THE EVOLUTION OF THE INCANDESCENT LAMP.

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The year 1820 probably marks the first attempt at making an actual incandescent lamp. In that year De la Rue built a lamp consisting of a coil of platinum wire in a glass tube the ends of which were covered with brass caps and from which the air could be exhausted.

In 1840 Sir William Robert Grove made an experimental lamp by attaching the ends of a coil of platinum wire to copper wires, the lower parts of which, or those most distant from the platinum, were well varnished for insulation. The copper wires were fixed erect in a glass of distilled water and another cylindrical glass placed over them, so that its open mouth rested on the bottom of the former glass. This prevented draughts of air from cooling the incandescent platinum, and the small amount of oxygen in the tumbler reduced the amount of oxidation of the platinum that would otherwise occur. He lighted the auditorium of the Royal Society with these lamps during one of his lectures, the current being supplied by a large number of cells of his improved primary battery.

During the thirty odd years following Grove's demonstration, several experiments, of more or less significance, were made on incandescent lamps. In 1845, J. W. Starr, a young American, invented two lamps. One had a platinum strip the length of which could be adjusted to fit the strength of the battery used. The other consisted of a carbon rod operating in the vacuum above a column of mercury as in a barometer.

In 1859, Professor Moses G. Farmer of the Naval Training Station at Newport, Rhode Island, lighted the parlor of his home at Salem, Massachusetts, with strips of platinum operating in air. The platinum strips of these lamps were narrowed at their terminals to increase the resistance of these points so that the strips were uniformly incandescent throughout their entire lengths. The terminals conducted the heat away from the burner tending to lower the temperature of the platinum at the points of contact which was offset by the greater resistance at these points.

In the year 1872, a Russian scientist by the name of Lodyguine made a lamp consisting of a "V" shaped piece of graphite operating in nitrogen gas. He lighted the navy dockyard at St. Petersburg with two hundred of these lamps.

Kosloff, another Russian scientist, in 1875, made a lamp having several graphite rods for burners which operated in nitrogen gas. They were so arranged that one rod operated at a time, and when it burned out, another was automatically put in circuit. During the same year, Konn made a similar lamp having the graphite rods operating in a vacuum.

Up to this time the development of the incandescent lamp was more of an experimental nature than commercial. The arc lamp had come to take its place in the field of commercial artificial lighting.

While the arc lamp was being commercially established, and though proving to be adaptable to various forms of industrial lighting, it was at once seen that it was too large a unit for household use. Of the many inventors who attacked the problem of making a smaller unit, the first of prominence was William Edward Sawyer, assisted by Albon Man.

In 1877, Sawyer developed his "electric candle" consisting of a rod of preferably white refractory substance, such as clays, lime, etc., around which was coiled a platinum wire or wires. An electric current heated the wires to incandescence. The heat of the incandescent platinum wires was transferred to the refractory substance, causing the latter to glow with a soft light.

Sawyer early realized that platinum was too costly a substance and the results too unsatisfactory to permit it to ever be developed for practical commercial use. Sawyer abandoned the idea in favor of carbon. In the year 1878, Sawyer made several lamps embodying a carbon burner operating in an atmosphere of nitrogen gas.

In February, 1878, Sawyer made a lamp consisting of a piece of gas-retort carbon heated to incandescence by an electric current in a Florence flask, through which a stream of ordinary illuminating gas was kept flowing. This atmosphere was employed because it contained no oxygen to unite with and destroy the carbon while in an incandescent state.

An experiment made on March 6, 1878, in which paper was accidentally carbonized while being used as a convenient receptacle for a fine line of powdered graphite, first suggested that this material might perhaps be made into carbon useful in incandescent electric lighting.

Sawyer and Man spent considerable time experimenting on the carbonization of paper. One time Man took a piece of paper embedded in graphite in a closed vessel and carbonized it by subjecting it to a high temperature in his kitchen range. He then took the carbon structure, all that was left of the paper, and placed it in a flask charged with hydro-carbon gas and brought it to incandescence by passing an electric current through it. The latter part of this experiment, that of heating to incandescence in an atmosphere of hydro-carbon gas the filament of carbonized paper, developed into a very important process in the manufacture of carbon lamps. This process was called "flashing," "re-carbonizing" or "treating" and was later developed to a very high degree of perfection. Before treating, all filaments, those of Sawyer's and Man's carbonized paper filaments and the later carbonized cellulose filament, varied more or less in diameter. At the points of smaller diameter the resistance was greater, and therefore the heat was greater, thus augmenting disintegration. In the process of treating, the filament was suspended in an atmosphere of hydro-carbon vapor, which was at a considerably reduced pressure and brought to incandescence by passing an electric current through it. The hot filament decomposed the vapor, depositing graphite on the filament. Due to the increased heat at the thinner portions of the filament, those portions were built up more rapidly than the thicker portions, until in a few seconds the entire filament was of a practically uniform thickness. This treating process considerably lengthened the life of the filament by giving it a uniform resistance throughout its length. Perhaps the most valuable and important result of the hydro-carbon treatment consisted in its capacity for giving to the filament surface the highest possible power of luminous radiation.

