by 1½ inches thick." This undoubtedly establishes the fact of the vessel being covered with railroad iron. At first she had two smokestacks, but when the Navy Department owned her she had but one smokepipe. What gave her such a reputation for her short career was the night attack made on the Union fleet at the head of the passes of the Mississippi River on October 12, 1861, when she rammed two of the vessels then lying at the station and doing herself as much injury as the vessels she attacked. When her ram struck

the U. S. S. "Richmond," it made a break about 5 inches diameter and caused a leak that made it necessary for the vessel to be taken to Key West, Fla., for permanent repairs. Just after this attack she was purchased by the Confederate Navy Department. Her only value lay, when handled with skill, in her offensive power as a steam ram, as was demonstrated in the engagement with Admiral Farragut's fleet before New Orleans, where she was finally run ashore and destroyed by the "Mississippi" of the Union fleet.

No less an authority than Spears's "History of Our Navy," in vol. 4, page 128, says of the "Manassas": "For motive power she had one compound engine and two screws, the high-pressure cylinder working one shaft and the low-pressure the other." So far as the type of engine is concerned this is an error, for the compound propeller engine was not built in this country until 1864, when they were constructed for the steam yacht "Octavia."

(To be continued.)

ELEMENTS OF ELECTRICAL ENGINEERING.—IV. ARC LAMPS.

BY A. E. WATSON, E.E., PH.D., ASSISTANT PROFESSOR OF PHYSICS IN BROWN UNIVERSITY.

Continued from Supplement No. 1660, page 270.

THE significance of the word "arc" is not altogether apparent. Davy introduced the expression, when he first produced the electric light a century ago; he observed that the path of the current from one electrode to the other was not straight, but crescent shaped. Though his source of current was batteries only, yet he employed a large number to operate a single light; as compared with modern practice he used an abnormal potential. A separation between electrodes of an inch or two was probably possible with his apparatus, and the curved path of the current might readily have approached the arc of a semicircle. Separation between the carbons of ordinary old style "open" arc lamps is very much shorter, and the "arc" is more nearly a ball, its real appearance being disguised by the intense incandescence of the points, but the greater separation of the carbons in the present "inclosed" lamps again reveals the real path of the current.

Davy's electrodes were made of wood charcoal, and at best could have lasted but a few minutes. Later, Foucault, having the advantage of methods of making artificial coal gas, cut the pencils from the retort coke or carbon. Though containing slag and other non-conducting substances, from some of which the heat of the arc liberated poisonous gases, this denser material was highly refractory, and a pair of the pencils, or "carbons" as they were soon called, would last for several hours. This permanency allowed scientific study of the operation of the arc, and brought out various facts and theories. One carbon was observed to be hotter and to burn about twice as fast as the other; it burned tapering, but the very end, instead of being pointed, was hollowing; this "crater," so called, is small, but its temperature is so high, perhaps 3,500 deg. C., that it emits the greater part of the light. The other carbon is only about half as hot—indeed, metal can be substituted for it—and burns pointed; this point may constantly be receiving deposits from the other carbon.

Heated vapors are really conductors of electricity. Fires in central stations, resulting from short-circuits, owe their chief ferocity to the conducting properties of vaporized copper. It is believed that between the heated carbons of an arc lamp there is the vapor of carbon; the presence of oxygen necessarily results in some combustion, so the carbons slowly disappear. Usually the light is desired below the lamp, and for that reason the hotter carbon—found to be the positive—is selected to be the upper one, thereby throwing its light downward; but in searchlights and stereopticons, the carbons may be disposed horizontally or at right angles to each other; or, for giving the best distribution for particular places, say for a drafting room, the hotter carbon may be the lower, to direct the light upward, against a white ceiling and there be reflected downward in a highly dispersed manner.

