

kerosene as fuel for this class of engines—an investigation necessitated by the increasing demand of gasoline and the limited supply available.

The study of the destructive distillation of coal and its combustion in gas producers, coke ovens, and furnaces, especially from the standpoint of physical chemistry, will be undertaken by several divisions.

The briquetting division, which occupies the large

room at the end of the building, is putting down one large additional German briquetting machine, while the previous apparatus of English and American manufacture that was used at St. Louis is installed in the same room. The work of this division will be chiefly the manufacture of briquettes from various run-of-mine coals of the Eastern fields, which will be tested on war vessels under the direction of the steam

engineering division. The further plans of the Geological Survey include tests dealing with the spontaneous combustion of stored coals, in which an effort will be made to simplify the methods for its prevention, while a corps of specialists will be detailed to investigate closely the whole subject of explosions in coal mines, with a view to eliminating danger from this source.

NEW DEVELOPMENTS IN ARC LAMPS AND HIGH-EFFICIENCY ELECTRODES.*

A COMPARISON BETWEEN METALLIC AND CARBON ARCS.

BY GEORGE M. LITTLE.

ARCS for lighting may be formed between electrodes of many different kinds. This paper deals with the development of the so-called magnetite electrodes and of a lamp suitable for burning them. A few points of comparison between these metallic-oxide electrodes and carbon electrodes will be considered, and some of the many interesting advantages possessed by the metallic-oxide electrodes and lamp will be touched

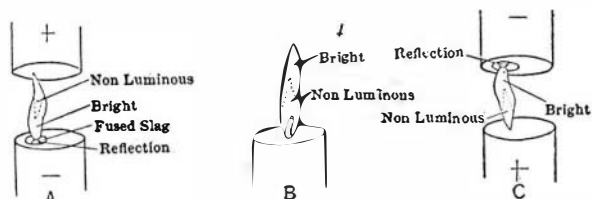


Fig. 1.—A. Metallic Arc with Negative Below. B. Candle Flame. C. Metallic Arc with Negative Above.

on. Among these are the long life, high efficiency, and good distribution and color of light.

The magnetite electrodes were so named because magnetite is usually one of the constituents of the negative or cathode, but it would be more satisfactory to call them metallic-oxide electrodes, as, in addition to the magnetite, there are always at least two other oxides present, namely, oxide of titanium and oxide of chromium.

These electrodes are made in a very different manner from the carbon electrodes. As is well known, the latter are squirted or molded from a plastic mixture and are baked, the carbon furnishing sufficient mechanical strength and electrical conductivity. metallic-oxide electrode cannot be made this way, for it is a familiar fact that a fine powder is a poor conductor, no matter of what it is composed, and as these electrodes are made for the most part from finely powdered oxides, it is evident that a conducting binder or a conducting case would have to be used. In practice, the mixture of oxides is tamped into a thin iron tube and the end sealed in an arc.

The oxides have distinct and separate reasons for their presence. The titanium oxide has the property of rendering the arc luminous; and it may be here noted that the metallic-oxide arc is a flame arc, the light not coming from a crater as with carbons. The oxide of iron gives conductivity to the fused mixture when cold, the other oxides being conductors only when hot. The oxide of chromium prevents a too-rapid consumption, so that by its use an electrode may be given a very long life.

The positive, or anode, used with these metallic-oxide negatives is generally a metal and is consumed much more slowly than the negative. This is con-

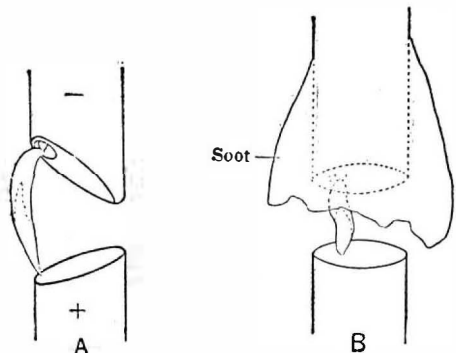


Fig. 2.—A. Showing How the Ends of Carbons Wasted Away to a Bevel Before Using the Down Draft of Air. B. Showing Accumulation of Sponge-like Masses of Soot Before Using the Down-Draft of Air.

trary to what would be expected, judging by the action of carbon electrodes.

