Electric lighting, 1884

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THE ELECTRIC LIGHT
IN OUR HOMES.

DRAWING-ROOM LIGHTED WITH ELECTRIC LIGHT

THE ELECTRIC LIGHT IN OUR HOMES.

By ROBERT HAMMOND,
The Hammond Electric Light and Power Supply Company, Limited.

SIXTH THOUSAND

WITH ORIGINAL ILLUSTRATIONS AND PHOTOGRAPHS.

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PREFACE.

IN the following pages there will be found the substance of the Lectures which, during the past twelve months, I have had the pleasure of delivering in many of the largest towns in England, on the subject of the "Electric Light in our Homes."

At each place I was asked for a popular lecture, and, being an excessively busy man, in no case did I prepare a written essay on the subject.

The matter, therefore, is now for the first time committed to writing, and in this form its length requires explanation.

The fact is that the lecturer without notes uses in each fresh lecture new matter, finding room for it by omitting some of the old; but when this process has been going on for months, and the lecture has finally to be written, an opportunity is afforded for using all the accumulated material, without the necessity arising for making any omissions.

My readers will therefore kindly acquit me of the charge of delivering the whole of the contents of this book on any single occasion.

If among my scientific friends there should be those who think that, in my endeavour to be simple, some of my analogies do not give an exact notion of the phenomena described, I have to plead that analogies never are absolutely correct in every particular, and to state that I shall be extremely pleased to insert in a second edition of this work, should it be called for, any better ones with which they may supply me.

My best thanks are due to my friend, Mr. HUGH ERAT HARRISON, B.Sc. Lond., F.C.S., Principal of the Hammond Electrical Engineering College, who kindly undertook the tedious task of reading through my manuscript, and who was good enough to discuss with me the best way of illustrating many of the phenomena referred to.

HILLDROP, HIGHGATE.

January, 1884.

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THE ELECTRIC LIGHT IN OUR HOMES.

CHAPTER I.

THE OLDER FORMS OF ILLUMINANTS AND THEIR DISADVANTAGES.

Electric lighting treated hitherto under its scientific rather than its social aspect—All older forms of lighting condemned by one common fault — Consumption of oxygen and pollution of the atmosphere — Chemical action in gas-flame—Value of oxygen—Candle-flame—Carbonic acid—Sulphur compounds.

DURING the past few years a gradually increasing amount of attention has been given to the subject of lighting by electricity, and the desire for more intimate knowledge of the laws which its phenomena involve, and of the modes of applying electric energy cheaply and simply to the lighting of our houses, is rapidly extending.

Hitherto, however, those who have written and spoken upon the subject have treated it under its scientific rather than its social aspect, describing the various improvements in the inventions relating to the supply and distribution of electricity, without dwelling upon the highly important domestic side of the question.

It shall, therefore, be my endeavour this evening * to avoid scientific terms as much as possible, and to deal with the subject from its social side.

The interest excited a few years ago in the question of lighting by electricity has spread almost all over the world, and, though England is already better lighted than any other country, in no other, with the one exception of the United States, has so much attention been paid to the subject.

It has been claimed by more than one writer that the measure of advance in civilization of a nation may be known by the mode of illumination which is adopted generally by it; and when one considers the very varied means of lighting at present in use in different parts of the world, one has good grounds for believing the assertion to be correct.

Having recently had the pleasure of making a journey of some 20,000 miles, I have lately been brought face to face with some very crude methods of lighting.

When the shades of evening fall upon the Nevada Cañons, the Red Indian still sits in the glow of his rude camp fire, as his forefathers did ages ago. On the banks of the Mississippi,

* This book is almost a verbatim report of lectures recently delivered by the author. (See preface.)

wharves are lighted by the flaring of bituminous substances piled up in the most elementary of cages, hanging from the ends of poles. The Greenlander has, for his only means of lighting, the oil abstracted from the blubber of the whale; in some parts of Europe there may still be seen the Etruscan lamp of two thousand years ago; in countries more civilized than these, the candle, which has been discarded by us as a general illuminant for twenty or thirty years, still holds its sway; in other places oil reigns supreme, and only in countries like England, France, and the United States has the use of gas become in towns almost universal.

Varied, indeed, are these methods of lighting, and varied, perhaps to the same extent, is the civilization of these peoples; but though, for instance, the divergence in manners between the Greenlander and the advanced European is so wide, the lights which they both use are in one respect closely allied.

To those who are accustomed to boast of the immense strides which have been made during the past twenty years in the modes of production, distribution, and consumption of coal-gas, it may seem absurd to liken gas-light, in any way, to the blubber-oil-light of the Esquimaux; but *one sweeping indictment can be brought against all the lights that are in use in the world at the present time*—against, indeed, all the lights that the world has ever known; for they have in common one serious fault, a fault which cannot be eradicated by any improvement, and which, in the opinion of many, absolutely condemns their use for indoor purposes.

I allude, as may be imagined, to the fact that *the greater or lesser brilliancy of these lights depends upon the greater or lesser amount of oxygen which they abstract from the air.*

In order to make this point quite clear, let me remind you of what takes place in the production of light from coal-gas and from candles.

I hope it will not be thought that I have forgotten my promise to avoid approaching the subject purely from its scientific side, when I make reference to the chemical constituents of the ordinary coal-gas we are accustomed to use for lighting purposes, which constituents may be stated as follows:—

Composition in 100 *volumes of Coal Gas*—*

Hydrogen (H) - - - - -	47·60
Marsh Gas (CH_4) - - - -	41·53
Heavy Hydro-carbons (C_nH_{2n}) -	3·05
(*Equal to Olefiant Gas* (C_2H_4) 6·97)	
Carbonic Oxide (CO) - - -	7·82
	100·00

When the gas-tap is turned on, these ingredients, in the form of gases, immediately rush into the room, but they do

* Roscoe's "Chemistry."

not chemically combine with the oxygen present in the atmosphere, until the air above the gas-pipe is warmed by a lighted taper, to the pitch necessary for the chemical union of hydrogen and oxygen.

When, however, the requisite amount of heat is applied, the hydrogen in the coal-gas combines at once with the oxygen contained in the fresh air in the room, and the compound so formed, dispersing, condenses in the form of water, which is deposited on the walls, ceiling, furniture carpets, &c.

This regular deposit of water may be seen by taking an ordinary flat-iron and passing it through the top of a gas-flame. The steam, which would otherwise pass into the room, is changed by condensation, on the cold metal, into drops of water.

Within the flame produced in the gas-jet by the union of the hydrogen and the oxygen, particles of carbon are raised to white heat, and are thereby enabled to give out light.

In the process of being raised to, and whilst at, this high temperature, the bulk of these particles of carbon feed, as it were, upon the remaining oxygen contained in the air, forming, in conjunction with it, the gas known as carbonic acid, which is disseminated through the room. A certain number of carbon particles, however, pass unconsumed through the flame, without combining with the oxygen, and these have the very unpleasant habit of settling down in a form to which ladies have so great a dislike — that of "smuts."

Now, it will be seen that the particles of hydrogen, as well as the bulk of the particles of carbon, in coal-gas, only act, in the production of light, by the consumption of oxygen; and when I remind you that the gaseous substance formed by the chemical combination of the carbon particles in the gas with the oxygen in the air—viz., carbonic acid—consists of nearly three parts by weight of oxygen and one of carbon, you will readily see how large an amount of oxygen is abstracted from the air, as long as the gas-jet is burning.

When, in our summer holidays, we seek those spots by the seaside, or on the mountain slopes, where fresh air is most readily obtainable, we are simply striving to breathe oxygen in its purest form.

The air which surrounds us, consisting of one part of oxygen to four of nitrogen, may very easily, if chemical actions be brought into play to affect it, lose a great proportion of its oxygen, and, therefore, any light which will rapidly absorb oxygen must be considered highly pernicious for use within our houses.

We have dwelt at some length upon the chemical action which is set up in the coal-gas flame, and many who have entirely tabooed gas from their houses, are probably feeling comfortable in reflecting that they are using, in its place, the pure and clean wax candle. One is sorry to destroy any illusion which they may be cherishing on this head, but I am compelled to state that, in proportion to their brilliancy, candles consume a much greater quantity of oxygen than coal-gas; because the chemical action, which takes place in the manifestation of light from the candle, does not occur under the same favourable condition as in the gas-flame.*

For instance, in the candle on the table, we have the ordinary wax and wick. When I take this match and ignite the wick, the heat generated by it immediately begins

* Dr. Meymott Tidy's "Handbook of Modern Chemistry," page 67 :—
"The following table shows the oxygen consumed, the carbonic acid "produced, and the air vitiated, by the combustion of certain bodies "burnt so as to give the light of 12 standard sperm candles, each candle "burning at the rate of 120 grains per hour :—

Burnt to give light of 12 candles, equal to 120 grains per hour.	Cubic feet of oxygen consumed	Cubic feet of air consumed	Cubic feet of carbonic acid produced	Cubic feet of air vitiated	Heat produced in lbs. of water raised 10° F.
Cannel Gas	3·30	16·50	2·01	217·50	195·0
Common Gas ...	5·45	17·25	3·21	348·25	278·6
Sperm Oil.........	4·75	23·75	3·33	356·75	233·5
Benzole............	4·46	22·30	3·54	376·30	232·6
Paraffin............	6·81	34·05	4·50	484·05	361·9
Camphine.........	6·65	33·25	4·77	510·25	325·1
Sperm Candles...	7·57	37·85	5·77	614·85	351·7
Wax	8·41	42·05	5·90	632·25	383·1
Stearic	8·82	44·10	6·25	669·10	374·7
Tallow	12·00	60·00	8·73	933·00	505·4
Electric Light *	**none**	**none**	**none**	**none**	13·8

* Added by Author.

to melt the wax, and set free the combustible gas contained therein, which in this case, as in the coal-gas flame, unites with the oxygen in the air around us, to form by condensation water; and, while this vapour is ascending, the bulk of the carbon particles in the wax and wick are turned, by the addition of more oxygen, into carbonic acid, and, as previously explained in the case of the gas-flame, these carbon particles throw out light.

If this very simple experiment were carried one stage further, one could show you, as was shown by that great master of physics, Michael Faraday, in his lectures upon "The Chemical History of a Candle," at the Royal Institution, some twenty-five years ago, that a great many of the carbon particles from the wick ascend, without being turned into carbonic acid, and distribute themselves as tiny pieces of soot all over the room.

In connection with this point I may refer to something which I saw a short time ago in the grand old cathedral at Exeter, where I felt that it would be sacrilege for anything to sully the whiteness of the glorious pillars rising all around me. Yet, while walking through the cathedral, I found the sacristan busily engaged, after the special afternoon service, in extinguishing the candles in front of the beautiful reredos, and from every one of the hundred arose a column of nasty vapour, sufficient to make a dirty mark upon everything with which it came in contact.

To return, however, to the question of the consumption of oxygen. What I have said in reference to the gas and candle-flame applies, as you doubtless know, with equal force to all other forms of artificial light, except the electric light, and I therefore think I may take it for granted that you admit I was right in saying, a short time ago, that one sweeping indictment could be brought in common against all the forms of artificial light that have hitherto been in use, because *they all, to a greater or lesser degree, consume the oxygen of the air.*

Not only do they consume the oxygen, but you will notice that, while absorbing the pure air, they give back carbonic acid, which in any considerable quantity is, in its effects upon animal life, most deadly.

Professor Meymott Tidy, in his "Handbook of Modern Chemistry," just referred to, says that "normal air contains 0·04 per cent. (or 4 parts in 10,000) of carbonic acid. Air containing 4 per cent. of carbonic acid (the quantity present in expired air) is perfectly irrespirable; air containing 1 per cent. of carbonic acid is extremely distressing; air containing 0·1 may be regarded as polluted." It is interesting to note that, when a test for *impurities in the air* is required, it is usual first to test for carbonic acid, and then if it be found to exist in an excess quantity, this is considered to be a sure indication of the presence of more noxious gases.

Many will remember reading the sad story of that young

French student, who, weary of life, determined in his last moments to make some slight addition to the science of the day, by describing accurately the frightful torture of a death caused by inhaling carbonic acid and carbonic oxide. He went into his room, and closing up every aperture, set light to a piece of pure carbon in the form of charcoal. This carbon, in its process of combustion, abstracted from the air of the room the oxygen it contained, giving back carbonic acid and carbonic oxide. A suffocating feeling crept over him —acute pain seized his head and heart—these greatly increased, and at last the pen describing his sufferings fell from his hand, for death prevented him continuing his terrible narration.

While the constant abstraction of oxygen from the air, and the production of carbonic acid are irreparable faults characterizing all the older forms of artificial light, the use of *coal-gas* is by far the most detrimental; for, though not mentioned in Roscoe's analysis, it almost always contains sulphuretted hydrogen and carbon disulphide. These are both inflammable, and the resulting compounds are not only very prejudicial to health, but act corrosively on most metals, and even on compounds of some metals, such as white-lead. Thus, not only does gas tarnish all the gilt-work of our books, and all the metal ornaments of our drawing-rooms, but it acts on most oil-paints; white-lead, for instance, which is the basis of most white paints, can be turned quite black by it.

CHAPTER II.

THE FIRST STEPS TOWARDS OBTAINING PERFECT LIGHT.

The conditions of perfect light—The search for the same—Lightning—Phosphorescence in plants—Particles of air—Effect of an electric current on them—On air in rarefied tubes.

We may feel persuaded that in such a scientific age as the present, when the most careful attention is given to the perfecting of all the arrangements connected with our homes, and when dangers from whose effects our ancestors were willing to suffer are carefully guarded against, we shall not be long content to continue using illuminants which have such overwhelming disadvantages as those in use up to the present time.

I have therefore to ask you to join with me in going over the various stages connected with the search for a new light for our homes, against which the objections just named cannot be urged.

First let us consider what a perfect light should be; then, after laying down certain lines of perfection, let us endeavour to obtain something which shall approximate to them as closely as possible. We may begin by saying that *the perfect light for our homes should fulfil the following conditions*.—

1.—It should not rob the air of our rooms of oxygen.
2.—Nor add noxious fumes to the air.
3.—Nor be a source of danger in the house.
4.—Nor be an unpleasant light.
5.—Nor be difficult to control.
6.—Nor be costly.

The conditions, you will notice, are those demanded by a *perfect light;* and though almost everything with which we are familiar in this life falls short of perfection, I hope, before we have finished, to show you a light very closely fulfilling the requirements specified, which one may confidently predict will in the future be universally and exclusively used.

Let us imagine ourselves introduced to a set of philosophers, living some thirty or forty years ago, anxious to discover this perfect light, and searching throughout the universe to find it. In following them in the prosecution of their quest, we shall no doubt, from time to time, walk along paths which have been traversed by inventors, though it may happen that some of our paths will be new.

You are aware that fifty years ago *lightning* displayed itself as vividly as it does to-day, and we can imagine our philosopher friends looking to it as that from which a clue to a new form of light might be obtained.

Lightning was rightly considered to be an electrical phenomenon, and electricity was also claimed* to produce light in other directions, for we have an account which relates how the daughter of Linnæus was once surprised to observe luminous radiations emitted by the flowers in a group of nasturtiums, and how the Swedish naturalist Professor Haggern declared that he frequently noticed faint flashes of light dart from a marigold, and had had his observations confirmed by independent witnesses.

In these manifestations of light, attributed, more or less correctly, to electricity, you will notice that the electric current was absolutely beyond control; but I will now show you an experiment illustrating what may fairly be looked upon as the first step towards obtaining, *and at the same time keeping under control,* light from electricity.

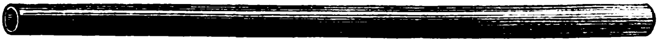

Fig. 1.

This is *an ordinary glass tube* (Fig. 1), which, being open at both ends, might be said to be quite empty; but you are asked to admit that this tube, through which water would of course run with rapidity, is, at the present moment, not

* "Phosphorescence," by T. L. Phipson, pages 79—87.

by any means empty, but on the contrary, full—*i.e.*, FULL OF AIR.

In describing this *piece of copper* (Fig. 2), you will

Fig. 2.

doubtless freely acknowledge that it may be quite correct to say that it consists of most minute *particles of metal,* firmly compacted together. But when handling the tube, and talking of the *particles of air* in it, I am dealing with a far less palpable mass than the mass of copper. You are called upon, however, to believe that the *particles of air* contained within this tube, are quite as real, though not palpable to the touch, as the particles of metal in the piece of copper.

In dealing with *particles,* you must permit the very free use of the word "million." Professor Tait, in his "Recent Advances in Physical Science," says,—

"The number of particles of water in a single drop may, as we have reason to believe, amount to somewhere about 10^{26} or 100,000,000,000,000,000,000,000,000," a number so vast that the human mind fails to grasp it, but which serves to show how closely "particles" are packed together in a drop of water; and when one speaks of the particles of air in this tube, you must regard them also as packed very closely together, though it is obvious that they exist in a freer state, *i.e.*, occupy more space than they would do if they were subjected to heavy pressure, or to a very low temperature; just as particles of water in the form of steam occupy much

Fig. 3.

more space than they do when they are condensed in the form of water.