Some speculations have been made as to the cause of the resistance of the arc. As far as the vapor alone is concerned, the resistance would appear to be only about 0.2 ohm, and yet the actual resistance encountered is equivalent to from 2 to 5 ohms. One theory holds that the arc is the seat of a counter electromotive force, the other that the resistance is purely ohmic; the latter idea seems to be most generally accepted: in reality it seems about as difficult to prove the one as to disprove the other theory.

As for the particular amount of energy consumed in an electric arc, there is some opportunity for variation in the number of volts and amperes, yet with the same number of watts the light is about the same. Gramme used about 30 volts and 15 to 25 amperes per lamp, but Brush found favor with 45 volts and 10 amperes. Weston adopted Gramme's practice, while Thomson followed Brush's. The lower potential results in an arc only about 1/32 inch in length, which emits a continuous hissing sound, but the light is very white, inclining toward the yellow, while the higher potential and less current allow an arc nearly ¼ inch in length, noiseless, but quite bluish in color. While a short arc is always hissing, a long one can

be made to hiss by sufficiently increasing the current. Higher potentials would result in still longer arcs; by concentrating the entire voltage of a 40-light machine in a single lamp, Brush obtained an arc two feet long. Economy in the cost of conductors argues for the

Fig. 17.—Direct and Alternating Current Arc Lamps for Use on Constant Potential Circuits.

adoption of the lesser current, and reliability of operation of the mechanism of the lamp is enhanced by the latitude of the longer arc. Open arc lamps are often operated at 45 volts and 6½ amperes, giving 1,200 "nominal" candle power, while the 10-ampere lamps are estimated at 2,000 nominal candle power. Open lamps operated by alternating currents run rather unsatisfactorily; 30 volts and 13 amperes seem to be about the best values, but the noise produced by the rapid heating and cooling of the air in the vicinity of the arc is disagreeable, and for some places, intolerable. The modern inclosed lamps take, with direct current, about 80 volts and 6½ amperes; with alternating, 72 volts and 7½ amperes. Since the noise

the arc, where the accumulation of dust readily interfered with the movement. Unnecessarily, the construction was further complicated by making the lamps of the "focusing" sort, i. e., having the arc burning in the same location. Even Gramme's lamps, though having the mechanism above the arc, retained the other two features of considerable clockwork, and of feeding the bottom carbon upward at a certain rate, about half an inch an hour, and the upper one downward about twice as fast, to meet the unequal rates of burning. Brush's type of lamp, compared with these, was a marvel of simplicity and reliability; in the first place there was entire absence of clockwork, a hollow brass rod instead of a rack being used for holding and guiding the carbon; this rod passed through a loosely fitting washer in the box over the arc; when allowed to rest in a horizontal position, the rod was therefore free to slide up or down without any interference; to the core of a solenoid was attached a hook that could lift on one side of the washer; when sufficiently energized with current, this solenoid would lift its core, tilt the washer, thereby engage the rod, and further movement would separate the carbons and establish the arc. Whatever the length of carbons, they normally rest in contact, and will be ready to separate by the action of the current. A suitably diminished current would allow the washer to be tripped and allow a slipping through of the carbon rod, and re-establishment of normal current. To prevent undue slipping, Brush filled these brass tubes with glycerine, and suspended in it from the protecting "chimneys" over the lamps loosely fitting pistons, so that the rods could not move without waiting for the glycerine to ooze through the narrow spaces. Simplicity was further provided by omitting all attempts at holding the arc in one place, for the lower carbon was fixed, gravity feeding the upper carbon downward, as permitted by the solenoid, at a rate to compensate for the burning of both.

Such a lamp works perfectly, if it is the only one in a circuit; for a greater or less length of arc will so vary the resistance as to make the current vary in inverse manner, and release or raise the clutch. Two or more such lamps in series will not operate at all well; for though the same current may pass through them, there is nothing in the mechanism to compel each to draw the same length of arc. If the

Fig. 16.—Diagram of Circuits of Thomson-Rice Non-Infringing Arc Lamp.

varies about as the square of the current, the latter sort are a considerable improvement over the 13-ampere open lamps, and are fairly acceptable—certainly as far as street lighting is concerned.