There are a number of advantages possessed by the metallic arc over the carbon arc. In the first place, the efficiency is much better; that is, a metallic arc lamp operating on a four-ampere current with approximately 65 to 70 volts at the arc will give a light

equal or superior to that of a 6.6-ampere, 75-volt, direct-current, inclosed-carbon arc lamp.

The distribution of light is far better. This is owing to the fact that in the inclosed-carbon arc practically all the light comes from the crater on the flat under-surface of the upper electrode, most of it being thrown down and not serving to illuminate the street between lamps. The light from the carbon arc itself is weak and of a blue color. This is very pronounced at times, especially if the flat under-surface of the upper electrode is somewhat inclined, thus hiding the crater. In the case of the metallic-oxide electrodes, the arc is itself the source of light, practically none coming from the crater, except by reflection. The metallic arc is much like a candle flame, having its luminous and non-luminous zones. The light is brightest near that end of the arc which is next to the negative electrode, and comes from a hollow cone-shaped mantle of volatilized oxide of titanium rendered incandescent by the heat of the arc, just as in the candle flame the light comes from a hollow cone-shaped mantle of carbon particles made white hot by the heat of the flame.

The voltage required to maintain a metallic arc is less than that of an inclosed-carbon arc. It is a familiar fact that an inclosed-carbon lamp will not burn properly with the arc voltage down to 65, while a metallic arc will burn well at less than 55. Metallic arcs are adjusted to burn at from 65 volts to 75 volts in different cases, while the carbon arcs are all set

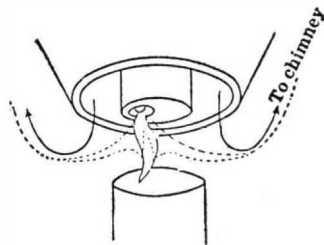


Fig. 3.—The Down-Draft of Air Forces the Soot to Take the Path Shown by the Dotted Line, Effectually Keeping It from Touching or Depositing on Anything.

at 80. This is a very evident advantage in favor of the metallic arc, as more lamps may be put on a circuit without raising the voltage on the line.

The life of carbon electrodes, as a rule, is not over 150 hours, while the metallic-oxide electrodes can go considerably longer.

The uniform white color of the metallic arc is in marked contrast to the changeable blue and white of the inclosed-carbon arc.

As the metallic-oxide electrodes are not burned "inclosed," there is no inner globe required on the lamp.

While it looked easy to secure all of these advantages, many difficulties appeared, but they have now practically all been overcome. In the first experiments the electrodes were trimmed with the anode or positive above and the negative or metallic-oxide electrode below, just as carbon lamps are trimmed, but a number of troubles presented themselves.

First—The bright portion of the arc was near the surface of the lower electrode, which cast a large shadow.

Second—The light reflected from the brilliant surface of the fused slag on the lower electrode was thrown upward and could only be partly saved by using a reflector.

Third—An under-feed mechanism was seen to be necessary, as, contrary to the action of carbon electrodes, the negative metallic-oxide electrode is the more rapidly consumed.

Fourth—Only a comparatively short metallic-oxide electrode could be used, as a long one would necessitate the use of an unwieldy long glass globe. This would limit the life and could only be met by adopting a negative electrode of large diameter, which it is evident would be undesirable.

Fifth—A particularly undesirable feature was the gathering of a large amount of reddish soot that would

collect in spongy masses around the electrodes, obscuring the light. This had to be removed by some mechanical means, such as scraping or shaking it off, and some receptacle other than the glass globe had to be provided to catch it.

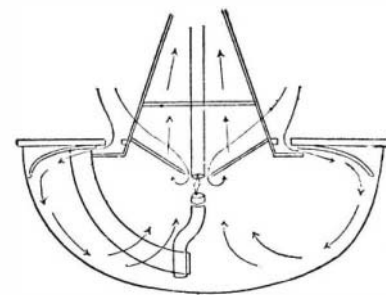


Fig. 4.—Path Taken by Air Currents in Lamp.

Sixth—The negative or metallic electrode was seen to burn to a blunt taper point, causing the arc to be very unsteady, as it tended to leave the end and run up the side in the manner of the carbon arc when flaming.

As noted above, the bright portion of the metallic arc is located near the surface of the negative electrode, and it was seen to be very desirable to burn the electrodes with the negative above, thus getting the bright portion of the arc in such a position that the shadow thrown down would be less, and that the light reflected from the brilliant surface of the fused pool of slag on the negative electrode would be thrown down and utilized instead of being thrown upward and wasted. The other advantages, noted above, possessed by the carbon lamp would be retained if this inverted position of the electrodes could be made practical.

