The centenary of the electric light

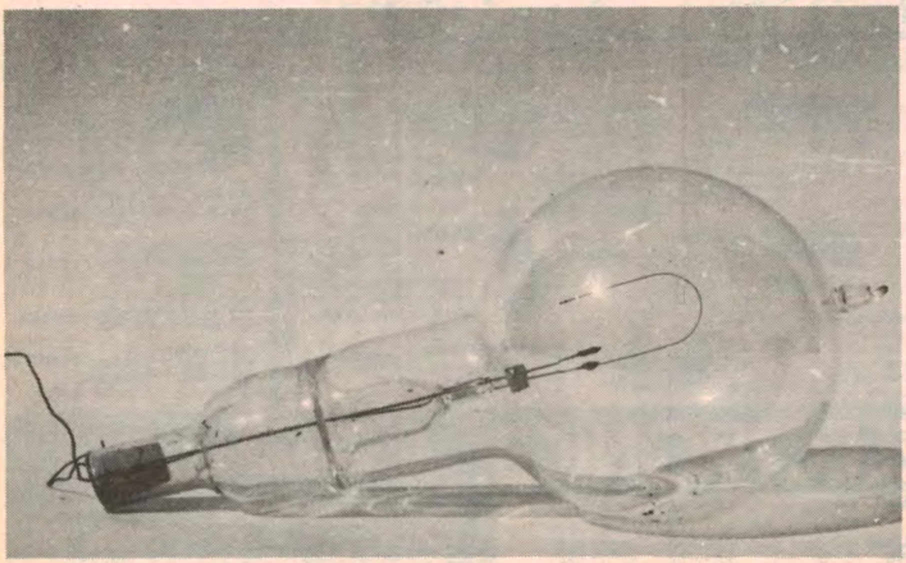
Was Thomas Edison its true inventor?

October 1979 marked the centenary of the development of the first commercial electric light globe by Thomas Edison. But the event has sparked off controversy in the technical press as to whether Edison should receive all the credit. This article sheds new light on the subject. It was originally published in a bound volume entitled "Science For All", and was written around 1885.

by T. C. HEPWORTH

The circumstances under which we live are much altered since the time when the curfew bell warned all loyal people to extinguish their fires and lights at eight o'clock pm. The simple lives and habits of our forefathers called for no more labour at their hands than could be accomplished between sunrise and sunset; so that artificial light was to them a matter of secondary importance. But now all is changed. We no longer consider that our day's work is over when darkness comes upon us; indeed, a large proportion of the population are more busy during the night hours than at any other time. Hence, the possession of some reliable and effective means of procuring artificial light becomes almost as much a necessity to us as our daily bread.

Oil-lamps and candles were the only sources of light available until the beginning of the present century, when gas was first introduced. Its adoption met with great opposition, and lecturers in all parts of the country proclaimed the direful effects that would follow its employment. The antagonistic feeling thus aroused may be compared to the strong prejudice previously evinced against the use of its parent, coal, as a fuel. Only two hundred years ago the citizens of London petitioned Parliament to forbid the burning of coal in the city, "on account of its stench". But the threatened failure of the wood supply helped them to forget their objections, and coal soon became the principal source of artificial heat, as it, has since become our chief means of obtaining light.



A replica of Edison's original successful lamp of October, 1879. This particular lamp was made in the USA for the 50th anniversary of Edison's invention in 1929.

Now, although gas represents a vast improvement on all previous modes of illumination, we are far from being altogether satisfied with it. It often contains impurities, which are not only prejudicial to health, but are most destructive to property. In fact, we want something purer and more wholesome. How common it is to hear the remark, "I must examine this or that by daylight before I can judge of it." Is not this an acknowledgment that our present resources are not equal to our requirements? That gas will be immediately supplanted is very improbable, but we hope that the day is not distant when some better means of illumination will be vouchsafed to us. Many circumstances have taught us to look for this boon to the magic power called "electricity."

Candles and lamps have become such common things of our every-day life that there is no sort of mystery about them, or, at least, about their composition. We all know that a candle is made of wax or animal fat, and that it has a cotton wick. These are things which we can see and touch, and which we can readily trace to their sources of production. In electricity we have a very different thing to deal with, for in character it partakes of nothing with which we are familiar. Invisible, neither solid, liquid, nor gaseous, we regard it as an intangible something in which we must believe in spite of ourselves, for we have constant evidence of its marvellous powers. Our present object is to explain how this wonderful natural agent can be made to afford light.