The first arc lamp mechanisms were of delicate clockwork construction, entirely out of keeping with the poor quality of carbons available. The train of wheels was usually placed in a frame located below

Fig. 15.—Diagram of Circuits of a Differential Arc Lamp.

regulator on the dynamo was really capable of keeping the current constant, the entire possibility of proper feeding of the carbons would be forestalled, for confessedly a variation in the current is essential to such operation; the current would keep on burning the carbons further and further apart—though with no two arcs of same length—requiring more and more voltage, until the maximum capacity of the dynamo

was reached. Some arc would then be ruptured, thereby breaking the entire circuit, all the carbons would fall, and constitute almost a short circuit for the generator at the moment when the regulator was in the position for maximum voltage. Some such accident as stalling the engine, throwing off the belt, or injury to the windings or commutator would surely result.

Possibly, Brush's greatest invention, or adaptation, was made in 1878, when he adopted the practical, yet simple, method of avoiding this obstacle to series arc lighting. It consisted in putting double windings on the solenoids of the lamps—one of coarse wire in the main circuit as theretofore, the other of many turns of fine wire connected as a shunt across the terminals of the lamp. This latter had a resistance of about 500 ohms; therefore, at an average working value of 50 volts, about one-tenth of an ampere was side-tracked through this circuit. Since this current does not go through the arc, it represents a direct loss as far as illumination is concerned, but for operating any desired number of lamps in series, it is an essential and marvelously effective device. Its efficacy lies in the fact that it is electrically connected in opposition to the action of the current in the main winding; the combination, therefore, constitutes a differential winding, and such lamps have consequently been designated as of the "differential" type. In the Brush lamps the shunt coils were wound on top of the series, but some makers have done just the opposite, while still others have preferred to make the coils entirely separate, though acting through suitable levers upon the same mechanism.

To make these two circuits clear a diagrammatic representation is shown in Fig. 15. Incidentally the scheme of the Brush "ring-clutch" is also included. In order for the upper carbon to be the positive, current must flow in the directions shown by the arrows. The soft iron core is a very loose fit in the solenoids and extends about half way through each. A thin sheet copper strip, cut with many slits, makes a good electrical contact with the rod without depending upon the guides or causing undue friction. With no current flowing, the core rests upon a stop, and the clutch is horizontal; the carbon rod is therefore free to slide and the carbons themselves are in contact. As soon as the main current flows it energizes the upper solenoid, sucks the core upward, tilts the clutch, engages the rod, thereby separating the carbons and establishing the arc. Thus far the operation is identical with the earlier lamps, and such as are now extensively used on independent circuits. As soon, however, as the carbons are separated, a certain difference of potential must exist between them to maintain the arc—with 10 amperes it being about 45 volts for a separation of $\frac{3}{32}$ inch—and this potential at once sends the small current through the shunt circuit, and its pull prevents the carbons from being drawn further apart and making a longer arc. When the carbons have burned off a little, somewhat more than 45 volts are required, and this higher potential sends a little more than normal current through the shunt coil, overpowering to a greater extent the action of the series coil, and causing a release of the clutch. The shunt current is continually trying to bring the carbons closer together, but the main current is trying to separate them, and the balance between these two forces exists with only one length of arc. By means of an adjustable spring to assist, or oppose, the action of one of the solenoids, the lamp may be adjusted to any desired length of arc, and after the shunt coil has acquired its final temperature and resistance, the variation in potential will not exceed 5 volts, and the successive feedings of the carbon will be in steps of not over one one-hundredth of an inch.

