R.P.M., 550 Volt, Form K Induction Motor alternating current induction motors. At one end of the erecting shop are placed driving wheel lathes, large boring mills, etc., to avoid the necessity of handling driving wheels and the heavier locomotive parts between the erecting shop and the machine shop.



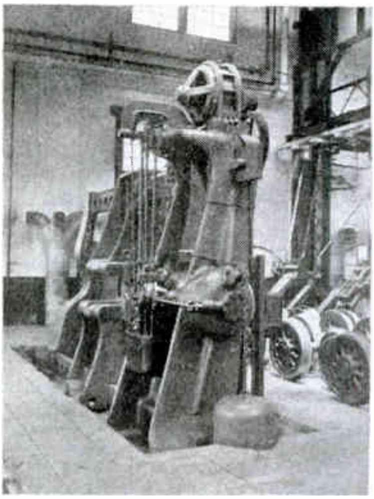
6 Ft. Radial Drill Geared to 5 H.P., 1500 R.P.M., 550 Volt Form K Induction Motor

The machine shop is of the same length as the erecting shop and occupies the opposite half of the building. In addition to the ground floor space in this department, there is also a gallery 35 ft. wide, the full length of the building. This gallery is used for brass work, bolt work, lubricator and injector repair work, electrical repair work, tin and copper work, and cab work. Hatches are located at intervals in the floor and an I-beam trolley is used both for transferring material in the gallery and for raising material from the ground floor to the gallery floor through the hatches. In the gallery are located two Sturtevant indirect radiation heating systems which provide heat for the whole building. The gallery floors are of 2 in. by 6 in. spruce laid diagonally on 8 in. by 16 in. joists and covered with 1 in. by 4 in. maple. At each end of the gallery are locker rooms with suitable lavatory accommodations and immediately below these locker rooms are others similarly equipped.

The heavier tools on the ground floor of the machine shop are located outside of the gallery and served by three 10-ton cranes. In addition to the traveling crane service, the more important machines have each an independent jib crane, so that material can be handled in and out without the necessity of waiting on the traveling cranes.

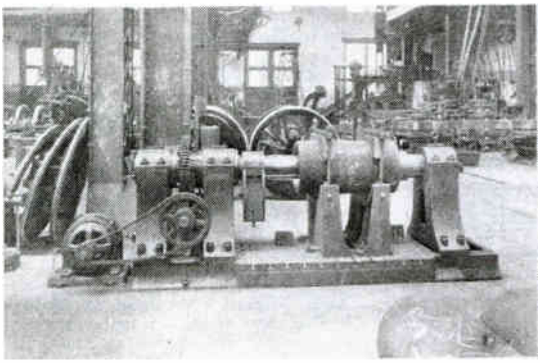
Beneath the gallery are located the lighter tools, which are operated in groups from line shafting running the full length of the shop. This line shafting is divided into sections, each section being operated by an independent motor. At the dividing point between any two sections is placed a flange coupling with the bolts removed. In case it is desired to take any motor out of service for repairs or other reasons, the bolts can be inserted in the flange coupling and two sections of the shafting run by a single motor; or, by connecting the flange couplings at each end of the section, two motors can be made to operate three sections of shafting.

The majority of large tools are independently motor driven, and tests on a large number of these motors, as well as tests on some of the group drive motors, may prove of interest and are included at the end of the article.



90 In. 600 Ton Wheel Press, Operated Through Gearing by 25 H.P., 750 R.P.M., 550 Volt, Form K Induction Motor

These tests, in so far as they refer to individually driven machines, were taken under average conditions; the groups, however, were not working up to their full capacity when the tests were made. While it is true that the results of these tests would not indicate the capacity of motor best suited to a given requirement, it can be inferred that the horse-power in the majority of cases varies in almost direct proportion to the metal removed, and it can therefore readily be ascertained whether or not the motors are of the proper size.



Cylinder Borer Driven by 7½ H.P., 750 R.P.M., 550 Volt, Form K Induction Motor

There is what might be termed a manufacturing tool room in the gallery, and immediately beneath this is a corresponding room on the ground floor for the distribution and grinding of tools. A central station for a complete shop telephone system is located in the distributing tool room, this arrangement saving the time that would be necessary for mechanics to go to and from the tool room. When any special tool is desired, it is called for by telephone and delivered by messenger, who takes a check as a receipt.

The blacksmith shop is in a separate building paralleling a portion of the erecting shop, but there are few points of special interest to be described in connection with this department.

The power plant contains the following equipment:

Six 400 h.p. Babcock & Willcox boilers, five of which are equipped with mechanical stokers, the remaining one being arranged for burning shavings and refuse from the planing mill. These boilers are provided with Sturtevant economizers.

Three 400 kw., 150 r.p.m., 600 volt, 25 cycle G.E. generators direct connected to Hooven Owens Rentschler Company's cross compound 18 in. by 28 in. by 30 in. non-condensing engines.

Two 50 kw., 280 r.p.m., 125 volt exciters driven by simple Watertown engines.

Two 12-B brush arc generators direct connected to one 200 h.p., 250 r.p.m., 550 volt motor.

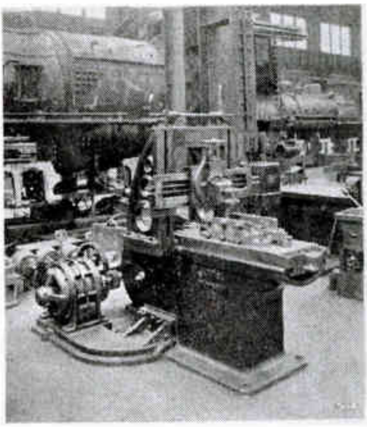
One 12-B brush arc generator direct connected to one 100 h.p., 500 r.p.m., 550 volt motor.

One 24 panel blue Vermont marble switchboard, equipped with General Electric Type TA voltage regulator.

One Franklin cross compound air compressor with a capacity of 1700 cubic ft. of free air per minute.

Two Franklin air compressors with a capacity of 1100 cubic ft. of free air per minute.

The piping, both that in the power plant and that connecting the power plant with other buildings of the shop, is painted in different colors, according to the purpose for which it is used. A table, as



24 In. Planer Driven Through Gearing by 7½ H.P., 750 R.P.M., 550 Volt, Form K Induction Motor

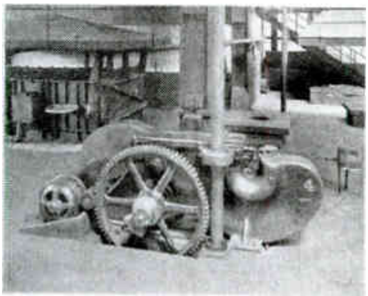
shown below, is provided at various points for the instruction of those interested:

White—High pressure steam.
Yellow—Exhaust and low pressure steam heat.
Black—Water, including boiler feed and feed water heater.
Green—Air
Blue—Drip and return.
Red—Fire service.

In addition to the building described above, there is a car department, which was, however, built a number of years ago. The machinery in this department is operated throughout by motors receiving current from the power plant described.

This entire plant is operated by 25 cycle alternating current, the only direct current apparatus being the exciters for the alternating current generators.

In the various departments are installed 173 motors with a total capacity of 3160 h.p., all of which are of General Electric manufacture. The average motor load at the switchboard varies from 600 to 700 kw., the average lighting and power load combined varying from 800 to 900 kw. It is therefore seen that the percentage of average load to total capacity of motors installed is about 30 per cent. The power factor throughout the day time is about 69 per cent., increasing to 71 or 72 per cent. when the lights are placed in operation.



Punch Driven by 10 H.P., 750 R.P.M., 550 Volt Form K Induction Motor

TESTS

80 IN. DOUBLE WHEEL LATHE (Putnam)
10 H.P., 750 R.P.M., 550 Volt, Form K Induction Motor.

Load	Kilowatt Input
Rolling axle, speed 15 feet per min	0.5–2.0
Turning axle, $\frac{1}{16}$ in. cut, $\frac{1}{8}$ in. feed Speed 15 ft. per min.	0.6–1.6

90 In. DOUBLE WHEEL LATHE (Putnam)
50 H.P., 750 R.P.M., 550 Volt, Form K Induction Motor

Load	Kilowatt Input
Running light	2.4
Full load	28.