The first attempt to burn the metallic-oxide electrode above and the metallic electrode below showed that there were serious obstacles to be overcome before it could become a practical method. In the first place, the electrode would not keep a square end, but would waste away on one side, and the arc would run up this bevel, or slope, giving a very unsteady light. In the second place, the volatilized oxides of iron, chromium, titanium, and so forth would condense on the sides of the electrodes and hang down as a fringe or curtain, hiding the light.

The first means taken to overcome these troubles was the introduction of a rotating draft of air around the arc. This had the effect of forcing the arc to hold to a central position, stopped the crooked burning, and steadied the light, but did not take care of the fumes. Attempts to blow the fumes away sideways gave only partial success. Finally, a current of air was directed down around the arc, and this gave excellent results. The electrode burned perfectly

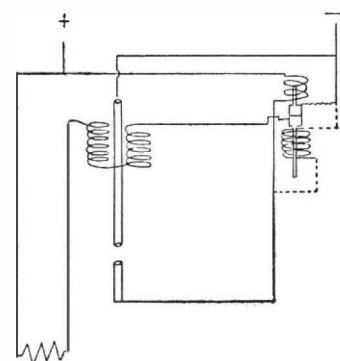


Fig. 5.—Diagram of Connections.

square, and the clean layer of air prevented any gathering of fumes. This was a very marked advance, as this did away with any need for a mechanical scraper or shaker, the soot practically all passing out of the chimney and not requiring to be caught in any receptacle, the globe remaining clean.

When burning metallic-oxide electrodes with the metallic-oxide stick below, copper was used as an anode with fair results. On reversing the position of the

* A paper read before the National Electric Light Association.

electrodes, it was found that the new conditions made it possible to improve on the action of a pure copper anode, and a number of changes were accordingly made. In the first place, if the arc plays for a time on pure copper, it will oxidize the surface. This oxide will fuse to a slag that becomes an insulator when cold, and on starting a cold lamp it is necessary to strike the electrodes together hard enough to break through the slag. To strike such a hard blow is undesirable, as if it is done while the lamp is burning—for example, when feeding—it is liable to spatter the fused slag out onto the glass globe. A simple remedy for this consisted in using an anode containing metals or alloys whose oxides, when fused together, would make a slag that is a good conductor when cold. The steadiness of the light largely depends on the composition of the slag, its uniformity and temperature. The anode surface is at all times covered with this slag, which slowly dissolves the metal and is itself slowly volatilized. If the arc plays on bare metal it consumes it rapidly, and it was found desirable to secure this slag cover from being knocked off. This was accomplished by providing a rough surface for it to cling to, and by running the entire anode tip very hot.

A characteristic property of the metallic arc has been a very noticeable dying-down or dimming of the light, which would occur at irregular intervals, especially after the electrodes had burned for twenty hours or more. These dim spells would last from a few seconds to two or three minutes, when the normal brilliancy would return. This is explained as follows: In the metallic arc, the brilliancy is largely due to the presence of volatilized oxide of titanium, and anything that interferes with the uniform evolution of vapors of titanium will cause the light to dim—for example, the presence of a high percentage of highly fusible oxide of chromium. This oxide of chromium is volatilized at a slower rate than the oxides of titanium and iron, and after the electrode has been burning some twenty hours the slag on the end of the cathode has become very rich in oxide of chromium,

which forms a film on the surface of the fused pool of oxides. When the film is not present there is a plentiful evolution of oxides of iron and titanium, and there is a bright arc. The oxide of chromium can be seen to gather on and finally entirely cover the surface of the pool. This stops the evaporation of titanium and iron, and the light burns to a bluish color and dies down until the chromium film is burned away again. This trouble was met by modifying the mixture in such a way that the oxide of chromium could not separate from the oxides of iron and titanium, thus doing away with the film on the surface and entirely doing away with the dim spells.