Though not shown in the diagram, another device in the lamp is essential to the maintenance of the circuit as a whole; a fault in one lamp must not be allowed to interrupt the operation of the rest. Failure of the rod to slide when the clutch is released may result from accidental bending or accumulation of dirt, or the carbons themselves may be sufficiently burned out, and the lamp require "retrimming." Brush added a small electromagnet with two windings, one of fine wire connected in the shunt circuit, the other of coarse, but out of circuit unless the armature was lifted. A retractive spring normally held this armature against its back stop. If a considerably longer than normal length of arc was drawn, say $\frac{3}{8}$ inch or over, about 75 volts would be required; this potential would then send nearly double the ordinary current through the shunt circuit, lift the armature of the "cut-out" magnet just mentioned, and short circuit the lamp; the shunt circuit immediately ceased to be energized, but the main current then flowing through the other winding would retain the armature and keep the circuit closed. As soon as the extinction of a lamp is noticed, the trimmer closes another switch which makes the short circuit sure, remedies the fault, if possible, and reinserts the lamp in circuit. Aside from the ex-

haustion of carbons, about the only troubles with arc lamps are the wearing of the rods and clutches and burning out of the shunt coils.

Brush secured a patent on the ring clutch, but the Weston Company infringed upon it, and in the litigation that followed he lost it, the courts claiming that the device was too simple to constitute the subject of a patent. On the differential winding the patent was more vital, and its ownership meant exclusive control of series arc lighting. As expected, infringement and attack at once began, the Thomson-Houston Company being logically selected for prosecution. While the matter was still unsettled in the courts, the defense adopted a double expedient—its management began quietly buying all the Brush Electric Company's stock that was on the market, while Prof. Thomson, with his first assistant, Mr. Rice, invented a non-infringing lamp. The specification of the Brush patent was clear and apparently proof against circumvention, "both windings are in use at the same time." A close study will, however, bring out a clear distinction in the functions of the two coils: the series is needed for starting only, while the real feeding of the carbons is performed by the varying current in the shunt. If these two functions could be completely divorced—that when the series coil was in use the shunt was not, and that when the shunt coil was doing its work, the series coil was cut out, the technicality of the patent would be avoided. This was what Prof. Thomson actually did. Since the series coil can exert merely a constant pull, with the starting of the arc as its principal function, he limited its use to that initial purpose only, and replaced its pull thereafter, in the running of the lamp, with an adjustable spiral spring. An additional magnet was needed for cutting the series coil out of use as soon as this one act was accomplished. Since the spring acted in the direction to separate the carbons, the lamp presented a unique appearance when idle, for the carbons were then separated, and it was not apparent how the current could ever jump the gap and complete the circuit. Of course the carbons must touch before the current can flow, and this condition was properly provided, as will be explained.

A diagram of the circuits of the Thomson-Rice lamp is given in Fig. 16. The large zigzag lines on the left represent the series coil, the finer ones the shunt coil within; on the right is the "starting" coil; "bridge" contacts are associated with the action of the latter, while "cut-out" contacts depend upon the motion of the main armature over the series and shunt coils. The main magnet has paraboloid shaped ends, and the armature pierced with two large holes is pivoted so as to be capable of considerable up and down movement just above them; of the two cut-out contacts, the lower one is fixed, and the upper one is on the same lever as the armature; and the fulcrum being still further to the right, the extreme downward motion of the armature will bring these two contacts together; the upper of the two bridge contacts is fixed, and the lower one is always held in contact with it by the tension of a spring, except when overcome by the action of the "starting" electromagnet. With this understanding of the mechanical arrangements, the electrical circuits can be comprehensively traced. Arriving at the positive pole there are three possible paths for the current. One is through the switch, if closed; combined with the switch is a cam that depresses the main armature, and releases the clutch, so that a trimmer will have no trouble in sliding the carbon rod. If this switch is open, the carbons are separated, yet the current has still a path through the lamp; it can flow through the series coil, and by the bridge contacts reach the negative terminal. The armature is thereby pulled down, releasing the clutch and allowing the carbons to come into contact with each other; as soon as this happens, the third path is provided, i. e., from the positive terminal through the starting coil to carbons and on to the other terminal; but the energizing of the starting coil separates the bridge contacts, and breaks the circuit through the series coil; no appreciable spark results at this rupture, for the current has an alternative path; under the action of the spiral spring the armature then flies up, re-engaging the clutch, separating the carbons, and establishing the arc. Thus the series coil has done its part and is cut out from further use. At a convenient place, really at the bottom end of the series coil, the shunt is attached; by this, the two windings become one, but the few turns of the coarse wire make only a small addition to the many of the fine shunt wire. As soon as the arc has been established, the difference of potential between the carbons sends a current through this shunt circuit; variations in the length of the arc, requiring similar variations in voltage, will be corrected by the action of the shunt as in the differential lamp. An extreme length of arc, say $\frac{3}{8}$ inch or over, resulting from burned-out carbons or from failure of the rod to slide, will require upward of 75 volts for its maintenance; enough current will then be driven through the shunt circuit to attract