Load consists of two heavy cuts on driving wheels, $\frac{3}{8}$ in. feed, $\frac{3}{8}$ in. cut, cutting speed 12 ft. per min. Kind of tool steel—Mushet high speed.

7½ H.P., 750 R.P.M., Form K Induction Motor

This motor is used to move tail stock.

Load	Kilowatt Input
Moving forward	1.8
Moving backward	1.8

600 TON, 90 In. WHEEL PRESS (Pond)
25 H.P., 750 R.P.M., 550 Volt, Form K Induction Motor

Load	Kilowatt Input
Running light	1.4
Pressing 6 in. crank pin from driving wheel	
Average load	2.3
Maximum load when pin started	3.5
Maximum pressure when pin started 260 tons.	

36 IN. X 12 FT. PLANER (Putnam)
10 H.P., 750 R.P.M., 550 Volt, Form K Induction Motor

Load	Kilowatt Input
Running light	1.8
Forward, no load	2.8
Reverse	22.
Back	4.4
Reverse	18.
Forward under load	3.6

Load { One $\frac{1}{16}$ in. cut, $\frac{1}{16}$ in. feed on cast iron, Tool steel, Midvale
One $\frac{1}{32}$ in. cut, $\frac{1}{16}$ in. feed on steel. Tool steel, Syrian
Forward 35 ft. per min.
Backward 70 ft. min.

48 IN. X 16 FT. DOUBLE PLANER (Woodard & Powell)
25 H P., 750 R.P.M., 550 Volt, Form K Induction Motor

Load	Kilowatt Input
Running light	2.
Forward, no load	4.
Backward, no load	4.
Forward, under load	13.

Load, two $\frac{1}{16}$ in. cut, $\frac{1}{32}$ in. feed on cast steel
Tool steel—Mushet high speed
Cutting speed 45 ft. per min.

72 IN. X 12 FT. PLANER (Pond)
25 H.P., 750 R.P.M., 550 Volt, Form K Induction Motor

Load	Kilowatt Input
Running light	1.7
Reverse	20.
Forward, no load	2.4
Backward	3.
Reverse	10.
Forward, under load	4.8

Load, 1 cut ½ in. with $\frac{1}{8}$ in. feed on cast iron
Tool steel—Mushet high speed
Cutting speed—18 ft. per min.
Return speed—54 ft. per min.

72 IN. X 30 FT. PLANER (Putnam)
35 H.P., 750 R.P.M., 550 Volt, Form K Induction Motor

Load	Kilowatt Input
Running light	3.4
Forward, no load	4.8

72 IN. X 30 FT. PLANER (Putnam) Concluded

35 H.P., 750 R.P.M., 550 Volt, Form K Induction Motor

Load	Kilowatt Input	
Reverse	32.	5 tons on bed
Backward	9.2	
Reverse	14.8	
Forward, under load	6.4	

Load, one $\frac{1}{4}$ in. cut, $\frac{3}{16}$ in. feed on cast iron
Tool steel—Mushet
Speed forward—30 ft. per min.
Speed backward—65 ft. per min.

CYLINDER BORER

7$\frac{1}{2}$ H.P., 750 R.P.M., 550 Volt, Form K Induction Motor

Load	Kilowatt Input
Running light	0.76
3 cuts $\frac{1}{8}$ in. by $\frac{1}{16}$ in. feed	4.8
5 cuts $\frac{1}{8}$ in. by $\frac{1}{16}$ in. feed	5.6

On 3 cuts, cutting speed 17 ft. per min. Tool steel unknown
On 2 additional cuts, cutting speed 25 ft. per min. Tool steel, one Mushet high speed; one Syrian

6 FT. RADIAL DRILL (Bickford)

5 H.P., 1500 R.P.M., 550 Volt, Form K Induction Motor

Load	Kilowatt Input
Running light	0.9
$\frac{7}{8}$ in. hole in cast steel	1.9

Feed, $\frac{1}{2}$ in. per min.
Speed of drill, 74 r.p.m.

5 FT. RADIAL DRILL (Bickford)

5 H.P., 1500 R.P.M., 550 Volt, Form K Induction Motor

Load	Kilowatt Input	Speed of Drill
Running light	.48	
One $\frac{5}{8}$ in. hole in steel, feed 0.45 in. per min.	1.3	52 r.p.m.
Two $\frac{1}{2}$ in. hole in cast iron, feed 0.16 in. per min.	1.5	24 r.p.m.
Two $\frac{3}{4}$ in. hole in steel, feed 0.375 in. per min.	2.4	20 r.p.m.

51 IN. BORING MILL (Bullard)

7$\frac{1}{2}$ H.P., 750 R.P.M., 550 Volt, Form K Induction Motor

Load	Kilowatt Input
Running light	1.8
Two $\frac{1}{4}$ in. cuts, $\frac{3}{32}$ in. feed, 40 ft. per min. on cast iron	4.6

Tool steel—Mushet high speed

47 IN. BORING MILL (Baush)

10 H.P., 750 R.P.M., 550 Volt, Form K Induction Motor

Load	Kilowatt Input
Running light	1.9
One $\frac{3}{32}$ in. cut, $\frac{1}{32}$ in. feed, 35 ft. per min. cast steel	3.
One $\frac{3}{16}$ in. cut, $\frac{3}{32}$ in. feed, 40 ft. per min. cast steel	3.5
One $\frac{3}{16}$ in. cut, $\frac{1}{16}$ in. feed, 50 ft. per min. cast steel	4.

Tool steel—Mushet high speed

BUFFER & GRINDER (Rawson)

3 H.P., 750 R.P.M., 550 Volt, Form K Induction Motor

Load	Kilowatt Input
Running light	0.4
Grinding 6 in. steam pipe to surface	0.5

COLD SAW (Newton)

3 H.P., 750 R.P.M., 550 Volt, Form K Induction Motor

Load	Kilowatt Input
Running light	.6
Cutting 6 in. cast iron	3.2

Slow feed 0.45 in. per min.
Saw 16 in. dia., 14$\frac{1}{2}$ r.p.m.

FLUE CLEANER (Ryerson)

25 H.P., 750 R.P.M., 550 Volt, Form K Induction Motor

Load	Kilowatt Input
Rolling	7.2
Lifting	17.

Loaded with 308—2 in. dia. tubes, 12 ft. long.

No. 5 PUNCH (Hilles & Jones)

5 H.P., 750 R.P.M., 550 Volt, Form K Induction Motor

Load	Kilowatt Input	
Running light	0.7	
Punching $\frac{3}{16}$ in. hole in $\frac{1}{4}$ in. boiler plate	1.3	Max.
Punching $\frac{3}{16}$ in. hole in $\frac{3}{16}$ in. boiler plate	1.2	
Punching $\frac{3}{16}$ in. hole in $\frac{3}{16}$ in. iron	1.5	
Punching $\frac{3}{16}$ in. hole in $\frac{1}{2}$ in. steel	2.32	

22 Punches per min.

NO. 4 PUNCH (Hilles & Jones)

10 H.P., 750 R.P.M., 550 Volt, Form K Induction Motor

Load	Kilowatt Input
Running light	.5
Punching $\frac{11}{16}$ in. hole in $\frac{1}{2}$ in. flange steel	4. (Max.)

NO. 9 PUNCH & SHEAR (Hilles & Jones)

15 H.P., 750 R.P.M., 550 Volt, Form K Induction Motor

Load	Kilowatt Input	
Running light	3.	
Punching 2 in. hole in $\frac{1}{4}$ in. boiler plate	5.	Max.
Punching 2 in. hole in 1$\frac{1}{2}$ in. wrought iron	22.	
Shearing 4 in. by 2$\frac{1}{2}$ in. hammered iron	10.	

NO. 3 SHEAR (Hilles & Jones)

5 H.P., 750 R.P.M., 550 Volt, Form K Induction Motor

Load	Kilowatt Input	
Running light	0.3	
Shearing round steel $\frac{1}{2}$ in. dia.	0.8	Max.
Shearing round steel $\frac{3}{4}$ in. dia.	1.1	
Shearing boiler plate $\frac{5}{8}$ in. by 2$\frac{1}{2}$ in.	2.	
Shearing boiler plate $\frac{3}{8}$ in. by 1$\frac{1}{2}$ in.	1.2	

SPLITTING SHEAR (Lenox Machine Co.)