In carbon lamps there was very little done to keep the impurities volatilized from the carbons from depositing on the globe. This trouble had to be met by the carbon manufacturers, who were prodded up to produce carbons containing less than 0.2 per cent of impurities, but this means was not to be considered in the case of the metallic-arc lamp. The metallic-arc electrodes, being chiefly composed of oxides of iron, titanium, and chromium, do not burn away to an invisible gas, as does a carbon stick, but are volatilized bodily, and the vapors instantly condense, on leaving the arc, to a fluffy reddish soot that settles on everything it touches, so that a chimney is a very necessary feature in the lamp. This soot, if it comes in contact with the reflector or globe, will smudge them badly in ten minutes. As was noted before, a current of air flowing down around the electrode served admirably to keep it clean, so it was applied to the reflector and globe with gratifying results. A thin layer of air is introduced at the top of the reflector and forms a shield through which the soot-laden air cannot penetrate, so that the reflector and globe will keep clean for a long time.

As the air currents play such an important part in this lamp, it became necessary to do a large amount of experimental work on the design of an air intake and of a chimney top. The chimney could not be made long enough to cause a very powerful draft, so the wind was very apt to blow down it; but by per-

sistent effort the openings have been so designed that the wind may blow from any direction (up, down, or sidewise), and the only effect is to increase the natural draft in the lamp. Incidentally, the increasing of this draft actually centers the arc and holds it quiet.

It was found advisable to run the lamp at 4 amperes and 65 to 68 volts at the arc with a cut-out set at 85. This low cut-out was made possible by the inverted position of the electrodes and by the peculiar arrangement of the air draft, which prevented any tendency of the arc to flame or to run up the side of the electrode. Without these features, a cut-out of 100 to 110 volts would be necessary. As the power-factor at which the lamps operate depends largely on the amount of variation of voltage in the arc, this 85-volt cut-out is seen to be very desirable. In actual service the lamps, including a mercury arc rectifier, run very well at from 65 to 70 per cent power-factor.

In several places above we have described special conditions that must be obtained for getting the best results with these electrodes, and these conditions, of course, must be supplied by the lamp in which they are burned. An example of a lamp well adapted for this service is here shown. A study of its design and construction will show that it is simple and rugged, as no float feed is used; it being necessary only to strike an arc and hold the electrode in a permanent position until, due to change in voltage, the cut-out causes the restriking of the arc. The lamp consists essentially of a base and top, connected by a chimney, a set of magnets for striking the arc, a shunt cut-out for causing the lamp to feed due to rise in voltage, and a series cut-out for disconnecting the striking magnets after the arc has been formed.

The special conditions described with regard to drafts are obtained, as seen here, by the down-draft tube, which directs the current of air down around the electrode, another current of air over the reflector and circling around the globe forming a means of protection to them, and a special construction of top and case for giving proper draft conditions when under all conditions of wind.

THE GRADUAL ADVANCE OF SCIENCE.

THE RISE OF CHEMISTRY AND PHYSICS.

BY PROF. CHARLES BASKERVILLE.

AMONG the Greek philosophers, of whom Aristotle was a leader, there prevailed the opinion that a body could be hot or cold, wet or dry. A body could not be hot and cold or wet and dry at the same time. It may, however, be hot and dry (fire), hot and wet (air), cold and dry (earth), or cold and wet (water). Earth, air, fire, and water constituted the four elements of the Greeks.

The Arabs, who contributed enormously to our knowledge of chemistry, made the first systematic effort to explain the observed diversities in matter by the nature of the constituents of which it is composed. But for many centuries the development of chemistry was but an incident in the history of alchemy, or the "black art," as it was sometimes designated. The genuine alchemist sought to transmute base metals into gold.

In the eighth century the Arabian alchemist Geber (Abou-Moussah-Dschafer-al-Sofi being his full name), a true worker in seeking "perfection," considered all metals as compounds of mercury and sulphur. A metal was supposed to exhibit the sum of the properties of its constituents. The mercury or quicksilver was the vehicle of the qualities of ductility, fusibility, and luster, while the sulphur or brimstone offered the quality of combustibility. The differences between the individual metals, like gold, silver, and copper, were said to be due to the relative quantities of these constituents and to the degree of purity exhibited by them. The accomplishment of the highest purity was the "perfection" sought, but never reached, by Geber.

Five hundred years later Roger Bacon, the great philosophic alchemist, the reputed, and at least an independent discoverer of gunpowder, maintained that it was as absurd to wish to transform lead into silver, copper into gold, as to pretend to make something out of nothing. He insisted that the first necessity was to remove from the rough earthy mineral a bright metallic substance like lead, tin, or copper, as Geber before him maintained. This was only the first step toward "perfection" for Bacon. According to him, the most perfect gold is that found in the native state. It is perfect because in its nature finished her work. Therefore, the alchemist should seek to imitate nature. Nature makes no note of the cycles necessary for her work, so something was needed which would accomplish in a short time that which nature did in ages. The alchemist, therefore, should seek the "philosopher's stone," with a pinch of which it was hoped the vast changes could be made.

