Art. VII.—ELECTRIC LIGHT AND ENERGY.

A LITTLE more than a hundred years ago Benjamin Franklin sought an open spot in the forest, away from the gaze of the five thousand inhabitants of Philadelphia, and there brought lightning from the clouds. To-day that forest is many miles of streets lit with electric lamps; each street is thronged with its many thousand inhabitants, in whose midst was lately held their Electrical Exhibition—a glorious tribute to Franklin, the ripe development of his daring effort. This development of electrical science is one of the many examples of the evolution of knowledge—a gradual evolution. Man, for centuries, simply beheld the lightning flash in the sky, until the daring Franklin brought it to the door of the laboratory; for long it dwelt there, bewildering and unruly. Manacled at last, man now sends it forth a minister to his daily wants.

In this article I purpose to treat of some of these newest electrical developments, but as a preliminary it may be well to point out what man now surmises concerning the nature of an agent so lately enveloped in mystery. The public generally are greatly mistaken as to the nature of this subtle agent; but perhaps their mistakes partly arise from the early conceptions, or misconceptions, of philosophers. In many of our textbooks electricity is spoken of as a fluid, and so has been looked upon by some in the light of a material substance. In the manner of the schoolmen, I will first confute these erroneous ideas, and state emphatically that electricity is no material fluid or substance. A wire along which a current of electricity is passing does not weigh any more than a wire in the ordinary state. If electricity were anything material the wire would have extra weight while the current was passing. Electricity is not matter, but a molecular condition of matter—a species of energy; a mode of motion. The theory of electricity, as first suggested by Faraday, and now becoming at last adopted by some of our more advanced scientists, can be perhaps best elucidated by the analogy of another form of progressive movement. Out of many familiar examples take the case of sound. A body may be in a state of motion in two ways—*i.e.*, in mass or in its minutest parts; in more scientific language, the motion may be molar or molecular. The molecular motion in the transmission of sound was aptly illustrated in the famous experiments of Sir Charles Wheatstone. In these musical sounds from instruments in a lower chamber were conveyed by the vibration of wooden rods from the lower chamber, through an intervening hall to an upper chamber, where they were gathered up through the media of the sounding-boards of harps, thence transmitted by the atmosphere to the drum of the ear, and in the human brain translated in some mysterious way into the harmony of music. In the case of a closed circuit of wire, which conveys the so-called current of electricity to light an incandescent electric lamp, there is a somewhat similar molecular movement to that which has just been described. In the case of Wheatstone's experiment the molecular movement of a rod of wood is gathered up by the medium of a sounding-board, and communicated through the atmosphere to the ear as sound. In the case of the electrical circuit the molecular movement of the copper wire is gathered up by the carbon filament of an incandescent electric lamp, and communicated by the invisible and intangible ether to the eye as light. Both the rod and the wire are composed of particles or molecules. A molecule is composed of atoms, held in place by mutual attraction and repulsion. In the case of the grosser motion of sound the molecules vibrate as a whole; in the case of electricity, however, the movement is much more complicated, subtle, and intense—so intense as to overcome the forces of the atoms, to rupture the molecules, and re-form them differently. By this theory the resulting "polarization," as it is called, of the molecules, is presumed to constitute "electrical action."

