THE EVOLUTION OF THE LAMP.*

BY ROSCOE SCOTT.

Synopsis: The following paper outlines the evolution of several illuminants—the candle, oil, gas and electric lamps—beginning with their primitive forms. A bibliography on the subject is appended.

INTRODUCTION.

The study of an evolution, whether it concern a living organism, such as man, or a manufactured product, such as the lamp, consists largely in reviewing a mass of prehistorical data. Accordingly persons of that pre-eminently practical mentality that distinguishes our hustling twentieth century, often profess indifference when evolution comes up for discussion, even when it relates to those objects in which they are naturally supposed to be vitally interested. Mr. Edison, for example, when interviewed some time ago by the writer, remarked "I don't like to go into things connected with ancient history, or the dead past,—what I am interested in is the future: in what is going to happen tomorrow." Yet even Mr. Edison has always made it a point to be familiar with the previous development of any product which he set out to improve.

But the evolution of the lamp is of more than academic interest, and its principal facts should form part of the illuminating engineer's education. Such a study discloses what types of men and circumstances have produced the greatest improvements in lamps and illumination methods, and leads one to predict that similar combinations of men and circumstances will produce important results in the future. Upon noting the cardinal dates in lamp history, and incidentally their increasing frequency in recent years, one may venture to extrapolate the "curve of progress" and form some idea of the extent to which lamps may be improved in the next generation. One may look forward to a day when, due to constant diminution of the cost and increasing of the standard of illumination, the world's total installation of lamps

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of all kinds will be 40 or 50 candle-power per inhabitant, although at present there are tribes, in Polynesia for example, that are known to have no lamps whatsoever,—that are at the same stage of development, from a lamp standpoint, that all mankind was, ten thousand years ago.

Lest anyone should carp at the phrase "evolution of the lamp," in the title of this paper, it may be well to mention that, except in a general sense as I am using it, to include lamps collectively, there is no "*the* lamp." Some persons may be so biased as to think that there will eventually be a "the lamp,"—a type or class of lamp in universal use,—but a study of the subject from the evolutionary standpoint leads to the opposite conclusion, namely, that we are getting farther and farther away from "the lamp." The ancients knew but one or two general types of lamp, while to-day there are many, and, for reasons too numerous to mention, many are required. It would seem about as logical to assert that, since the highest development in the animal kingdom is *genus homo,* therefore *genus homo* must, forsooth, supersede all other forms of animal life, as to predicate that simply because this or that lamp represents the highest point reached in modern lamp development, it will drive all others from the face of the earth. No evidence exists in support of either contention. On the other hand, it must be admitted that there may very easily be a lamp so far superior to others for general purposes that it may be recognized as the highest development in the field.

The analogy between the evolution of the lamp and that of living organisms is strikingly brought out by the following quotation from an authority on the last mentioned subject:

> In general, the progress of evolution has been from the simpler toward the more highly organized and specialized types, though many examples of retrograde evolution or reversion to a simpler type occur.
>
> The various living and extinct types do not form a simple series, but a genealogical tree whose branches exhibit very different degrees of divergence from the parent stock. Many branches have died out completely, and are known only by fossils.*

To relate, in detail, the evolution of the oil lamp, or of the inverted mantle gas lamp, or of the tungsten filament lamp, would

[1] See definition of evolution, Webster's Unabridged Dictionary.

require a paper many times the length of this one. Evidently, then, I can attempt only to trace broadly the unfolding of the major groups, and a few of the more important sub-groups, into which illuminants naturally divide themselves.

A bibliography is appended to the printed edition of the paper, for the benefit of any who may wish to investigate, in some leisure season, the lamps that lighted the paths of our forefathers.

Taking the barbarian camp-fire as probably the earliest form of artificial illuminant, or lamp in its broadest sense, in the following paragraphs will be discussed successively the evolution of lighting arrangements employing solid, liquid, and gaseous fuels and lastly those energized by electricity.

FIREFLY LAMP.

Just in passing, I may mention a curious primitive lamp or lantern, which falls under no ordinary classification. It can hardly be called an artificial illuminant; perhaps it might best be called an artificial collection of natural illuminants. I refer to the West Indian firefly-box shown in Fig. 1. Many travelers have recorded the use of fireflies as lamps by natives of the tropics. The box here illustrated is on exhibition in the New National Museum, Washington, D. C., and forms part of an extensive and highly instructive collection of fire-kindling and light-producing devices brought together largely through the efforts of Dr. Walter Hough.

SOLID FUELS USED AS LAMPS.

The pine knot blazing in the camp-fire, or the fire-brand, snatched from the latter for light and protection during the savage's nocturnal excursions, served the purpose of lamps until, as dwellings grew larger and men—or more likely women—came to appreciate the virtue of cleanliness in housekeeping, it was found desirable to provide a special holder for the burning wood. Fig. 3.

It may be presumed that the making of special holders for splint-lights dates back to the earliest times when men first learned to fashion rude household implements of stone. Homer mentions "metal braziers filled with blazing pine knots," and refers to the torch as the ordinary means for lighting dwellings.

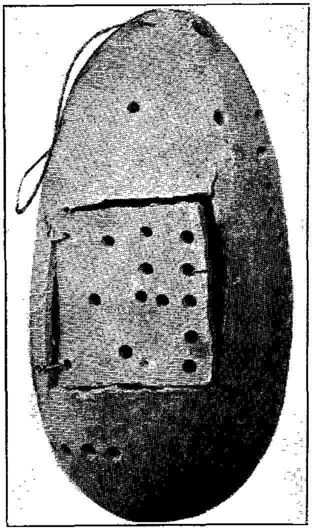


Fig. 1.

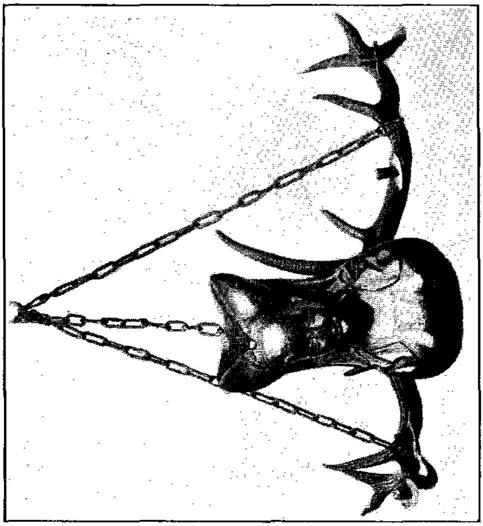


Fig. 19.

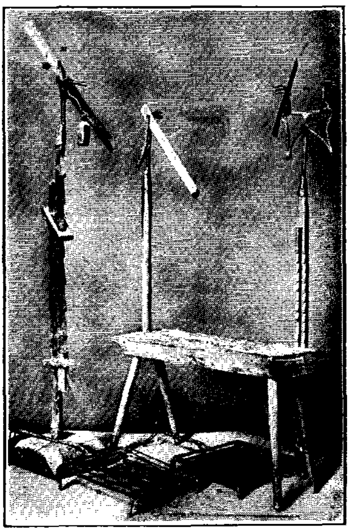


Fig. 3.

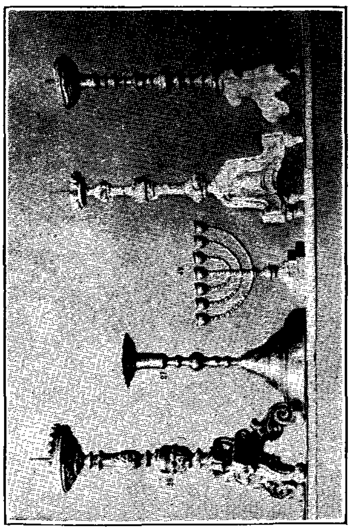


Fig. 20.