If we take a bone and burn it, we get fire, the ash

(earth) left behind, water given off, and a gas produced. If that ash be mixed with powdered coal and heated in a retort, as was done by the alchemist Brandt in the seventeenth century, we obtain a yellow substance known as phosphorus. This "light of Satan" was exhibited in all the courts of Europe as a new and remarkable substance because it glowed in the dark and eventually took fire when exposed to dry air, burning with a brilliant light. No other substance was known to possess these qualities, hence it was called an element. Later it was learned that if this yellow, spontaneously inflammable body be heated just below red heat in a close tube with no air present, it acquired a red color, no longer glowed in the dark, or took fire. The former substance is very poisonous, whereas this red variety is harmless. Under proper conditions the red may be changed back into the yellow phosphorus. These facts are related, as they have an important bearing upon that which immediately follows.

During the latter part of the seventeenth century, a German physician of the name of Becher explained the process of combustion as a form of destruction, a dissolution of the combustible substance into its components. According to this, what we now term an element cannot burn. His pupil, Stahl, elaborated the hypothesis by assuming that each combustible substance consists of the product of combustion united with an inflammable principle called "phlogiston"; a metal and this principle of fire combined together. From the observations made, there was good reason for accepting this hypothesis, but as Henry James has said, "we grope in the dark, carrying each our poor little taper of selfish and painful wisdom." Facts are facts, when accurately observed. Explanations are quite different. They constitute merely scaffolding for the structure of science and are to be cast away as soon as they shall have served their purpose.

It remained for Lavoisier, whom the French delight in calling the "father of chemistry," although they executed him during the revolution in the last quarter of the eighteenth century, to weigh the metals before and after the burning. He proved that nothing had been lost—in fact, there was a gain. No phlogiston or burning principle that was weighable had been given out. The principle of the conservation of mass or weight was thus established.

Just a century ago the Englishman John Dalton learned by experiment that a metal, when burned, always gained the same in weight. This he explained by stating that matter consists of very small indivisi-

ble particles, called atoms, which possess definite weights. These weights are unchangeable. These atoms, about eighty different kinds being known at present, make up all the various kinds of matter with which we are familiar. They enter in different proportions, but never in less weight than that of the atom, although many atoms may be in a substance. If these atoms are different we have a compound, just as in the bone mentioned we have our phosphorus, calcium, and oxygen. If the atoms be alike, as in our phosphorus, we have an element—an element being a substance which has not yielded anything simpler than itself.

The determination of the weight of an atom is a delicate operation, dependent upon great skill and many matters of technique familiar only to an expert. In studying the figures obtained, Prout noted that many of them approximated whole numbers. The approximation he attributed to defects in the methods or apparatus employed. If perfected, whole numbers would result. For example, oxygen, having an equivalence of 15.9, was really 16. Therefore he maintained that all the elements were actually composed of the smallest. If we could condense sixteen of hydrogen into the space of one, we should have oxygen. In short, for the transmutation of the elements it was only necessary to secure a machine which would do the work. This was in 1815. To test this, the Belgian chemist Stas determined many of the atomic values. This was a monumental labor subsequently equaled only by the classical work of Theodore Richards, of Harvard, who, as exchange professor, lectured this year in the University of Berlin.

One element—chlorine—a constituent of common table salt, always gave a value of about 35.5. In an effort to harmonize these facts a Frenchman, Dumas, said that all elements were made up of half atoms. This did not prove satisfactory, so Zangerle, in an effort to account for all the fractions obtained, said that hydrogen should be subdivided into one thousand parts. These speculations were not substantiated by the facts observed, so they constituted merely an event in the history of chemistry to be revived within the past decade apparently with experimental proof.

Just before our civil war began, two Germans, Bunsen and Kirchhoff, devised the spectroscope. With this instrument a beam of white light may be broken up into a rainbow of colors. If the light be from some element which is burned we get definite bright lines in fixed places. These lines are characteristic for the particular element experimented with. By common consent we regard a substance an element which has