Having agreed, then, that an open tube may be described as being full—viz., full of air—you will be quite prepared to admit that this *closed-up tube* containing air, and hermetically sealed at both ends (Fig. 3), has enclosed within it millions of millions of particles of air.

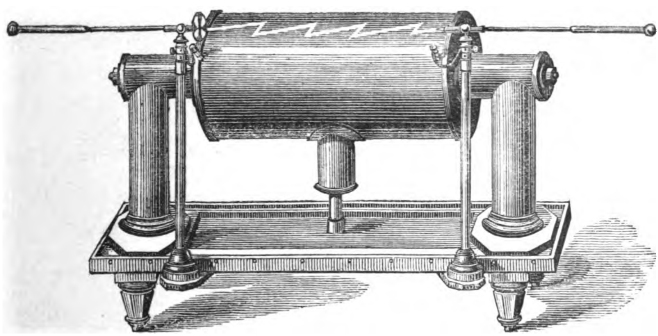

Fig. 4.—Ruhmkorff Coil.

Into each end of this closed-up tube there is inserted a piece of wire; these wires do not run right through the tube, but only extend about a quarter of an inch into it at each end.

On the table there is an electrical apparatus known as a

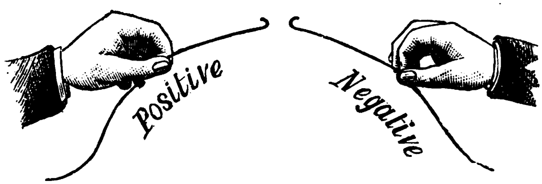

Fig.5.

Ruhmkorff coil (Fig. 4). In my left hand I hold the wire which leads from the positive, and in my right hand the wire which leads from the negative pole of the coil.

When the ends of the two wires are kept a short distance

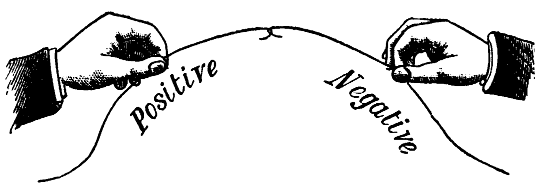

Fig. 6.

apart (Fig. 5), the current of electricity from the Ruhmkorff coil does not flow, because it is unable to jump over the intervening space in the open air.

When, however, the positive and negative wires are joined together (Fig. 6), the electricity is able by this junction to pass, in the form of an electric current, round the whole length of the wire, and there is established what is technically called a "circuit." Round this circuit then the current flows, just as water flows through a carefully joined pipe.

When I go one step further, and fix the end of the positive wire, in my left hand, to the wire protruding from one end

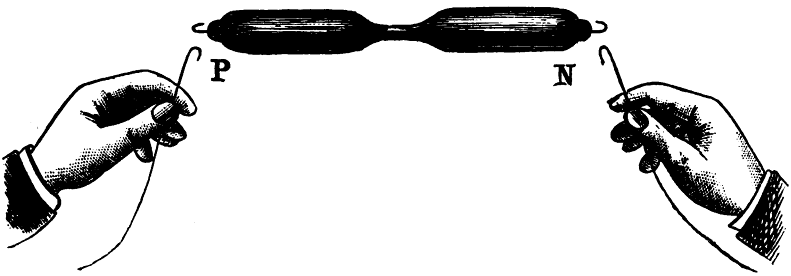

Fig. 7.

of the hermetically sealed tube, and also attach the negative wire, in my right hand, to the wire protruding from the other end (Fig. 7), a path is formed, which in its central portion consists of particles of air, inside the tube.

Though you are made aware, by the flashes from the Ruhmkorff coil, that electricity is being generated, you see no manifestations of light whatever proceeding from the air inside the closed-up tube.

When, however, this tube is taken off, and another put in its place (Fig. 8), and the current again switched on, you observe a very different result; for from the whole length of the hermetically sealed tube, which has now been inserted, are coming beautiful manifestations of light.

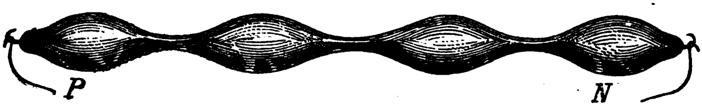

Fig. 8.

This second tube is one which also contains nothing but particles of air, but it contains them in very much smaller quantity than the tube upon which we first experimented, a certain number of the particles having been taken out by means of an exhaust-pump. It is utterly impossible to get all the particles out, but this particular tube has been *exhausted,* as it is termed, to the extent of about 999 particles in every thousand.

The remaining particles, to the extent of about one in every thousand, when agitated by the electric current, on its passage from one end of the tube to the other, have room to move more freely, and by their motion throw out a certain amount of light.

In the first tube, the particles were packed so closely together that practically such movement was impossible; but in this tube they move because they have room to do so.

On showing this experiment lately to a gentleman who had been to a ball the night before, he seemed to have a lively appreciation of the whole thing. He explained to me that about three times too many people had been packed into his friends' rooms, and dancing was therefore impossible; but when two-thirds of the guests left, at about two o'clock in the morning, the remaining third, whom he irreverently termed the "*particles not exhausted,*" danced with some liveliness.

My friend's image may appear to be a far-fetched one, but it serves as a means of fixing in our minds the phenomena illustrated by these tubes.

Let us indeed adopt it, modifying it however to the extent of supposing that a figure in the cotillon was being danced, in which the favours were placed at one end, and had to be caught up and carried to the other end of the room.

It is obvious that, in the crowd of guests which my friend complained of, this transference was practically impossible. Take away a certain number of the guests, so that each couple can move freely, and the transference goes on rapidly enough. Conceive the guests to be particles of air, and the favours to be electricity. A particle of air comes in contact with the wire at one end of the tube, and seizes hold of a certain quantity of electricity. If free to move, it proceeds, with certain collisions, no doubt *en route*, to the other end of the tube, strikes against the other wire, and gives up its burden.

This fairly well describes the action which took place in the second tube from which light proceeded, and which could not take place in the first tube on account of the crowd of particles.

The light obtained by this means is certainly not a very brilliant one, though it might serve some useful purposes;

Fig. 9.—Early form of Lane-Fox Lamp.

for instance, when my watch is brought close to it, I can tell the time distinctly, but it would only very feebly assist in the illumination of a house; and we will therefore pass on to consider the various stages which have resulted in the production of the particular lamps which are lighting this room. These lights are produced by the action of the electric current upon the particles of a certain substance, and just as we have seen the effect of the passage of the electric current through the particles *of air* more or less rarefied, we will now proceed to examine the effect of the same current upon particles *of metal.*

CHAPTER III.

THE INCANDESCENT LAMP.

Effect of electricity on particles of metal—Breakage of copper at the stage of white heat—Platinum—Iridium—Carbon—Early inventors—The carbon filament able to withstand intense heat—Must be sealed up in a vacuum—Result.

To ILLUSTRATE the effect of the electric current on particles of metal, there are on this table half a dozen rods of various sizes. The piece which I am now holding, being

Fig. 10.

the largest of the set (Fig. 10), consists, like the others, of copper, or, in other words, of *particles of copper,* adhering very closely together, and forming a compact mass of solid metal.

In the same manner as we passed the current from the coil through the rarefied air contained in the exhausted tube, we will now pass a current of electricity through this copper rod.

I join the end of the fixed conductor at my right hand to one end of the rod, and attach the conductor at my left hand to the other end (Fig. 11), so making the rod

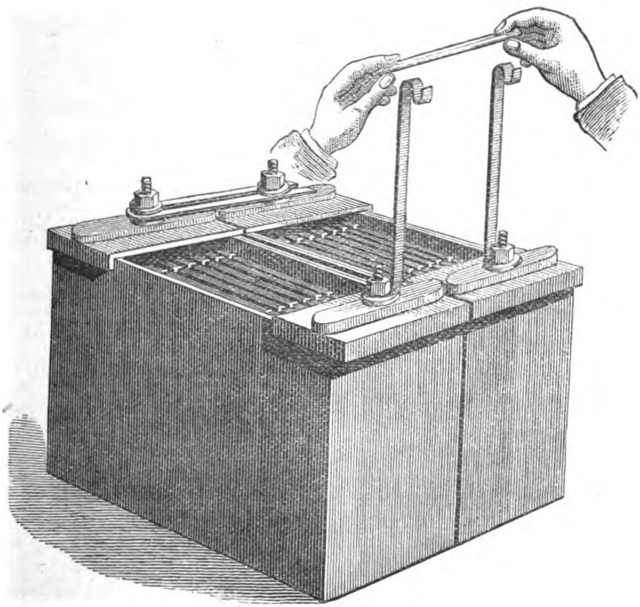

Fig. 11.—Accumulator containing stored electricity

complete the circuit and take the whole of the current through it, just as, in the former experiment, the rarefied air completed the circuit and carried the electricity.

You will notice, however, that this has no visible effect on the piece of copper, for, as a matter of fact, the agitation which the electric current sets up in the particles of copper of which it consists, is not of sufficient intensity to make them manifest either light or heat by their movement.

It may at the present moment, indeed, be likened to a large pipe; and the electric current may also, though very roughly, be likened to a flow of water through the pipe.

You are aware that if you run a small quantity of water through a large pipe, the water trickles through without affecting it in any appreciable way. If, however, you were to try under pressure to force through the same pipe a

Fig. 12.

quantity of water too great for it to carry, then the effect would undoubtedly be disastrous to the pipe; and though one does not wish to draw too close an analogy between the flow of water in a pipe and the flow of electricity in a conductor, I ask you to bear the comparison in mind, since it will help you to understand the effect which will be produced if we force through this rod a larger current than it can bear, or if we force the same current as that which we have just used, through a smaller rod, like the one which I now hold in my hand (Fig. 12).

When this is placed in contact with the *same* conductors carrying the *same* current of electricity, and you have an opportunity in the darkened room of seeing the result, you will find that the current, which had no visible influence on the larger rod, has a very marked effect upon this one.

In the former the current had room to spread itself out and take life easily, but in this rod it is confined into a smaller space, and the effect will be that the particles of metal will be thrown into violent agitation, and the rod will rapidly become red hot.

(The light in the room was now completely extinguished, leaving it pitch dark. For a few seconds nothing was visible,

Fig. 13.

but at the end of that time the wire began to get red hot at both ends, and this red heat gradually spread along its whole length. The light then being turned up, the lecturer resumed.)

I do not think there is any one in this room, however far distant he may be from the platform, who doubts that this wire is red hot; but, in case there may be such an one, perhaps the Mayor in the chair would kindly take hold of the wire. However, as he does not seem inclined to do so, we will set light to this piece of paper to prove how great is the temperature produced.

Let us now subject a smaller wire (Fig. 13) to the same treatment, and see what the effect will be. It is placed across the same conductors, and red heat obtained very much more rapidly, because, the wire being still smaller, the particles of copper are thrown into still more violent agitation.

We now go to the last stage, and take this extremely

Fig. 14.

thin piece of wire (Fig. 14). You notice that when it is placed across the conductors it becomes red hot immediately, and indeed, for one second, looks as if it would pass into the state of white heat; but at this moment it breaks.

We repeat the experiment with another small wire

Fig. 14*a*.

(Fig. 14*a*); but still we get the same result—*breakage;* so that, at the moment when the electric current, by making the wire white hot, is likely to give us *a good light,* the wire breaks. What then must be our next step? Naturally, we must determine the cause of the breakage, and, if possible, guard against it.

This will neither be found a difficult nor a tedious task. You are probably aware that the wire which has just broken through the great temperature to which it was raised by the electric current, may have broken for one of two reasons, or for both combined, *i.e.*, it may either have been

(*a*) burnt,
(*b*) fused or melted.

The distinction between the two being that, in the one case, the wire was destroyed through the combination of its heated particles with the oxygen of the air, *i.e.*, by its oxidation; or, in the other case, it was destroyed through its particles being torn asunder, and thereby being turned into its liquid or molten state by the passage of the electric current through it.

It is necessary, therefore, if we wish to guard against the destruction of the thin wire or filament, to take means *first* to banish from it the oxygen of the air, and *secondly* to use such a material as will stand no chance of being disintegrated by the high temperature to which it is raised during the passage of the current through it.

Taking first the question of a suitable material, one is glad to be able to state that the early inventors of the incandescent electric light, confronted with the difficulty, worked upon it for many years, and did not leave it without practically solving it.

Many substances are evidently better than copper for use as thin filaments, because, when drawn very fine, it can be easily melted. Platinum, on the contrary, has a very high fusing-point, and as far back as 1841 incandescent platinum was used. Iridium and its alloys were also tried, but all other substances at last gave way before *carbon,* as the following table will show:—

Inventor.	Date of Invention.	Substance used.
Moleyns	1841	Platinum.
Starr and (or) King	1845	Carbon.
Greener and Staite	1846	Carbon.
Petrie	1849	Iridium.
Lodyguine	1873	Carbon.
Konn	1875	Carbon.
Bouliguine	1876	Carbon.
Lane-Fox	*Dates disputed*	Carbon.
Swan	*Dates disputed*	Carbon.
Edison	*Dates disputed*	Carbon.
Maxim	*Dates disputed*	Carbon.

It is known that all substances may exist in one of three forms—the solid, the liquid, or the gaseous. But of the substance in question—carbon—it has been said that its passage from the solid to the gaseous is so rapid that it apparently omits the melting, or liquid, stage. Some, indeed, have declared that it is infusible, *i.e.,* never melts, but simply sublimes; and, in summing up its advantages, Wilde wrote, in 1873 *:—

* Hospitalier's "Modern Applications of Electricity," Vol. I., page 324.

"Carbon has, at equal temperature, a greater radiating power than platinum; so that the same amount of heat raises a carbon point to a much higher temperature than a platinum wire. Besides, the electrical resistance of carbon is about two hundred and fifty times greater than that of platinum; the carbon may, therefore, be made much larger while raising the temperature as much as the metal. Finally, carbon is infusible, and its temperature may be raised without any danger of fusion."

With Wilde's last remark we have already dealt, and it now only remains for us to consider the form under which carbon is used in the present incandescent lamp.

Earlier in the evening carbon was referred to in its objectionable state, as consisting of "smuts" in our rooms, and, later, it was described, in connection with the suicide of the French student, as *charcoal.* To many, carbon is only known in this form; but let me remind you that it is to be found throughout all nature, and that the ferns which are standing upon this table consist almost entirely of carbon and water.

This substance was therefore ready at hand in very many shapes for the use of the early inventors of the incandescent lamp.

Edison originally used brown paper, but has finally replaced his paper carbons by carbons made of fibres of bamboo. Swan has used from the beginning carbons made of cotton; Maxim employs carbonized cardboard; and Lane-Fox a vegetable fibre.

Indeed, it may be roughly said that all the filaments in the incandescent lamps at present before the world (*i.e.*, those of Edison, Swan, Maxim, Lane-Fox, Crookes, Woodhouse and Rawson, Swinburne, &c.) are produced from some vegetable substance; and it may be confidently claimed that a filament has been perfected which, unlike the thin copper wire just experimented upon, will not easily fuse, but which will bear the passage of a very intense current through it; a current strong enough to raise it to white heat, thereby enabling it to give out light without disappointing us by breaking, as the copper wire did, at the very moment when we had reached the point of turning electric energy into light.

These carbon filaments are twisted by different makers into various forms, for each of which certain advantages are claimed, and on the following page there are a few illustrations of them (Fig. 15).

It will, of course, be understood that before these carbon filaments are ready for use in electric lamps, they have to undergo certain processes of manufacture, and have to pass through very delicate handling; but we need not here enter into the extremely technical description of these processes. It may simply be stated that each carbon filament having been properly prepared, its ends are attached to two little platinum wires which have previously been sealed into the neck of a glass bulb, platinum being the only metal which will make an air-tight joint with glass.

Having then in the end obtained a filament which, for all

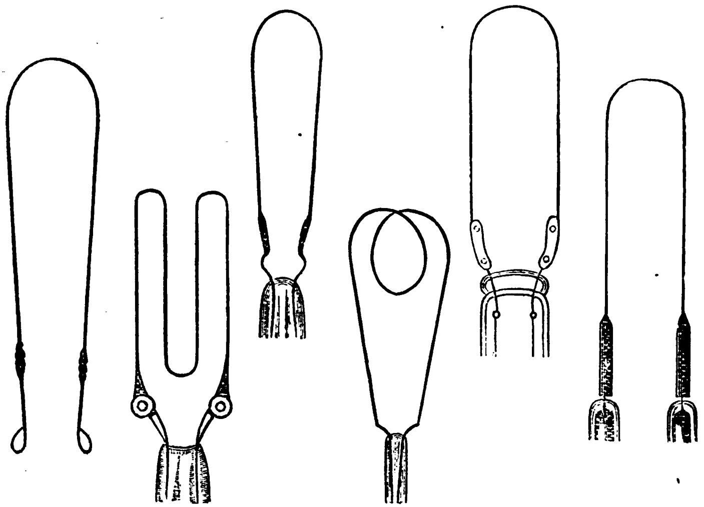

Fig. 15.—Carbon Filaments of various Makers.

practical purposes, will not disintegrate by the passage of the electric current through it, there only now remains for us to examine the mode by which oxygen can be prevented from coming into contact with it, in such a way that, when raised to white heat, it will not oxidise, or, in other words, burn and turn into carbonic acid.