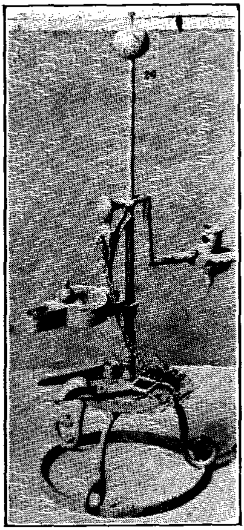


Fig. 21.

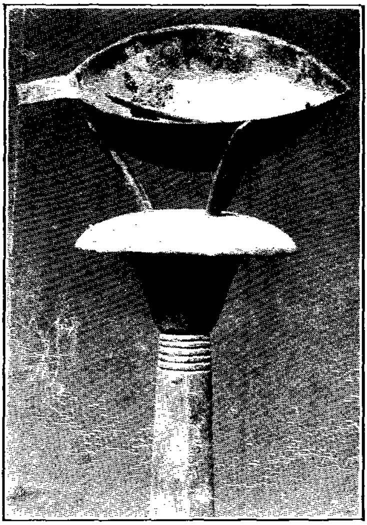


Fig. 27.

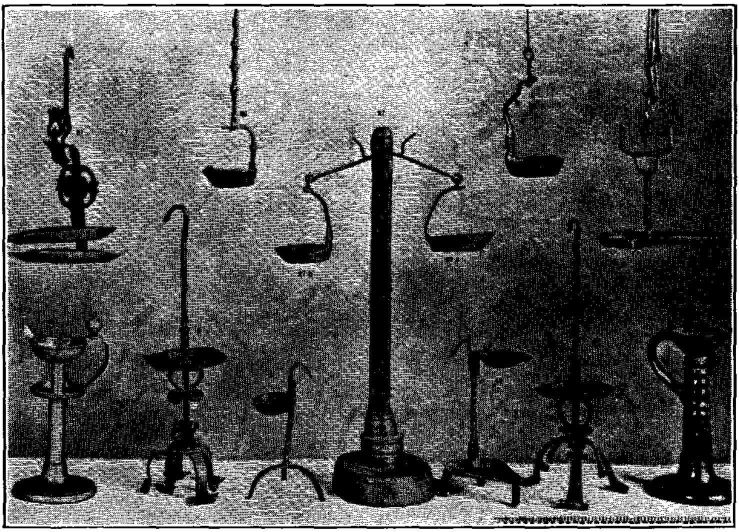


Fig. 22.

The making of splint lights must have assumed, about the seventeenth century, the proportions of an important industry in Europe, judging from the specimens that have been preserved. The holders, or fixtures, passed through successive stages of evolution until elaborate forms like those shown in Fig. 3, appeared—with ash pans, vertically or horizontally adjustable arms, and even chimneys, all to improve an illuminant that was, at its best, little better than the primeval fire-brand. Huge clumsy planes, some of which required four men to operate them, were commonly used in preparing the fuel for these archaic lamps. Splint-holders furnished light for king and for peasant, just as our modern illuminants are found in both cottage and mansion.

Owing to its wide distribution, wood, especially resinous woods, such as pine, was pretty generally used as a source of light in former times. Various vegetable substances were also burned in their crude state in the localities where they were most abundant. The Malays used a torch consisting of a piece of resinous gum wrapped in palm leaves,—a sort of candle with the wick on the outside. The East Indian candle-nut, or candle-berry, which yields two oily seeds that are burned for light by the natives, may also be mentioned in this connection. Oily carcasses of fish and birds have been used as lamps or torches of a crude sort. The stormy petral with a wick in its bill is burned for light in the Orkney Islands. A "candle-fish" held in a split stick has been used in Alaska.

THE CANDLE.

From these primitive candles it was but a few steps in evolution to the true candle, although just when or by whom those steps were taken is as unknown as the name of the man who invented the bow and arrow. The Patent Office records of that day and age have passed into oblivion.

It is known, however, that wax-candles* (*cereus funis*) were known to the Romans, as early perhaps as the beginning of the Christian era. The tallow candle (*sebaceus*) was probably of later invention, being mentioned in the writings of Apuleius, a second century author.

[2] **Wax candles may be of Phoenician origin. See art. by Dr. C. Richard Böhm, *Lond. Il'g. Engr.*, Feb., 1908.**

The not infrequent references to "candlesticks" in the Bible have given rise to an erroneous impression in the minds of some persons regarding the antiquity of the candle. The fact is that all these references should be translated "lamp stand" rather than candlestick.

Candles also came into use in Japan and other Oriental countries at an early date. With the rise of the Christian church in Europe, the candle became inseparably associated with the lore of the church, and the candle-stick, with its myriad diversified forms and appurtenances, became, for a thousand years or more, the most familiar lighting accessory.

Tallow candles have been for centuries an article of domestic manufacture.

Rush-lights, *i. e.*, rushes dipped in tallow, were undoubtedly of very early invention,—earlier perhaps than the candle itself. They were well known in Pliny's time,* and have remained in use, notably in England, almost up to our own day.

Innovations or noteworthy improvements in candle-making were conspicuous by their absence throughout the Middle Ages, when the famous guilds of the waxchandlers and the tallow-chandlers flourished, and indeed up to comparatively modern times. Early in the 18th century the pursuit of the sperm whale was begun, and spermaceti was first used as a substitute for tallow about 1750. Nearly a hundred years more elapsed before the first important step was taken towards the elimination of those erstwhile necessary nuisances, the snuffers. Composite candles, or "composites," composed of stearic acid and stearin, were first manufactured about 1844. This change in the material used for candle-grease, together with a change in the design of candle wicks from a circular to a more or less elongated cross-section, and the pickling of the wicks in salt resulted in practically complete combustion of the wicks and the relegation of snuffers to the rubbish heap, the attic, and the antique shop. Composites are now commonly made of stearin and paraffin, the composition being varied according to the climate whither the product is to be shipped. Indeed, with the development of elaborate candle-

[3] E. B. Taylor's Anthropology, Chap. 11, p. 273.

moulding machinery in recent years, the ancient trade of candle making has now evolved into an exact science.

To enable him to work at night with both hands free on his immense mural painting "The Last Judgment," Michael Angelo fitted a candle-socket to his cap, and with the aid of the flaring light from this weird portable, produced one of the world's master-pieces.

Although this paper deals with the evolution of the lamp rather than of the chandelier, it is of interest to note that one of the earliest forms of the latter was of natural origin—the "suspended antler" chandelier as shown in Fig. 19 (from the Swiss Museum in Zurich). From the suspended antler to the simplest manufactured hanging fixture was an obvious step, but it marked the birth of an industry. It is by no means uncommon in this twentieth century to see decorative electroliers consisting of antlers wired and equipped with incandescent lamps,—a rather striking example of the persistence of one of the earliest and most primitive kinds of fixture.

Space limitations forbid more than an allusion to the evolution of illuminants used in religious worship and ritual from the most primitive altar-fires down to such elaborately ornamented candlesticks as are shown in Fig. 20. The three large prickets came from Roman Catholic churches; the stick designated 27 is from an Oriental temple, while that marked 42 is practically an exact reproduction in form of the seven-armed lamp-stand in the ancient Jewish temple, so far as may be ascertained from the bas-relief on the Arch of Titus.