7$\frac{1}{2}$ H.P., 750 R.P.M., 550 Volt, Form K Induction Motor

Load	Kilowatt Input
Running light	0.4
Cutting $\frac{1}{4}$ in. boiler plate	1.7

Cutting speed 7.2 ft. per min.

10 FT. BENDING ROLLS (Hilles & Jones)

10 H.P., 750 R.P.M., 550 Volt, Form K Induction Motor

Load	Kilowatt Input
Running light	1.2
Bending $\frac{1}{2}$ in. boiler plate. Av.	2.8; Max 4.4

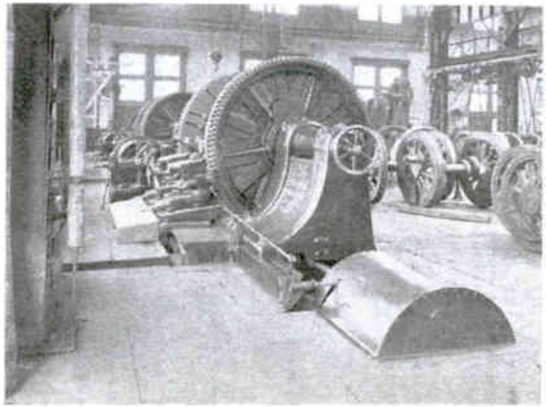
Boiler plate was 6$\frac{1}{2}$ ft. wide and was bent to a radius of 30 in. in 5 rollings
Rolling speed 6.6 ft. per min.

63 IN. BOSTON CUPOLA & FORGE BLOWER

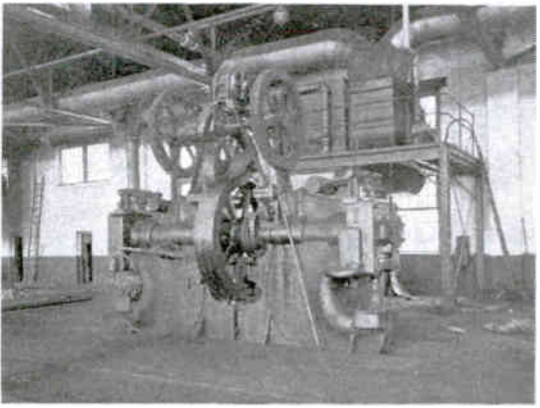
30 H.P., 750 R.P.M., 550 Volt, Form L Induction Motor

This blower furnishes air for one flange fire, two flue fires, and a four burner Ferguson annealing furnace, made by the Railway Materials Co.

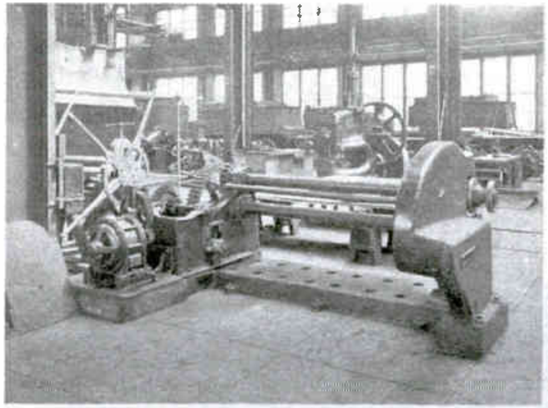
Load	Kilowatt Input
All full blast	13.8
Two flue fires only	9.5



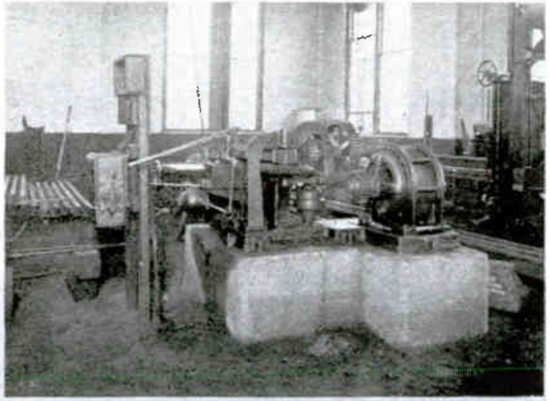
90 In. Double Wheel Lathe Geared to 75 H.P., 715 R.P.M., 550 Volt, Form K Induction Motor



Punch and Shear Driven by 15 H.P., 750 R.P.M., 550 Volt, Form K Induction Motor



Splitting Shears Driven by 7½ H.P., 715 R.P.M., 550 Volt, Form K Induction Motor



Rail Bender Driven by 10 H.P., 750 R.P.M., 550 Volt, Form K Induction Motor

NO. 7 BLOWER (Sturtevant)
BULLDOZER (Ajax)

35 H.P., 500 R.P.M., 550 Volt, Form K Induction Motor

Blower furnishes air for 5 furnaces

Load	Kilowatt Input	
Blower with 3 furnaces operating	16.3	
Blower & Bulldozer	28.3	Max.

Bulldozer was making 2–90 degree bends on ¾ in. by 3 in. iron

STURTEVANT BLOWER

35 H.P., 750 R.P.M., 550 Volt, Form K Induction Motor

Blower furnishes air for
One double furnace
Four single furnaces
Five double forges

Load	Kilowatt Input
3 single furnaces at work 1 double furnace at work	17.6
3 single furnaces at work 1 double furnace at work 1 double forge full vent	18.6

BLOWER (Buffalo) } For 20 forges and
EXHAUSTER (Buffalo) } 2 furnaces

50 H.P., 500 R.P.M., 550 Volt, Form L Induction Motor

Load	Kilowatt Input
11 forges and 2 furnaces in operation	21.5

NO. 3 SHEAR (Hilles & Jones)

10 H.P., 750 R.P.M., 550 Volt, Form K Induction Motor

Load	Kilowatt Input	
Running light	1.	
Shearing 1½ in. wrought iron .	5.5	Max.
Shearing 2¾ in. wrought iron .	6.	

5 FT., 6 IN. RADIAL DRILL (Niles, Bement & Pond)

5 H.P., 750 R.P.M., 550 Volt, Form K Induction Motor

Load	Kilowatt Input
Running light	1.2
Drilling ¾ in. hole in steel, feed 0.67 in. per min.	1.5
Drilling 2½ in. hole in steel, feed 0.075 in. per min.	1.8

MILL SHOP NO. 1
SWING CUT-OFF SAW (Rogers)

3 H.P., 750 R.P.M., 550 Volt, Form K Induction Motor

Load	Kilowatt Input
Running light	0.74
Cutting 2 in. by 12½ in. spruce .	2.4

Size of saw 19 in.
Speed 2080 r.p.m.

SWING CUT-OFF SAW (Rogers)

3 H.P., 750 R.P.M., 550 Volt, Form K Induction Motor

Load	Kilowatt Input	
Running light	0.9	
Cutting 5 in. by 8 in. hard pine .	6.	Max.
Cutting 2 in. by 10 in. hard pine .	5.	

Size of saw 18 in.
Speed 1840

RAIL SAW (Newton)

7½ H.P., 750 R.P.M., 550 Volt, Form K Induction Motor

Load	Kilowatt Input
Running light	0.56
Sawing 6 in. steel rail . . . Av.	1.6 Max. 2.4

Feed 0.21 in. per min.
28 in. saw
5.15 r.p.m.

RAIL BENDER (Watson & Stillman)

15 H.P., 750 R.P.M., 550 Volt, Form K Induction Motor

Load	Kilowatt Input
Running light	1.
Bending 79 lb. rail to 24 ft., 11¼ in. radius	8.

Speed of rail 100 ft. per min.