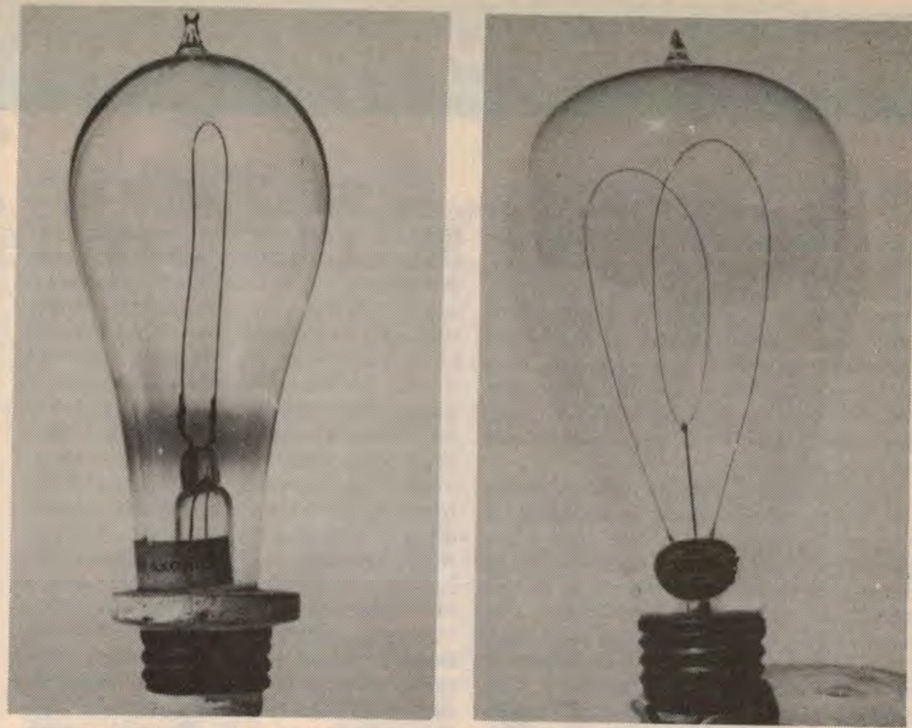
Without detailing the many theories which have been advanced to explain electrical phenomena, and avoiding such elementary points as can be obtained from all the excellent text-books on the subject now published, we shall prefer to plunge headlong into the matter, with the statement that there are two methods by which we can produce an electric light. (1) By the current afforded by a battery, and (2) by that obtained from a magnetic machine. For experimental purposes, or where a light is required for some special service for a short time, a battery can be employed.

The form of battery suitable is that known as a Grove battery, or in its modified form known as Bunsen's. The first form of cell consists of an earthenware or ebonite vessle, holding a bent zinc plate immersed in water, rendered acid by the admixture of about one-eighth part of sulphuric acid. Held within the embrace of the U-shaped zinc plate is a porous pot full of nitric acid, within which is a piece of platinum foil. The Bunsen battery exhibits the same arrangement of parts and the same fluids, but the platinum is represented by a plate of carbon. To obtain a powerful light, at least fifty of such cells must be employed, joined up in such a manner that the zinc of one cell is in contact with the platinum or carbon of the next. From the last carbon of the series, as well as from the last zinc at the other end of the row of cells, a wire is led off for use.

Upon bringing the free ends of these two wires together, a brilliant spark is seen, and the copper of which they are composed becomes sensibly heated. By furnishing each end with a pointed piece of carbon, by means of the simple piece of apparatus shown at Fig. 1, we can obtain the electric light. A few particulars regarding the use of this little contrivance will be necessary, if we wish to understand the conditions which have to be met in the construction of electric lamps or regulators.

In the first place, there is no light until the carbon points actually touch one another. Then, and only then, they begin to glow with intense heat. They can now be separated for a short distance, and although separate, a most brilliant light is maintained between them. This "arc," as it is called, will remain until the carbons waste away to such an extent that they are too far apart to be longer bridged over by it. It now becomes necessary to bring the points once more together before the arc can be re-established. One more circumstance is noticeable, and that is, that one carbon wastes away twice as quickly as the other.