Fig. 21 shows what may be called a "link" between a lower and a higher development in the scale of illuminants. It is a combination candlestick and primitive oil lamp (from the Imperial Austrian collection). One may well believe that at one time such combinations were by no means uncommon, just as combination fixtures of quite a different sort are in considerable use to-day.

THE GREASE LAMP.

The oil lamp, while in many localities doubtless invented previous to, or without reference to, the candle, is nevertheless so closely related to the latter, physically, that it may be treated as an outgrowth. In fact, there is an intermediate step between the candle and the liquid oil lamp namely, the grease or tallow lamp, a number of which are shown in Fig. 22.

Nor is it necessary to search far for a "missing link" between the candle and the grease lamp. In some of the historical collections may be seen a kind of candle holder having at its base a container worked in the form of a saucer to catch grease drippings from tallow candles; an auxiliary wick was placed in a depression in the rim of this grease-pan or container which could then be utilized as a grease-lamp.

It is probable that the burning of fat or grease in open vessels or braziers preceded the construction of the oil lamp proper, even in the earliest times.

Open soapstone saucers, burning grease, are depended upon for artificial light even to-day, in the land of the Eskimos, where such lamps have been in use since time immemorial. In fact, the Eskimo depends upon them for his very existence—for heat as well as for light.

The fuel used in these lamps is blubber, which the heat of the lamp itself causes to yield oil. The wick consists of moss, rubbed to a powder and carefully laid in a thin line along the saucer. "The flame," according to Dr. Hough,[4] is about 2 inches high, clear and smokeless if the wick is properly cared for."

THE OIL LAMP.

Probably the most primitive form of oil lamp was a skull in which fats taken from animals killed in the chase were burned, producing a fitful light and warmth. Probable remains of such lamps, according to Hopkins, have been found in the former abodes of cave-dwellers.

It is common to hear the "invention of the oil lamp" ascribed to the ancient Egyptians, chiefly perhaps on account of its ascription to them by Herodotus; and in view of the undoubted extensive use of oil lamps in the Nile country it is strange that so very few Egyptian lamps have been found. Fig. 27 shows one of these rare relics, discovered in the sepulcher of Ka, and

[4] "The Origin and Range of the Eskimo Lamp".

Fig. 29.

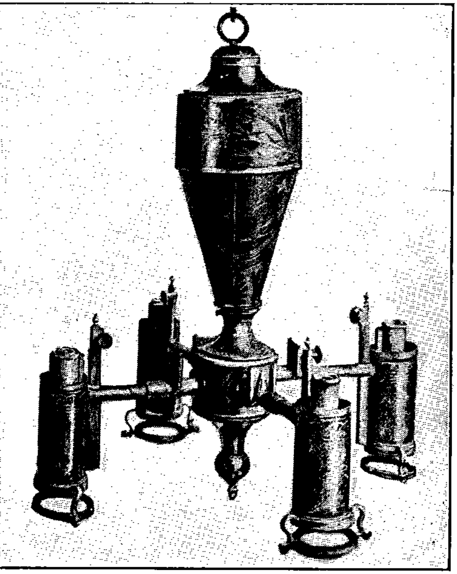


Fig. 41.

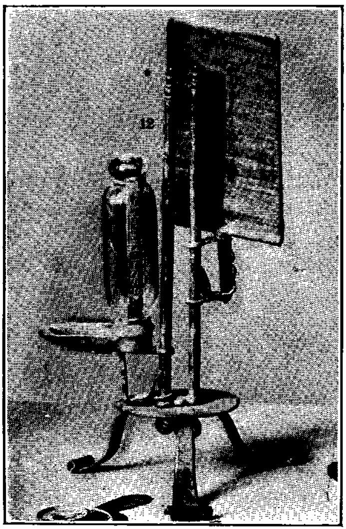


Fig. 39.

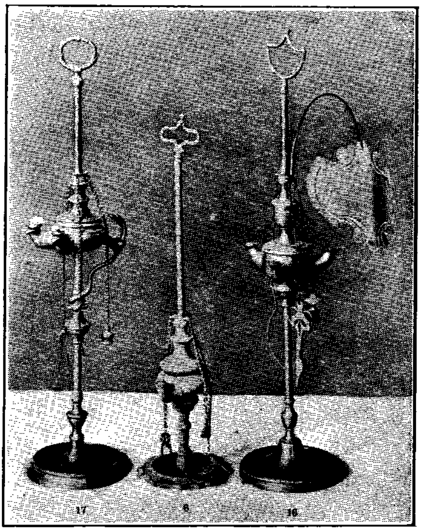


Fig. 40.

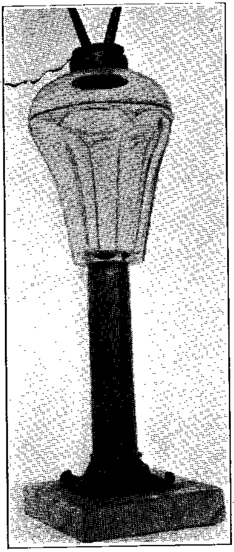


Fig. 43.

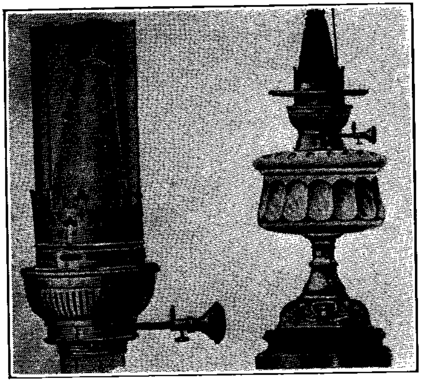


Fig. 44.

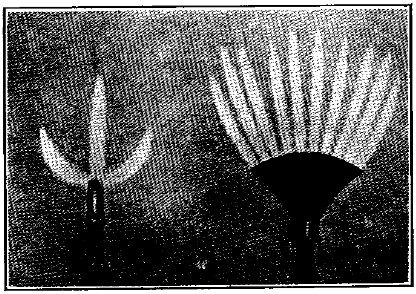


Fig. 47.

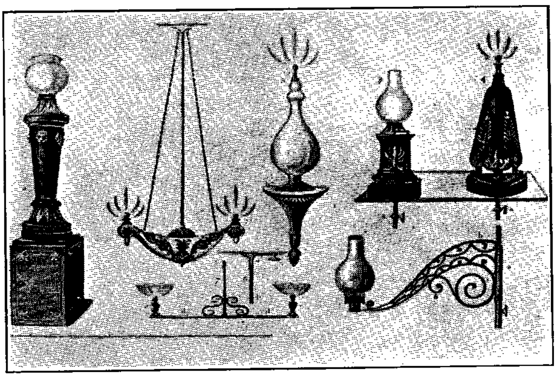


Fig. 46.

now in the Gizeh Museum at Cairo. It certainly evidences no great amount of artistic skill; the base is of limestone, the upright support of wood, and the lamp proper of bronze.

According to Herodotus, the Egyptians were using, at their sacrificial feasts, open saucers filled with salt and oil, with wicks that floated on the surface. At the same period asphaltic oil was collected from the surface of a lake on the island of Zante, off the Grecian coast, by means of myrtle branches which were allowed to drain into stone receptacles, the oil being used in lamps.

Discoveries by French archaelogists have shown that the oil lamp was in use at the close of the bronze age among the prehistoric lake dwellers of Switzerland, and up to the present time, according to Dr. Hough, these are the most ancient objects which have been found that are unmistakably lamps.

The collection of primitive oil lamps in the National Museum at Washington includes shell lamps from Japan and the Orkneys, and terra-cotta saucers from China, Syria, India, etc.