The first observation of an electrical phenomenon is ascribed to Thales in the year 600 before Christ. The philosopher found that when amber was rubbed it attracted small particles of matter to it. There are a great many other substances in Nature which possess this property in a similar degree; every one has tried for himself the experiment of rubbing a stick of sealing wax and then observing its attractive power; vulcanite is an especially good substance for such an operation. If a vulcanite comb is only once passed through the hair of the head it will have become endowed with this electrical power. These simple experiments embody the principle of the frictional machines of which there are various forms. The first frictional machine was invented by Otto von Guericke. It consisted of a ball of sulphur, which was turned upon its axis by one person while another held his hands upon the ball, thus causing the friction necessary for the production of electricity. Hawksbee substituted a globe of glass for the sulphur. In Ramsden's machine, the more modern form, the electricity is produced by the friction of a plate of glass between two rubbers. Induction machines are now very much more used for experiments in statical electricity than are frictional machines. In these a small initial charge induced by friction is worked up into a very powerful one. Static electricity has been looked upon as useless in practical application, but it is a barren tree that bears no fruit whatever, and although the applications of static electricity are limited, there are one or two intensely practical in their nature. A gaslighter has been invented based upon the principle of the induction machine, in theory everlasting; in the stem of this little instrument is the miniature induction machine. The simple act of pressing a knob causes the machine to revolve, and thus the electric spark, potent to ignite the gas issuing from a jet, is produced. Another use of induction machines has lately been proposed by Professor Lodge at the last meeting of the British Association in Canada. The Professor proposes to dissipate fogs at sea by means of sparks produced by Holtz's machines. The spark would be discharged at the mast's head and worked by the available steam power. Professor Lodge bases these assumptions on experiments recently made by him: a miniature artificial fog has been thus dissipated successfully, and the extension of the experiment to the reality would without doubt be interesting.

The age of practical electricity may be said to date from the discoveries of Galvani and Volta, who made manifest to the world the so-called *current* of electricity, produced, as some say, or at any rate maintained, by chemical action. In its simplest form the voltaic cell consists of (1) two plates of dissimilar metals—for example, platinum and zinc; (2) an exciting fluid—*i.e.*, dilute sulphuric acid. The two plates of dissimilar metals are partly immersed in this exciting fluid. While the two metals are disconnected we have no electrical action in progress, but directly we connect the two plates together by a conductor of electricity, chemical action is in progress. There is combustion of the zinc with the oxygen of the dilute acid, and the hydrogen escapes. Consequent upon the combustion of zinc is the production of a current of electricity in the circuit. This passes from the platinum plate through the circuit to the zinc plate, from the zinc plate through the liquid, and thence again to the platinum plate. A combination of such cells as has been described constitutes a chemical primary battery. Although a chemical primary battery is in many instances a useful source of electricity, for, *e.g.*, working the telegraph, for electric bells, for electro-gilding, and especially convenient in military operations for blasting, firing torpedoes, &c., yet it is not an adequate means for producing the torrents of electric power required to produce on a large scale what is the main subject of this paper—viz., the electric light. Its production upon a large scale depends, not upon the conversion of chemical energy into electric energy, but upon the conversion of mechanical energy into electric energy in the modern dynamo-electric machine. Before describing this engine of the future, it may be well to trace out its evolution from the classic experiment of Faraday which revealed to mankind magneto-electric induction.

Arago had discovered that when a bar of soft iron was surrounded by a coil of wire and a current sent through the coil, the bar became a magnet while the current was passing, but that it lost almost every trace after the current had ceased to circulate in the coil surrounding the bar. The fact that it does not lose every trace, but retains a faint degree of magnetism called technically residual magnetism, is an important one to remember, as it has been turned to practical account in the development of the dynamo-electric machine. The discovery of the electro-magnet, therefore, proved that a current of electricity was capable of producing magnetism. It was the illustrious Faraday who discovered that the converse of this experiment was also true, and that magnetism would produce electricity. In his discovery of magneto-electric induction, made in his passionate search for truth in nature, lay the germ of the dynamo-electric machine. The minds of some men only reflect for us the light of knowledge, but Faraday's mind, prism-like, gives us the innate splendour of each ray. His historical experiment was as follows: he took a coil of wire, this he connected with his galvanometer, that instrument which, by the deflection of a needle, is used for detecting the presence, the strength, and direction of a current of electricity in a circuit. Into this coil of wire he inserted an ordinary steel magnet. He found by the deflection of the needle that a momentary current was induced in the coil as the magnet was inserted, and that another current was produced when it was withdrawn, this time in the opposite direction. Here we have the principle of the dynamo—*a rendering of mechanical energy into electric currents by means of the interaction of magnets.*

The principle of all dynamos is the same; they only differ in certain minor details. They consist of two essential parts—(1) the field of magnetic force, (2) the armature. The field of force consists of one or more magnets, the armature of soft iron round which are wound coils of copper wire; this revolves in the field of magnetic force. In the earlier applications of Faraday's experiments the magnet used was an ordinary steel one. The difference between a dynamo-electric machine and a magneto-electric machine is simply that in the dynamo an electro-magnet is used to produce the field of force instead of an ordinary magnet. When electro-magnets were first used to produce the field of force, the current was always started from some extraneous source. This process is not always necessary, owing to the residual magnetism of soft iron. We owe this simplification of the dynamo to the eminently practical mind of the late Sir W. Siemens.