It seems self-evident that if by any means it could be made to become white hot inside a glass bulb *from which all air is excluded*—containing, indeed, a perfect vacuum—the problem would be completely solved.

When the early inventors were working upon the electric lamp, the difficulties of creating a high vacuum were apparently insurmountable; but those familiar with Professor Crookes's Radiometer (Fig. 16) are aware that these difficulties have been completely conquered, and at the present time almost a perfect vacuum is obtainable.

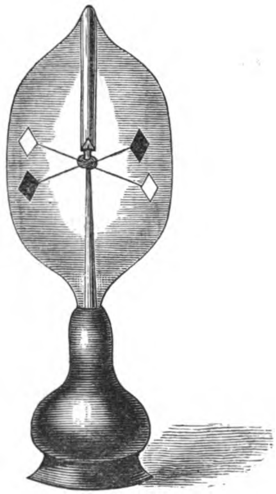

Fig. 16.—Radiometer.

You have already heard, in reference to the second hermetically sealed tube through which we passed the electric current, that the exhaust-pump had been brought into play upon the particles of air contained within it, and had only left *one* particle in *one thousand*, and I am now able to state that by means of a very delicate piece of apparatus, the particles of air have been so thoroughly exhausted from this little "Hammond Company" lamp (Fig. 17), that only *one* particle *per four millions* is supposed to remain therein.

Since air consists of one-fifth oxygen and four-fifths nitrogen, it naturally follows that by the abstraction from the bulb of these millions of millions of particles of air the oxygen has almost entirely disappeared, and you will therefore have a right to expect that when the electric current is passed through the carbon filament which is sealed up within it, the filament will not only refuse to melt on account of its having so high a fusing-point, but will also not burn up, *i.e.*, oxidise, in consequence of the almost entire absence of oxygen from the interior of the bulb.

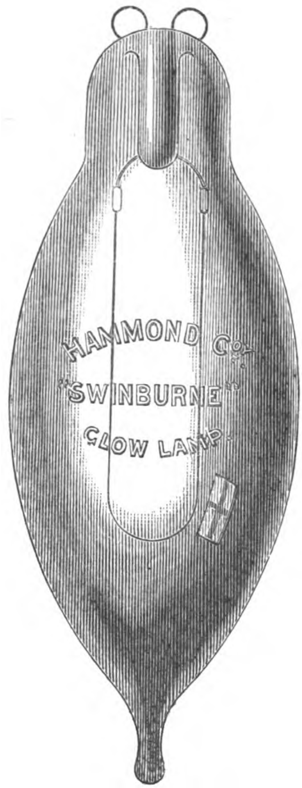

Fig. 17.—Hammond Company Glow (*i.e.* Incandescent) Lamp.

I am careful, you will notice, to say *almost* entire absence of oxygen, because we must admit that however perfect the exhaustion of the lamp may be, we have not, nor is it possible that we shall ever arrive at, a perfect vacuum, since an absolutely perfect vacuum can only be obtained by the abstraction of every single one of the billions of particles of air which are present when the process of exhaustion is first started.

To practically prove, however, whether our conclusions are correct, let us attach the finished lamp to this standard, and you see that the moment the attachment is made, and the electric current passed through the carbon filament, or

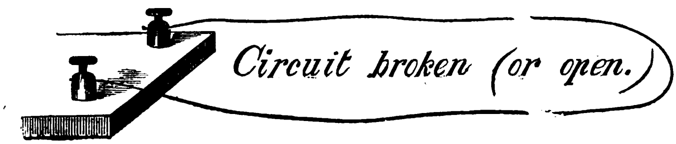

Fig. 18.

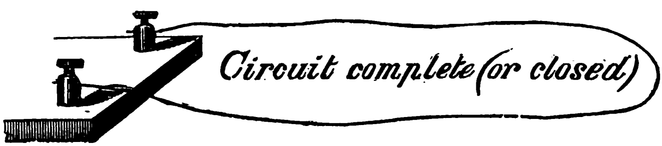

Fig. 19.

conductor, inside the lamp we get a most beautiful light without any indication of cessation.

It would of course be a fair corollary to this experiment to ask you to wait to see how long the filament lasts without giving way; but as I feel confident that it will stand at least three hundred nights, one fears that you would not care to accept the invitation. We will, however, leave the lamp burning for the remainder of the evening.

It might, at this stage, interest you to have an explanation of something that may be puzzling you, *i.e.*, the reason

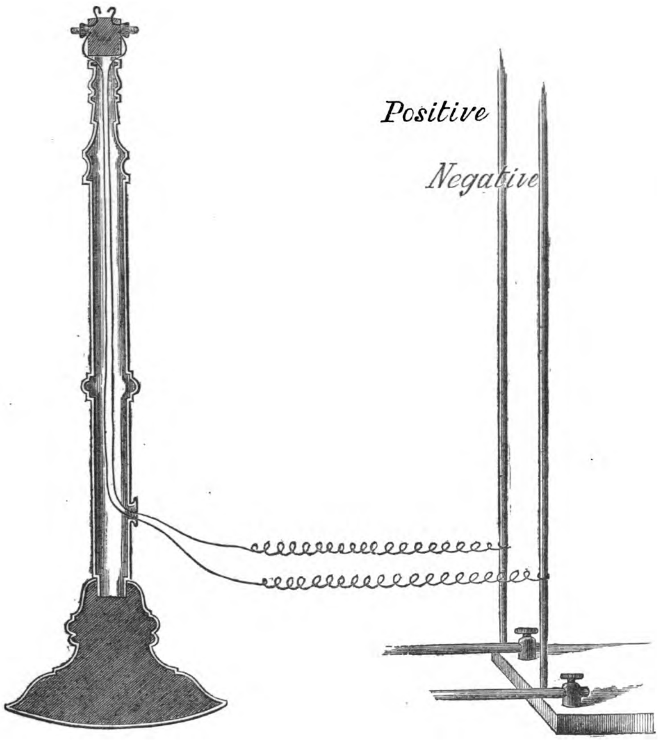

Fig. 20.—Leads and Conductors to Lamps.

why, the moment the lamp was fixed to the standard, the filament became white hot and gave out bright light.

You are probably aware that though the electric current

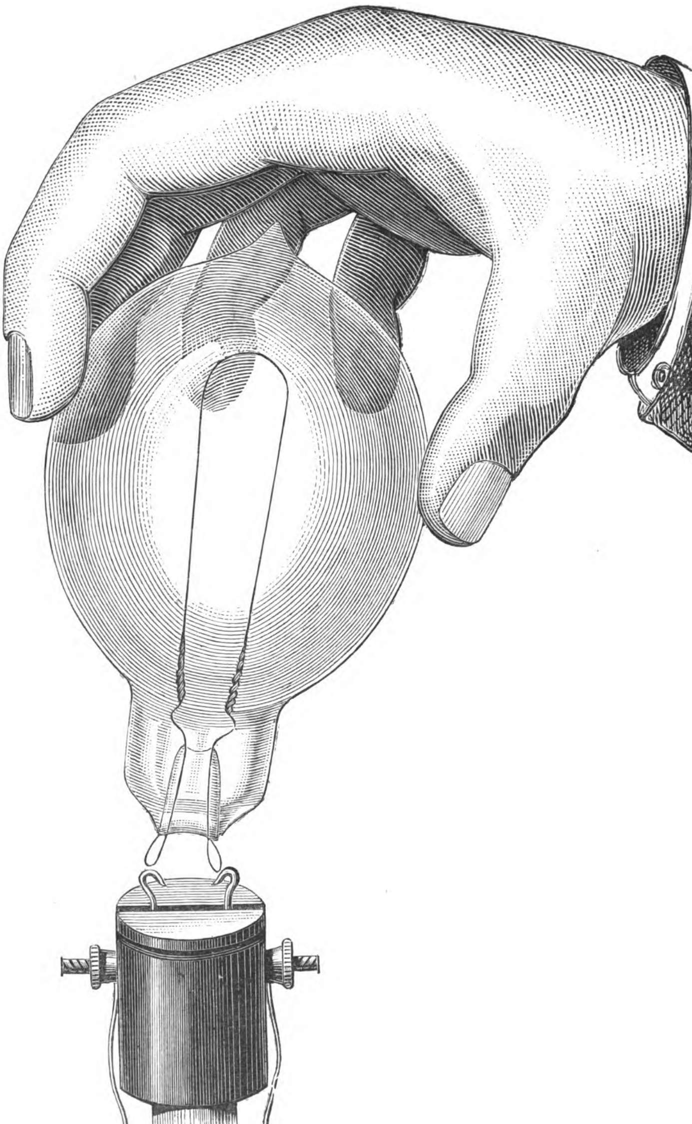

Fig. 21.

will pass through a wire or cable of almost any length, its course is immediately stopped if the wire be cut in two, because the current will not, as already shown, jump over the space intervening between the broken ends (Fig. 18):—

In the next illustration, also representing an open circuit

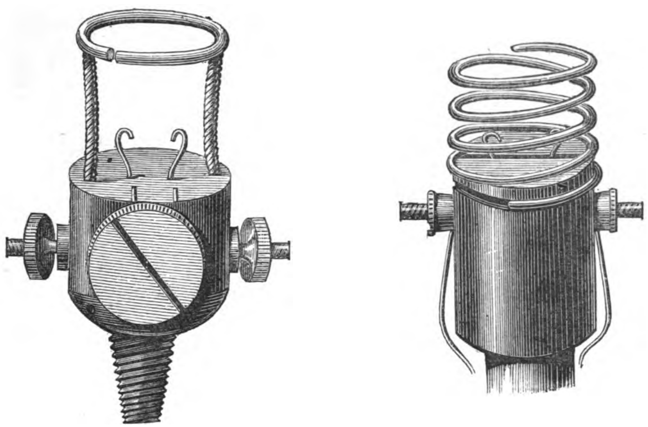

Fig. 22.—Holders with Spiral Springs.

(Fig. 20), the positive and negative wires are not joined at the ends, and a lamp-stand forms a connecting-link between the positive and negative leads or conductors; and to show you exactly what carries the electric current to the lamp, the inside of the lamp-stand is sketched.

You will notice that the wires go through the pipe, and end in two little hooks, which are distant from each other

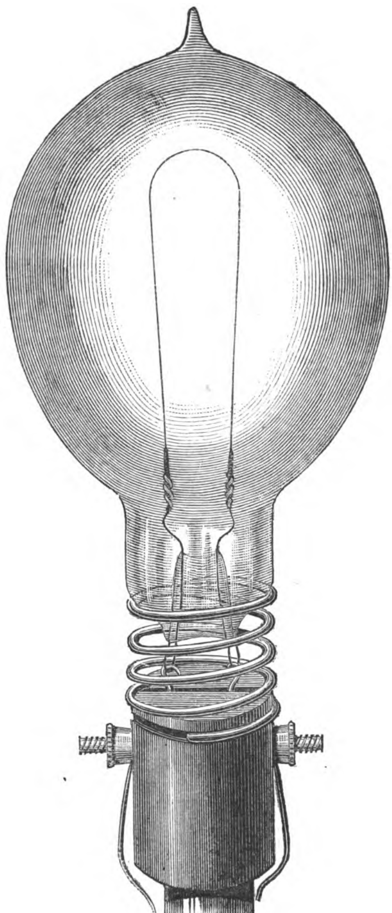

Fig. 23.—Lamp showing Path for the Electric Current within it.

about half an inch, so that if an attempt were now made to pass an electric current through the wire, the current would not be able to pass from the positive to the negative lead, because it could not bridge over the space between the two hooks at the top of the lamp-stand.

If, however, the incandescent lamp be held above the two hooks (Fig. 21) you will observe that the carbon filament inside the lamp makes a bridge, and if the two little eyes of platinum at the foot of the lamp be attached to the hooks, and kept in their place by a spiral spring (Fig. 22), the current will be able to get from hook to hook by the way of the little bridge inside the lamp (Fig. 23); and in passing through the very thin filament of carbon, it causes it, on account of its extreme thinness, to become white hot, and thereby light-giving.

So that if you have, say, nine pairs of wires, and attach them to the conductors leading from the positive and negative

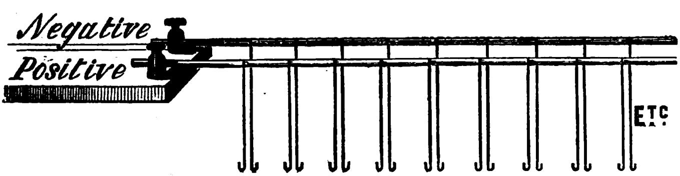

Fig. 24.—Circuit Open.

poles of an electric machine or battery (Fig. 24), and leave them unjoined at the tips—as seen in the above sketch—you will have provided no path for the electric current, because it cannot jump across the little space between the ends of the hanging wires; but if you attach to each pair of wires an incandescent lamp (Fig. 25), you bridge over the intervening space by means of the carbon filaments within the lamps.

The light so obtained is, then, that which we have arrived at in our search after a *perfect light*; and we must now proceed to test it by the conditions laid down, and decide whether it fulfils any or all of them.

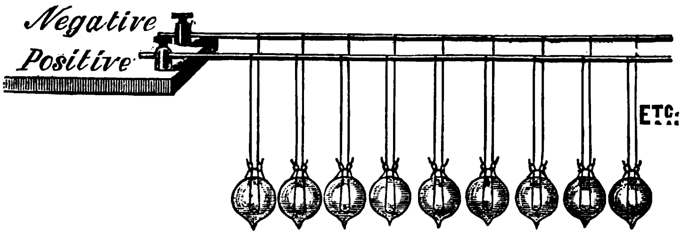

Fig. 25.—Circuit Closed with Lamps.

CHAPTER IV.

EFFECTS OF THE ELECTRIC LIGHT ON THE ATMOSPHERE OF OUR ROOMS.

No consumption of oxygen—No production of carbonic acid—No pollution of the atmosphere—The opposite and bad effects of gas.

A REFERENCE to the set of conditions* which the perfect light ought to fulfil, will show that the one we placed first was—

1.—*The perfect light should not rob the air of our rooms of oxygen.*

Well, there can be no doubt that the electric light which we have just produced exactly complies with this condition, for we have seen that, if oxygen could be absorbed, for only one second, by the carbon filament within this lamp, it would burn up, and the light would go out. In fact, in the incandescent electric light we have identically the reverse of the chemical phenomenon which is exhibited by all the older forms of artificial light.

While the existence of these depends upon a constant

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* Page 12.

supply of oxygen, the electric light depends for its existence upon the absence of oxygen.

How charming, then, for home use, and for use in our hotels, theatres, public halls, churches, railway trains, &c., will this light prove!

The headache which is the frequent consequence of the assembling of ourselves together, and which is generally produced by the scarcity of oxygen in the air, will be known no more.

Ladies, whose endeavour has been, for one hardly likes to say how many thousands of years, to look their best when the husbands or would-be husbands return from their daily toil, will not in future be made pallid by the absorption of this necessary element from the air. They will, indeed, be as fresh and as fair in the evening hours as when they are walking along the esplanade at Brighton, or taking a canter over its downs.

For this reason, I am sure that my plea for the introduction of the electric light into our homes will have their warm sympathy and hearty support.

To turn from the ladies to the doctors present—they will, I feel certain, agree that, under this head alone, I have proved the absolute necessity of the use of the electric light becoming general; for they know, far better than I, how insidious is the effect, in confined spaces, of the scarcity of oxygen, and how great a boon would be the universal adoption of a light which does not rob the air of one particle of this precious substance.

Let us think of the opposite effect which is produced by six gas-lights in an ordinary room, each light producing more deleterious effects on the atmosphere than five human beings. How uncomfortable you would feel if, on entering such a room, you found thirty people sitting in it and consuming the fresh air! Your first thought would be that the room would soon get uncomfortably "close," and you would not be consoled by your host telling you that these thirty people were doing no more harm than six gas-jets, with which you would doubtless be prepared to put up with perfect equanimity.

2.—*The perfect light must not add noxious fumes to the air.*

Again you may be referred, with complete confidence, to this little lamp, which has been manufactured as it were in all its stages under your eyes, and which you will observe is still shining as brightly as when we first passed the electric current through it.

We have just determined, in reference to this lamp, that on the slightest admission of the oxygen in the outside air the filament would burn up, and the light would go out; so it is evident that no possible aperture can exist in the glass bulb; and if no aperture for ingress exists, there is no place, even of the size of a pin's point, from which fumes, noxious or otherwise, can escape.

The only effect upon the air which this little lamp is producing, in addition to that proceeding from its light, is the radiation of a certain amount of heat, which has been calculated to equal one-twentieth of that generated by a gas-jet of the same illuminating power.

There are some who actually object to the electric light on account of the small amount of heat which it generates, and who say that gas is of immense use in the house for the purpose of heating the rooms; but when they are convinced that gas can only raise the temperature by distributing noxious fumes, they will, I feel certain, prefer in future to heat their houses by a more healthy method.

How charming, then, again one may urge, will be the presence in our rooms of light which will not be steadily adding noxious fumes to the air, and how much more healthful and enjoyable will the evening hours be rendered, when once the use of the electric light becomes general!