In tracing the evolution of the tubular spout for the lamp wick, one first finds a slight depression appear in the side of the saucer, —a rest in which the wick could be laid, as in the Egyptian lamp (Fig. 27) shown. This depression, in the case of terra-cotta lamps, was easily pinched into the form of a short tube. The so-called "Punic" lamp, of which many specimens have been found in Crete and elsewhere are among the very early forms. Finally, the spout emerges as a distinct part of the lamp, with a special name, as for example in the three Etruscan mortuary lamps, dating from about 400 B. C., shown in Fig. 29. These Etruscan lamps, which are now in the Carnegie Museum, Pittsburgh, are shown on account of their marked individuality, the middle one in particular being radically different from the small squatty lamps that were in general use among the Greeks and Romans.

The oldest lamps found in Rome date from the third century B. C., and are thought to be of Campanian fabric.[5] They are quite different from the ordinary types. It would appear, therefore, that the Romans originally borrowed their lamps from Southern Italy.

[5] See Walters' History of Ancient Pottery, chapter xx.

From about the first century B. C., the Romans, instead of making their lamps on the potter's wheel, as had previously been the practise both in Greece and Italy, almost invariably manufactured them from moulds, in a harder and finer clay than the pattern. The top of the lamp is ordinarily depressed, as a guard against overfilling.

While the making of lamps was considered but a lowly occupation by the ancients, yet those who pursued it often accumulated considerable wealth. Hundreds of specimens of the product of certain Roman lamp manufacturers have been found, each lamp stamped with the manufacturer's name or trade-mark. One L. Cæcilius Sævus, in particular, appears to have been a very prosperious magnate.

For special purposes lamps were made with a plurality of spouts, some specimens boasting of as many as eighteen or twenty. These were the "high candle-power clusters" of the ancient world.

Lead, alabaster marble, glass, and even amber lamps have been found. Tow, papyrus and linen were among the materials used for wicks.[6]

There was no really notable progress in lamp development from an evolutionary standpoint—no new principle enounced—for a period of perhaps 2,200 years, or until the appearance of the Argand burner in 1784. The ingenuity and talent which the modern lamp manufacturer expends in an endeavor to discover new principles, new materials, new processes, greater efficiency, a wider range of application, the ancient lamp manufacturer lavished in fashioning his lamps in curious, beautiful, symbolical, or grotesque designs and patterns. Thus among the subjects represented on Roman lamps are fishermen, ships in harbor, goatherds, gladiators, slaves and circus riders, while freak lamps were made in such curious shapes as pine cones, negroes' heads, gladiators' helmets, etc.

The principal point of difference between the lamps we have just been considering and those of the early Christian era is that in the latter, portrayals of the miracles of Scripture, and figures

[6] See Daremberg & Saglio's "Dict. des Antiquites," article on Lucerna.

of saints, supersede the satyrs and gladiators as subjects for lamp decoration.

While the oil lamps of the Middle Ages and of early modern times were mostly lacking in artistic merit as compared with the classical *lucernae,* they at least began to display traces of mechanical invention and of that same tendency to adapt the lamp to all sorts of specialized uses which has already been noted in connection with candlesticks.

An interesting lamp with a reservoir calibrated into divisions for the purpose of indicating the time is shown in Fig. 39. As the latter lamp is blessed with a shade, it may have been intended for the sick-room, although these "horological lamps" were probbly more often used as student lamps. In any case, they lend a very vivid significance to that hackneyed phase "the midnight oil."

Accordingly to D'Allemagne, there were many of these time-telling lamps in use in the 18th century; Father Lana had constructed a similar lamp in 1670. As chronometers, they lacked fully as much in accuracy as they did in satisfactoriness as illuminants.

Before taking up the evolution of the oil lamp late in the 18th century from a mere vessel with a spout—incapable of producing anything but a yellow, smoky, flickering flame—into a device scientifically designed to produce light, I might refer to the so-called Venetian lamps, which were in use in even as late as the 19th century. As seen in Fig. 40, they were made in a variety of very graceful styles, and are provided with little picks, extinguishers, and snuffers for regulating the wick, and sometimes in addition with shades. They are the final development of the ancient ideals in lamp manufacture.

The principal trouble with the archaic vessel and spout variety of oil lamp was that the form of the flame was not such as to permit a free enough access of air for adequate combustion. This fact, due to the ill-suited solid cylindrical wick, together with the lack of a chimney to produce a draft, meant a low-temperature, wavering flame.

In 1783, Leger, a Parisian scientist, is said to have devised the flat wick and burner that survived in the small hand lamps for kerosene which we can all remember stood on the kitchen shelf. As far back as the 16th century a philosopher named Cardan—"the first of the moderns," we may call him, from a lamp improvement standpoint—had devised a lamp with an elevated oil tank and gravity feed, a scheme especially adapted for heavy oils. Both this idea and that of the flattened wick, together with a new conception, that of creating a draft right up through the center of the burner, were used by the Genevan physicist Argand in his invention of the justly celebrated Argand burner in 1784. Fig. 41 shows an early fixture with Argand lamps. Note the clumsy mechanical arrangement for raising the wicks; the screw burner had not yet been developed. Argand, let it not be forgotten, was a research engineer, with a good technical education for his day; and his memorable invention was made while he was engaged in experimental work in certain French distilleries. The laboratory of the specialist has ever been a birthplace of notable developments in the means of illumination.

The lamp-chimney, first of metal, supported above the flame, and later of glass, supported on a perforated gallery, was the next development—almost an obvious one, to improve the draft of the Argand burner. So indispensable a feature of the lamp has the chimney since come to be regarded, that the following incident, for which the writer will vouch, occurred in a Kansas store not long since. The "oldest settler," tottering up to the counter and picking up a tungsten filament incandescent lamp, drawled out "Does these hyar new chimbleys give more light than them old 16 horse-power ones they uster burn?"

During the early years of the 19th century, whale oil was chiefly depended on for consumption in lamps, and whales were already becoming scarce. A chimneyless double flat wick, similar in shape and size to lamp shown in Fig. 43, was used for the whale oil.

About 1857 petroleum was struck in Pennsylvania, and in '59 the American petroleum industry received a strong impetus by Col. E. L. Drake's successful borings, which opened up a boundless supply of illuminating oil at prices with which whale-oil could no longer hope to compete. The first American

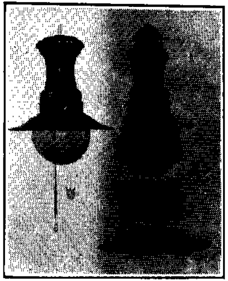


Fig. 49.

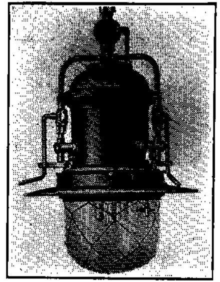
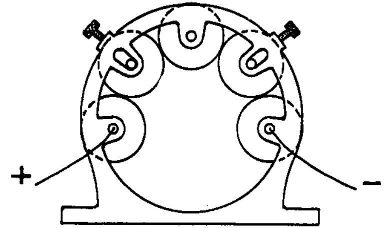


Fig. 50.