At present there is a great variety of dynamos in the market.

There is the "Gramme," in which the armature coil is wound upon a ring the principle of which was invented by Pacinotti. In Siemens' well-known construction the field magnets are flat and connected by pole pieces, and the wire is wound lengthways in the armature. In the "Brush" the wire is wound in sections on a ring. In the "Edison" the field magnets are of great length, and in the large machines the armature consists of copper bars. It has been found in practice that large machines are more economical than small ones for working installations of any considerable size. A giant machine has lately been constructed by Mr. Gordon. It weighs from eighteen to twenty-two tons. It can light 9,000 or 8,000 lamps of some twenty candle-power, or about 20,000 lamps of a lower candle-power. It was said but a little time ago, by those who disparaged the idea of the introduction of the electric light upon a large scale, that the reason why it would never become a commercial success was that the current was incapable of minute division. Recent achievement proves these criticisms to be unfounded. The same power of man which wrenched from Nature the secret of the voltaic arc has now accomplished this minute division. In the Gordon dynamo we have an example of a prodigious force split up into some 20,000 points of light. In this dynamo the ordinary rule of the armature being movable and the field magnets stationary has been ignored. It is, in fact, an inversion of the ordinary type, the electro-magnets being rotated between the coils in which the current is excited.

To go farther into the details of the various dynamos now in the market would be to go beyond the scope of this article, and it is necessary to be content with the elucidation of the underlying principles in which all the various types resemble one another. The study of detail, however, is far from unimportant; the efficiency of the dynamo depends upon the arrangement of detail—the more perfect the arrangement of detail the greater will be the efficiency of the dynamo. An improvement has lately been made, in America, in the core of the armature of the Brush machine. It is now built of segments of iron riband instead of solid cast-iron. This apparently trifling alteration enables the machine to maintain sixty-five powerful arc lights instead of forty, as before.

The dynamo may be used in another capacity besides as a produce of currents—viz., as a motor; its action is reversible. This fact is of extreme value to the motive power of the future. We can use one dynamo to produce currents, or we may send those currents into another dynamo close by, it may be, or many miles distant, and thus set the second dynamo in motion. The results which are likely to follow from this fact will aid the strong tendency of science to annihilate space and time. We now convey our coal laboriously from Newcastle to work our gasometers in London; but coal in the future, as it lies in the seams, will light our cities, and work our factories, and drive our locomotives; and when we have exhausted our coal-mines, we can harness to our electric motor the endless forces of waterfall, wind and wave. It has been said, on the highest authority, that there is more power running to waste in the Falls of Niagara than would be required to perform the whole mechanical work of the world. We are far as yet from realizing its importance as a universal engine, but even now its use is not quite ignored. A dynamo in a mill at Niagara supplies the electricity to work 3,000 telephones in 300 cities and towns (500 of the instruments being in Buffalo, twenty-five miles from the Falls). This takes but a fraction of its powers indeed, but the successful adaptation of this minute fraction may suggest the use of a little more of its energies to supply light and power around the States.