A short time ago, at a dance at my house, lighted, as one need hardly say, with the electric light, the rooms were found to be almost as cool and the guests as fresh at three o'clock in the morning as they were when the music began. This is very strikingly different from one's ordinary experience, for, after a dance, the brain is in a morbid state from exhaustion the rest of the night, and sleep is therefore difficult to obtain.

This exhaustion cannot be traced to the exertion of dancing, but almost directly to the inhaling of the bad air thrown off by the illuminants in the room. Our popular game of lawn-tennis, for instance, finds players among both sexes, who will start at nine or ten o'clock in the morning, and play, with only an hour's pause for luncheon, till six or seven in the evening, and, after that heavy amount of exertion, enjoy perfect and sound sleep.

On the other hand, if the same players were to begin dancing at nine o'clock in the evening, and continue till six or seven in the morning, what a different sleep would be theirs! In the one case the exercise is taken with a constant supply of oxygen to breathe, and with no carbonic acid or sulphur compound fumes to debilitate. In the other, an atmosphere is breathed whose vitality has been removed, and been replaced by poisons.

If the electric light were in general use, ladies would the next morning feel no worse effects from spending an evening at a party or at a theatre, than if they had spent the same number of hours in sitting on the esplanade at the seaside.

In the use of gas, not only is carbonic acid manufactured in our rooms, but certain noxious sulphur compounds are constantly arising from the gas-flame. These have a very distinct and disastrous effect upon our health, and also upon our decorations, furniture, paintings, picture frames, books, &c., &c.

At a lecture which I gave, a few months since, at Leeds, where the gasworks are in the hands of the corporation, it was stated, by one of the members of the municipality who was on the platform, that very recently a large number of volumes in the Free Library had to be re-bound, in consequence of the bindings having been almost totally destroyed by the sulphur compounds arising from the gas.

It is the experience of us all that a newly-decorated house, coming spick and span from the hands of the decorator, begins, from the day that it is lighted by gas, candles, or oil, to gradually lose its freshness, until a time comes when the whole of the work has at great cost to be done over again, and it is then discovered, too late, that the insidious chemicals, introduced into the house by the illuminants, have in some cases done a damage, especially to pictures, furniture, and books, which is irreparable.

On this point one may reproduce what has been written recently on the subject by Dr. F. W. Griffin, of Bristol:—

"Notwithstanding the obvious convenience of gas as an "illuminant, it has very serious drawbacks. It is com-"paratively poor in carbon, so that a large amount has to "be consumed to produce the necessary light. The illu-"minative portion does not exceed ten per cent. of the "whole, while the remaining ninety parts, though nearly "valueless for giving light, equally produce heat, and throw "off moisture and carbonic acid gas from their combustion.

"Hence rooms become far hotter and the air more vitiated "where gas is burnt than when the same light is obtained "from oil or candles.

"Any one who has never tried the experiment would "be astonished were he to mount a pair of steps and feel "what the air is like near the ceiling of a sitting-room in "which gas has been burning for some time. This alone "would injure wall-papers and hangings, as well as goods "on the upper shelves of shops; but the large amount of "water generated by the gas-flame adds to the mischief. "Sixty burners will produce on the lowest computation "two gallons of water per hour, hence in a November "evening many large shops filled with delicate goods will "have a nine-gallon caskful of water thrown into their "atmosphere in the form of steam, to condense on any cool "surface, as we often see it trickling down the windows in "winter. But worse remains behind. The sulphur, always "present in gas in larger or smaller proportions, according to the character of the coal employed, burns into "sulphurous vapour, which passes in the air to the state of "oil of vitriol.

"The eminent chemist, Dr. Prout, exposed water in a "drawing-room in which gas was burnt, and found that it "absorbed sufficient of these vitriolic emanations to redden "blue litmus, and show the presence of free sulphuric acid. "The fumes from gas will indeed, in the long run, dis-

" colour every sort of fabric, rust metals, rot gutta-percha, " and reduce leather (as in the binding of books) to 'a " scarcely coherent powder with a strongly acid taste.' The " late Dr. Letheby, in an able 'Report on the Coal Gas " Supplied to the City of London,' gives numerous instances " of the destructive effects of these products of gas-lighting. " Enormous damage had been done to the binding of the " books in the libraries of the Athenæum Club, the London " Institution, and the Royal College of Surgeons. In the " first-named, wherever the books had been exposed to the " atmosphere containing the vapours of burnt gas, they " were as rotten as tinder; indeed, it often happened that " the covers gave way in attempting to remove a book " from its place on the shelf.

" Bookbinders and booksellers gave similar testimony.

" A leading article in the *Times* (Jan. 14, 1854) stated " that the books in one of the rooms of the *Times* Office, " where gas was constantly burnt, shrivelled up and broke " after two or three years' exposure. The librarian of the " Newcastle Literary and Philosophical Society wrote that " a book which had been missing for thirty-six years was " sound and good when recovered, while the leather on the " books in the same binding which had remained in the " library had been utterly destroyed. He further wrote " that 'ventilators having been fitted over the chandeliers " of the library, half a gallon of water is collected of a

" night from the gas which is burnt there; this water is " so corrosive from the presence of sulphuric acid, that it " attacks all the metal fittings with which it comes into " contact, and thereby acquires a metallic impregnation of " copper and iron.' In the water which condensed in the " cistern of the ventilating burners of the Athenæum Club " House, Dr. Letheby found as much as 1¼ ounces of " sulphate of copper to the pint. My own laboratory is " supplied with distilled water from a small copper boiler " set over a ring gas-burner. The metal is strongly " attacked above the flame, and the slate beneath is covered " with flocculent sulphate of copper arising from its corro- " sion by the acid vapours. Drapers know to their cost " how the edges of pieces of dyed fabrics become faded " and rotten when kept long on the upper shelves of gas- " lighted shops; no plant will grow in a room were gas " is burning, and cut flowers quickly wither; while those " who work long and habitually in close gas-lighted rooms " become blanched and sickly."

These facts are so familiar to you all, that I need not, I am sure, dwell at greater length upon them nor upon the immense benefits which the electric light, by doing away with the evils alluded to, confers; so I content myself with drawing your attention to the indisputable fact that it completely fulfils the first and second conditions laid down by us as necessary in the perfect light,—

(1) *That it should not rob the air of our rooms of oxygen.*

(2) *Nor add noxious fumes to the air.*

CHAPTER V.

DOES DANGER ARISE FROM THE USE OF THE ELECTRIC LIGHT?

Danger to life—High tension *versus* low tension currents—Covered wires—Danger of fire—Safety fuses—Explosions impossible—Danger to health—No vitiation of fresh air—No leakage.

3.—*The perfect light should not be a source of danger in the house.*

It will be felt by all that this is a crucial point, and one with which I shall have to deal most completely if a case has to be established for the electric light; for there exist many who are willing freely to admit the great advantages already pointed out, but who are afraid that the introduction of the electric current into their homes will bring with it an insecurity far outweighing the comfort it will produce.

Though the gas industry has been fully developed for more than fifty years, we still hear almost daily of serious and sad accidents occurring through the use of gas; but, in consequence of the constant recurrence of these accidents, the public pay absolutely no attention to them, and the press satisfies itself with very meagre reports of calamities which have ceased to be novelties. Whereas, on account of its newness, any accident which occurs in connection with electricity is immediately reported and fully commented upon.

It is, indeed, well to remember that ranged against electricity is one of the strongest monopolies that the world has ever seen; and with shareholders in gas companies plentifully scattered all over the kingdom, there is present everywhere an active body of intelligent men ready to condemn the electric light, and to magnify the dangers arising from it.

While we must admit that serious accidents have occurred in connection with the distribution of very high tension currents in the past, we are able most positively to state that there is no chance of these accidents occurring in connection with the house-to-house electric lighting of the future.

It is a popular notion, but a fallacious one, that death or serious injury must inevitably result from touching wires conveying any electric current, be it strong or weak; but in order completely to dispel that illusion, if it be held by any one present, I will firmly grasp the two conductors charged with the electric current, which has been used from time to time this evening, for the purpose of making the wires red hot, and for the other electrical experiments (Fig. 26).

You will notice that, though the copper conductors are uncovered, and though there is no insulating material in my hand, I am able to grasp the two conductors with

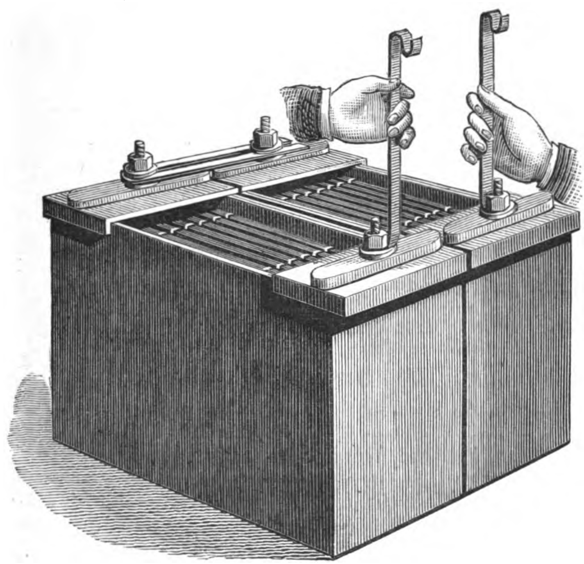

Fig. 26.

impunity, nor do I feel any unpleasant sensation whatever from the contact.

These two batteries are, however, capable of producing a very feeble current. Speaking technically, it has only an electro motive force of 4 volts, and a volume of 25 ampères—total, 100 volt ampères. It may interest you, therefore, to know that one may grasp, as I have done with equal impunity, the terminals of a very large dynamo machine, yielding an electro motive force of 100 volts, and a current of 650 ampères—total, 65,000 volt ampères.

Yet, on the other hand, you are doubtless familiar with the details of the sad accident that occurred at Lord Salisbury's, where a gardener lost his life by taking hold of the two wires leading to and from the dynamo electric machine.

What is there distinguishing the two cases? Simply the *tension,* or what we will call the "pressure," of the electricity used on each occasion. The current which proved fatal to Lord Salisbury's gardener, was that which was in use for arc lighting purposes, and *was of high tension*—again speaking technically, it had an electro-motive force of 800 volts;—whereas the current required for the incandescent lamps, proposed to be used in our homes, is a *low-tension* current, like the one flowing in the conductors which I am grasping, and from the *alternating current* dynamo machine, whose terminals I grasped, without feeling any ill effects.

We dispose, therefore, of the question of (1) *danger to life* by declaring most emphatically that—

(*a*) *The only current at the present time suitable for incandescent lamps is one which can be of no danger to human life.*

Your attention, however, must be drawn to the fact that the wires which were touched by Lord Salisbury's gardener, and also those which I am now touching, have no insulating material round them; and, though it has been demonstrated to you that no possible danger can arise from touching these particular naked wires, because they are carrying a low tension current, yet, as a matter of fact, all the wires conveying the electric current into our houses and into our rooms will be covered with some insulating material—cotton, silk, india-rubber, asbestos, bitumen, gutta-percha, &c., &c.

In my own residence the main wires running up through the house are heavily covered with india-rubber, which is again covered by a thin outer material of a similar colour to the walls. In the rooms, the thin wires leading from the larger mains are covered with silk of a colour to match the decorations, so that on this head one is able to say that—

(*b*) *Even if the wire did convey a current dangerous to human life, it would not be possible for any one in the house to be affected by it; because all the wires will be carefully covered by an insulating material.*

From the consideration of the question of *danger to life,* we pass on to the other latent danger which is supposed to lurk in electric lighting, that of (2) *danger of fire.*

You will remember that at an earlier period of the evening you saw how easy it was, by passing the electric current through a wire too small for it, to make the wire red hot. If that wire had been hidden away under a cornice, or embedded in a wall, the danger to surrounding woodwork is apparent; but the electric current and its conductors are so capable of easy manipulation that this danger can be absolutely guarded against.

This may be illustrated by a small experiment.

This conductor (Fig. 27) consists at each end of copper, but in the centre there is a piece of lead.

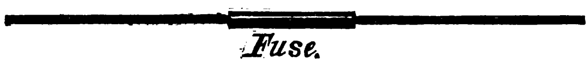

Fig. 27.—Conductor Joined with Fuse.

Now, lead not only has a higher resistance, but has also a much lower fusing-point than copper, and, therefore, a particular size of lead is far less able to withstand melting, by a given electric current, than the same size of copper; so that if the piece of lead inserted in the conductor be made of exactly that size which will break at the moment when an excessive amount of current, sufficient to heat the conductor, be passed through it, the immediate breakage or the lead will prevent the excess current from passing further and making hot the portion of the conductor which is beyond it.

Pray understand that under a proper electric light system this irregularity is not likely to arise; but to completely rob it of any danger, all we have to do is to take care that, at the entrance to every dwelling, where the house mains or conductors of the electric current join on to the main in the street, and again at the junction of the conductors through the house with those in the separate rooms, little safety-joints of lead or other suitable metal, in a handy form, be placed, care only being taken that they are of sufficient weakness to break immediately, and so stop the further passage of the electric current into the house or into the separate rooms, in case an excess current, sufficient to make the mains or conductors hot, should, by any mischance, be generated.

Let me illustrate this by passing an electric current through the conductor which I hold in my hand (Fig. 27). The end in my right hand represents the main coming in from the street; and the other, the conductor which passes through the house. Let us suppose that the current supplied from the central station becomes, by some very unlikely accident, sufficiently strong to make the house-main hot, if it should be allowed to pass along it, then its very strength will at once break the lead safety-fuse connecting the street main with the house main, and by its breakage prevent the entrance of the excess current into the house.

Suppose, however, that the current be not strong enough to overheat the house main, but is strong enough to overheat one of the little conductors running from the house main into an adjoining room, then again the same principle comes into force, for whenever a subsidiary and smaller main leaves a larger one, the same device can be used, thus (Fig. 28). Therefore it is evident that—

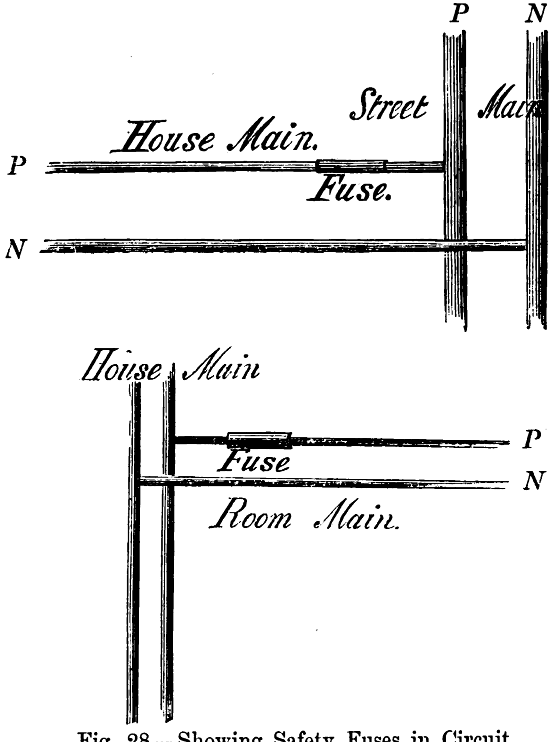

Fig. 28.—Showing Safety Fuses in Circuit.

(*c*) *By the insertion of safety-joints, the danger of fire in a house can be completely guarded against; because the moment the current enters the house, or any one room, in* *sufficient intensity to overheat the mains, it would be cut off in its progress, and allowed to go no farther.*

So fully is this recognized by the insurance companies, that, provided these safety-fuses be adopted, they are willing to take the fire risk in electric-lighted houses at the same premium as in houses lighted by other means.

I feel, indeed, justified in looking forward to the time, and that at no great distance, when the insurance companies will be prepared to place the electric-lighted houses or premises upon a more favourable rate than those lighted by gas; for I contend that, with the electric light wires properly run, the danger of fire in a house or in a factory is minimized, and almost completely guarded against.

It is universally admitted that fires in private houses, country seats, factories, &c., may almost always be attributed to something connected with the lighting: a candle is left burning by a bedside and sets the bedclothes on fire; a naked gas-bracket is pushed too close to the wall, and the woodwork of the room ignites; a lamp is accidentally overturned, as in the case of the recent Hampton Court Palace fire, and the room is in a blaze immediately; a falling candle touches an actress's dress, and a life passes away in agony; the naked gas-jet sets fire to the flies, and in a couple of hours a theatre is destroyed; a spark from the taper that is used for lighting the gas smoulders between the oaken boards, and one of the noblest country seats in England is reduced to ashes;

the almost invisible films of cotton floating in the air in a factory encounter the naked gas-flame, and £50,000 worth of damage is done in a few hours; the ignition of the escaped gas from a gas-jet left on all night, in a small room, causes an explosion and a fire which destroys one of the most valuable mills in Oldham; a lace-worker in Nottingham, peering for the broken threads on the lace machine, brings the gas-jet at the end of the "universal joint" an inch too near, and a factory and thirty lives are sacrificed. *

Surely this unhappy state of things which characterizes our present defective modes of lighting will be no longer tolerated in our country, and careful consideration ought now to be given to the immense advantages which the electric light offers, in providing complete immunity from fire risks.