the armature downward until the cut-out contacts meet; this act short-circuits the starting coil, again allowing the bridge contacts to complete the circuit through the series coil. The arc is at once extinguished, the shunt coil ceases to be active, but the armature is securely held by the pull of the current in the series coil. Though some words and time have necessarily been used in the description of the real shifting of the circuits, it is almost instantaneous.

Aside from the ingenious devices for dodging the patent, this type of lamp has some actual advantages over the differential lamp. The first of these is that the likelihood of starting the dynamo is increased. Arc circuits are often 15 to 20 miles in length, yet unless the resistance of the circuit is low, the series dynamo will not excite its fields; forty or more sets of carbons in series constitute an appreciable resistance, and if some bit of non-conducting material be on the end of one, it may, in case of the latter type, interrupt the whole circuit, with considerable delay in locating and removing the fault. With the Thomson lamp there is a good metallic circuit through all the lamps, at start, and when the carbons do drop, their ends are pulverized into good electrical contacts. Even if the rod in one lamp is stuck, the rest of the lamps will suffer no interruption. Again, the resistance of the series coil is not encountered in the normal running of the circuit; this makes a slight economy of working over the differential lamp. Finally, the latter type is necessarily adjusted to a critical value of the current, when just the right balance between the opposing forces of the two coils exists; the other type is not so sensitive, for the current may vary several amperes below normal without extinguishing the light. Certain it is that though the Brush Company lost its suit and a controlling interest in its own stock, the Thomson-Houston Company continued to make these celebrated "M. & K." lamps until within a few years.

It seems that the real ground for the loss of this patent was the earlier invention of the differential lamp by Lacassagne and Thiers, in France. These experimenters used it in single lamps only. Brush recognized the principle as the one to make the series operation of a large number of lamps possible. Brush invented and maintained the patent for the double carbon lamps, whereby when one set was burned out the second set was automatically brought into use; the device was as simple as the rest of his inventions—he only made the clutches slightly different, so that one would lift its rod before the other, the arc forming at the separation of the second set. When this set was burned out, the slight further relaxation of the solenoid would allow the second set to begin feeding. This invention was especially applicable to all-night lighting, for the two sets of carbons would last about sixteen hours—sufficient for the long winter nights. Brush also improved the quality of the carbons and cheapened their cost; he patented the device of copper plating them to reduce their resistance.