15 IN. SLOTTER (Dill)

5 H.P., 1500 R.P.M., 550 Volt, Form K Induction Motor

Load	Kilowatt Input
Running light	0.4
One ⅜ in. cut, $\frac{1}{32}$ in. feed on steel	0.9

Tool steel—Mushet high speed
Strokes per minute, 23

ELEVATOR

5 H.P., 750 R.P.M., 550 Volt, Form K Induction Motor

Load	Kilowatt Input
Motor running light	0.56
Elevator up with one man	Pump back on line
Elevator down with one man .	4.2
Elevator up with 1400 lbs. . .	1.2
Elevator down with 1400 lbs. .	2.2

24 IN. EXTRACTOR

3 H.P., 750 R.P.M., 550 Volt, Form K Induction Motor

Load	Kilowatt Input
Extractor filled with oily waste .	0.96–0.88

Speed of extractor, 1080 r.p.m.

NO. 3 GAINER (Wood)

6 H.P., 750 R.P.M., 550 Volt, Form L Induction Motor

Load	Kilowatt Input
Running light	2.4
½ in. by 1½ in. gain in hard pine .	4.4
2 in. by 4½ in. gain in hard pine .	7.2

NO. 2 FORGING MACHINE (Ajax)

10 H.P., 750 R.P.M., 550 Volt, Form L Induction Motor

Load	Kilowatt Input	
Running light	1.6	
Punching $\frac{9}{16}$ in. hole in a 1$\frac{1}{16}$ in. rivet	5.0	Max.

NO. 5 FORGING MACHINE (Ajax)

20 H.P., 750 R.P.M., 550 Volt, Form L Induction Motor

Load	Kilowatt Input	
Running light	3.7	
Loaded	16.1	Max.

Load consisted of gathering a 1⅞ in. hemispherical head on a 1⅛ in. rivet.

GROUP (Gallery)

7½ H.P., 750 R.P.M., 550 Volt, Form K Induction Motor

Machines	Load	Kilowatt Input
1 Two spindle irregular moulder (Carey) .	Running light	7.
1 39½ in. band saw (Carey)	Running	
1 Double saw table (Carey)	Running	

When test was made saw was ripping 2 in. pine and saw bench ripping 2 in. oak.

GROUP

10 H.P., 750 R.P.M., 550 Volt, Form K Induction Motor

Machines		Load	Kilowatt Input
4 Flue cutters	2 Running	light	4.
	2 Running		
1 Flue welder . . .		Running	

GROUP

10 H.P., 750 R.P.M., 550 Volt, Form K Induction Motor

	Machines	Load	Kilowatt Input
1	28 in. Vertical drill (Blaisdell)	Running	6.2
1	40 in. Vertical drill Bement)	Running	
1	38 in. Vertical drill (Prentice)	Running	
2	34 in. Lathes (Putnam)	1 Running	
5	22½ in. Vertical drills (Barnes)	1 Running	

GROUP

15 H.P., 750 R.P.M., 550 Volt, Form K, Induction Motor

	Machines	Load	Kilowatt Input
3	24 in. Lathes (Reed)	2 Running	8.
1	40 in. Vertical drill (Bement)		
1	42 in. Boring mill (Bullard)	Running	
1	24 in. Shaper (Stockbridge)		
1	15 in. Slotter (Betts)		
1	18 in. Slotter (Putnam)	Running	
1	30 ton arbor press (Chamsberberg)		

GROUP

15 H.P., 750 R.P.M., 550 Volt, Form K Induction Motor

	Machines	Load	Kilowatt Input
2	30 in. by 8 ft. planers (Woodward & Powell)	2 Running	8.
1	26 in. by 10 ft. milling machine planer type (Becker Brainard)		
1	5 ft. radial drill (Bickford)	Running	
2	No. 2 horizontal boring mills (Betts)	2 Running	
1	25 in. vertical drill (Barnes)		

GROUP (Gallery)

15 H.P., 750 R.P.M., 550 Volt, Form K Induction Motor

	Machines	Load	Kilowatt Input
1	24 in. lathe (Fitchburg)		Av. 12. Max. 24.
2	20 in. lathes (Schumacher)	1 Running	
4	18 in. lathes (Prentice)	2 Running	
3	18 in. lathes (Schumacher)		
4	2 ft. by 24 in. flat turret lathes (Warner & Swasey)	2 Running	
2	2 ft. by 24 in. flat turret lathes (Jones & Lampson)	1 Running	
1	40 in. vertical drill (Bement)		
1	25 in. vertical drill (Barnes)		
1	3 in. bolt cutter		
1	1½ in. bolt cutter (Acme)		
2	double bolt cutters (Acme)	2 Running	
1	double bolt cutter (Niles, Bement & Pond)	Running	

GROUP

15 H.P., 750 R.P.M., 550 Volt, Form L Induction Motor

	Machines	Load	Kilowatt Input
1	Trip hammer (Bradley)	Running	Av. 13. Max. 19.
1	No. 2 emery grinder (Diamond Machine Co.)	Running	
2	40 in. vertical drills (Bement)	2 Running	
1	Grindstone		
1	Hammer (Bradley)		
1	No. 2 shear (Hilles & Jones)		
1	1½ in. forging machine (Ajax)		
1	2 in. forging machine (Ajax)	Running	
1	3½ in. forging machine (Ajax)	Running	

GROUP

25 H.P., 750 R.P.M., 550 Volt, Form K Induction Motor

	Machines	Load	Kilowatt Input
2	30 in. boring mills (Bullard)	1 Running	16.
2	24 in. lathes (Reed)	2 Running	
2	18 in. lathes (Reed)		
1	24 in. turret lathe (Gisholt)	Running	
1	30 in. planer (Woodward & Powell)		
1	16 in. shaper (Gould & Erbhardt)		
1	24 in. shaper (Stockbridge)	Running	
1	16 in. shaper (Stockbridge)		
1	30 in. planer (Putnam)		
1	42 in. vertical milling machine (Hilles & Jones)		
1	Double rod borer (Newton)		

GROUP

30 H.P., 750 R.P.M., 550 Volt, Form L Induction Motor

	Machines	Load	Kilowatt Input
1	No. 300 Hollow mortiser (Wood)	Running	Av. 22.2 Max. 30.3
1	No. 225 Hollow mortiser (Greenlee)	Running	
1	30 in. Single planer (Rogers)	Running	
1	30 in. Single planer (Fay) Heavy load	Running	

GROUP

35 H.P., 500 R.P.M., 550 Volt, Form K Induction Motor

	Machines	Load	Kilowatt Input
2	Irregular moulders (Wood)	2 Running	26.3
1	60 in. three drum sander (Fay)	Running	
1	42 in. three drum sander (Fay)	Running	
2	Grindstones	Running	
1	42 in. band saw (Fay)	Running	
2	Turning lathes (Wood)		
1	Dowel machine (Fay)		
1	Rip saw	Running	
2	Copper sheathing machines Heavy load		

GROUP

40 H.P., 750 R.P.M., 550 Volt, Form L Induction Motor

	Machines	Load	Kilowatt Input
1	No. 214 jointer (Invincible)		20.3
1	Universal jointer (Fay)	Running	
1	Saw table (Roolston Engine Works)		
1	End tenoner (Berry & Orton)		
1	5 spindle borer (Wood)	Running	
1	5 spindle borer (Greenlee)	Running	
1	Self feed rip saw (Wood)		

GROUP

50 H.P., 500 R.P.M., 550 Volt, Form L Induction Motor

	Machines	Load	Kilowatt Input
1	Chain mortiser (New Britain)		18.3
1	Buzz planer and drill (Fay)		
1	48 in. band saw (Fay)	Running	
1	10 in. outside moulder (Wood)	Running	
1	36 in. band saw (Atlantic)		
1	Tenoner (Fay)		
1	Double cabinet saw (Carey)		
1	Tenoner		

THE EFFECT OF SUPERHEAT, VACUUM, INITIAL PRESSURE AND FEED WATER TEMPERATURE ON THE WATER RATE AND COAL CONSUMPTION OF TURBINES

By Dr. Ernst J. Berg

By referring to the equations given in the first paper[†] or to the tabulation of theoretical water rates, the theoretical water rate can be determined for any values of initial pressure, superheat, and vacuum.