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* While going to press, we extract the following from the *Electrician* of January 5th, 1884:—

"THE BURNING OF THE BRUSSELS HOUSE OF PARLIAMENT.—A Belgian contemporary points out that the burning of this national building was brought about by the use of sun-burners, as they are called, or an aggregation of gas-jets beneath a reflector. It reminds us that electric lighting on two systems, the Lampe-Soleil and the Edison were tried some time since in portions of the house, notably the library, and given up as being too dear. Our contemporary asks what is the difference between the extra amount to be paid for electric lights and security, and gas which leads to the loss of an invaluable library and costly building, the rebuilding of the latter of which will take many a pound out of the pockets of the nation, whilst the former cannot be replaced?"

In the first place, no match or taper has to be used to light the electric light; it can be turned on and off as frequently as may be desired by simply twisting a tap or pressing a button. One turn of a switch in my own house can start every light into existence, and a touch of a knob at my bedside extinguishes every lamp.

In the second place, it is evident that when the light is burning there need be no fear of the ignition of neighbouring curtain or woodwork, for the heat generated is too feeble to do any damage.

It will be noticed that hitherto we have referred solely to the dangers arising from the *wires* in an electric light system, and there only now remains the question of *the danger from the light itself.*

On this point I am sure that you will allow me to be brief, for if anything has been demonstrated this evening, it certainly is proved that no possible danger can arise from the lamp itself, since any breakage of the globe immediately extinguishes the light.

But this may be further shown by a small experiment.

Here is a light piece of gauze, dipped in an inflammable material; and when it is torn in halves, and one piece ignited with a match, you notice how rapidly it burns; so rapidly, indeed, that if it came into contact with a candle or gas-flame in an ordinary house, the house might quickly be in flames.

We will wrap the other half round this reading lamp (Fig. 29), and proceed to break it.

It looks so frail that you will doubtless be surprised to hear it is not very easy to do so; for though these bulbs

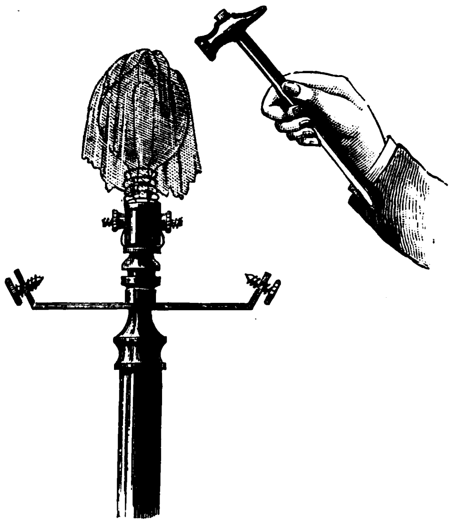


Fig. 29.

are extremely light, and the glass is by no means thick, the shape is such that pressure from without is resisted. By dint, however, of using this small hammer the lamp is broken (Fig. 30), with the result, you will notice, that the light is immediately extinguished, and that the piece of gauze, which now contains the broken glass and filament, is absolutely unsinged. You will see, therefore, that—

(d) The breakage of the incandescent lamp, though it may be surrounded with a piece of inflammable material, does not set that material on fire.

How perfectly, then, is the danger of fire eradicated by the use of the electric light! Though addressing you this evening on the subject of the electric light *in our homes,*

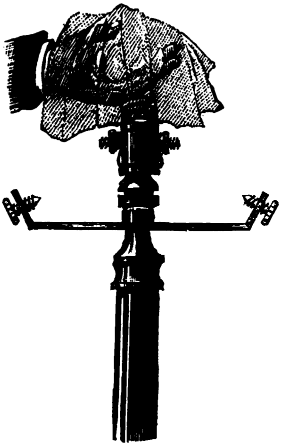


Fig. 30.

one may venture to point out to you, in passing, how extremely valuable will this light be when it is generally applied to manufactories throughout the kingdom. How often do we hear of cotton, calico printers', lace, paper, and hosiery mills, &c., being entirely destroyed through the ignition of some little scrap of material by a naked gas-flame!

We have now considered fully all the possible dangers arising from the adoption of electric lighting in our homes; but you will not be surprised to hear that there are many who imagine that far greater and more latent dangers exist than those which I have referred to.

To give an instance. A new servant came into our house some little time ago, and everything went happily for the first day; but when she found that we were lighted with the electric light, she passed a restless night, and appeared the next morning with a touch of haggardness in her countenance.

This look of distress, indeed, did not wear off with a few days' experience, but got more marked. At last she begged to be allowed to leave a house where she was put into so much terror. It was in vain that the other servants explained to her that no danger could possibly arise, and showed her—for my servants are great authorities on the electric light question—that she had nothing to dread. She persisted in her intention of going, fearing evidently that some night she would find herself, bed and all, blown into the street.

This you may perhaps consider to be an exaggerated case; but at a meeting of the Town Council of one of the most enlightened boroughs of England, not more than a month ago, a discussion on electric lighting took place, in which two members, at least, shared my servant's opinion, that a "blow-up" might at any moment occur.

When we deal, a little later on, with the *production* of the electric current, we shall see that, though the danger of a possible explosion, with all its fearfully disastrous consequences, is always present in a house lighted by gas, *an explosion from the electric light is absolutely impossible.*

The only thing that can occur in electrically-lighted houses is the overheating of the wires, which overheating, we have seen, would certainly be completely guarded against.

Having therefore shown you that there is (1) *no danger to life,* and (2) *no danger of fire* in the use of the electric light, I consider that my task under this head is accomplished. But before leaving the subject of danger, I may also urge that there is (3) *no danger to health.*

This point has been pretty fully dealt with under the head of the non-abstraction of the oxygen of the air, and the non-vitiation of the atmosphere; but I may illustrate the absence of another danger by a short anecdote.

A friend of mine whom I had missed from my club for a long period, accosted me a few days ago, and on my expressing surprise at the time that had elapsed since I last saw him, he told me that he had been a sufferer for many months from a disease which his doctors had all failed to trace to its right source.

He felt greatly debilitated at home, and was constantly urged to try the effect of a change of air. Whenever he went away his health was restored; but, when he returned, ill health again attacked him. His physician questioned him very closely as to the state of the drains in his house, and he had them thoroughly overhauled and declared perfect. At last, at the close of one of his calls upon his physician, that gentleman insisted upon going to examine my friend's house himself, and after failing to discover any clue to the cause of his illness in any other part, he went into his bed-room, where he immediately detected an escape of gas, which had become so familiar to my friend that he had not noticed it. This escape of gas was found to occur a few inches from the bedside, and whenever he returned home, he had unconsciously, night after night, been inhaling a poison. This leak having been stopped, his health was restored, and he is now as strong as any gentleman in this audience. I need, perhaps, hardly say that the electric light *does not leak,* and that from its use such a case as this could not arise.

CHAPTER VI.

THE ARC AND INCANDESCENT LIGHTS COMPARED.

Importance of the verdict of the fair sex—Arc lighting unsuitable for home use—The arc light and its flickering explained—Effect of the electric light upon the eyes.

4.—*The perfect light should not be an unpleasant light.* This statement may appear a little vague; but in it how much is involved! For if with all the advantages of the electric light it should prove a nuisance in the house, it would be universally rejected; and if, on the other hand, it prove a source of comfort, how much more welcome it becomes!

At an early stage of the world's history, every one no doubt retired to rest when the sun went down; but in these days it may be said that, whatever the rank in life, the brightest and best portion of our lives is spent in the evening hours, when the cares of the day can be set aside, and all the comfort within our reach be thoroughly enjoyed.

In this home life the gentle sex play so important a part that I appeal confidently to those present to decide whether

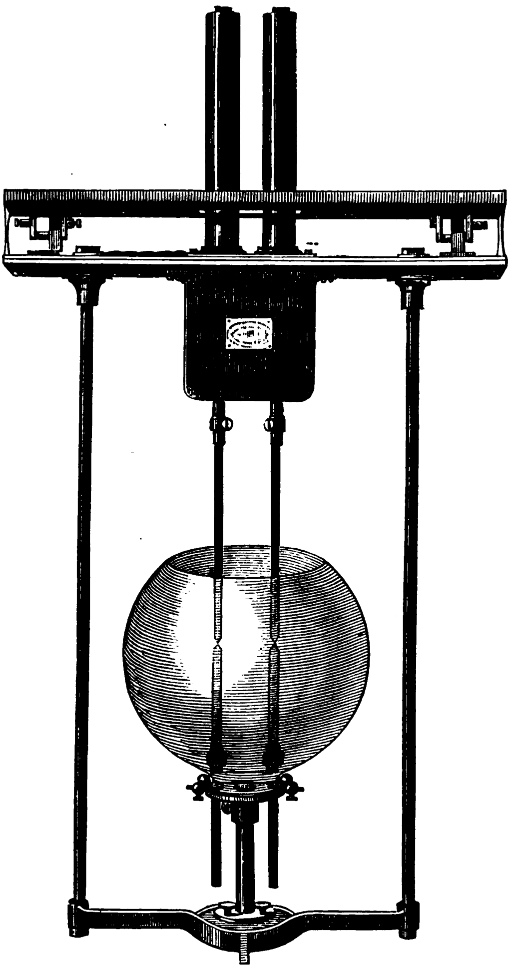


Fig. 31.—Arc Lamp.

the light surrounding us this evening is a "becoming light or not; for if I have their adverse vote upon this question, I think I had better at once give up the advocacy

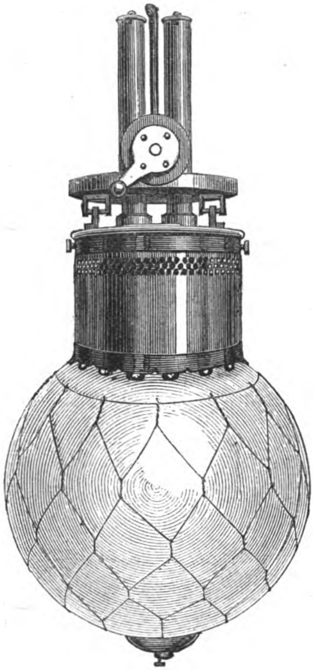


Fig. 32.—Arc Lamp.

of the new illuminant. If, on the contrary, they decide that it will improve their good looks, instead of detracting from them, I shall feel much more hopeful.

Up to the present time one fears that the electric light has not had the support of the ladies of England, because, till now, their experience of it has been almost entirely

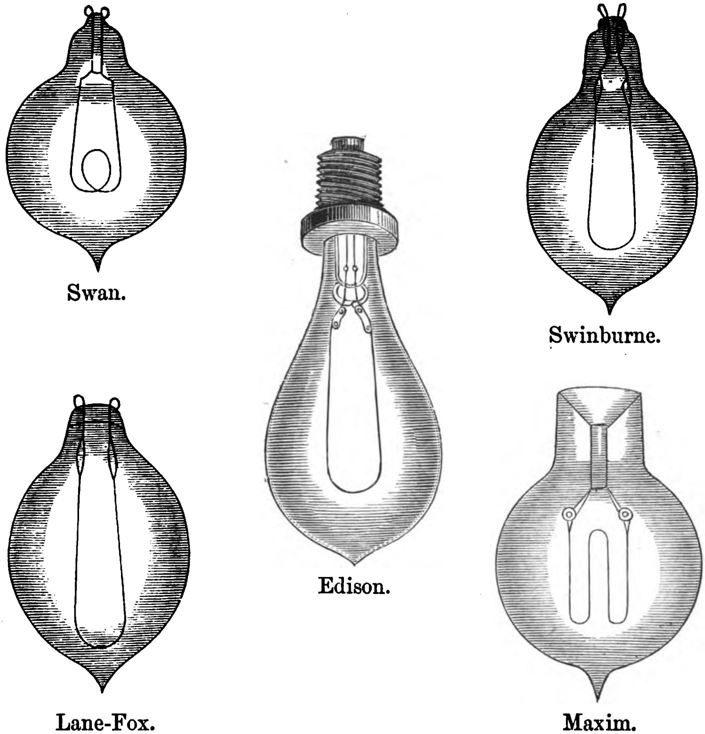


Fig. 33.—Incandescent Lamps of various Makers.

confined to the arc lamp (Figs. 31 and 32), yielding a light which, though admirably adapted for streets, public halls, railway stations, ship yards, docks, harbours, steel works,

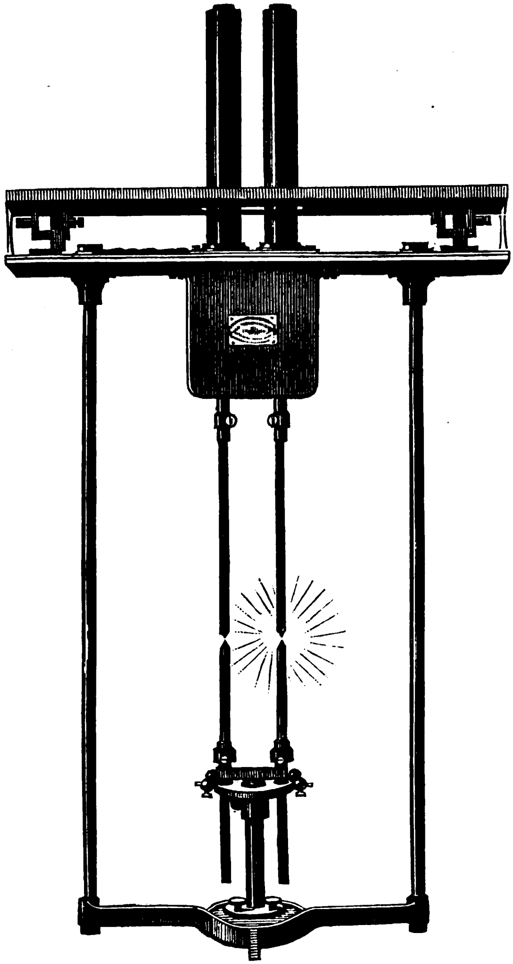


Fig. 34.—Arc Lamp.

manufactories, &c., is absolutely unfit for home use; whereas the light which is brought before you this evening, as thoroughly suitable for the illumination of our homes, is that obtained from the incandescent lamp (Fig. 33).

To show how widely different the two forms are, it may be well to explain how light is obtained from the arc lamp, and why the flickering in it takes place. When the globe is taken off, you notice that the light is proceeding from one point in a very intense form (Fig. 34), and when you closely examine this spot, through a piece of darkened glass, you see the crater from which the light is proceeding (Fig. 35).

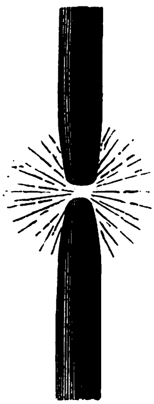


Fig. 35.—Crater in Arc Light.

When dealing with the source of light in the incandescent lamp, we decided that the electric current could not, unaided, jump from one point to the other, whereas in the arc lamp the intense light obtained is emitted from the little open space of air through which the electric current is steadily leaping; but to render it possible to perform this leap it has had a little assistance, the nature of which I will explain.

When an arc lamp is at rest, before the current is passed through it, there is no vacant space between the carbons, as the top one is resting on the bottom one (Fig. 36). This is absolutely essential to the lighting of the lamp, because if the two points were even only a slight distance apart (Fig. 37) no current would pass, the circuit, as already illustrated, being broken.

With the carbon points touching each other, however (Fig. 37A), the circuit is complete, and when the dynamo machine is set in motion a current passes from point to point; but the contact between them not being very perfect, the two points begin to glow with great heat, and then by a very ingenious piece of mechanism inside the box at the top

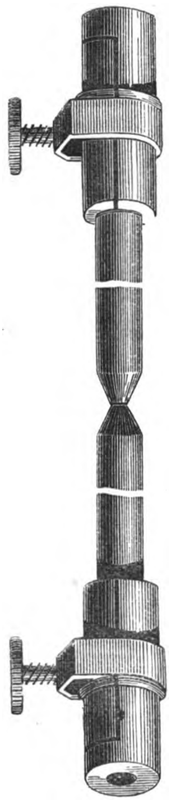


Fig. 36.

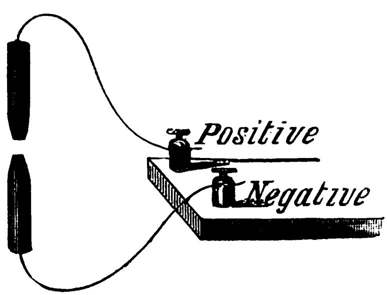


Fig. 37.—Carbons Apart.

of the lamp (Fig. 38), the moment the current has passed, and a complete circuit has thereby been formed, the top carbon is slowly drawn upwards, and a space of about a quarter of an inch left between the top and bottom carbons.

The electric current which was passing between the two points when they were touching each other, is not broken by the points being pulled slightly apart (Fig. 35), because air, when intensely heated, becomes a conductor.