The article then goes on to describe how a dynamo works and, in particular, describes machines developed by Gramme and Siemens. We resume the story where the author takes up the development of incandescent lamps — Ed.



1881 Edison lamp (left) and Edison lamp of 1910 (right).

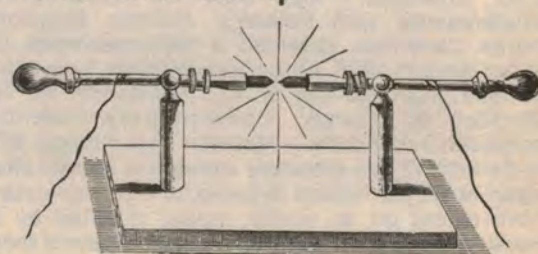
The arc form of electric light is so extremely brilliant that its use is almost confined to the illumination of large open spaces, and we may feel quite certain that if there were no other method available, we should hear very little of the fear that gas would cease to be used for domestic lighting. By means of what is known as the incandescent system, electric lamps, giving a beautifully soft but brilliant light, can be made of from five to twenty-five candle-power. To understand this sytem we must once more glance back at a simple battery experiment, which can easily be performed with half-a-dozen Grove or Bunsen cells.

If the terminal wires from such a battery are bridged over with a piece of thin iron binding wire about eight inches in length, it will get redhot, owing to the resistance which it offers to the passage of the current, and will eventually fall to pieces in a shower of brilliant sparks. A platinum wire will behave in much the same way, but it will hold together far longer than the iron, being a much more refractory metal; indeed,if the length of the wire be carefully adjusted to the strength of current available, platinum can be kept at a white heat for some time. During this period of incandescence the little wire will give out a wonderful light, but sooner or later if falls to pieces, owing to the action of the atmosphere upon it. We may substitute for the iron or platinum wire in this experiment an extemely thin pencil of carbon, but with the same result. Although it will afford a brilliant light for a certain time, it will soon fall to pieces.

It will be readily seen that to any one in search of an improvement upon the usual means of obtaining an electric light, the experiment just detailed must have been a most suggestive one. That it was so is proved by the numerous patents which were taken out about thirty years ago, which detailed methods of obtaining light by the incandescence of metals or carbon in the way described. These early inventors saw that the enemy they had to guard against was the air. So in these pioneer

Basic scheme for the arc lamp

Fig. 1: the basic idea behind the arc lamp. The two carbon rods must first be brought together and then separated by a short distance so that an arc is maintained between them.



lamps we find that the platinum or carbon employed is enclosed in a glass globe exhausted of air, or in some cases charged with a gas such as nitrogen, which is quite inert. The first of these inventions is that of E. A. King, dated 1845, who used a ribbon of platinum-foil held between two supports in a globe of glass. In a later invention the platinum is replaced by a stick of carbon contained in a glass vessel exhausted of air.

The following year lamps on much the same principle were introduced by Messrs Greener and Staite, and their patent specification is noteworthy as being the first to call attention to the quality of the carbon employed. The rough carbon from the gas retorts had been exclusively used for electric lighting purposes up to this time. The material is full of impurities, which give rise to irregularities and other difficulties. Messrs Greener and Staite recommend the employment of specially manufactured carbon, made of lamp-black purified with acid, and moulded under pressure. The importance of this innovation may be estimated when we state that in the present day the manufacture of carbon pencils for electric lighting purposes constitutes a distinct branch of trade, for only manufactured carbon is now employed.

By the year 1871 lighting by incandescence had reached such a forward place in the estimation of many, that a company was formed at St Petersburg for its installation on a large scale in that city. In the result no fewer than 200 lamps were exhibited on one electrical circuit. The machine used was of the "Alliance" pattern. The excitement which this installation caused may be likened to that which we have more than once seen within recent years as improved lamps or machines have been brought forward. But the scheme altogether collapsed, and we may say that lighting by the incandescent system was altogether forgotten until a few years back, when Edison commenced experiments in the same direction. He began by using platinum wires enclosed in a vacuum, and he was more fortunate than his predecessors in having an air-pump at his disposal — such as that of Sprengel — which gives far more perfect results than those of older pattern.