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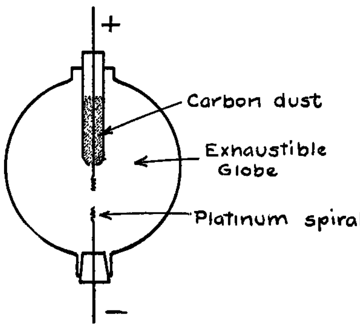

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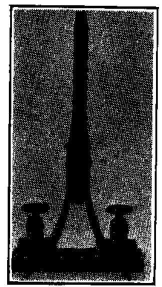

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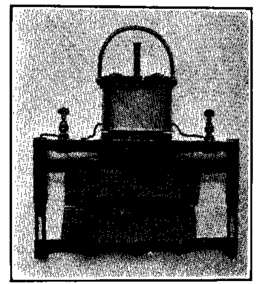

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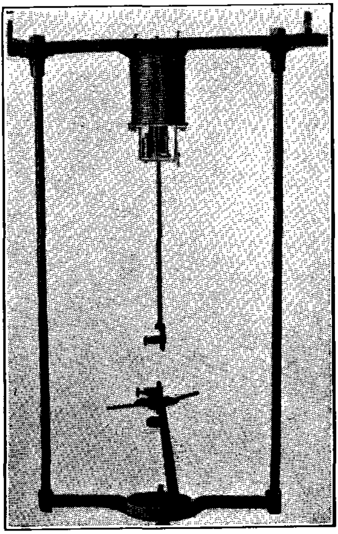

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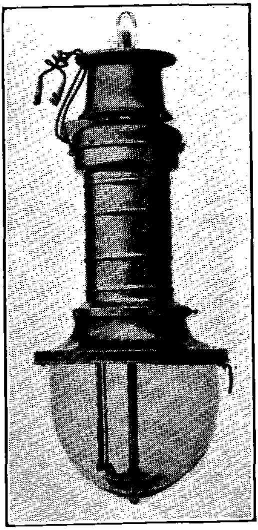

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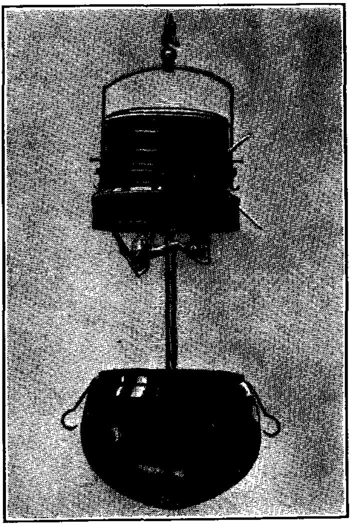

Fig. 57.

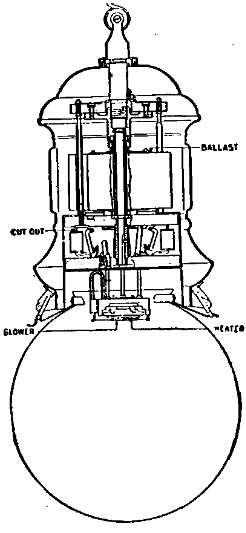

Fig. 58.

patent on a petroleum lamp was taken out in this same year. As the sperm whale had now become so exceedingly scarce that the hardy whalers were forced to push their pursuit of it into the Arctic and Antartic Seas, the introduction of kerosene as a cheap substitute for the costly whale-oil was indeed fortunate. It was at least a better substitute than that murderously explosive combination of turpentine and alcohol known as "camphene," or "patent fluid," which had come into competition with whale-oil to a considerable extent. A camphene lamp is shown in Fig. 43. Note the long tubes.

The different kinds of oil lamps that might be alluded to, including lamps in which heavy oils had to be pumped mechanically to the wick, are legion.

Fig. 44 shows another so-called "link" in the chain of illuminants,—namely, the oil-gas lamp, although it is in no sense a chronological "link." From the standpoint of luminous efficiency, lamps of this general type, in which the oil is used to impregnate a current of air, thus forming a gas that is burned under a small incandescent mantle, represent the latest development of the oil lamp. The particular lamp shown is of German manufacture.

THE GAS LAMP.

Coming to the gas lamp proper, it may safely be asserted that no other class of lamp has had a more logical history. Starting with the simplest sort of an orifice in a bladder or pipe—a mere outlet for gas under pressure—the experiments of specialists have caused it to evolve from this simple but inefficient form into one that is relatively complex, yet far more efficient—namely, the inverted mantle burner. It has been an evolution in every sense.

The modern practise of obtaining light from a medium transmitted from a distant generating point originated, of course, with the gas industry, and one hundred years ago had hardly begun to be known. The use of pipes and distributing systems had been more or less familiar to civilized peoples since remote antiquity. Remains of ancient waterworks systems are well known. Indeed, it seems probable that the Chinese had learned to pipe natural gas from salt mines through tubes of bamboo, and to use it for local lighting purposes centuries before the word "gas" was invented. These Chinese, however, did not have the central station idea, nor is there any record of their manufacturing gas for illumination or any other purpose. They "staked out the claims," it would appear, to a good many of our modern inventions, and then failed to "improve the property."

It is a curious fact that the first important experiments on artificial illuminating gas form a direct line of evolution from experiments on natural gas. There was, it appears, for many years, a natural gas-well underlying a ditch of water near Wigan, in Lancashire, England. The water was continually bubbling and heaving, causing, undoubtedly, many superstitious beliefs among the good folk of the neighborhood.

In February, 1659, Mr. Thomas Shirley, impelled by a desire to obtain some scientific data on this unruly "spring," made the significant discovery that the phenomena "did arise from a strong breath, at is were a wind."

It is indicative of the ignorance which existed for milleniums concerning substances in the gaseous state, that a generic name had to be invented for them as soon as scientists really began to make their acquaintance, so to speak. They had been known almost indiscriminately by such terms as "spirit," "breath," "vapor," "halation," "wind," "Spiritus Sylvestris," etc. Van Helmont (1577-1644) was the man who "invented gas"—that is to say, he invented the word, which, after being almost forgotten, was resurrected and extended in its meaning by Lavoisier, about 175 years later.

Shortly after Shirley's researches, another person of enquiring disposition, the Rev. Dr. John Clayton, turned his attention to the "ditch," near Wigan, and made some momentous discoveries. In an historic communication to the famous scientist Robert Boyle, written probably about 1664, he tells how he caused the bubbling water to be drained off, whereupon the inflammable gas continued to emanate from the ground itself. There was a coal-mine nearby, and Dr. Clayton suspected some connection between the two circumstances. Accordingly, he distilled coal in a retort, and was successful in collecting the coal-gas in bladders.

In his letter to Boyle he refers specifically to the luminous power of carbureted hydrogen.

For more than a century after Dr. Clayton's use of artificial gas as an illuminant, the gas light was unheard of except in scientific circles. Jean Pierre Minckelers, professor of natural philosophy at Louvain, Belgium, was commissioned by the Duke of Arenberg, in 1784, to experiment on means of producing light gases for balloons, which had just been invented. Minckelers distilled many substances, including coal, published an account of his "discovery" of the gas light, and in 1785-6 lighted his lecture-room with gas. On this account he is recognized by the Dutch as the inventor of gas lighting, and in 1904 a statue in his honor was unveiled at his birth-place. Professor Minckelers, however, and Professor Sickel of Würzburg, who is also said to have illuminated his laboratory with gas in 1786, did not carry the practical science of gas lighting much beyond the point where Dr. Clayton left it in 1664. Their lamps were probably simple, inefficient jets.

The author does not care to embroil himself in the interminable international debate as to whether the redoubtable title of "Father of Gas Lighting" really belongs to William Murdoch, the Cornishman, or to Philippe Lebon, the Parisian.