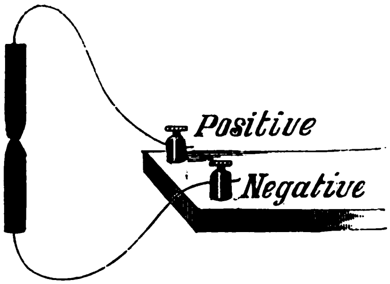
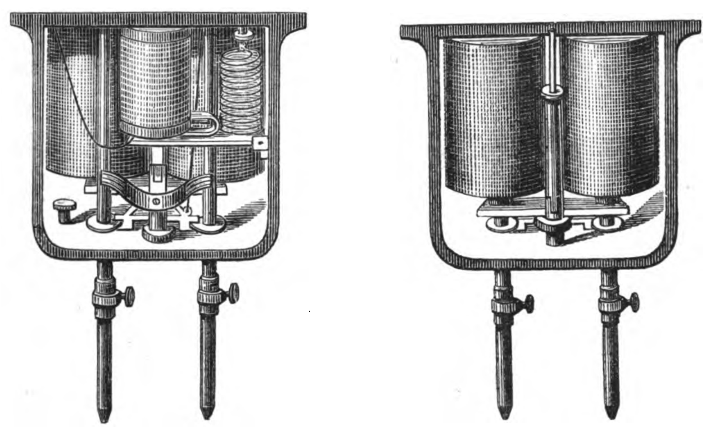


Fig. 37A.—Carbons Joined.

It leaps, therefore, from point to point with almost incredible rapidity, tearing away in its passage particles from the top stick of carbon, and depositing the unburnt particles on the lower one, rending also the air contained in the intervening space, and, as a net result of its chained fury, throwing out intense light.

If from any cause the intervening space between the carbon points be unduly lengthened, the current, having, as it were, a limited leaping power, will be broken and cease to flow, so that, as the carbons are being steadily burnt away as long as the light lasts, it is necessary that some mechanism, per sketch below, should be provided by which the top carbon shall be pushed down at identically the same rate as that at which both carbons are being consumed.

This mechanism is of course very delicate, and the diffe-



FRONT. BACK.

Fig. 38.—Regulating Apparatus in Arc Lamp.

rence between the arc lamps of the various inventors is a difference in the mode of adjusting or "feeding" the carbons.

However exact the mechanism, it sometimes happens that the top carbon is pushed down too far, with the result that the light for a few seconds becomes very dim, because the space between the carbon points has been made too small;

at other times the top carbon is held too far away, and then the light becomes unusually brilliant.

The endeavour of the mechanism of the lamp to keep the carbons at an exact distance apart, when successful, produces steady bright light, and, when unsuccessful, is the cause of those various "bobbings" and "flickerings" which, though of practically no importance when a number of arc lights are erected in one large open space—as in a railway station, on an esplanade, or in works—would be justly regarded by you as great drawbacks if an attempt were made to introduce the arc lights into our drawing and dining-rooms.

The light itself, too, is popularly called a blue light, and does not, I must acknowledge, show off to advantage the natural beauty of the Anglo-Saxon race.

Two years ago the stewards of a fashionable ball in a garrison town thought they would provide a pleasing surprise in lighting the ball-room with the electric light. Now, unfortunately, the light chosen by them was the searching arc light, and I am sorry to say that, for some reason—up to the present time, of course, quite unknown to me, for one does not in any way pretend to understand the mysteries of ladies' toilets—two or three noble ladies preferred to sit in the shade during the whole of the evening, rather than dance in the full effulgence of the arc light. We may, however, be inclined to think that some question of colour came into play—whether it was too much colour or too little, the ladies present are at liberty to judge. I certainly determined from that hour never again to be a party to placing any lady in such a delicate position as that in which those unexpectedly found themselves that evening. This form of electric lamp has, however, been used with very great advantage in some of the large drapers' establishments in London and in the country.

You will, however, kindly remember that we have banished the arc light entirely from the domain of domestic electric lighting, and are dealing only with the incandescent lamp, which adds to, instead of detracting from, the beauty of the home.

The dark shadows thrown by arc lights sparsely placed, are banished by the use of incandescent lights of moderate power, which, in proportion to their brilliancy, cast no more and no less shadow than other forms of artificial light.

It will, perhaps, enable you to form a sounder opinion upon this branch of the subject if the arrangements which I have in use in my own house at Highgate are described to you; but before entering upon this description, there is one point bearing upon this part of the subject to which it will be well to refer.

I have ventured throughout my lecture to trespass occasionally upon the domain of the physician; and in these days, when everything affecting our body is so carefully considered by the medical papers, I feel bound to touch upon the question whether the electric light affects the eyes unfavourably or not.

One is ready to confess that, if you sit and gaze steadily at the little filament inside an incandescent lamp, your eyes suffer in consequence; but, on the other hand, if you watch the softened form of electric light which has been placed before you this evening, as little as you watch a gas or candle-flame, your eyes will not suffer more.

Indeed, I am inclined to go further, and to say that, while the constant fluctuation of a gas-flame keeps the retina of the eye in a constantly varying vibration, the uniform volume of light received from an electric lamp makes it more comfortable and less dangerous to the eyes than any other form of illuminant known.

Of course there are some present who will tell me that the electric light is always "bobbing" up and down; but you who have been gazing uninterruptedly upon the lamps around me this evening, have seen lights in which no flicker has occurred; and you will have a perfect right to demand the same steadiness when you have the electric light put into your homes.

But supposing, from any irregularity, a change took place in the amount of current passing round the circuit, it must be remembered that though an excess of current would make the lights go up in brilliancy, and a diminution of the current would make them go down, yet the change in the intensity would only affect the lamps for one second, and they would then continue to give the same volume of light, from moment to moment, instead of fluctuating every tenth part of a second, as a gas-flame does.

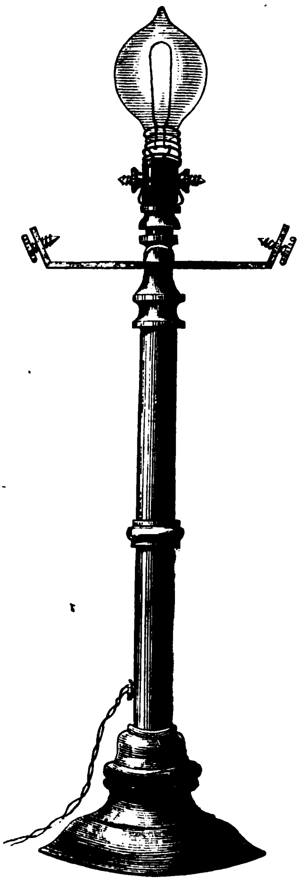


Fig. 39.

Let me afford you a slight illustration of what can be done with the electric light where weak eyes are to be considered. There is fixed to the reading-stand before me, an incandescent lamp of low resistance giving a very bright light (Fig. 39), and I see some, in the front row, who are gazing steadily at it, blinking their eyes. This is, however, the usual result of looking at any bright light. In gazing directly at this one, you are, of course, acting in an exceptional manner; for one has yet to meet the man engrossed with professional, business or political cares during the day,

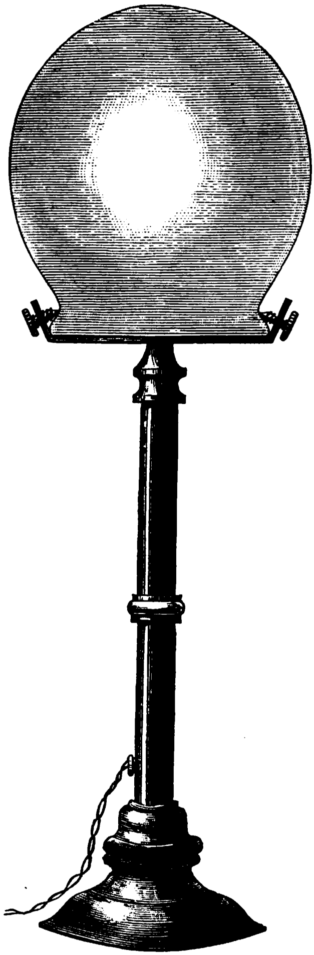


Fig. 40.

or the lady with her multifarious occupations, who spends the evening hours in gazing at the light which illuminates the room. But if, by chance, an occasional glance should be directed towards this bright lamp, and such a glance should affect the eye unfavourably, let me show you how easily it can be covered.

We take this creamy-white globe, which you will notice is not open at the top like a gas-shade, because we are able to make our outer globes, when their use is considered necessary, of a pretty oval form. With the reading-lamp covered in this manner (Fig. 40), how nicely moderated the light becomes!

"Ah!" says one, "but I don't like white light in any form. I have an intense yearning for the beautiful, and would prefer a peacock-blue to the purest white you could show me."

Well, here is a globe of that colour, and when it is fixed on the lamp-stand, which you will notice can, as far as the wires covered with silk will allow, be moved from table to table with ease, we have a "thing of beauty," which the closest adherents of that gentleman who was disappointed in the Atlantic, and thought Niagara a vastly overrated performance, would desire to look upon. In fact, one could imagine a disciple of his spending hours in the contemplation of this charming light, varied only by an occasional sniff at a lily, or a sigh over a sunflower.

Enough, however, has been said to show that the electric light can be so arranged as to prevent it affecting the eyes unfavourably, for it can be manipulated and moderated to any extent that may be required.

CHAPTER VII.

THE ELECTRIC LIGHT UNDER PERFECT CONTROL.

No scientific knowledge required in the handling of an electric light switch—The lights can be turned off in groups or singly—The light can be moderated—A home lighted by electricity—All the conditions of perfect light fulfilled.

In the course of the description of the electric light installation in my own house, I will show you how simple the whole system is, and, in doing so, you will, I hope, be convinced that the electric light fulfils completely the fifth condition laid down, *i.e.*,—

5.—*The perfect light must not be difficult to control.*

It has been stated that if the use of the electric light were general, our cooks, housemaids, and footmen would have to be trained electricians and mechanics in order to manage it. Well, if you will watch me going the round of this room, you will see how unscientific are the means used to turn on and off the lights.

One has simply to twist the switch (Fig. 41) near the door to put out the whole of the lights in the room. With a backward movement of the switch they are all turned on again.

No need for matches—that latent source of danger in every house. No need to have droppings from wax tapers on our floors and tables. The moment the light is required

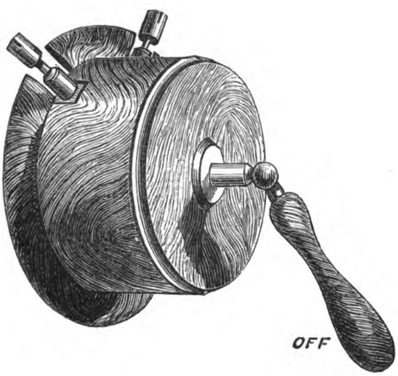


Fig. 41.—Switch.

it can be had, whether in the middle of the day or in the middle of the night.

The lamps in the room are now all on again; and by pushing upwards this switch (Fig. 42) at the side of the mantelpiece, the lights in the chandelier in the centre of the room are turned off. A push downwards turns them on again.

In Figs. 43 and 44 you have a different form of switch, in which the cause of the going out and coming in again of the light is manifest. It will be noticed by Fig. 43

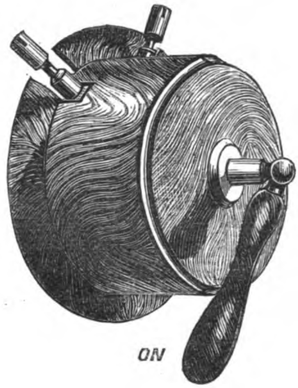


Fig. 42.—Switch.

that when the knob is brought down, contact is made

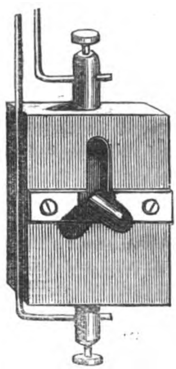


Fig. 43.—Current Switched On.

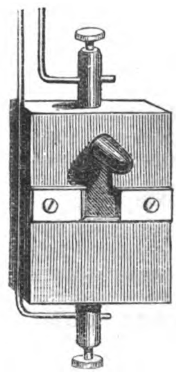


Fig. 44.—Current Switched Off.

between the two pieces of brass with which the positive wire is joined, and when the knob is pressed upward the connecting piece of brass disappears, and there is no path for the electric current, the circuit being in the same state as if it were cut in two, and the current thereby broken.

When the chandelier switch is left on and we reach up to each individual light, we can turn them out separately.

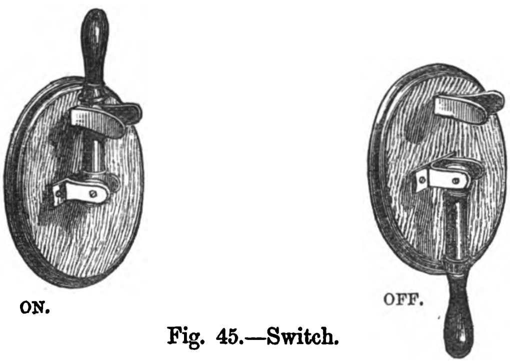


Fig. 45.—Switch.

A twist of this little switch (Fig. 45) puts out the light above the fish globe in which the fish have been disporting themselves the whole of the evening with so much evident pleasure. A twist of that one extinguishes the light on the reading desk, and a turn backwards produces it again.

Can it really be said, after this, that the electric light does not fulfil the condition of being under perfect control? Why, my little boy, of seven years old, knows as much about this part of the subject as I do, and, with a switch attached to his bedside, can turn on the light in his bed-room whenever he requires it.

At one of my lectures a lady was heard remarking that it was a disgraceful thing for me to allow a child so young to have a light in his bed-room at all. This lady, apparently, was unable to divest her mind of the danger accompanying the use of lights in a child's room, because, with matches and a gas-flame or candle, he would almost certainly set the house on fire. Hence the deeply-rooted objection, born of a quarter of a century's experience of gas, to put a light under a child's control.

But let it be understood that, in the electric light, all these dangers are banished, and you will no more hesitate about putting an electric light in the children's nursery or in their bed-rooms than about placing a glass of water there.

"Yes," it has been said, "I see you can turn the light on and off; but you cannot turn it down so that only a faint light is burning." Well, on this point one feels that, as long as it is possible to get light as often as you require it, by twisting a switch, it is no use providing for turning it down at all; especially as it is an extremely unhealthy practice to have a light, however moderated, burning in a bed-room, complete darkness being a necessity of healthy sleep.

In order, however, to enable me to reply to the objections of the most captious critic, there has been fixed upon the wall something which will, I think, work to your entire satisfaction.

We first turn out the whole of the lights in this room, with the exception only of those in the central chandelier, containing, you will notice, five lights burning at their full power.

One little turn of this handle has reduced their brilliancy slightly.

A second turn is given it, and we get less brilliant light; at the third turn, still less brilliant; the fourth turn, still less; the fifth turn, feeble light; the sixth turn, a mere glimmer; and at the seventh, complete extinction.

The process is now reversed.

The first turn gives a mere glimmer; the second a trifle more light; the third more light; the fourth still more light; the fifth still more light; the sixth almost full light; and the seventh complete brilliancy.

You therefore see that the electric light can, if necessary, be turned down to any extent.

Having shown how absolutely the lamps on this platform are under control, I will proceed to describe the electric light as it is fitted up in my home at Highgate.

On approaching the house, the bright light issuing from the lamp hanging in the porch marks it out from its neighbours (Fig. 46). Within the globe there are three incandescent lamps, and by using a little switch there can either be one, two, or three lamps alight at once.

On opening the front door, one finds in the inner hall a couple of electric lamps hanging in a lantern made up of coloured glass (Fig. 47).

In consequence of the absence of uncovered flame con-

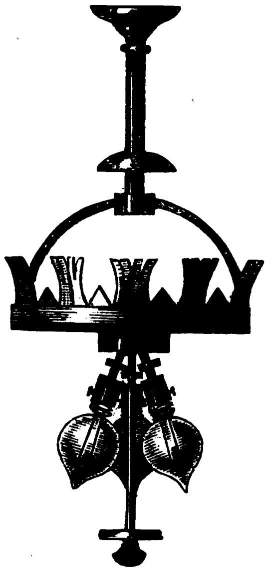


Fig. 46.—Porch Lamp, with Globe Detached.

stantly darting upwards in the electric lamps, they lend themselves very readily to almost all forms of decoration, and we shall be able to see later on that they can be put into positions where neither gas nor candles could figure.

In a little anteroom used for hats and coats, &c., there is one light with a switch attached to it, so that it can be brought into use on entering the room; and as this room of course only used for a few minutes at a time, it is very

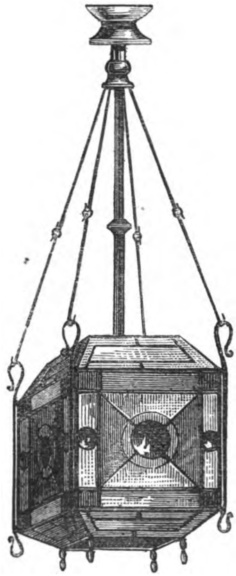


Fig. 47.—Hall Lamp.

handy to be able to switch on the lamp on entering, and to switch it off again on leaving.

In the inner hall there are two lamps (Fig. 48), shedding a beautiful light through the hall and up the staircase.