So for instance with 200 lbs. absolute initial pressure, dry saturated steam, and 28 in. vacuum, the theoretical water rate is 10.2 lbs. per kilowatt hour. At 29 in. vacuum it is 9.6 lbs. per kilowatt hour, and at 27 in. vacuum, 10.75 lbs.; therefore, using 28 in. vacuum as a basis for comparison, there is a decrease in water rate of 5.9 per cent. when increasing the vacuum 1 in. and an increase in water rate of 5.4 per cent. when lowering the vacuum by 1 in.

Thus on an average, we conclude that around 28 in. vacuum each inch of vacuum changes the water rate by about 5.7 per cent.

With steam at 200° F. superheat, the theoretical water rate at 28 in. vacuum is 9.1 lbs. per kw-hr.; at 29 in. vacuum it is 8.55 lbs. per kw-hr.; and at 27 in. vacuum, 9.6 lbs.; thus the average change in water rate per inch of vacuum is also 5.7 per cent.

Therefore, in general we can state that, disregarding the condition of the steam (at about 200 lbs. absolute initial pressure and 28 in. vacuum), there is a change of water rate per inch of vacuum of about 5.7 per cent. With lower initial pressure, as for instance 140 lbs. absolute, the average change of water rate is 6.4 per cent. per inch of vacuum, or considerably greater than at the higher initial pressure, as could be expected.

The effect of superheat on the water rate can also be determined from the equation of available energy, or by referring to the table. For instance, at 200 lbs. absolute pressure and 28 in. vacuum, the theoretical water rate is 10.2 lbs. with saturated steam. With steam at 200° F. superheat, it is 9.1 lbs.; thus the decrease in water rate is 10.8 per cent., for each per cent. decrease in water rate requires 18.5° superheat. This value remains practically the same whether the vacuum is 27 in. or 29 in. It is also practically the same for all commercial initial pressures.

It is an interesting fact, however, that while the gain in water rate by vacuum is practically that demanded by theory, the gain by superheat is almost 50 per cent. greater. The fact that the gain by vacuum is as much as theory demands is interesting, since it indicates that the operation of the lower stages must be very efficient with high available energies, and corresponding high steam speeds, as the lower, or indeed the last stage, is practically the only one affected by the change of vacuum and may with high vacuum convert far more energy than each of the upper stages.

The large gain by superheat is no doubt due to the fact that the rotation loss is less than with initially saturated steam. It has been found that this loss is a function of the quality of the steam. A mixture of steam with a considerable amount of water acts to some extent as a water brake.

The great saving effected by the use of high vacuum is in the coal consumption; the per cent. saving corresponding practically to the gain in the water rate by increased vacuum. For instance, assuming the efficiency of the turbine to be the same when operating at 27 in. vacuum and at 28.5 in. vacuum, the gain in water rate at average commercial initial pressure is 9 per cent. and 9 per cent. in water means substantially a saving of 9 per cent. in coal.

The gain in water rate by superheat only slightly affects the coal consumption. As an example, the relative coal consumption will be determined for a turbine operated at 200 lbs. absolute initial pressure with dry saturated steam and 28 in. vacuum, and again with the same pressure, but 100° F. superheat.

The total heat per pound of saturated steam at 200 lbs. pressure is 1198.3 B.t.u.; the heat corresponding to 100° superheat (assuming Cp as .5) is 50 B.t.u.; and thus the increase in heat with superheat is

$$\frac{50}{1198.3} = .0417, \text{ or } 4.17 \text{ per cent.}$$

The available energy in the superheated steam between 200 lbs. and 1 lb. is 275,200 foot pounds; in saturated steam it is 261,000 foot lbs.; and thus the increase in available energy is 5.37 per cent., and the gain in coal $5.37\% - 4.17\% = 1.2\%$. As stated above,

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[*] The second of a series of three papers read before the employees of the Commonwealth Edison Company, Chicago.

[†] July, 1910, Review.

the gain in water rate is considerably greater than that which corresponds to the gain in available energy, and is about 8 per cent.; thus, in practice the gain in coal saved by 100° F. superheat is $8\% - 4.17\%$, or 3.83%. In this calculation it has been assumed that the flue gases leave at the same temperature, and that the thermal efficiency of the boiler in one case and boiler with superheater in the other is the same. In all probability this is not quite the case; nevertheless, there is a decided gain.

The initial pressure bears an important relation to economy, but the gain by increasing the initial pressure is very small compared with that derived by a few inches of vacuum.

Referring again to the tabulation of the theoretical water rates:

At 200 lbs. pressure, saturated steam, and 28 in. vacuum, the theoretical water rate is 10.2 lbs. per kilowatt hour; at 175 lbs. absolute and the same vacuum, it is 10.45 lbs.; thus the gain in water rate by raising the initial pressure 25 lbs. is 0.25 lbs. or 2.5 per cent. for 25 lbs., or 1 per cent. for each 10 lbs.

Effect of Feed Water Temperature on Steam Economy

It is generally recognized that it is well to supply steam boilers with water of as high temperature as possible. There are many good reasons for this practice outside of the gain in economy, but it is well worth doing on that score alone.

To illustrate this, a few typical cases will be considered.

1. When there is *no feed water heating*, which case might exist in a plant using electrically driven auxiliaries only.
2. *Exhaust from the auxiliaries is used to heat the feed water.*
3. *Feed water is heated partly by live steam and partly by the exhaust from the auxiliaries.*
4. *Feed water is heated partly by the exhaust and partly from a turbine which is "bled."*

No Feed Water Heating

We will consider a plant with main turbines of 540 kw. capacity and auxiliaries requiring 40 kw.; thus the useful output is 500 kw.

It will be assumed that the turbine is supplied with dry saturated steam at 165 lbs. absolute pressure, that the vacuum is 28 in., and that the water rate 19 lbs. per kilowatt hour. The flow per hour is then $19 \times 540 = 10{,}250$ lbs. At 28 in. vacuum the temperature of the condensed steam is 102° F.; at the boiler it is 366° F. Thus we need to supply $366 - 102 = 264$ B.t.u. as liquid heat per lb. of water. The latent heat at 165 lbs. pressure is 855.6 B.t.u.; thus each pound of the flow requires $855.6 + 264 = 1119.6$ B.t.u. and the total heat required is:

$1119.6 \times 10{,}250 = 11{,}500{,}000$ B.t.u.

Engines or Turbines Driving the Auxiliaries and their Exhaust (at Atmospheric Pressure) used to Heat the Feed Water

As in the first case, it will be assumed that the useful output is 500 kw., at a water rate of 19 lbs. It will be of interest to determine the water rate of the small engines or turbines, which at 40 kw. output will give sufficient exhaust steam at atmospheric pressure to raise the temperature of the feed water to 212° F. Since the temperature of the condensed steam from the main turbine is 102° F., we will require $212 - 102 = 110$ B.t.u. per pound of steam; thus, since with 500 kw. output at a water rate of 19 lbs. the flow is 9500, the heat required is $9500 \times 110 = 1{,}045{,}000$ B.t.u.

Assuming that the exhaust from the auxiliary engine contains 4 per cent. moisture, the heat input is the latent heat of 96 per cent. of the flow.

Let f be the flow from the auxiliary engine, and a the latent heat at atmospheric pressure, which is 965.8 B.t.u.

We have then, $965.8 \times 0.96\ f =$ heat input $= 1{,}045{,}000$ B.t.u.

Thus the flow $f = 1130$ lbs., which corresponds to a water rate of the auxiliaries of $1130 \div 40 = 28.2$ lbs. per kilowatt hour.

This water rate is far better than could be expected from small non-condensing turbines or engines; thus the heat in the exhaust is more than enough to bring the temperature of the feed water to 212° F. Some of the steam would have to exhaust into the atmosphere and would be lost.

If the water rate were 40 lbs. per kilowatt hour, which is likely, then the amount of surplus steam would be $40(40 - 28.2) = 470$ lbs. This steam would have to be supplied from the source of water, which might have a temperature of 60° F., but before entering the boiler it would be heated to 212° F. Thus the total heat necessary to be supplied is:

For that part of the water which has to be drawn for the water supply:

B.t.u.
Liquid heat $= 470(366 - 212) = 72{,}400$
Latent heat $= 470 \times 855.6 = 403{,}000$
475,400

For the rest of the flow (9500 + 1130 = 10,630 lbs.)