For six years (1792-8) Murdoch was experimenting at his home with apparatus for distilling different kinds of coal. He lighted his own house in 1792 by coal gas. While he was thus industriously making his preliminary experiments, Lebon, in Paris, was no less industriously, and independently, elaborating his "Thermolampe," which he patented in 1799. This "Thermolampe," was a self-contained affair for the production of illuminating gas by distillation from wood, coal, etc. Lebon, and his widow, who took up her husband's work after his early demise, never got much further than the lighting of a few houses and gardens in Paris, although unsuccessful attempts were made to market the "Thermolampe" in America. Lebon had, however, a disciple named Wintzler who deserves to be called the "Father of the Central Station idea," for he caught a vision of the possibility of lighting a whole city, and, coming to London, became the enthusiastic promotor of the first company in the world to supply lighting service to the public through a system of distributing mains.

Those first gas mains would, to be sure, provoke the mirth of a modern engineer. The principal mains laid in 1815 in the world's largest city were but 2 inches in diameter. Wrought iron pipes were unknown, and many house services were formed of musket barrels, threaded and connected up in series, muzzle to breech.

Meanwhile Murdoch, after his six years of private experimentation, had entered the employ of Boulton and Watts, pioneer engine builders, with whom he continued his researches. The principal building of their factory at Soho was illuminated by gas in 1798, and in 1802, as a great public spectacle in celebration of peace between France and Britain. The towers of the factory were illuminated with bengal lights (*i. e.*, flaring open burners) and, to quote a writer of the day, "the whole front of that extensive range of buildings was ornamented with a great variety of devices that admirably displayed many of the varied forms of which gas light is susceptible."

The first extensive experiments on the economy of different sorts of gas-burners were conducted under the auspices of Boulton and Watts, who went into the matter, as they considered, quite exhaustively, laying out over $200,000 on experiments. Murdoch used tallow candles consuming 175 grains per hour as standards in measuring the candle-power of his burners with different qualities of gas.[7]

The earliest gas burners were designed to produce flames like those of tallow candles and oil lamps.

Fig. 46, taken from the original (1815) edition of Accum's Treatise on Coal Gas, shows some of the gas burners of the day. The "cockspur" and "cockscomb" burners (see Fig. 47), and the Argand burner, an adaptation of the Argand principle to gas lamps, were popular early forms. Burners were rated in "pounds"—a 4 l. burner, for example, being an Argand burner of a size for which gas service was supplied at a charge of 4 pounds per year,—not a very flexible system, but it must be remembered that the gas meter had not yet been introduced.

[7] See paper by E. L. Nichols, TRANS. I. E. S., 1905. p. 844.

The common batswing burner, which causes the flame to take the form of a thin sheet, evolved directly and naturally from the cockscomb burner. Not until 1820 did J. B. Nielsen discover the principle of the fish-tail burner, namely that two jets of flame can be made to impinge so as to spread themselves into a fan-shaped sheet of flame. While no more efficient than the batswing, the fish-tail burner gives a higher, better shaped flame, and hence was more suitable for use with globes.

While the evolution of the gas lamp, if judged superficially, was not very rapid during the first half of the nineteenth century, important experimental work was done which paved the way for the introduction of the mantle and mantle burner. Goldsworthy Gurney in 1826 showed that a cylinder of lime became dazzlingly brilliant if the flame of an oxy-hydrogen blowpipe were caused to impinge upon it,—a fact which Henry Drummond, shortly after, put to practical use in his famous "lime-light." Nine years later W. H. Fox Talbot discovered that even an alcohol flame will heat lime to incandescence, if the latter be sufficiently finely divided; this he accomplished by soaking blotting-paper in a solution of a calcium salt and later burning out the paper.

Gillard, who introduced the intermittent process of manufacturing water-gas in 1848, came even closer to the practical mantle. His gas gave a blue, practically non-luminous flame, hence he devised a mantle of platinum gauze to fit over it, but the useful life of the lamp thus constructed was only a few days.

About 1855, Dr. R. W. von Bunsen invented the atmospheric, or "Bunsen" burner. It was while experimenting in Dr. Bunsen's laboratory at Heidelberg, thirty years later, that Karl Auer von Welbach discovered the practicability of improving the luminous efficiency of the gas lamp by the use of mantles made by saturating cotton fabric in a solution of certain salts and burning out the organic matter. His early mantles, which were made with erbium salts, gave a pronouncedly greenish light, and it was several years before the ingredients and their proportions for a thoroughly successful commercial mantle were finally worked out. The thoria-ceria mantle, placed on the market in 1890, finally overcame the difficulty.

As has proven true also with tungsten-filament electric lamps, the earlier gas mantles were considerably more fragile than the improved product of recent years. In consequence of this fragility many so-called "anti-vibration" burners were contrived. About 1900, the practical inverted Bunsen burner (Fig. 49) was evolved and shortly afterwards came the inverted mantle gas lamps which soon so generally superseded the upright.

The gas mantle has, of course, stimulated the use of natural gas and lean gases for illuminating purposes.

It would be out of the question here to review in detail the schemes for improving gas lamp efficiency that have been exploited with varying degrees of success since the introduction of the gas mantle. Prominent among these are the pre-heating of the gas before it reaches the burner, and the use of high-pressure air or high-pressure gas to obtain a more intimate mixture, more perfect combustion and higher candle-power, as in the lamp shown in Fig. 50.

So much for the gas branch of the lamp family. Before tracing the evolution of the electric lamp, mention should be made of special illuminating gases such as acetylene, and gases liquefied under pressure, of which "Pintsch gas" is an example. Acetylene (C_2H_2) is a comparatively recent chemical discovery, the possibility of its generation from calcium carbide having been first demonstrated by Thomas M. Willson in 1892. The common acetylene burner, with its ducts for admitting the necessary air for the proper combustion of this very rich gas, is too familiar an object to need illustration here.

THE ELECTRIC LAMP.

As the early scientific work on coal-gas was prompted by the investigation of a burning well of natural gas, similarly the early researches that paved the way for the electric light are linked up to lightning, and the other natural manifestations of that light, through the classic experiment of a tallow-chandler's son,—Benjamin Franklin, who flew the historic kite in 1752. And as a century and a quarter elapsed between the investigation of the Wigan gas-well and the commercial beginnings of the gas-light ing industry, so nearly a century and a quarter elapsed between

Franklin's experiment and the first electric lamp to be extensively commercialized. I refer to the Jablochkoff "electric candle," which was brought out in 1876, patented in many countries, and widely used for several years.

It should not be inferred that there were no electric lamps between Franklin's time and Jablochkoff's. Far from it. But these lamps may be divided into three classes: (1) those which were entirely impractical; (2) those which possessed considerable merit, but were confined to the scientific laboratory by the fact that no cheap method of generating the necessary electric current was then known, and (3) those which found restricted commercial application, as in lighthouse service, photography, etc.

During this period at least one inventor, young Starr of Cincinnati, hampered by the lack of a practical current supply, literally worked and worried himself to death in attempting to solve the problem of the incandescent lamp; another, Henry Goebel of New York, made electric lamps without suspecting that there could ever be a world market for them.

The electric arc lamp, of course, suffered under the same limitations as the incandescent. Discovered in 1801 by Davy, the arc light was not publicly exhibited until 1809, when, the dynamo being unknown, Davy's mammoth battery of 2,000 primary cells served as a cumbersome source of current.

Perhaps a description of the first arc lamp patented in England (the Wright arc of 1845) may be of interest. It consisted, as shown (Fig. 52), of five carbon discs in series, of which two were movable by means of hand-screws serving to draw out the four arcs. No less curious is the Wallace arc shown in Fig. 53, a type which, in conjunction with the Wallace-Farmer dynamo, was used for street lamps in Baltimore in the late seventies.