In the electric storage battery we have a valuable helpmate to the dynamo. In the dynamo, when used alone, we have electricity evoked for our instant use; in the storage battery we have means of storing up the energy of the dynamo, and therefore rendering those various forms of energy which are intermittent and uncertain in their action a useful and reliable source of power. For private-house lighting, the use of these electrical accumulators is almost indispensable. For instance, if a dynamo machine alone is used to light a house, light can be only obtained while the dynamo is actually working. Most people would object to keeping a steam-engine at work all night. If, however, the energy of an engine and dynamo is stored at a time of day that is convenient, the electric light can be switched on at any time of the night we choose. It is possible to have electric night-lights; we can have the switch which completes the circuit, if so we choose, beneath our pillows. The use of storage batteries also ensures an absolutely steady light so essential to the eyesight. The principle of the storage of energy is very simple. In order to store energy, work must be done against some force which opposes our efforts, and the action done must be one that is reversible. We can do work against mechanical force or chemical force, and in both these cases store up energy. Numerous examples of such storage of energy will at once present themselves to the mind, such as a raised weight, a stretched bow, the wound-up watch spring—*i.e.*, mechanical energy; a lump of coal, a piece of zinc, a mass of gunpowder—*i.e.*, chemical energy; in all these cases work has been done against opposing forces. It was an effort for the hand to draw back the string of the bow, and by the exertion the individual lost so much muscular energy.

What he has lost remains stored up—in more technical language, "latent," "potential"—in the stretched string. And the flight of the arrow when released represents the actual mechanical energy of his arm once more converted into the energy of motion—kinetic motion. Then take the case of the zinc: when found in the earth the zinc was in combination with oxygen, atom of the one linked to atom of the other. By certain processes the zinc has been separated from the oxygen, and ever since atom was torn from atom there has been a tendency for them to recombine. By this separation energy is stored up; give the separated atoms the opportunity and they will recombine. When in the voltaic cell, as described above, the zinc combines with the oxygen of the dilute acid, we have an example of such a chemical reunion. The energy which has been stored up in the zinc becomes apparent in the external circuit, either as light, or heat, or in the ringing of a bell, or the movement of a telegraph needle, according as we present to it the opportunity of displaying itself under any of these aspects.

The so-called electric storage battery is an example of chemical storage. By a current of electricity we separate atoms before closely united by the tie of chemical affinity. While separated, these atoms represent a store of potential energy which becomes again active when we allow the separated atoms to reunite. Coexistent with the chemical energy of reunion we have electrical energy. It is thought by many that the storage battery is a new invention; it is true that it has been only lately developed into a practical form, but we should remember that the various achievements which can be accomplished by the storage battery of the present time, are the fruit of seedlings sown long ago. Ritter, in 1803, constructed a secondary or storage battery, using platinum as the plates. Sir W. Grove, forty years later, somewhat extended these experiments. There is an instrument, known to many, called the voltameter. It is used in the laboratory for the decomposition of water into its constituent parts—oxygen and hydrogen. It consists of a glass vessel in which there are two platinum plates immersed in acidulated water. When these platinum plates are placed in connection with the poles of a chemical battery, the acidulated water is decomposed by the current, and the resulting gases may be collected at the platinum plates. Now Sir W. Grove found that while the two platinum plates were in this dissimilar chemical state—one plate being covered with a film of oxygen, the other with hydrogen—if the plates were connected together by a conductor of electricity, a current of electricity flowed along the wire in the opposite direction to the current which was originally used to decompose the acidulated water. A series of voltameters in this condition, coupled up in the manner of an ordinary voltaic battery, was able to produce a current of considerable strength. Ritter and Sir W. Grove, therefore, were the first pioneers in developing the electrical storage of energy. Practical adaptation, however, always lags far behind theoretical discovery, and it was left for the ingenious mind of Monsieur Planté to translate mere laboratory experiments into a practical commodity. In 1860 he constructed his storage battery. In this two sheets of lead are rolled up and immersed in weak sulphuric acid. The lead plates take the place of the platinum used in the voltameter experiments of Sir W. Grove, and under the action of the current they too become covered respectively with films of oxygen and hydrogen gas; while in this condition chemical energy is stored up which can be converted into electrical energy when the plates are connected together. If the cell be then charged again in the reverse direction, more gas will be absorbed by each plate, and after the repeated process of charging and discharging in opposite directions, the surface layers of the lead plates become in an extremely porous condition. The process of forming the cell essential to the Planté battery was improved upon in the happy idea hit upon by Mr. Faure in 1880. He coated the surface of the plates with red lead, thus expediting the formation of the battery. A still further development of the storage cell is to be seen now in the Faure-Sellon storage battery, which has already gained considerable popularity, not only in the form of cell used for the lighting of buildings, but to supply the current for locomotive purposes. It has already found its place on tramcars, and in one or two cases it has furnished the current to propel an electric boat. Having now dwelt upon the various ways in which electricity can be generated, transmitted and stored, it is time to consider how its transformation into light is accomplished.