B.t.u.
Liquid heat = $10630(366-212)$ = 1,638,000
Latent heat = 10630×855.6 = 9,110,000
10,748,000

Thus total heat = 11,223,400 B.t.u.

In this case then, when a considerable portion of the exhaust steam is wasted, the gain is only slight, being about 2.4 per cent.

In large stations where the amount of power taken by the auxiliaries is a much smaller percentage of the useful power, the gain is very considerable. For instance, if the auxiliaries required only 5.6 per cent. of the useful power instead of 8 per cent., as was the case above, then no exhaust steam would go to waste and the total heat required would have been 10,748,000 B.t.u.

The saving in coal would then have been 6 per cent.

In very large stations the amount of exhaust steam is frequently insufficient to raise the temperature of the feed water to 212°. It is then of interest to inquire whether any economy would result if live steam was delivered to the feed, or if steam at substantially atmospheric pressure was drawn from the turbine.

As an illustration it will be assumed that the auxiliaries require only 4 per cent. of the main flow, that the water rate of the main turbines is 15 lbs. per kilowatt hour, and that the vacuum is 29 in. For the sake of simplicity we shall make the calculations for each 1000 kilowatts of output of the main turbines. The temperature of the condensed steam is 80° F. and the amount of condensed steam, 15,000 lbs. per hour. The mixture of the condensed steam and the exhaust will take a certain temperature t, which is higher than 80° and lower than 212°.

The heat required is the liquid heat between temperatures t and 80° F.; thus the heat required in B.t.u. units is $15{,}000(t-80) = 15{,}000\,t - 1{,}200{,}000$. The amount of the exhaust steam is $0.04 \times 15{,}000 = 600$ lbs. Thus the heat given by the exhaust is:

Liquid heat = $600(212-t) = 127{,}200 - 600\,t$.

Latent heat = $0.96 \times 600 \times 965.8 = 557{,}000$.

Thus $15{,}000\,t - 1{,}200{,}000 = 127{,}200 - 600\,t + 557{,}000$; thus $t = 121°$.

The heat required is:

Liquid heat for a flow of
B.t.u.
15,600 lbs. = $15{,}600(366-121)$ = 3,820,000
Latent heat for a flow of
15,600 lbs. = $15{,}600 \times 855.6$ = 13,350,000
17,170,000

To raise the temperature of the feed water to 212°, we obviously need:
$15{,}600(212-121) = 1{,}420{,}000$ B.t.u.
With p pounds of live steam supply, we get from the latent heat $855.6\,p$(B.t.u.).
From the liquid heat $p(366-212) = 154\,p$.
Thus a total amount of heat of $1009.6\,p$.
Thus $1009.6\,p = 1{,}420{,}000$ B.t.u.
or $p = 1410$ lbs. per hour.
In this case, then, the total flow will be
$15{,}000 + 600 + 1410 = 17{,}010$ lbs.
and the heat required: B.t.u.
Liquid heat $17{,}100(366-212)$ = 2,620,000
Latent heat $17{,}100 \times 855.6$ = 14,550,000
17,170,000

Thus there is no gain or loss except in so far as it is better to supply the boiler with the hotter water.

As was shown above, to raise the feed water temperature to 212° will require 1,420,000 B.t.u.

The second stage of the turbines usually has about atmospheric pressure; thus, since the latent heat at atmospheric pressure is 965.8 B.t.u., we require:

$$\frac{1{,}420{,}000}{965.8} = 1{,}470 \text{ lbs. of steam.}$$

At atmospheric pressure (since the steam probably contains 4 per cent. moisture)

$$\frac{1{,}470}{0.96} = 1{,}530 \text{ lbs. per hour.}$$

This steam has done some work in the main turbine, the amount of work being governed by the ratio of the available energy in the steam between the initial pressure and atmospheric pressure, to the total available energy. As can readily be calculated from the equation for the available energy and as can be seen from the tabulation of theoretical water rate, the available energy in the steam between the boiler pressure and the atmospheric pressure is approximately one-half of the total it would have had had it expanded to 29 in. vacuum.

Thus the water rate for that part of the steam which passes through the upper part of the turbine only and which is exhausted in the feed water is, say, $\frac{15}{0.5} = 30$ lbs. per kilowatt hour. The output of 1,530 lbs. is, therefore, $\frac{1{,}530}{30} = 51$ kw.

Therefore the steam which goes through the entire turbine need give only 949 kw.

Thus the total flow of steam is:

Lbs.
Main turbine (in its entirety) $949 \times 15 = 14{,}240$
Main turbine, non-condensing part $= 1{,}530$
Flow from auxiliaries $= 600$
$16{,}370$

Thus the heat required is: B.t.u.
Liquid heat $16{,}370(366-212) = 2{,}500{,}000$
Latent heat $16{,}370 \times 855.6 = 14{,}000{,}000$
Total heat $= 16{,}500{,}000$

The saving effected by bleeding the turbine is thus $17{,}170{,}000 - 16{,}500{,}000 = 670{,}000$ B.t.u. or 3.9 per cent.

In general it is safe to say that the most economical way of operating the auxiliaries is either to use a high class reciprocating engine which has a low water rate or else to have them electrically driven, and in the latter case, supply the necessary heat to the feed water by bleeding the turbine. The installation of small inefficient turbines for driving the various auxiliaries is not good engineering and the loss incidental to their use even if all the exhaust steam can be used for heating the feed water, amounts frequently to several percent of the total output. This is evident from the fact that there is practically as much heat from the exhaust of an efficient turbine at atmospheric pressure as from an inefficient turbine, and consequently the difference in output in the two types of turbines is a net gain to the general station output; therefore, if the total auxiliaries in a large plant amount to say, 200 kw., and these auxiliaries are driven largely by small turbines, it is safe to say that at least 100 kw. out of the 200 kw. could be saved by using electrical drive instead of turbine drive. The necessary mechanical arrangement for bleeding the turbines is so simple that there is practically no complication involved in its use. I relaize, of course, that there are frequently good reasons why steam driven auxiliaries should be given preference to motor driven auxiliaries, but I think that very frequently an unnecessary amount of small steam driven auxiliaries are used, and their justification has been the erroneous assumption that the efficiency of the small auxiliary is immaterial as long as its exhaust can be used to advantage to heat the feed water.

LUMINESCENCE*

BY DR. CHARLES P. STEINMETZ

Since the old primeval days, when fire was first used for heat, light and as a protection against animal foes, down to the present, the art of illumination has been advancing—very slowly at first, then more and more rapidly; developing from the wood fire, through the torch, the candle, and the oil burners to the gas and electric lights.

Light which is produced by heat, or temperature, we call incandescent light. The heat energy which a current of electricity produces in the resistance of the filament must escape from it, and this appears as radiation. Light, and radiation in general, are forms of energy differing from heat, but by the interception of the radiation by some opaque body, heat is produced. For instance, if you place your hand so that the radiation energy impinges upon it, this energy is destroyed as radiation and becomes heat.

By raising the temperature we obtain more rapid vibration and higher frequencies, until ultimately frequencies are reached that produce visible radiation, or light. In the lower frequencies that produce light, this light appears red. Increasing the temperature further, the amount of radiation increases and we have rays of orange, yellow, green, blue, violet and ultra violet; the color of light changing with increasing temperature from red to orange, to yellow, to yellowish white, and then becoming whiter and whiter.

If the temperature could be increased beyond that at which white light is produced, the light would become bluish, or ultra-violet, but long before this we are close to the limit of temperature which even the tungsten lamp can stand, because the filament will melt. If we wish to use a still higher temperature, we start an arc between two carbon terminals. As the current passes through the stream of vapor between these two terminals, the stream is at the boiling point of carbon (about 3700° C.) and heats the terminals to this point, thus producing a light that is whiter than that seen in the tungsten lamp. The arc lamp operates at the highest temperature—the boiling point of carbon—and gives the most efficient incandescent light. Thus the efficiency increases, and the colors change with the increase in temperature.

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*Lecture delivered before the Schenectady Section A.I.E.E.

The total range of radiation, from the lowest frequency to the highest, compasses something like 12 octaves, of which something less than one octave is visible—all the other being invisible. It should be understood that the lowest frequency within these 12 octaves is still hundreds of millions of cycles per second.