The Jablochkoff candle (Fig. 54), as the first electric lamp to be extensively commercialized, is a sufficiently prominent link in the evolution of the lamp to warrant a little further attention. These candles were ordinarily operated on alternating current; lamps intended for direct current operation had to have the positive carbon twice as large in cross-section as the negative. Many substances were tried out for the barrier between the two carbons,—analogous in some respects to the "wick" of a tallow candle. A mixture of sulphate of lime and sulphate of barytes was finally adopted. The rated life of the various types of Jablochkoff candle, which worked on a voltage of about 42, varied from 1 hour and 20 minutes to 3 hours and 20 minutes. Copper coating of the carbons was found to increase their life.

The invention of a really practical direct current dynamo by Gramme in 1870 marked the beginning of the period which saw the electric lamp break into the company of everyday illuminants.

Charles F. Brush of Cleveland, exhibited his first arc lamp with the wonderfully simple ring-clutch feeding arrangement in 1877 (see Fig. 55), and in the following year brought out his series arc dynamo, and started campaigns of arc light introduction in both hemispheres. Four years later Brush arc lamps were in regular operation in Shanghai and Tokio. Many other manufacturers entered the field. The arc lamp had come into its own.

The invention of the practical enclosed carbon arc lamp was announced at a convention of the National Electric Light Association in 1894, when Mr. L. B. Marks described the first lamp, which he had patented, embodying the points that made the inner-globe arc, for a period of about ten years, the favorite unit for high candle-power electric lighting in America.

Five years later the Bremer flame arc lamp was announced, and was soon followed by other types of lamps having impregnated electrodes or electrodes of special composition, designed to increase the luminous efficiency and intensity. Fig. 56 shows a well-known form of the general class of lamps just mentioned. This brings the evolution down to "modern times" as regards the arc branch of the genealogical tree, except that the mercury-vapor arc has not been mentioned. Originated in 1892 by Arons, although suggested at a much earlier date,[8] this special case was later developed by Cooper-Hewitt to a point of commercial practicality. The more recent construction of mercury lamps with quartz tubes, thanks largely to the work of the German Heraeus, by improving the color and efficiency of the light, gave rise to the most recent steps in the evolution of this branch of the family (see Fig. 57).

The Jablochkoff candle was in a way the forerunner of the Nernst glower lamp, for Jablochkoff observed, doubtless while

[8] See W. S. Franklin's "Electric Lighting."

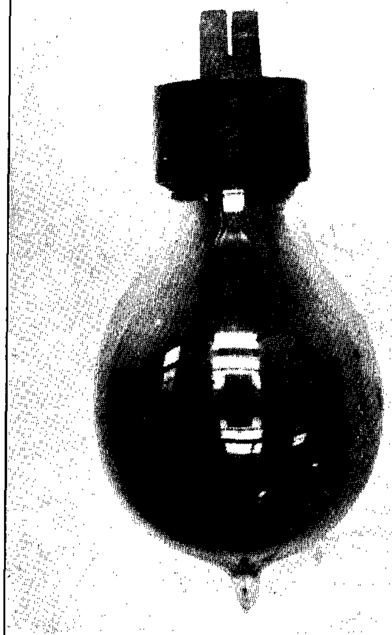

Fig. 60.

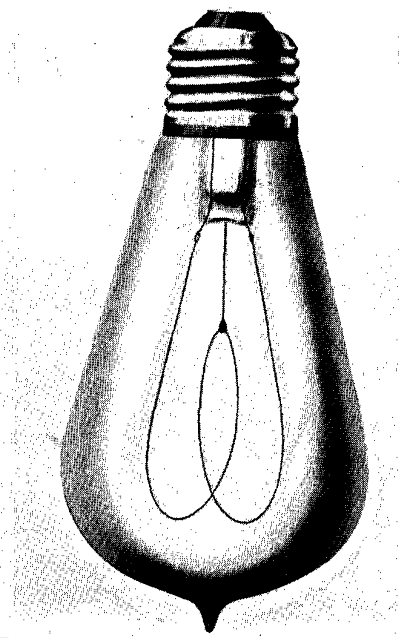

Fig. 64.

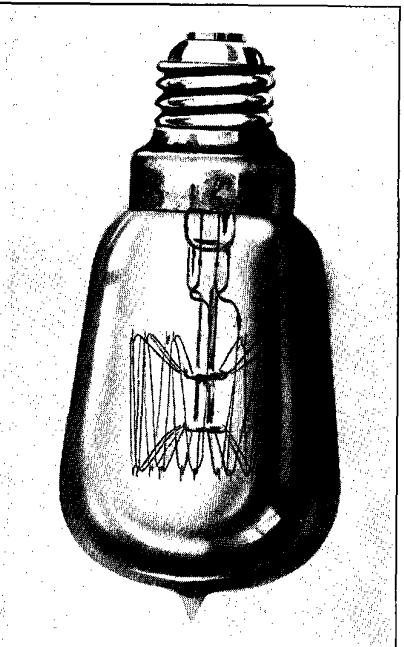

Fig. 63.

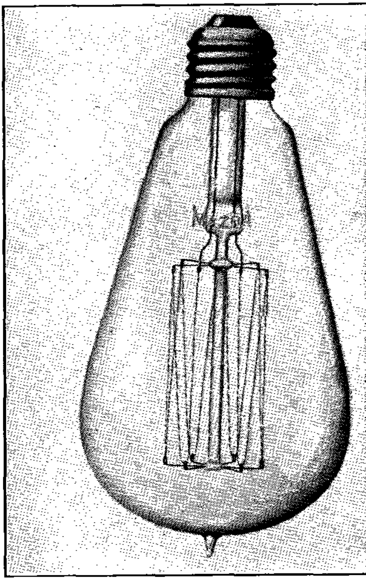

Fig. 68.

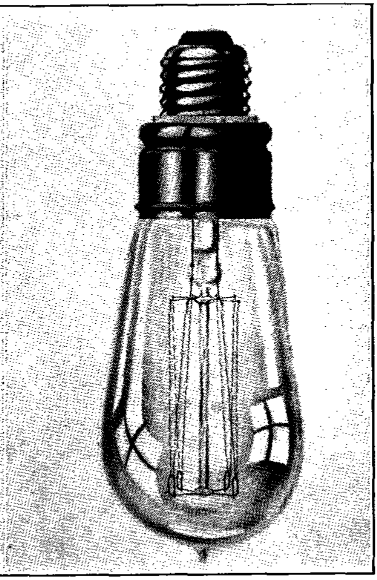

Fig. 65.

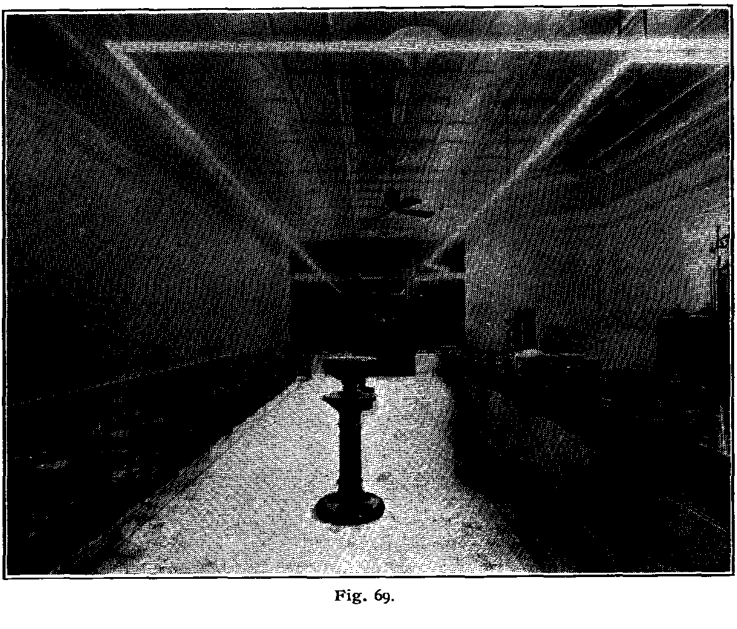

Fig. 69.

experimenting with different compositions for the so-called "wick" of his candles, that kaolin, magnesia, and several other substances normally non-conducting, became conductors when hot, and he succeeded in incandescing a strip of kaolin as far back as in 1877, and actually constructed a lamp on this principle in 1879. Twenty years, however, elapsed before the same principle, under the hand of a distinguished chemist, Dr. Nernst, was utilized as the basis of a commercial lamp (Fig. 58). One of the main difficulties, of course, to be overcome was the tendency of the glower to "run away," technically speaking,—*i. e.,* to become overloaded and burn out as its resistance, with increasing temperature became less and less.