On entering the drawing-rooms (*see frontispiece photograph*), many of the very pretty effects from the use of the electric light are observable. There is, in the first place, no glare. From the photograph it will be noticed that the lights are almost all arranged round the walls. They spring from the centres of shields or sconces (Fig. 49). The oval-shaped glasses (Fig. 49A) which are used for covering

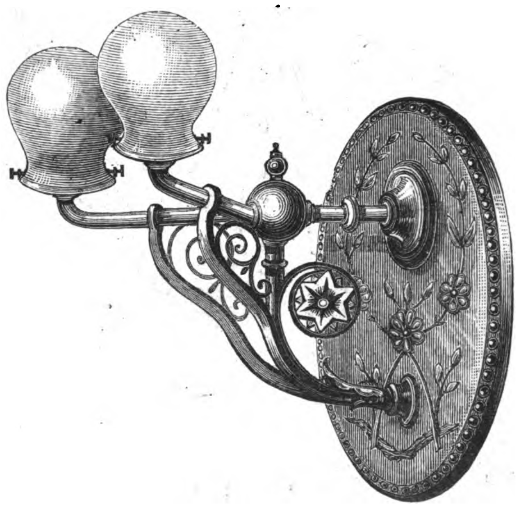


Fig. 48.—Double Bracket Lamp.

up the light are of different colours, and therefore the light in the room becomes beautifully softened, and the effect of the milky-white globes, in contrast with the dark-pink coloured ones, is extremely pretty.

Above the alcove between the two rooms there are two lamps which are not covered by globes (Fig. 50), and these

DINING-ROOM LIGHTED WITH ELECTRIC LIGHT

shed a bright light into both rooms; and there is a lamp above a bowl of fish (Fig. 51), having a pretty effect.

Wherever the light goes colours are beautifully preserved, and cut flowers can be kept in the room for many days without fading.

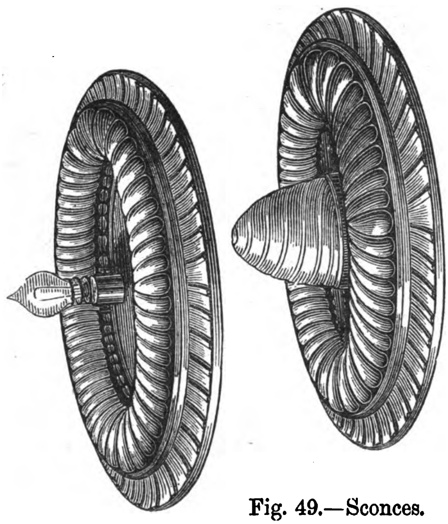


Fig. 49A.
Covering to Sconces.

Fig. 49.—Sconces.

The general effect of the electric light in these rooms has been considered very pleasing by all who have seen it, and ladies have been the first to declare that, fitted up in this way, it is a pleasant light.

Each light in these rooms can be turned out separately, and the whole of the lights in either can be turned out at once, so that if we are sitting in the smaller room we can, if we desire, have the other in complete darkness, or *vice versâ.*

Passing from the drawing-room into the dining-room (*see photograph*), you find exemplified a different mode of arranging the lamps.

It will be noticed from the photograph that, with the excep-

Fig. 50.—Light over Folding Doors.

tion of a light on each side of the mantelpiece and one above the fish-bowl, the whole of the light is thrown down upon the dinner table; and as the central chandelier is one which you may like to examine more minutely, I show you a sketch of it (Fig. 52). Each one of the lamps in this chandelier can be turned out singly, or, when the dining-room is left, the whole can be turned out with one switch, leaving only the two lights at the mantelpiece and the hanging light over the fish-bowl to illuminate the room while the things are being cleared away from the table.

This central chandelier has a beautiful effect. The flowers under the pure white light preserve their natural

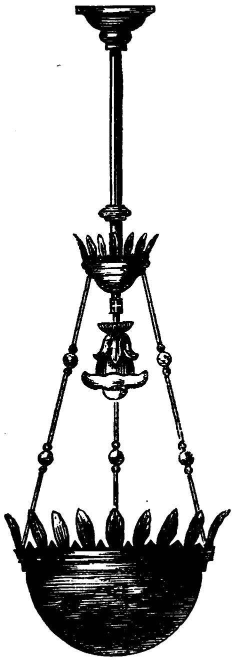


Fig. 51.—Light above Fish-globe.

colours, and look their very brightest, and the glass and the silver are set off to the best advantage.

I do not wish to weary you with the description of all the remaining lights in the house, but I may say that every nook and cranny in it is so lighted, there not being a single gas-jet in use nor a gas-pipe in the house; indeed, electric illumination in my house has been carried so far as to have even the coal-cellar lighted with it.

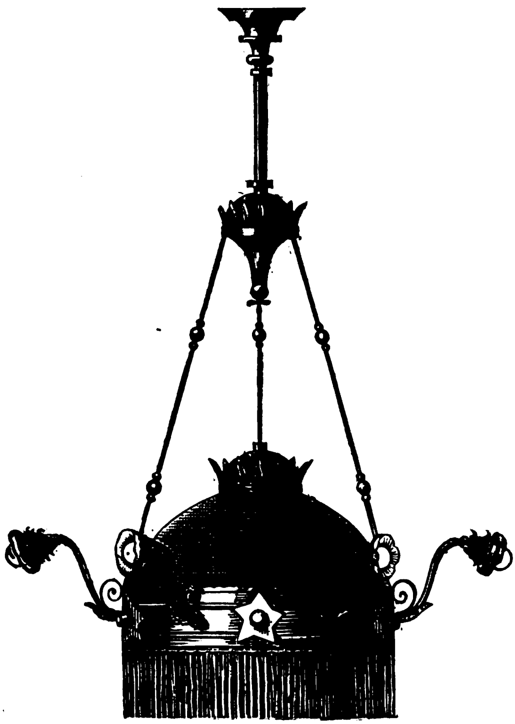


Fig. 52.—Dining-room Chandelier.

In the wine-cellar it is extremely handy, because during the few minutes that are spent there a bright illumination can be obtained by turning the switch attached to the electric lamp; and there is no danger of a candle setting fire to straw, &c., nor of a gas-jet being left burning.

In the bed-rooms, the lamps are covered with milky-white globes (Fig. 53), and in the nursery we are able to indulge the children with a Chinese lantern arrangement (Fig. 54), without running the risk of setting fire to it.

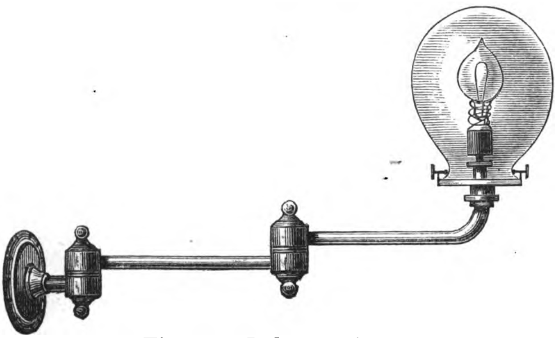


Fig. 53.—Bed-room Lamp.

In the small library there are two lamps, one (Fig. 55) being suspended from the ceiling, giving a light under which it is very comfortable to read. The books are as fresh as when new, no damage whatever being done to the covers by the illumination.

We are able to light the conservatory and to have plants growing there in the evening, as when the sunshine has been absent almost all day, the electric light to a certain extent supplies its place.

At the end of the garden the summer-house is illuminated with a lamp hanging from the ceiling, so that on summer evenings fresh air and a book can be enjoyed at the same time.

Fig. 54.—Chinese Lantern Arrangement for Nursery.

The London correspondent of the *Western Times* has referred to the lighting of my house as follows:—

"The great point is the fascinating beauty, coolness, softness, and charm of the light, in the various forms of lamp in operation in the household, and the happy simplicity of its manipulation. The manner in which the light is summoned, increased, or banished by the movement of a finger is like enchantment. The colour and tone of the illumination are exquisite. And it spoils nothing. This is a matter as worthy of the attention of the tradesman in his shops and warehouses as of the lady of the house considering her pictures, her upholstery, and the articles of luxury and delicacy wherewith her rooms are made attractive. It is a most especial acquisition in the ball-room, which, supplied with gas, can never be kept cool enough. There had been a dinner party in the dining-room, but the atmosphere of the apartment was on my arrival exactly like that of the drawing-room, and was really cooler than is a drawing-room illumined by wax candles."

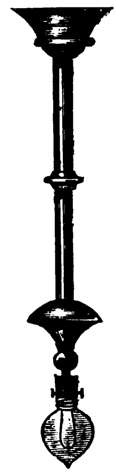


Fig. 55.—Library Reading-lamp hanging from Ceiling.

Passing from this particular instance of house lighting to the general question, it will be noticed that we have now carefully gone over all the conditions that were laid down by us as those which should be fulfilled by a perfect light, except the one relating to *cost;* and we have seen, in each case, how completely the electric light fits in with these conditions.

It is under complete control;

It can be applied so that it does not affect the eyes unfavourably; 7

It is a pleasant light for the home;

It may be fitted up so that it is absolutely no source of danger, but rather an element of safety, in the house;

It is completely free from the objection of adding noxious fumes to the atmosphere, and it exists by its non-combustion, instead of its absorption, of oxygen.

You have followed me so closely, and have given so many marks of your appreciation, that I feel emboldened to take it for granted that you consider I have proved most conclusively the desirability of your using the electric light; and in looking round, one can vouch for at least twenty ladies in the front rows who have made up their minds to have it fitted up immediately. We will therefore pass on with confidence to deal with the last, and perhaps the most important, condition—

6.—*It must not be a costly light.*

In order that you may be able to arrive at an opinion as to cost, it will be well for me to first explain, as accurately as it is possible in non-scientific language, the mode by which the electric current is produced and distributed; and we will then deal with the means at present available for obtaining this current for use in our homes.

CHAPTER VIII.

HOW THE ELECTRIC CURRENT IS PRODUCED.

Electricity from chemicals—From the movement of magnets—Faraday's discovery — The dynamo machine — The armature — The steam engine—The most economical size of dynamos—The older and newer forms of armatures.

Many are under the impression that there is a certain amount of electricity present in the air, just as oxygen and nitrogen are present, and that it is drawn out of the air for consumption in these little lamps.

I remember once getting into conversation with a gentleman at Scarborough, who, not knowing how interested I was in the subject, told me very seriously that he quite expected these electricians would be put down by law, because if they consumed as much electricity out of the air as they proposed to do, they would upset the balance of nature, and probably jeopardize the existence of vegetable and animal life upon the earth.

One need hardly tell you that this is an erroneous view of the way in which we obtain the electric current.

There is, however, a very much larger number who be-

 7—2

lieve that it is produced entirely by friction; for, knowing that friction between different kinds of materials does produce charges of electricity, they fancy that the powerful currents now in use for electric lighting are obtained in the same way. But friction is not the agent that produces these currents.

You are probably all familiar with the simple electric

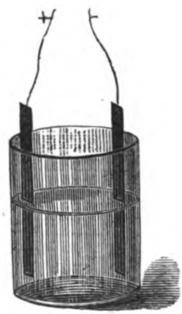


Fig. 56.—Primary Battery.

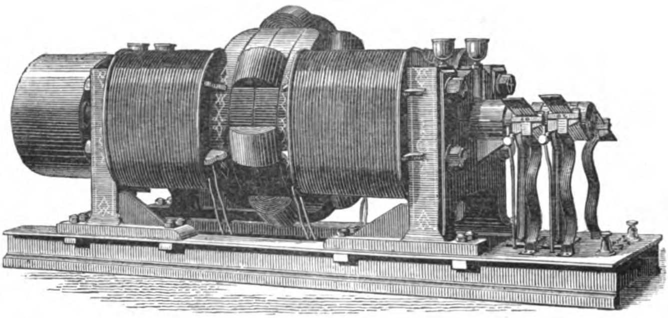
or voltaic battery, by means of which the electric current is produced from chemicals, and which acts by the transformation of chemical energy into electric energy. In the preceding illustration (Fig. 56) you see the simplest form of battery.

The liquid contained therein is dilute sulphuric acid, the so-called burning agent, and the pieces of metal consist, the one of zinc and the other of copper. There is continuous action between the zinc and the sulphuric acid, provided the ends of the wires attached to the two pieces of metal are joined together, when a slight current of electricity passes; but if an incandescent lamp were placed between the two poles, no light would be visible, as the current would fall far short of the intensity required to make the carbon filament within the lamp white hot.

It may, indeed, be taken for granted that no chemical battery is commercially suitable for the production of the current for electric light purposes; for though the battery might be made of much greater power than the one described above, the constant consumption of expensive chemicals and metals would make the light obtained very costly for even small installations, and the number of cells for running 10,000 lights from a centre, or from house to house, would from a commercial point of view be something appalling; and though electricity can also be obtained in a form of apparatus known as the thermopile, from heat, the currents which are now being used for electric lighting are, almost without exception, produced in so-called *dynamo-electric machines* (Fig. 57), and I will now proceed to explain as simply as possible how these machines do their work.

I hold in my right hand a rod of ordinary iron which has no magnetic properties, and which is known technically as *soft* iron; in the other I have a length of copper wire, covered with India-rubber to insulate it, and made into a spiral form or helix.

BRUSH 16-Lighter (Arc).



"FERRANTI" 1,000-Lighter (Incandescent).

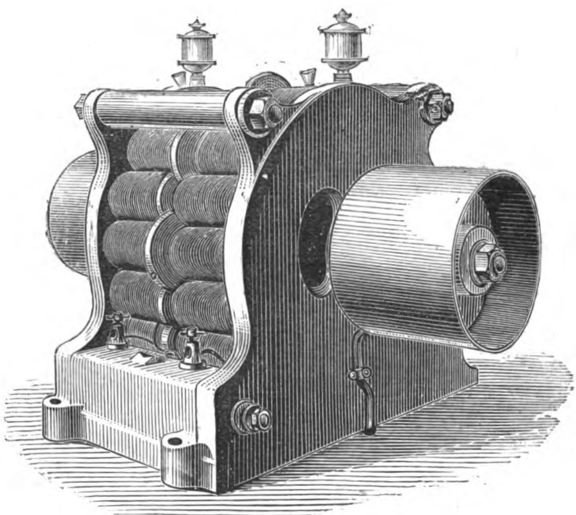


Fig. 57.—Dynamo Electric Machines.

Through this wire is passing an electric current from our battery.

I insert the rod into the helix (Fig. 58), and at once the piece of iron becomes a powerful magnet, as may be

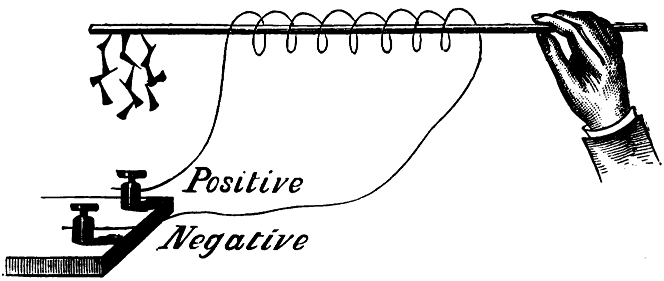


Fig. 58.—Electro-Magnet.

seen by the attraction it has for the nails which are hung on to the end, and you will notice that each nail has itself become magnetic, for each nail is able to attract and hold up another nail.

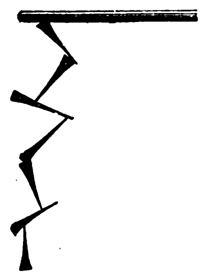


Fig. 58A.

The moment the passage of the current through the outer helix of copper wire is stopped, the magnetism of the inner bar of iron vanishes, and the nails fall off.

In this experiment, then, it is evident that magnetism was produced in a bar of iron by placing it in the neighbourhood of an electric current, which magnetism lasted as long as the current continued to flow; and if the process be reversed, and a permanent magnet, of the simple kind that is dear to the heart of every schoolboy, placed in close proximity to a coil of copper wire not connected with a battery, but with its ends simply joined together, you will be interested to know whether a current of electricity will flow, and continue to flow through the coil as long as the magnet is in its neighbourhood.

Well, it happens that, as long as both the magnet and the coil of wire surrounding it remain stationary, there is no current set up; but *if either move,* a current flows, or is said to be "induced" in the wire as long as the movement is continued.

This phenomenon was Faraday's great discovery of 1831, *and it is the basis of the production of currents of electricity from dynamo machines, which machines may be regarded solely as apparatus by which the rapid movement* (1) *of magnets in proximity to copper conductors, or* (2) *of copper conductors in proximity to magnets, is obtained, and electric currents thereby produced and distributed.*

In the machines of the different inventors these movements are of various kinds, for each of which certain advantages are claimed; but as an illustration, we will take the latest and perhaps the simplest form of dynamo machine, that made under the patents of Sir William Thomson and Ferranti and Thompson, and known as the "Ferranti" Machine.

In the "Faraday" experiment referred to above, an ordinary permanent magnet was used, and in the earliest forms of dynamo machines such horseshoe magnets were employed, and conductors of various forms were made to revolve near them.