Most illuminants give a yellow light, because the temperature is naturally lower than that necessary to obtain a white light. Green light it is impossible to get, with a temperature radiation, green being in the middle of the visible range. The color of ordinary incandescent light is seen in the light produced in the candle—the most reliable illuminant which human ingenuity has ever devised.

If we take an alcohol lamp, and hold in the flame a piece of platinum wire which has been dipped in thallium chloride, the flame assumes a green color. Now this color is not due to incandescence or temperature radiation, since it is a green, a color, which, as stated, can not be obtained from temperature radiation. If instead of thallium chloride, the platinum wire is dipped into lithium chloride, the flame assumes a bright red color. Again using sodium chloride we get a yellow light. It is a curious thing that we can get green, red and yellow lights in the same flame, the temperature being the same in all three cases. Here we find a kind of radiation which is not due to incandescence. It is not temperature radiation, for with it we cannot obtain a green light; furthermore we get different colors at the same temperature, whereas in temperature radiation the color is a function of the temperature, and ranges from red to white according as the temperature is low or high.

If we take some calcium nitrate and expose it in the alcohol flame, the flame becomes yellow. Again, if we take the same calcium compound and put it in the carbon arc at 3500° C., we shall see the same yellow light. Thus at the low temperature of the alcohol lamp, which does not exceed 1000° C., and at the very high temperature of the carbon arc, the color remains the same. We have, therefore, different colors at the same temperature, and also the same colors at different temperatures. This, however, is not always the case. Some compounds change the color of the light with changes of temperature, but the change of color does not follow the regular law of incandescence.

In the mercury vapor lamp the temperature is relatively low—not much above the boiling point of water—still we get an intense light—a green light. If we increased the temperature, the mercury light would change in color from bluish green, which it has at low temperature, to a whiter color, and at extremely high temperature it becomes a pinkish-red. In the mercury arc the average frequency decreases with increase of temperature, which is just the reverse of the case of temperature radiation.

If a platinum wire with thoria at the end of it is held in the flame, it grows much brighter and glows with a greenish light; whereas some platinum gauze held in the flame glows with the yellow light of incandescence. The temperature of the flame being relatively low, the platinum gives incandescent radiations of yellow, orange and violet. If now we take the gauze of thoria and platinum together we shall see the two different colors produced at the same temperature, again showing that it has nothing to do with temperature radiation.

There is, therefore, the possibility of producing light radiations which do not follow the temperature laws. The interesting feature of this is that while we can produce light from incandescence, we are limited in color. Excepting at extremely high temperature, we cannot get a white light. Green we cannot get at all. Red we can get only at relative inefficiency, as it is produced only at very low temperature radiation, where the efficiency is low. Furthermore, even at the highest temperature allowable, the efficiency is relatively low.

As we have shown, however, we can get radiation and not follow the temperature laws, but get different colors at the same temperature, or the same colors at different temperatures, as well as different colors at different temperatures.

It is worth while to investigate and find out whether with radiation that does not follow the temperature law and that is not due to incandescence, but which we call luminescence or selective radiation, we could reach efficiencies higher than those possible by incandescence.

The color of luminescent radiation is not a function of the temperature, but depends upon the material which luminesces. Thallium, in the alcohol flame, produces a green light; sodium, a yellow light, and lithium a red light—all at the same temperature. Barium produces a yellowish green.

If the color is a function of the material, this means that the frequency of radiation obtained depends upon the kind of material used. Suppose a material were found in which those particular frequencies at which luminescence takes place were in the visible range that the eye can see, that material would give 100 per cent. efficiency in light production. Again, in another material, if the radiation of luminescence was in the invisible range, that would be a very inefficient light producer.

The light, and, in general, the radiation, given by a vapor conductor between terminals is due to luminescence, or the transformation of the electric energy into radiation. The frequency of radiation in the arc stream is not due to temperature, but the frequencies are determined by the chemical nature of the luminescent body, or arc stream. Thus the light efficiency does not depend upon the highness of temperature, as in temperature radiation, but rather the reverse. The arc of lowest temperature, the mercury arc, is one of the most efficient. The color of the light depends upon the character of the material which luminesces. However, in luminescent radiation the temperature is of importance, not that we want very *high* temperature, but rather the *right* temperature; the one that is suited to the particular material used. The change of colors in luminescence do not follow a definite law, as in temperature radiation.

In the titanium arc the light is white, the lines in the spectrum being quite uniformly distributed over the entire visible range. The light from the ordinary iron arc is also white and very brilliant, the lines of the spectrum being similarly distributed. If we greatly increase the temperature of this iron arc, by using a condenser discharge between the terminals, the arc gives little visible light but gives a large amount of ultra-violet radiation.

In selective or luminescent radiation there is the possibility of producing light at higher or lower frequencies and getting different colors, depending upon the material used. The question is, how does this radiation come about; how is luminescent radiation produced, and how can we picture this?

We assume that all materials are composed of smallest parts—molecules, atoms, or whatever they may be. If we take a piece of graphite, carbon or titanium and heat it, the molecules or atoms will be set in motion; they will vibrate and communicate their vibration to the ether. This produces the ether waves, and the energy sent out we see, at the proper frequency, as light. Consider the molecule or atom or particle, whatever it is, vibrating. It has definite mass, definite force, and therefore the conclusion is that it would vibrate at a definite frequency—just like a tuning fork or any other body vibrating at a definite frequency. If we heat a tungsten filament, we set the molecules vibrating. We do not, however, get a definite frequency of radiation, but a mixture of an infinite number of frequencies over a wide range of many octaves. What is the cause of this? We know the tuning fork will vibrate at a definite tone and definite frequency. The air in the organ pipe, when set in motion, will vibrate at a definite frequency—so also should the atom or molecule. If we take a mound of sand, however, and attempt to set it in vibration, each particle of sand will vibrate at a definite rate, depending on its mass and the forces acting upon it; but as a part of the mound it cannot vibrate freely because its vibrations are continually interfered with by the other sand particles. The continual interference of the other particles prevents the particle from properly completing its vibration, and instead of the whole mound of sand vibrating at a definite rate, there are all kinds of frequencies; each grain of sand having a different rate from the other grains, depending upon the interference of the particles around it.

If we look at the energy distribution in the spectrum of a radiating body, like tungsten filament, what we see is the probability curve of vibrational frequency for any single molecule. What it amounts to is that each individual molecule would, if by itself, vibrate at a definite rate. In the solid mass, however, due to interference between molecules, there can be no uniform vibration, but a mixture of all possible rates of vibration—all possible frequencies.

The problem is to find a material in which the atoms, or molecules, or whatever the radiating particles may be, are free from interference with each other. In solids and liquids there is this interference, which practically destroys the individual vibration of the particles and gives only the total. Some solids there are, however, which to some extent give their specific vibration, as for instance some of the rare earths, thoria and ceria. The particles do not so completely interfere as to wipe out entirely the individual vibration. These materials do not follow the temperature law; they radiate light at an abnormal efficiency. Thoria alone does not give the selective radiation to any great extent, but combined with ceria in the Welsbach mantel produces an efficiency of light many times higher than the gas flame alone could give. The specific vibrations of thoria in the Welsbach mantel are very prominent at low temperature. Once the vibration gets energetic enough, due to high temperature, the independent vibration of the particles, even of the Welsbach mantel, practically ceases. The vibrations at higher temperatures are more energetic, extend over wider distances, and the chance of interference is greater.

If the problem of selecting a material with which to produce luminescence or selective radiation depends upon finding one in which the particles do not interfere with each other, a gas or vapor might be used. In this the molecules are so far apart as not to interfere, and for this reason it would be an ideal material for the purpose. In a solid if particles are set in vibration by heat it becomes incandescent. If we heat a gas or vapor we get motion of the molecules it is true, but not as in a solid, for instead of getting radiations, we get pressure. If then, temperature does not produce luminescence in a gas but at the same time the gas or vapor would be the ideal material for luminescence, we must find some other way of producing vibration. There are two convenient ways: chemical excitation and electrical excitation. The chemical method is that of bringing the luminescent material into the focus of intense chemical reaction; the electrical, that of using it in the vapor state as a conductor of electric current. Both methods of producing luminescence have found commercial applications.