There are three kinds of electric lamps before the public at present. These are popularly called (1) the arc lamp; (2) the incandescent lamp; (3) the semi-arc and incandescent lamp. The difference between them is not one of kind but of degree. The light of all electric lamps as of all artificial luminaries, whether candle, oil, or gas, is due to incandescence—*i.e.*, solid matter in a state of ignition. In electric lamps the light is due to the opposition which a conducting body presents to the current. In the arc lamp the resisting material is twofold—carbon and air. The carbon points, after being made to touch, are separated a short distance, and the air completes the circuit. To the air it owes its name of "arc," namely, the shape which the incandescent air and vaporized carbon assume. The discovery of the arc light is usually ascribed to Sir H. Davy in 1805, but some ascribe its origin to Dr. Watson in 1746; others, to Etienne Gaspard Robertson in 1802. The arc light exhibited by Sir H. Davy at the Royal Institution was maintained by the powerful battery of 2,000 elements, which in the hands of that distinguished investigator became a revealer of more than one of Nature's secrets. Shortly after the production of the electric arc, this same battery, in the hands of Sir H. Davy, decomposed potash and soda, and thus added to the list of metallic elements—potassium and sodium.

In incandescent lamps there is one continuous filament of carbon raised to a white heat by the passage of the electric current through it. This filament of carbon is enclosed in a glass globe which is exhausted to a very high degree of air. The filament in the lamps of various inventors is of different materials and shape. For instance, Mr. Edison uses Japanese bamboo, Mr. Swan, cotton thread, Mr. Maxim, cardboard, Mr. Lane-Fox, bass-broom. These are examples of the earlier forms of electric incandescent lamps, which, notwithstanding the claims of younger rivals, still hold their own in the market. As examples of the latter types of lamps, one may mention (1) the Woodhouse and Rawson; (2) the Bernstein. Messrs. Woodhouse and Rawson claim a high efficiency for their lamp; they base this claim upon the fact that their carbon filament consists of a pure deposited carbon, and assert that this form of carbon gives a far higher efficiency than one that is formed from a fundamental substance. This idea of depositing pure carbon for this purpose, by means of an electric spark, seems due to Mr. J. M. Boulton in conjunction with Mr. I. Propert and Mr. A. Soward, who a year or two ago took out a patent.

This method of preparing carbon filaments is very interesting and suggestive of many variations. In some of the older forms of incandescent lamps, carbon deposited from gas had been employed, to render filaments prepared from some fundamental substance, such as bass-broom, more homogeneous, and the idea occurred to some of depositing the carbon upon a metal, and then deflagrating or dissolving away the metal. The presence, however, of a metal is not necessary. If a globe of glass or other suitable vessel is filled with a carbonaceous gas, or vapour, such as marsh gas, and the gas thus introduced is decomposed by the passage of electric sparks through it, a slight deposition of carbon takes place upon the end of one of the electrodes; this deposit is by degrees built up, by a rapid succession of sparks; a bridge of carbon thus spans the space separating the electrodes, which latter may be two pieces of platinum wire. Such a carbon is unsurpassable in purity, and as the filameut has been built up by the agency of the current, its molecular construction is such that the action of electric currents through it does not produce disintegration. The filaments are rendered comparatively thick or thin by regulating the size of the spark and the degree of rarefaction of the gas. Good results are said to be obtained from filaments 1,000th of an inch in thickness. Whether such lamps as I have described above are in every respect superior to those which have a fundamental substance, is a question for time and experience to answer. The question is often asked, which is the best incandescent lamp? It is very difficult to give an answer. Uniformity in manufacturing is the great desideratum in incandescent lamps, and to decide fairly upon the merits of any given maker, one or two thousand lamps have to be tested. Again, the younger lamps have not yet had time to prove a superiority in lasting power.