For half a century it has been known that with a reduced atmospheric pressure a longer arc could be sustained than was found under ordinary conditions, and with an increase in the potential, a much smaller current would give equally good illumination. Various impractical devices, involving the use of air pumps, or other such suction appliances, were proposed to utilize this idea. A practical realization of some of the advantages of the "inclosed arc" was first exhibited in Chicago in 1893—the invention of L. B. Marks. It had some obvious defects, and these were so slowly overcome that popular approval was delayed for several years. First, the mechanical construction was bad, the carbon being held on a rod, like the open arcs; counting in the restricted opening in the top of the globe, there were thus three guides, and a crook in the rod or carbon or frame would prevent the proper feeding. This defect was remedied by omitting the rod altogether, and letting the clutch operate directly on the carbon itself—the considerable separation and smoothness of the carbons readily allowing this expedient to be successful. For cheapness, it was desirable to make the globes as small as possible, and small ones really lasted longer than large ones; but qualities of glass and porcelain that were hard enough to withstand the heat without softening would crack, and those that would not crack would soften by the action of the heat. When the proper quality of material was found and the globes made of the right shape, and the lamps subjected to practical use, troubles were experienced with the carbons; if too hard, they would flame, and if too soft, they would smoke the globes. European "soft" carbons with central portion or core of still softer grade than the exterior, were found to be the best. The ordinary sort for the $6\frac{1}{2}$ and 10-ampere open lamps is made from mixtures of pulverized charcoal and coke mixed with molasses or sugar syrup, formed in iron molds and then baked at almost white heat for ten to twelve hours. The soft quality is made from lamp black, and it is only within a few years that American firms have adopted European methods of manufacture.

After the General Electric Company had purchased the Marks patents and definitely discarded the open arc, there was proof that the inclosed arc had overcome all its early obstacles. Several important advantages are gained with this present standard type of lamp. The partial vacuum, due to the heat, allows a longer arc, and that becomes the main source of light instead of the tips of the carbons, and the lower temperature of the latter together with the meager entrance of oxygen into the inclosed space so diminishes the combustion that even initially short carbons will last from 100 to 150 hours. Necessity of trimming once in a week or two, in place of daily, represents a great saving in attendance. Again, the reduced current makes possible the satisfactory operation of lamps for extensive interior use in multiple on the same circuit with incandescent lamps. With a given allowance loss in transmission, the size of the copper wires required varies as the square of the current, consequently a $6\frac{1}{2}$ ampere lamp would require only about 40 per cent as large wires as one consuming 10 amperes; the open lamp could utilize only about 50 volts out of the total 110 or 115 ordinarily existing on a constant potential circuit, the rest being wasted in a rheostat; with 80 volts, as needed in the inclosed lamp, only 30 would be wasted, the watts being only 200 as compared with 600; the economy is therefore much greater, and the reduced size of rheostat, or resistance, makes it an inconspicuous adjunct. Some resistance is always needed in series with such lamps, otherwise at the start there would be a disastrous rush of current, and in case the clutch failed to lift the carbon at all, a short circuit would exist. In regular operation, the arc is so variable as to have constant need of the steadying effect of some additional ohmic resistance. Single lamps connected across 110-volt mains require the series winding alone in their operating mechanism; two in series on a 220 or 250-volt circuit, or four in series on a 500-volt power circuit, would need the differential winding. Alternating currents successfully light inclosed lamps; if for multiple use, on 104 to 110-volt circuits, a reactive, or "kicking" coil, replaces the resistance coil used with the direct-current lamps;

such a device generates a counter-electromotive force, and though it creates an undesirable lag in the phase of the current, it minimizes the energy of operation. The cores of the solenoids of such lamps must be laminated or composed of a bundle of fine wires, instead of being solid, or they would become ruinously hot from the flow of eddy currents. Fig. 17 shows views of standard direct and alternating current "multiple" lamps with the casings removed to expose the mechanism.

Within a year, a new arrival among arc lamps has come from Germany. It is called the "flaming" arc. Heretofore, the flame has carefully been avoided, and such voltages, current, and qualities of carbons adopted as would be free from it. In exterior appearance the lamp is rather longer than the inclosed type, and has a nearly spherical opal globe, that allows the free entrance of air at the top. It is essentially then an open lamp, and requires new carbons every 10 or 12 hours. Both carbons move downward at a very acute angle with each other—in this respect resembling some of the curious lamps made a quarter of a century ago. The two supporting side rods are electromagnets, and their action "blows" the arc between the carbons into a deep U. By this action, the light-giving area is so much increased that with no greater expenditure of energy than is used in the old open lamps, about five times as much illumination is secured, the makers claiming 10,000 to 12,000 candle-power. The otherwise bluish tinge of the arc is replaced by yellow, white, or red, by impregnating the carbons with suitable chemicals; yellow is ordinarily preferred, obtained by mixing salt (sodium chloride) in the carbons. Since at the temperature of the arc all chemicals undergo decomposition, chlorine will be liberated; in order to prevent the escape of this highly poisonous and corrosive gas, ammonium carbonate is also included in the mixture for the carbons, thereby ammonium chloride (sal ammoniac) and sodium carbonate are formed and harmlessly deposited as white powders, along with the carbon dust, on the inside of the globe. Though suffering the handicap of required daily trimming, it is probable this form of lamp, giv-