After spending considerable time experimenting with carbonized paper, wood and other fibrous materials, Sawyer and Man, had by June, 1878, constructed incandescent lamps capable of burning for many days. One lamp was run for many weeks at a luminosity of from one hundred to two hundred candle-power.

Thomas A. Edison began experimenting with the incandescent lamp in the Spring of 1878. Edison first made many experiments to confirm the failure of Sawyer and Man and others. Convinced of the seeming impossibility of carbon, he turned his attention to platinum as a light giving element. After considerable experimenting, he made a lamp having a long coil of fine platinum wire mounted on pipe clay. This was put in a one-piece all glass globe from which the air had been exhausted to effect a high degree of vacuum.

This lamp was expensive to make and to renew. By this time Edison was beginning to realize the impracticability of using platinum for the burner and, as had his predecessors already deemed it expedient to do, was turning his attention to carbon. After several trials he finally was able to carbonize a piece of ordinary sewing thread, with which he made a carbon filament vacuum lamp. On October 21, 1879, current was turned into the lamp and it lasted 45 hours before it failed. A patent was granted on this lamp January 27, 1880. All incandescent lamps made today embody the basic features of this lamp. The efficiency of the lamp was about 1.4 lumens per watt. Edison immediately began searching for the best material for a filament and soon found that carbonized paper gave several hundred hours life. The first commercial Edison incandescent lamps had carbonized paper filaments. The first commercially successful installation of the Edison incandescent lamps was made on the steamship Columbia, which started May 2, 1880, on a voyage around Cape Horn to San Francisco, California.

The carbonized paper filaments were quite fragile. Carbonized bamboo was found to be not only sturdy but it made an even better filament than carbonized paper. Carbonized bamboo filament lamps were introduced early in 1880. The filament material for this lamp was selected from about 6000 specimens gathered from many parts of the world. The average life of these lamps was 792 hours, though occasionally some would burn as long as 3000 hours.

The efficiency of these lamps was about 1.6 lumens per watt.

The year 1886 marked the introduction of the squirted cellulose filament lamp. The filaments of these lamps were made according to what was known as Swan's Squirting Process. By this process a perfectly structureless and uniform thread was produced by pressing a viscid solution of nitro-cellulose or of cellulose through glass jets into a coagulating liquid. The thread as it emerged from the jet had sufficient tenacity to maintain continuity until it was deposited in a coil on the bottom of the vessel containing the coagulating liquid which was usually alcohol of a certain strength. The coil was transferred to washing vessels and treated until nothing remained but a beautifully smooth and transparent length of pure and structureless cellulose thread. This cellulose thread was dried under tension, passed through polishing dies and carbonized. The squirted cellulose filament lamps not only had a longer useful life than the former carbon lamps, but were much more uniform in quality. The efficiency was increased to 2.5 lumens per watt.

In 1893 the filaments of the carbonized bamboo lamps were "treated" by the hydro-carbon process developed by Sawyer and Man.

In 1896 the squirted cellulose filaments were also "treated." By this time lamps were being made in relatively large quantities. The treated cellulose filament lamps had a longer life and their efficiency was about 3.3 lumens per watt.

Dr. Auer Von Welsbach, the German scientist who had produced the Welsbach gas mantle, invented an incandescent lamp having a filament of the metal osmium. It was commercially introduced in Europe in 1905 and a few were sold, but it was never marketed in this country. It had an average efficiency of 5 lumens per watt. Osmium is very rare and difficult to obtain. It is also very brittle, so that the lamps were extremely fragile.