In the Bernstein lamp, which professes to be a high candle-power lamp and more especially adapted for street lighting, the old plan of the fundamental substance is followed, the substance carbonized being a thin hollow silk ribbon. This gives a large illuminating surface, and it is in this respect that it differs from all other forms of incandescent lamps.

The chief feature which distinguishes the incandescent lamp from the arc and semi-incandescent lamps is that the incandescent lamp is enclosed in a vacuum. The exhaustion of the glass globe which contains the filament of carbon is essential. If the current were passed through the filament of carbon before the globe is exhausted, there would be no electric light; the filament would be immediately destroyed by its combustion with the oxygen of the air. Sometimes an incandescent lamp is cracked to so small an extent that it would be only through a microscope that the damage would be discernible. The oxygen would, however, all the same find its way to destroy the filament.

From this, it stands to reason that the more perfect the vacuum the longer the filament will survive. It was the discovery of the method of obtaining comparatively high vacua by the use of the mercury-pump that made the incandescent lamp a practical commodity. In theory it had existed for some years back. As long ago as 1845, King patented carbon lamps *in vacuo*, and it was the imperfect nature of the vacua then obtainable that made the discovery of little value. It is principally to the researches of Mr. Crookes that we owe the attainment of high vacua, containing not more than a millionth of the normal amount of air.

The instrument called Crookes's radiometer is an instructive one. It consists of a glass globe exhausted of air as far as is possible with our present instruments. Even in this comparatively perfect vacuum there is contained in each cubic centimètre no less than 250 billions of molecules of air; a sufficient force of matter to turn round vigorously the little vanes inside the radiometer when the heat rays from a source of light fall upon it. Now it is those active molecules which are so busily employed in turning round the little vanes that are the bugbears to the practical electrician in his incandescent lamp. They sap the life of his carbon filament and place a limit to its durability.

In arc lamps, owing to the air and vapourized carbon forming part of the circuit, and also to the difficulty of adjusting the carbon points, the light is often flickering and unsteady. In the semi-arc and incandescent lamp a more solid medium than air is used as an attempt to rectify the unsteady action. One of the most successful of these is the Sun lamp. In this the carbon points impinge upon a block of marble, which latter becomes incandescent under the intense heat of the arc. It is in fact an electrical lime-light, and would be a good substitute for the usual lime-light apparatus in theatres where the electric light is used for effects; steadiness of light is absolutely essential for this purpose, incandescent lamps would not give sufficient power, and the arc lamp is too unsteady for the purpose. The Sun lamp gives a brilliant white light, resembling the light of the sun more than does any other artificial luminary. Semi-arc and incandescent lamps have not, however, been so widely adopted as the arc and incandescent. The Joel lamp is worthy too of mention. In this, a pencil of carbon impinges upon a steel plate and the carbon pencil is raised to a state of incandescence. This lamp has the advantage of working with a low intensity of current.

At one time the arc lamp was the only practical form of electric light, and it still holds its own in the lighting of large and open spaces. In several cases its intense rays have been most effectual for carrying on open-air work at night. This is a great boon to builders, who can now fulfil their contracts in time by working at night. In war the arc light is invaluable—for search lights—as was demonstrated in the bombardment of Alexandria; for camp lights, as now used in the Egyptian campaign. For several reasons it is not so well adapted for a domestic house light as is the incandescent system. (1.) Its flickering and intensity are injurious to the sight. It is said by some that we need not look at it, but, as Mr. Sprague aptly remarks in his new treatise on electricity, "neither need a moth fly into the flame, and light draws the eye to it as the flame does the moth." (2.) Its somewhat ghastly effect. If the light of the arc lamp proceeded *alone* from the incandescent *carbon* points we should have a light whiter than sunlight; but the light of the *arc* itself consists in part of blue and violet rays, from its specific gases, which give it a glitter so well described as "steely" by the author I have just quoted above.

While mentioning one drawback to the employment of the arc light—viz., its unsteady action—it is only fair to note the rapid improvement in this respect in the last three years. To realize this it is only necessary to recall the first exhibition of electric light in this country at the Crystal Palace, and compare the arc lamps then exhibited with those now to be seen at the Inventions Exhibition. In the mechanism for regulating the position of the carbon points the great desideratum is simplicity combined with efficiency. The Pilsen lamp perhaps fulfils these two conditions better than its contemporaries.