ing the most powerful artificial light yet produced, will receive extensive adoption for out-of-door uses.

Very small arc lamps have not given entire satisfaction; the mechanism must accomplish identical results with the large lamps, yet is comprised in smaller space; the illumination is not proportionate to the energy expended, for a given amount of energy expended in a number of small lamps does not equal in illumination that which would be obtained from a smaller number of large lamps. This is a peculiarity not of arc lamps alone, but is a matter of regular experience with incandescent and gas lamps. For street lighting the 500 watt arc lamps are generally adopted, but for stores, especially when the lamps are connected in multiple, 350 to 400 watt sizes are common, a little sacrifice in economy being permissible in consequence of the better distribution obtained from the relatively large number.

The real candle power of the arc light is a matter of difficult determination; there are no standards of the same quality of light with which to compare it. Twenty years ago the 45-volt, 10-ampere open lamps were guessed to emit about 2,000 candle power; more modern measurements assign the actual figures as more nearly 500. The 80-volt, $6\frac{1}{2}$ -ampere inclosed arc gives about the same amount, but for street lighting, especially, the latter gives the more satisfactory results, for the greater prevalence of the horizontal rays gives a better average illumination; directly under an open lamp the rays are very intense, but rapidly diminish as distance from the arc increases. Unless the flaming lamp can be made in small sizes, it would seem to be limited in use to public squares and for exhibitional purposes.

Standard sizes of hard carbons for open lamps are 12 inches long, $\frac{7}{16}$ inch and $\frac{1}{2}$ inch in diameter, the softer grade for inclosed lamps 8 inches long, $\frac{3}{8}$ inch, $\frac{7}{16}$ inch, $\frac{1}{2}$ inch, and even $\frac{5}{8}$ inch in diameter. The smaller diameters give the better light, but, naturally, do not last as long as the larger ones.

The fifth article will consider the topic of "Constant Potential Generators" for direct currents.

(To the continued.)

EDDY CURRENT BRAKE FOR RATING GASOLINE MOTORS.

BY THE ENGLISH CORRESPONDENT OF THE SCIENTIFIC AMERICAN.

A NEW and novel type of electromagnetic brake has been designed for determining the rating of gasoline, electric, or other motors with accuracy and ease by Messrs. Morris & Lister, engineers, of Coventry, England. The apparatus is of simple design, comprising two copper disks mounted on a bush which is keyed to the spindle or crankshaft of the motor to be tested. Between these disks is an aluminium casting, which acts as a floating central hub, carrying the magnetizing coils, the external yoke rings, and the graduated and balance levers. The coils are excited by a direct-current supply, and produce a powerful multipolar magnetic field in the gap in which the disks revolve. Eddy or Foucault currents are generated, and the output of the motor is thus expended in heating the copper disks. The potential of the induced currents, and consequently the brake horse-power absorbed, depends upon the intensity of the magnetic field, and this is readily controlled by means of a rheostat in the exciting circuit. The forces resulting from the inaction between the magnetic field and the induced currents in the disks tend to drag the floating system or aluminium hub round. The energy, however, is opposed by a gravitational force due to the weighted lever. When these two forces become equal, the lever floats between its stops. The torque or turning moment exerted by the motor in pounds-foot is then equal to the product of the weight in pounds into its radius of action in feet. The output of the motor is given by

$$2\pi \times \text{radius in feet} \times \text{weight in pounds} \times \text{R.P.M.} \\ B. H. P. = \frac{\quad}{33,000}$$