In 1905 the Gem Metalized Filament Lamp was put on the market. The filament of this lamp was carbon which had been so changed by subjecting it to the intense heat of an electric furnace that it more nearly resembled a metal in its resistance characteristics; hence the term "Metalized

Filament." Like the metals, the filament of the Gem lamp had a positive temperature co-efficient, causing an increase in resistance with increased temperature. This feature gave the lamp in a measure, the self regulating quality of the high efficiency metallic filament lamps that were later developed. The Gem lamp could be burned on a slightly fluctuating voltage with comparatively small variation in light output. The efficiency of these lamps was 4 lumens per watt.

Von Bolton produced the tantalum lamp which was put on the market in this Country in 1906. The metal tantalum had been known to science for about a century. After considerable experimenting, he finally obtained some of the pure metal and found it to be ductile so that it could be drawn out into a wire. It has a low specific resistance so the filament had to be much longer and thinner than the carbon filament. It had a good maintenance of candlepower during its life, having an average efficiency of about 5 lumens per watt. The life on alternating current was considerably shorter than on direct current, due to more rapid crystallization of the filament.

The first tungsten lamp was placed on the American market in 1907. It had a pressed tungsten filament, produced by making a paste of tungsten powder and a carbonaceous material and squirting the paste into a thread through diamond dies. The pressed tungsten filaments were quite fragile. These lamps had an efficiency of 8 lumens per watt.

After several years of experimenting, Dr. W. D. Coolidge of the Research Laboratories of the General Electric Company, made the remarkable discovery that under proper conditions of working, the crystals of the metal tungsten were drawn out into fibres and in that state the tungsten filament was no longer brittle but ductile. His first success was obtained by repeatedly drawing a tungsten filament under careful heat conditions through heated dies. On the basis of this discovery a commercial process was developed and drawn tungsten filament lamps were put on the market in 1911.

This improvement brought the efficiency of vacuum lamps to about 10 lumens per watt.

Soon after the introduction of the tungsten filament vacuum lamp, chemicals were put in these lamps to improve their maintenance of candlepower during their life. "Getters" was the name given to these chemicals. One of the getters used had thallic chloride as a base. This salt dissociated with heat, releasing chlorine gas which combined with the tungsten as it vaporized from the filament while the lamp burned. The otherwise black deposit of tungsten on the inside walls of the bulb was converted into tungsten chloride which is light in color, thus cutting off less light from the filament during the life of the lamp. Many improvements have been made in the use of getters. By the method now in use, the getter is put directly on the filament and when the lamp is lighted for the first time, the getter vaporizes, condensing on the inside walls of the bulbs, coating them with an invisible layer ready to take care of the vaporizing tungsten as it strikes the bulb. By the use of getters the mean efficiency of lamps throughout their life is improved by about 10 per cent.

The higher the temperature at which an incandescent lamp filament can be operated, the more efficient it becomes. The limit is reached when evaporation of the tungsten becomes so rapid as to appreciably shorten the life of the lamp. If, therefore, the evaporating temperature can be slightly raised, the efficiency will be greatly improved. This was accomplished by Dr. Irving Langmuir by operating a tungsten filament in an inert gas, namely, nitrogen. This gas principle had been tried by Edison and others many years before but it was not successful with the straight filament on account of heat losses through the gas in the bulb. To overcome the excessive heat losses, the filament was coiled, thus presenting a smaller surface to the currents of gas and thereby reducing this loss. The gas-filled lamps were commercially introduced in 1913.

The first gas-filled lamps were the 750 and 1000 watt sizes. To offset the heat that is constantly being conducted away by the gas of these lamps, an increased amount of electrical energy is required. In the vacuum lamp, this heat loss is held to a minimum, the filament tending to stay hot on the principle of the vacuum bottle. This loss in a gas-filled lamp becomes relatively great in a filament of small diameter, as the surface in proportion to the volume of the filament increases with decreasing diameter. Hence, there is a point where the gain in temperature is offset by the heat loss. Below this point the efficiency of the gas-filled lamp decreases. By the end of the year 1914, the smallest gas-filled lamp was the 200 watt size. However, in 1915, the use of nitrogen gas in the gas-filled lamps was discontinued and argon gas was used. Argon has a poorer heat conductivity than nitrogen, thereby reducing the heat loss of the lamp which becomes of increasing importance the lower the wattage of the lamp. The present day gas-filled lamps contain argon gas. It is now possible to make an efficient commercial lamp as low as 50 watts for 115 volt circuits. The present standard 1000 watt gas-filled lamp has an efficiency of 21 lumens per watt. The 1000 watt projection lamp has an efficiency of 26 lumens per watt.