I will now endeavour to point out the advantages which, as a domestic light, the incandescent lamp possesses over every other form of artificial light. They are many. The most important perhaps is its sanitary claim. Firstly, it is the only artificial light which does not pollute the atmosphere by its use. In the case of gas each added light means an increase of carbonic acid gas—lung poison, and decrease of oxygen—the support of animal life. This lamp leaves the air as it found it; fifty lamps have no more effect upon the chemical properties of the air than one. This is an incalculable benefit to humanity—a triumph in the science of hygiene. People little know what prejudicial influence they sustain from the heated and vitiated air of theatres, churches, and other public places. The giddy oppression and general uneasiness ensuing upon the attendance at a ball are not the consequences of the essentially wholesome exercise of the waltz, but of the carbonic acid poison with which the lungs of the guests have been fed throughout the evening.

The second great advantage of the incandescent lamp is the small degree to which it heats the atmosphere. An incandescent lamp gives only one-tenth the heat of an equal gaslight. The Criterion Theatre, in its old days, afforded an atmosphere which will still be remembered by many as intolerable. Since the introduction of the electric light it is one of the most comfortable and airy theatres in London in all seasons. The manager claims that on one day last summer the thermometer registered higher outside the theatre than inside. Light is one of man's greatest needs, mental and physical. The adoption of a light which in a great degree fulfils the conditions of sunlight, promises to the human race unprecedented health and spirits. It has been noticed that in factories where the electric light is now employed there has been a marked increase in the healthy high spirits of the men and women employed—now fed by a healthy atmosphere, devoid of the poisonous products which gas sheds around it; those poisonous products which are so destructive to many of our belongings. They tarnish our gildings, blacken our ceilings, and damage the bindings of our books; but incandescent lamps, burning in a vacuum, can work no harm outside themselves. The absolute white colour and steadiness of these lamps is invaluable to the eye, and for the illumination of the objects upon which the eye may wish to rest. The eye is not the only sense which benefits by the use of the electric light; the ear does also. It is well known that sound travels at a different rate through different media. In air it travels at the rate of 4,092 feet per second, and in carbonic acid gas at the rate of only 858 feet per second. Now a row of gas footlights in a theatre throw up a screen of carbonic acid gas—this sound-delayer between the voices and the audience.

The third great advantage is its independence of surroundings. The incandescent lamp will burn as brightly beneath the surface of water as above. This will be a boon to the diver in his submarine explorations. He may thus carry his lamp with its brilliancy unabated many fathoms deep. Against danger of fire this lamp is our surest safeguard. If the globe in which the incandescent filament is enclosed is broken the light is extinguished by the instantaneous combustion of the filament. Therefore it is practicable to place the incandescent lamp with impunity amongst the most flimsy curtains, in spirit vaults, gunpowder magazines, and in coal-mines. If a lamp which is lit is wrapped in muslin and then broken the light goes out and the muslin is unsinged. Explosions in coal-mines are still so frequent as to remind the inventor that science has not yet done her best to lessen their occurrence. It is, I think, to electricity that we must look for aid in preventing these disasters. For an electrical miner's lamp to be practical it is necessary for the miner to carry with him his source of electricity as well as his lamp, and the difficulty is to obtain a primary or storage battery, combining compactness, lightness, and efficiency. A run of some twelve hours without recharging is required, and a battery small and light enough for this purpose has yet to be developed. Mr. Swan and M. Trouvé are working in this direction. The philanthropic object ought to stimulate many others to produce what may reasonably be considered to be within the range of possibility. It would be folly to say that there is absolutely no danger of fire from the use of electricity. Thus, if overheated by too powerful a current, the wires which convey it to our houses become in themselves a source of danger. Electricians guard against this danger by the interposition of safety fuses in the circuit. These are made of substances which fuse at a much lower temperature than the conducting wires, and thus cut off a too powerful current.