Edison was the first to study the curious and important phenomenal changes which occur in platinum wire when subjected to heat. The metal contains gases which, if the heat at first applied be above a certain temperature, is expelled with such violence as to split up its surface; so that in preparing the platinum wire used in his first form of incandescent lamp, the following procedure became necessary. The platinum wire, enclosed with a glass bulb in connection with the air-pump, was subjected for about ten minutes to a current tending to raise its temperature to 150°F. This moderate heat expelled the gases, which were drawn off by the air-pump kept in action the whole time. After a quarter of an hour's rest the heat would be raised to 300° for another short period. With like intervals of rest the heat was gradually raised to incandescence, with the result that a wire which before such treatment would give a light of only 3-candle power before it melted away, would now afford one of 25-candle power without risk of destruction.

Edison next turned his attention to "carbon wire," and he found that it needed the same treatment before it was fit for permanent use — becoming very homogeneous and hard. After trying cotton-thread, and various carbon compounds rendered plastic and rolled out into wire, he came to the conclusion (at least, so says one of his patent specifications) that the carbon used should preserve its structural character, either cellular or otherwise. After experimenting with fibres of jute, bast, manilla, hemp, &c, he chose bamboo, as being, on the whole, the best for his purpose, and of that material the car-

Edison — "a skilled practitioner of systems

In an article in the February 1979 issue of IEEE "Spectrum", Christopher S. Derganc, a Ph.D student at the University of Pennsylvania, describes Edison as "a skilled practitioner of systems engineering, not the tinkerer of legend."

According to Derganc, "Edison's single, immense contribution to the field of electric lighting was his ability to locate, assimilate, and then synthesise state-of-the-art science and technology into an economically feasible system. This was the key to his success". He goes on:

"Edison made no revolutionary breakthroughs in electric-lighting technology. Joseph Swan, an English inventor, produced a high-resistance carbon lamp almost simultaneously with Edison's. Another Englishman, St. George Lane-Fox, patented a high-resistance platinum-iridium lamp in 1878. Albon Man (William Sawyer's partner) had also proposed use of high resistance, but had been overriden by Sawyer. Contemporary inventors Elihu Thompson and Edwin J. Houston had publicly announced the benefits of low armature resistance shortly after Edison began work; the Edison dynamo, in fact, was essentially an improvement on an earlier model invented by Siemens. Finally, Sawyer and Man anticipated Edison's feeder-main design by almost two years."

Derganc describes how Edison with assistance from Grosvenor P. Lowrey (general counsel for Western Union and Edison's longtime friend and advisor) set up a well-equipped laboratory at Menlo Park, Calif. using funds supplied by such people as William H. Vanderbilt and J.P. Morgan, the controlling interests in Western Union. The result, says Derganc, "was one of the best and most versatile electrical laboratories in the world, a facility not unlike the modern industrial research laboratory in its reliance upon machine tools and scientific instruments."

The laboaratory was also well staffed . . . "In the early phases of the project, he (Edison) maintained an intimate working and personal relationship with his relatively small group of some 30 assistants, of whom perhaps half were actively involved in the work on lighting. After the essential system components had been invented and work had progressed to the development stage, the staff were enlarged to perhaps as many as 100 and a hierarchal management structure was established".

One concludes, from reading Derganc's article, that Edison's genius lay in directing his research staff to make the electric light a viable commercial proposition. His laboratory not only produced successful lamp and dynamo designs, but ensured their commercial success by inventing or improving various auxiliary devices such as meters, lamp bon loop in the modern Edison incandescent lamps is made. Let us briefly describe its preparation.

A bamboo rod is cut to the length required, divested of its hard siliceous coat, and split into six pieces, each one of which is reduced in thickness until its diameter is not much greater than a horsehair. Each thread of bamboo is then placed in a mould formed by cutting a U-shaped depression in a plate of nickel, another plate of the same metal covering it over. The mould is then placed in a muffle, and subjected to such a heat that the horse-shoe-shaped fibre is carbonised. It is then placed in a glass bulb in connection with an air-pump, and is gradually coaxed into order in the way already explained.