This ingenious brake possesses many advantages over the ordinary types of absorption dynamometers. In the first place, it can be more easily and rapidly adapted to any type or size of motor, while owing to the brake being carried by the motor spindle no separate frame is necessary. It is very sensitive in working, the load is uniform, while a fine degree of accuracy is obtained, since there are no sources of appreciable error. The balance can be secured in a few moments, and the lever kept floating by means of the rheostatic control. Wear is reduced to a minimum, while all the difficulties attending the utilization of burnt blocks, bands, ropes, and the necessity of water for cooling as in the ordinary brake testing system are obviated, while furthermore the formula for calculating the horse-power does not vary with the conditions of working.

The eddy current brake, however, is not advocated for time tests except under special conditions, since these can be more economically undertaken by either of the various regenerative methods available. The

EDDY CURRENT BRAKE FOR RATING GASOLINE MOTORS.

great advantage of the eddy current brake is the rapidity and accuracy with which efficiency of a motor can be determined before and after a prolonged test. A complete set of six or eight observations of efficiency between no load and 50 per cent overload can be obtained in as many minutes. The brakes are consequently rated to absorb a given power for fifteen minutes without undue heating, but they may be overloaded up to 100 per cent for two minutes, and will absorb smaller powers for longer periods. The speeds of the brakes range from 1,500 revolutions per minute for a motor of 2 horse-power to 750 revolutions for a 30-horse-power motor. These speeds, however, may within certain limits be increased by 50 per cent, but more satisfactory results can be obtained by employing a smaller type of brake, since the best results are insured by working the brake at its designed speed. If necessary the brake may be fitted with suspension links, by means of which the weight of a brake can be carried from an overhead fixing, thus relieving the motor bearing of any stresses. But under normal conditions, however, such suspension is not requisite, as the weight due to the brake is considerably less than the pull due to a belt drive.

In connection with the Austrian governmental establishment for the preparation of uranium products,

there has been built in Joachimsthal, Bohemia, a laboratory for working up radio-active substances found in the tailings and by-products of the uranium minerals. There will also be erected a bathing establishment, where the radio-active mine water will be used for healing purposes.

CATHODE RAYS AND THE AURORA.*

By C. CHREE.

SEVERAL physicists have advanced the theory that cathode rays play a part in aurora. Prof. Birkeland has described a number of phenomena produced by cathode rays in the neighborhood of a magnetized sphere, which resemble various types of aurora. He supposed the sun to be a primary source for cathode rays, which might set up secondary rays in the earth's atmosphere. Mr. C. Stormer has carried out elaborate calculations as to the possible ways in which electrified particles coming from a great distance can approach a magnetized "earth"; his results tend to limit the approaching particles to the space near the magnetic poles. Prof. S. Arrhenius has supposed electrified particles to be driven from the sun by the repulsion of light and to reach the earth's atmosphere in about two days, originating aurora and magnetic storms.

In a recent article on this subject, M. Villard refers to Arrhenius's theory, but seems somewhat skeptical as to the supposed solar origin of the electrified particles. His own views appear to be a combination of theory and observation as to what happens to ions or electrified bodies of any kind moving in a magnetic field. In a uniform field the ion, when traveling with uniform velocity, describes a regular helix on a cylinder the axis of which is parallel to the lines of magnetic force. The radius of the cylinder varies directly as the component of the velocity perpendicular to the lines of magnetic force, and inversely as the intensity of the field. Suppose, however, that the magnetic field is not uniform, but increases in intensity in the direction in which the ion travels; then, as has been shown by Poincaré, the path forms a curve with diminishing spirals on a cone, and before actually reaching the summit of the cone the particle ceases to advance, and retires, the spirals gradually opening out. If, for instance, the field is that due to two elongated parallel poles, then if the particle gets under way between the poles, traveling obliquely to

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