There is another contrivance called the magnetic cut-out. It acts most accurately. Its action depends upon the attraction of an electro-magnet upon its armature. The armature carries two arms which usually dip into mercury cups. This forms part of the circuit. When the armature is attracted the contact of the arms with the mercury is broken, and consequently the circuit. The ease with which the incandescent lamp adapts itself to ornamentation has been well displayed in the various electrical exhibitions. A pretty idea has been lately executed for ball-room decoration. The plants and flowers which on those occasions often abound, of themselves form the supports for the lamps, and the close vicinity of light and colour is extremely beautiful. When once properly installed in a house the electric light is very easily managed. The switches which are used to close the circuit are now manufactured in much variety. There has been much needless alarm concerning the possibility of the inmates of a house lighted by electricity receiving dangerous shocks from the conducting wires. These fears have been based upon one or two fatal accidents. It is possible, however, to light a house completely by currents of so low an intensity that the conducting wires might be grasped with perfect impunity. It would be hardly right to have dwelt so long on the value of the electric light in our homes without saying a word or two on the subject of cost. It is a difficult task to consider this question in a few words, so much depends upon surrounding circumstances. I will not attempt to quote a number of statistics. Figures are often misleading—often, like a shower of gold-dust, they glitter as they blind. Besides it is an unfair comparison to quote the cost of gas against electric light, because these two illuminants are not on the same footing at present. Gas is supplied to us from a central station, and all benefit financially in being subscribers to a general source. In the case of electricity, unless the user happens to be under peculiarly advantageous circumstances, he is much in the same position as one who has to supply his own gasworks on the premises. In this case naturally the cost of electric light does not compare favourably with gas. Before electricity will be a cheap light it must be supplied from a central station, and when the expense of a central station is divided amongst the subscribers, then it will be possible to estimate what that expense is compared with its rival. There is but little experience, however, in large installations, and some that are now in progress will be watched with great interest. What can really effect the introduction of these central stations? It is not likely that they can be numerous until there is a greater desire on the part of the public themselves for this advantageous illuminant. Supply is always regulated by demand. The universal demand of the public has not yet been realized.

It must, however, surely come at last. It were folly indeed for the children of civilization to reject one of its [illegible] pure and wholesome illuminant. The depression which lately fell upon the electric-light trade has surprised and disappointed many who placed their faith in the new illuminant. It is, however, not difficult to trace its cause. It was a necessary consequence of a period of excited and reckless speculation. The sudden development of electrical appliances turned many a brain. Company after company was speedily formed, some of which undertook to light up the world without experiment, without experience, and in many cases without competent electricians. No wonder it was that money thus invested was money lost; that in the confusion and turmoil of law-suit and litigation, good and indifferent seemed hardly discernible, that the electric light business looked gloomy in the extreme. But even through this depressing period electrical application made steady progress, and after the would-be electricians had disappeared from public gaze, the labour of the patient and persevering remained to regain the public trust.

I mentioned above that there are some cases where persons are advantageously placed with respect to the electric light, and where it can be produced at an almost nominal rate. Owners of waterfalls, for example, have only to use a turbine to work their dynamo, and so pay nothing for their power. Again, in factories where steam-power is at hand, a fraction of the power may be utilized to produce the light. On this principle many large steamships are fitted with incandescent lamps. There is a proverb which tells us to kill two birds with one stone. I used to know an Oxford tradesman who did this very aptly. The steam gas-engine which ground his coffee by day lit up his shop by night with electric light. Such is the progress of electrical knowledge, a progress which nothing can arrest, and for this reason: it is a consequence of the evolution of the mind of man, which, as it develops, grasps the proportion of Nature's many sides, the mind then too vibrates in harmony, and finds its power in the unity between mind and matter. In the infancy of civilization, man knew Nature only through the medium of his senses as far as he could see or hear, and thus was his power limited. Now his subtler intellectual sense is revealing to him the atoms of which all is built and their functions—a knowledge potent with possibilities. Space shall he annihilate: as Tennyson says in his "In Memoriam," "nothing stands." Nature evolves in poetic unity before our gaze, and our knowledge grows from more to more.

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