Chemical Excitation

If we take materials like the salts of which I have spoken, and in the flame vaporize them or split them up into their elements, the atoms are set in motion, and in vapors they are free to vibrate without interference; so that they have a definite frequency and give color to the light, independently of the temperature.

A gas flame gives relatively low light efficiency. By increasing the temperature of the gas flame, we get a more rapid rate of combustion but no more light; but if we use this temperature to heat the thoria and oxides of the Welsbach mantel to a high temperature, then the flame is luminescent, and gives an efficiency several times higher than the gas flame.

Chemical luminescence is a very convenient method of producing colored lights of very high intensity, and is used industrially in fireworks, and in colored signal lights. To a considerable extent it is used for purposes of amusement.

Electrical Excitation

As stated, electrical excitation consists in using the material as a conductor of electric current. There are two possibilities: we may use gases as radiators by having them conduct the electric current (as in the Moore tube, in which the gas is a conductor of electricity, carries the current and is made to luminesce) or we may use electrode vapor.

Gases are extremely poor conductors. In the Geissler tube, if the voltage drops below a certain value there is no current, and thus a high voltage is required. Of the gases which have been investigated, nitrogen gives the best efficiency; this is not quite as good as that of the tungsten lamp, but is high compared with the gas flame or ordinary incandescent lamp.

Good conductors, however, are the metal vapors in the arc stream. The arc has first to be started between the terminals—a conducting bridge must be produced by the expenditure of energy. There are several ways of starting the arc conduction, such as bringing the terminals together, closing the circuit, and then separating them; or by raising the voltage between the terminals so high that a static spark passes between them; or again by the supplying a vapor stream from another arc, etc. The current, having started its own conductor by evaporation of the electrode material, maintains it by maintaining a supply of conducting vapor. The color is therefore that of the electrode material, and not that of the gas which fills the space in which the arc is produced; the nature of this gas has no effect on the arc.

The three materials which give an efficiency of light production which is many times higher than can be reached by incandescence are mercury, calcium and titanium. Mercury gives a bluish-green light, because the visible radiation is mostly in blue and green. Calcium, which is used in the flame arc, gives an orange-yellow light, because most of the visible radiation is in the orange and yellow. Titanium gives a white light, the visible radiation being scattered uniformly all over the visible range. These three materials seem to give fairly closely the same efficiency. Possibly titanium is highest—all three are used. The mercury vapor lamp is not used as much as it deserves because in the bluish-green color people do not look pretty.

Luminescence is used to produce colored lights, and to produce higher efficiencies. Luminescence was the first step in advance in the method of light production through all the ages, from the wood fire of the primeval savages down to modern times, replacing incandescence by selective radiation, or luminescence.

We are only at the very beginning or entrance to the field of luminescence—especially on the electrical side. On the chemical side, in the Welsbach mantel, much has been accomplished. There is the possibility in the future of light efficiency which we have never dreamed of, and which in incandescent material we could not hope to even approach.

AN INTERESTING METER INSTALLATION

By B. E. Semple

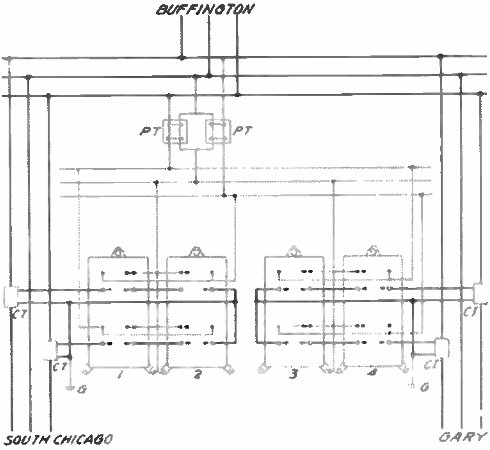
The Illinois Steel Company, South Chicago, Ill., generates its power at 2200 volts, 3-phase, 25c cyles; the Indiana Steel Company, Gary, Ind., generates its power at 6600 volts, 3-phase, 25 cycles. These two plants are about sixteen miles apart and operate in parallel with each other through a 22,000 volt line, suitable step up transformers being in use at each station.

The plant of Universal Portland Company is located at Buffington, Ind., about five miles from Gary and eleven miles from South Chicago, and receives its power from the 22,000 volt line connecting South Chicago with Gary.

At times Gary furnishes power to South Chicago and also to Buffington, and at other times to South Chicago alone or to Buffington alone. Likewise South Chicago at times furnishes power to Gary and Buffington, or to either separately.

This state of affairs demanded a system of metering whereby the proper billing amounts could be arrived at, and it was found that by using four three-phase, three-wire meters at the Buffington sub-station, connected as shown in the accompanying diagram, the correct amount of energy consumed by the Buffington plant, coming either from South Chicago or Gary, could be recorded, as well as the amounts of energy passing from one generating station to the other.

All four meters are equipped with ratchet devices so arranged as to move the recording hands only when the rotating elements are revolving in the proper direction; the meters being free to rotate in either direction, depending on the direction in which the current is flowing.



When South Chicago is feeding Gary and no energy is being used at Buffington, meters No. 1 and No. 3 are registering, since they are connected in series.

When Gary is feeding South Chicago and no energy is being used at Buffington, meters No. 2 and No. 4 are resistering, since they also are connected in series.

When South Chicago is feeding Buffington alone, no energy being sent to Gary, meter No. 1 registers.

When Gary is feeding Buffington alone, no energy being sent to South Chiacgo, meter No. 4 registers.

In billing, therefore, the amount shown by meter No. 1, less the amount shown by meter No. 3, is charged to Buffington, and credited to South Chicago; the amount shown by meter No. 2 is charged to South Chicago and credited to Gary; the amount shown by meter No. 3 is charged to Gary and credited to South Chicago; and the amount shown by meter No. 4, less the amount shown by meter No. 2, is charged to Buffington and credited to Gary.

BOOK REVIEW

THE COPPER HANDBOOK, VOL. IX

1628 Pages **Price $5.00 (Sent on Approval)**

The ninth annual edition of the Copper Handbook, edited and published by Horace J. Stevens, of Houghton, Michigan, lists and describes over 7,000 copper mines and copper mining companies throughout the world; the descriptions being the same as in the preceding volume, except that over eight hundred titles have been added to those contained in previous editions.

The book also contains a number of miscellaneous chapters covering the history, chemistry, mineralogy metallurgy and uses of copper; other chapters being devoted to substitutes, alloys, brands and grades. The chapter of statistics, containing upwards of forty tables, has been fully revised and, as nearly as possible, brought to date.

Anyone interested in the subject of copper, as producer, consumer or investor in shares, should find the Copper Handbook of much interest.

OBITUARY

Clinton Charles Burr, Chief Engineer of the Northern Electrical Manufacturing Company, Madison, Wisconsin, died at Lincoln, Nebraska, May 28th. Mr. Burr had been in failing health for some months past, and in March last went to Lincoln for treatment; then his health improved for a time, but finally failed gradually until the end came.

He was born at Albion, Michigan, December 30th, 1870; prepared for college at the Albion High School, and later entered the University of Michigan at Ann Arbor, where he took the course in electrical engineering. He then entered the employ of the General Electric Company at Schenectady and while still in their service, went to Quito, Ecquador, where he superintended the installation and starting of a large hydro-electric plant, continuing in charge of its operation through the years 1899, 1900 and 1901. Returning to this country, he was identified for a period of one year with the Lincoln Traction Company, Lincoln Nebraska, leaving there to enter the engineering department of the Ft. Wayne Electric Works, where he remained until the year 1905. He then became Chief Engineer of the Phoenix Electric Company, Mansfield, Ohio, and later of the Mechanical Appliance Company at Milwaukee, entering the employ of the Northern Electrical Manufacturing Company at Madison in 1908. Very shortly thereafter he was appointed Chief Engineer of the Northern Electrical Manufacturing Company, which position he occupied at the time of his death.

Mr. Burr was a man of wide experience and acquaintance in the electrical field where, and because of his technical ability, his unfailing courtesy and cheerful disposition, he was held in the highest esteem by all those with whom he came in contact.