The two ends of the horse-shoe carbon thread are fastened to platinum wires which are sealed into the glass, and the ends of these wires form conductors for the electric current. One is in connection with a kind of outer collar surrounding the foot of the lamp, and the other is fastened to a screw socket. The mere act of screwing a lamp to its fittings places it at once in electrical communication with the supply.

Swan, in England, claims to have made incandescent lamps upon this same principle many years ago. He does not hold to Edison's opinion that the carbon employed should possess structure, for his lamps contain cotton-thread loops which, previous to carbonisation, have been "parchmentised" by immersion in sulphuric acid. That they answer their purpose most efficiently is proved by the fact that they have been in use for many months without requiring renewal — all this time giving the most satisfactory results in every way. Maxim, and many others, have introduced lamps on the same principle, with slight variations of treatment, which have been sufficient to give them the protection of the Patent Office.

The principal public "installations" of the incandescent system in this country have been at the Savoy Theatre, London, which is entirely lighted by Swan lamps; at the International Fisheries Exhibition, 1883, where more than one thousand were seen on one circuit; at Holborn Viaduct, which thoroughfare, with the houses adjoining, has been lighted by Edison's lamps; and at the Electrical Exhibition at the Crystal Palace, where the suitability of the system both for public and private use was most successfully demonstrated.

To Edison must always attach the credit of having been the first to serve entire streets with a supply of electricity for lighting purposes in lieu of gas. The details which he has worked out with regard to fittings, conducting cable, switches for turning the current on and off, much in the same way as people have been accustomed to in turning gas on and off, besides meters for measuring the amount of current utilised by each consumer, exhibit the greatest ingenuity and constructive ability. To the meter especially we may devote a few words.

The amount of electricity used by each house-holder is measured by the amount of metal deposited upon zinc plates in a special form of cell attached to the fittings. The collector exchanges these plates for new ones, and takes them to the chief office, where they are carefully weighed. The difference between their original weight and that now indicated gives the exact amount of metal which has been deposited by the action of the current, and from this sum the total amount of electricity supplied to the consumer can be accurately gauged. Another slightly more complex method of arriving at the same result is exhibited in Edison's continuous "current counter," where dials, after the manner of a gas-meter, show the amount of current which has been used. The Edison Company fix their unit at the quantity of electricity which will give a light equal to that produced by the combustion of one cubic foot of gas, so that the three familiar dials can be still employed.

engineering"

sockets and bases, switches and fuses. Says Derganc:

"Edison timed his entry into electric-lighting research almost perfectly. Most of the ideas and concepts necessary for a commercial system were either already available or about to emerge from the expanding research front. It was Edison's wide-ranging approach to invention — his inventive style, if you will — that allowed him to bring them into focus."

Conceptual difficulties

Derganc's article also highlights one of the major conceptual difficulties that confronted early researchers of electricity. The problem of the "subdivision of light" — or, more accurately, the subdivision of current — was a topic of heated debate among scientists and engineers in the late 1870s. The prevailing opinion was summarised by Sir William Preece, a noted English engineer, during a speech to the Royal United Service Institution in February 1879:

"Theory shows unmistakably that to produce the greatest effect we must have only one machine (dynamo) to produce one light . . . But the moment we attempt to multiply the number of lights in circuit this power diminishes . . . It is . . . . easily shown (and that is by the application of perfectly definite and well-known scientific laws) that in a circuit where the electromotive force is constant . . . a subdivision of the electric light is an absolute *ignis fatuous.*"

The fallacy of this argument obviously lies in the assumption that only a fixed amount of current is available. Early dynamos employed a high-resistance armature and so behaved as constant current generators with very poor voltage regulation. This meant that, as additional lamps were added in a parallel circuit, each lamp was progressively dimmed.

It was this characteristic of early generators that misled the researchers. They thought that all dynamos would produce a constant current, regardless of their construction and the electrical circuit connected to them.

Edison was among the first to realise that this was not the case. The problem of the subdivision of light could be overcome simply by employing a constant voltage generator having a low internal impedance and by using relatively high impedance lamps. The amount of current drawn from the generator would vary, depending on the number of lamps connected across the circuit (i.e. the electrical load). The generator would not "squeeze out" a fixed amount of current for all load conditions, as Preece and others had thought.

With acknowlegement to IEEE "Spectrum", February, 1979.