From what older illuminant did the incandescent filament lamp evolve? The answer to this question is that, in so far as it may be said to be an outgrowth at all, it is an early offshoot from the arc lamp "stem." Numerous attempts, some of them involving much ingenuity, were made to produce the so-called "incandescent-arc" lamps that would work satisfactorily, and much money was sunk in valueless patents. One lamp of this sort was De Moleyn's. The lamp consisted of a glass globe with plugged openings for connection to a vacuum pump; through the upper end of the globe a tube containing carbon in finely powdered form was tightly inserted; a movable copper wire runs the length of this tube and through the orifice at its lower end, the said orifice being just large enough to allow the carbon dust to trickle through slowly, making contact with the platium spiral electrode that comes up through the bottom of the globe.

With the record of the "incandescence-arc" contrivance just described, and of many others equally impractical, before them, Swan, Edison, Sawyer, Man and Lane-Fox, all of whom were working on the incandescent lamp problem in 1879, at least knew some things to avoid. That same year witnessed the solution of the problem, and the exhibition of a complete system of incandescent electric lighting. Fig. 60 shows an early carbon filament lamp. This lamp was made before the art of "pasting" the filament to the leading-in wires was known; at that time the filaments had to be attached by clumsy mechanical devices of various sorts, such as tiny bolts, nuts and washers, or special shaping of the filament ends, which were then clamped into the flattened ends of the leading-in wires. Furthermore, it was thought necessary to use thick wires of platinum, nearly an inch long, in the seals, adding very materially to the cost of the lamps.

In 1891 the cellulose process of making carbon filaments was developed, and two years later the cellulose filament was generally adopted in place of the bamboo. An Italian, Arturo Malignani, devised the "chemical exhaust" in 1895, enabling the average quality of incandescent lamps to be improved, and reducing both the expense of their manufacture and the price to the consumer. Meanwhile the process of "treating" filaments in hydrocarbon vapor to render them more uniform and improve their radiating properties had been introduced.

As facilities and experts for conducting research multiplied with the growth of the industry, improvements, first of minor importance, but in recent years of a revolutionary nature, were evolved. The substitution of moulded bulbs for "free-blown" bulbs, about 1892, and the invention of the turn-down lamp in 1898, belong, relatively speaking, in the category of minor improvements. The first exoteric evidence that the metal filament lamp might eventually supersede the carbon came about 1898, when Dr. Welsbach produced his first osmium filament lamp. Curiously enough, tungsten had been tried for filaments as early as 1889 by Lodyguine and Tibbets, but without success, as these experimenters did not realize the necessity of extreme purity for the metal.

The discovery of ductile tantalum was announced by von Bolton in 1901, and the first experimentally successful tantalum lamp was built a year or so later, although tantalum lamps (Fig. 63) were not in a condition to be placed on the market for several years more.

Meanwhile, in 1905 the Gem (metallized carbon) lamp (Fig. 64), which had been developed in an American laboratory, made its appearance, and served as a sort of stepping-stone to the lamps of still higher efficiency that were about to make their appearance.

In 1907 came the pressed-filament tungsten lamp (see Fig. 65), a curiosity that one hardly dared look at for fear of breaking it, or dared buy for fear of "breaking" ourselves. This lamp was gradually evolved into the strong, durable, cheap drawn-wire lamp of to-day (Fig. 68). The very newest line of development, *viz.*, the use of bulbs filled with an inert gas instead of a vacuum, with a resulting efficiency of about 0.5 w. p. c. should greatly broaden the usefulness of the tungsten-filament lamp, particularly in the direction of very high candle-power units, say 1,500 candle-power and above—a field heretofore not covered by incandescent lamps.

One class of electric lamps remains to be mentioned, namely the high-tension discharge tubes containing rarified gases, as for example the nitrogen and carbon dioxide tubes (Fig. 69) of Moore and the neon tube lately heralded from France. While such tubes represent a unique departure in lamps as regards the dimensions of the light-source and the high voltages skilfully managed, yet they must be regarded as closely akin to, and doubtless suggested by, the small Geissler tubes used in college lecture-rooms to demonstrate the phenomena of electric discharge through a partial vacuum.

CONCLUSION.

In this review the evolution of the lamp has been traced from a mere fire-brand or stone saucer, not indeed to its culmination, which none of us may expect to see, but to its modern exponents in the oil, gase and electric branches of the family. A broad view of the lamp's past history must confirm the opinion that development has not come to a halt, but on the contrary is proceeding at a rate that to former generations would have seemed astounding.

A hardly less fascinating story than that of the lamp would be the evolution of the reflector, from the simple flat circular candle-shades of former times to the wonderfully efficient commercial reflecting and diffusing media that are to-day available in addition to the wide range of beautiful shades intended primarily for decorative purposes. The vehicle lamp, the signal light, and the street lamp are further examples of progressive development which, owing to their specialized nature, cannot be taken up here. Mr. Albert Scheible has outlined the progress of street lighting from the days of the linkman with his torch to our modern "white ways."[9]

Except for a few short sighted surmises, based on theoretical considerations or on our knowledge of promising experimental work now being done in the laboratory, the interrogation point is, after all, the most that any of us can offer. We can, however, say with practical certainty that the better lamps of the future, whatever they may be, will owe their betterness to the concentrated research work of expert scientists in the great development laboratories existing for this specific purpose. Such men as Argand, Murdoch, Lebon, Boyle, Faraday, Bunsen, Welsbach, Steinmetz, von Bolton and Feuerlein, Just and Hanaman, and a host of others too numerous to mention, each specializing with all his might on some particular phase of research, have evolved the lamps of to-day. To encourage, therefore, and to foster all scientific research along illuminating engineering lines, even if such research can promise no immediate commercial result, would seem the surest way to speed the lamps of tomorrow. Happily there are a number of laboratories in existence where such research work is being carried on by scientists well equipped for their respective tasks. These men are unconsciously evolving the lamps of our descendants.

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NOTE:—For the reader's convenience, after each reference is placed a Roman numeral, I, II, III, IV, V or VI, indicating the period or periods in the history of the lamp with which the reference chiefly deals. The numerals have the following significance:

I................Entire history previous to Christian Era.
II................A. D. 1–A. D. 1000.
III................A. D. 1000–A. D. 1500.
IV................A. D. 1500–A. D. 1800.
V................A. D. 1800–A. D. 1900.
VI................A. D. 1900 to date.

[9] *Elec. Rev. & W. Elec.*, April 1, 1911, et. seq.

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The Lamp of the Eskimo*........	Hough	V
The Origin and Range of the Eskimo Lamp	Hough	V
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Note:—In several instances, the topic of special interest in connection with this paper is noted below, rather than the actual title, which may be necessarily too comprehensive for this purpose.

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