In the experiment, however, in which we passed a current of electricity (Fig. 58) round a bar of soft iron, and caused

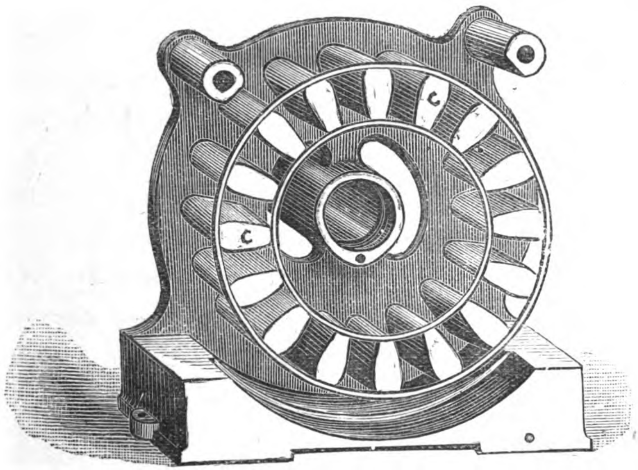


Fig. 59.—Half of "Ferranti" Machine.

that bar to become magnetic, we made, of the piece of iron, what is called *an electro-magnet,* and since electro-magnets of equal weight with permanent magnets are vastly more powerful, the former are now always used in the manufacture of dynamo machines.

By referring to Fig. 57 of the Ferranti dynamo machine, you will notice that on each side there are a series of bobbins, and when the machine is taken into halves, and the copper wire stripped off the bobbins, the faces of the magnets appear as shown in Fig. 59. These magnets consist of pieces of soft iron, and when insulated copper wires are wound round them, they become *electro-magnets.*

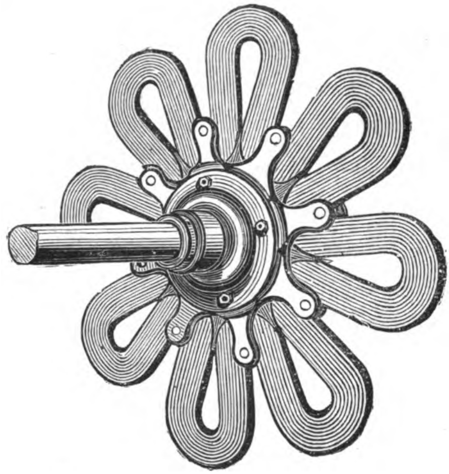


Fig. 60.—Armature of "Ferranti" Dynamo Machine.

It is known to all of you that if a magnet be suspended, as in the case of the mariner's compass, it will point north and south, the end which points to the north being called the north pole of the magnet, and the end which points to the south the south pole.

The magnets are so arranged in the Ferranti machine that two north poles never come together, and when the two sides are placed opposite each other, a north pole has a south pole on each side of it and opposite to it. Thus:—

N	S
S	N
N	S
S	N

When the two sides of the machine consisting of electro-magnets are joined, a space of about one inch is left, and in this intervening space there is made to revolve a wavy ring of copper (Fig. 60), which ring or *armature,* revolving, as it were, in a bath of magnetism radiated by the electro-magnets, gets an electric current "induced" in it. The ends of the revolving conductor are connected with two brass rings, and the current of electricity is drawn off by the two pieces of metal or "collectors" (Fig. 61) constantly pressing on a portion of the wheel as it goes round.

I have referred to this armature as revolving rapidly between the magnets, and, to take a simple illustration, I would ask you to think for a moment of the ordinary grind-stone, and to remember what a great amount of work it requires to keep it constantly going in one direction and at a high number of revolutions, and how very tired the arm of a man would be who attempted to turn it for six hours at a stretch.

If it were absolutely necessary for a grindstone to be revolved constantly and rapidly, a little steam-engine would no doubt be used, having its revolving wheel connected by a belt to what would be termed the pulley of the grindstone.

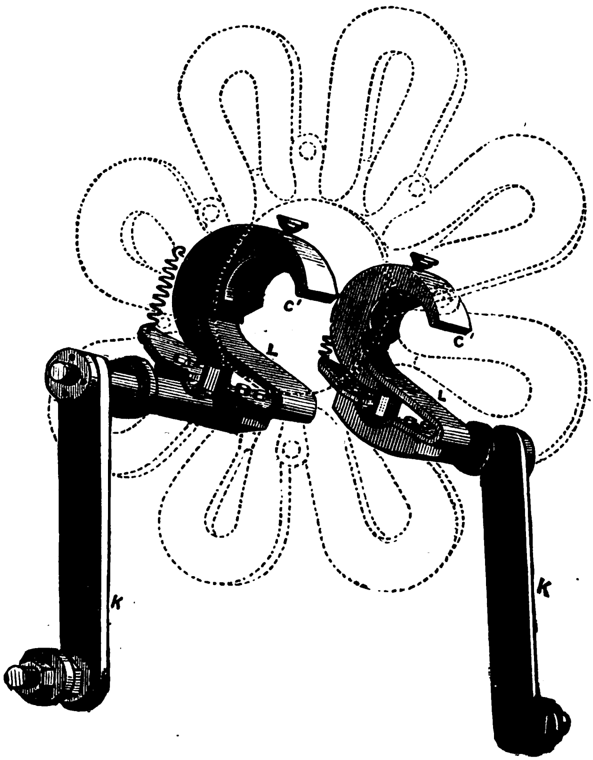


Fig. 61.—Collectors in "Ferranti" Machine.

So with the dynamo machine: the work that has to be done to force the electric current through the lamps is, in consequence of the high resistance of the thin carbon filament, so great that a man's strength would prove of no avail, and therefore the steam-engine is brought into play.

Many have been puzzled to know what the steam-engine has to do with the production of electricity, and you will now see that what the steam-engine does is to keep the armature of the dynamo machine turning round as rapidly as may be required (Fig. 62). A violent agitation being produced within the metal of the armature, this agitation is set up within any conductor directly connected with it, and when that conductor, in the form of a copper wire, extends over twenty miles—as in the case of one of our English towns, viz., Chesterfield—the disturbance within that wire spreads itself throughout the whole length. Then, if an electric arc lamp be placed in the circuit, the electricity on its path, passing from carbon point to carbon point, will throw out light.

Or, if batches of these little incandescent lamps be placed in the circuit, the particles of the carbon filaments will be made to vibrate rapidly, and, thereby becoming white-hot, they will throw out light similar to that which you now see round this room.

To keep up, however, all these agitations, or, in other words, the steady flow of the electric current, much *power* has to be expended in driving the dynamo machine, and if this is being done by a steam-engine, a constant consumption of coal is taking place to keep up the steam.

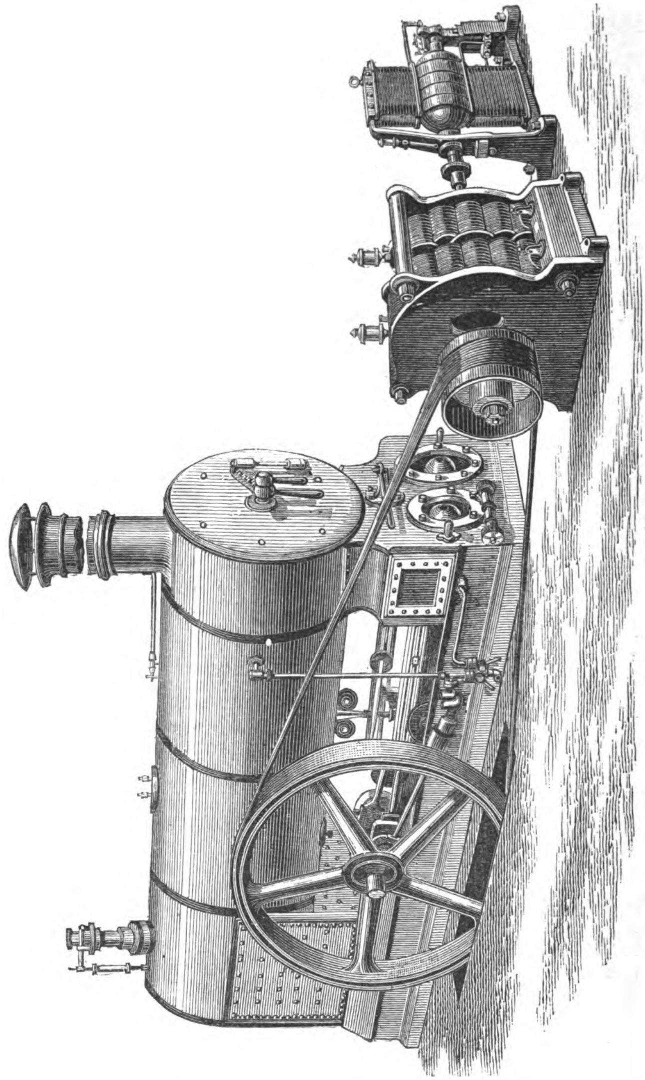


Fig. 62.—Steam-Engine Driving Dynamo.

Now, it is a fact extremely well known to engineers that, within certain limits, the larger the steam-engine, the more cheaply it can in proportion be constructed, and the more economically, especially as far as its consumption of coal is concerned, is it capable of working; it is therefore evident that as the electric current is generated in its cheapest form by coal in the steam-engine, the larger the size of the plant, the more cheaply the current will be produced.

At an earlier stage of the invention a dynamo machine capable of producing current for fifty 20 candle-power lamps was considered to be a good sized one, and when this size was increased to a "100-lighter" the manufacturers thought they had advanced very materially.

One of the well-known makers of dynamo machines still offer the "100-lighter" as the largest size they can make, and ignore the fact that "100-lighters" are likely to be about as much out of place in the incandescent work of the future as 10 horse-power engines would be when a plant involving the use of 5,000 horse-power had to be laid down.

Another leading electric light company has got as far as "250-lighters," and only last month their secretary calmly recommended a corporation, who have decided to become the suppliers of electric light in their town under the "Electric Lighting Act, 1882," to use these 250-lighters, and to add to them one by one, as the business extended, up to the contemplated 10,000 lights.

Now, it has been, for some time past, evident to most engineers that only those dynamo machines would survive whose construction was such that they could, if necessary, be increased twice, four times, or even ten times, in size, without in any way detracting from their mechanical, but with an immense increase in their electrical, efficiency.

No mechanical difficulty arises in largely increasing the size and weight of those parts of a machine that are at rest; but it is evident that the revolving armature cannot be so increased unless it contains, to start with, very little metal, and has that metal so arranged that the rapid revolutions in a machine to give off current for, say, 10,000 lights, would present no difficulty mechanically.

A short time ago an announcement was made of the completion of a dynamo machine to "run" 5,000 lights, but its revolving portion weighed seven tons; and it was felt that, on account of its cumbrousness, it did not materially help towards the solution of the house-to-house lighting problem.

On the other hand, one is glad to be able to say that the machines made by S. Z. de Ferranti, for running 1,000 lights in the First Avenue Hotel, have armatures only weighing 84 lbs., that a larger machine by the same inventor for running 2,000 lights has an armature weighing only 129 lbs., and that he claims that his 20,000-lighter, differing only from his smaller machines by the increased size of its parts, will require an armature weighing less than one ton, so that its revolution will again present no mechanical difficulty, especially as the larger the machine the more slowly the armature will be turned, for a large armature can be turned with a much greater peri-

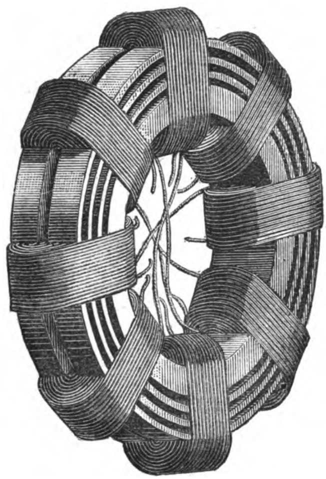


Fig. 63.—Armature of Brush Dynamo Machine.

pheral speed than a small one, the centrifugal force being proportionately less.

When this form of armature is compared with one of the older types (Fig. 63), it will be seen what great strides have been made towards the easy production of the electric current by large machines, and how possible it now is to generate and supply that current on somewhat the same scale as gas.

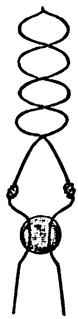
There are no doubt many who say that, just as the dynamo machine has passed through many phases of improvement before it has been brought to the present state of perfection, so it is probable that, during the forthcoming years, many further improvements will be made in it, and that the industry is hardly at the stage when prudent commercial men would sink their capital in dynamo machines of the present type; but I am glad to be able to state that the dynamo machine referred to above can not only be constructed at a low cost, but is absolutely giving back, in electrical energy, over 90 per cent. of the amount of the energy which is delivered into it by the steam-engine.

So that in a few years, such has been the advance that we have attained the position of wasting only 10 per cent. in the change of mechanical work from the steam-engine into electrical energy in the dynamo machine. The margin of improvement is therefore narrowed down to 10 per cent., and as it is, of course, impossible that the whole of the energy put into the dynamo machine can be given out by it, the margin for possible further improvements, instead of 10 per cent., is practically less than 5 per cent.

Some may consider it difficult to measure, in electrical power, the equivalent of one horse-power; but these measurements can be made with positive accuracy, and you may be interested to know that the equivalent of one horse-power is 746 units of electrical power, and that in the

Ferranti dynamo machine, for instance, 680 units of electrical power are available for use in the external circuit.

Before examining the figures connected with the cost of erecting the necessary plant and supplying the current, we will consider the question of the means at our disposal for its distribution.



Filament.

CHAPTER IX.

HOW THE ELECTRIC CURRENT IS DISTRIBUTED.

Conductivity of various metals—Street mains—The Ohm—Volt—Ampère—No consumption of electrical energy unless lamps lighted—The Watt—Current proportional to number of lamps switched on—Direction of future reductions in cost—Consumer charged by meter.

You have already seen an illustration of the little lead or conductor inside this lamp-standard through which the electricity is flowing, and I wish to explain to you how it brings the electric current from the source of supply to the lamp.

The conductor consists of a wire of copper, with an outside coating of insulating material. This metal has been chosen because of the ease with which electricity can flow along it, or, in other words, on account of its high conductivity.

Taking silver as a standard, the following table will show the conductibility of various metals:—*

* "Electric Illumination," by J. Dredge. Vol. I., page 322.

Silver	- - - - -	100
Copper	- - - - -	80
Gold	- - - - -	55
Zinc	- - - - -	27
Tin	- - - - -	17
Iron	- - - - -	14
Palladium	- - - -	12·5
Platinum	- - - -	10·5
Lead	- - - - -	7·8
Antimony	- - - -	4·3
Mercury	- - - - -	1·6
Bismuth	- - - - -	1·2

In conductivity, copper, it will be noticed, stands very high, and is likely for many years to hold its own as the most suitable conductor of electric light currents.

If one were to attempt to explain to you what takes place in the copper by the passage of the electric current through it, and how the particles of metal take up and part with their charge of electricity across the ether pervading all space, which probably surrounds them, you would, I fear, only be wearied with hypotheses; for upon the questions involved it is impossible at the present moment to hold fixed views; so I will content myself with saying that, whenever a conductor is joined on to another conductor, through which electricity is flowing from a dynamo machine or from a battery, it will become charged with electricity.

This sketch (Fig. 64) represents the mains, of course very much out of proportion. (A) leading under the street from the dynamo at the central station; (B) leading into the houses *en route*; (C) branching off into the various rooms.

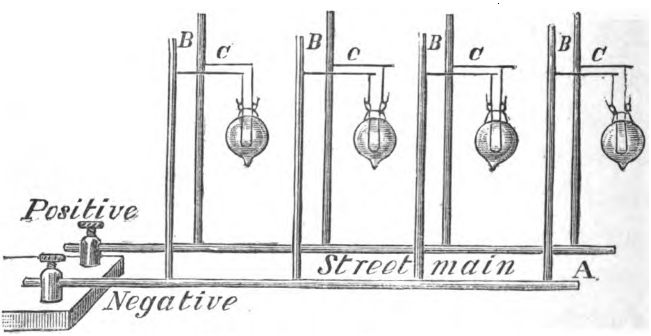


Fig. 64.—Showing the Mode of Carrying Electricity from Dynamo at Central Station to Lamps in the Houses.

As soon as a current of electricity is generated in the dynamo, it at once "charges" the whole of the system of mains connected with it.

Those who are disinclined to believe that electricity can act with this instantaneous rapidity, may be reminded that telegraph messages between England and America are conveyed in a shorter time than a bird takes to flap its wings, and that there is nothing whatever to separate the one electrical phenomenon from the other.

Indeed, one may appeal to the successful working of submarine cables all over the world, after the scheme of submarine telegraphs had been decried for years, as a presage of the triumphs which, in spite of equal incredulity, await the electric light engineer in carrying into effect the distribution of the electric current, over large areas, from house to house.

It is true that the mains will have to be large to carry large currents; but, just as a fourfold water supply can be distributed throughout large towns by doubling the diameter of the pipes, so there is no difficulty in conveying current for the supply of 5,000, 10,000, 25,000, or 50,000 lights, as the only thing needed is to have mains of sufficient size.

In determining the right size of the pipes in a water supply, consideration is given (1) to the quantity of water to be conveyed; (2) to the "head" or pressure at which the water is put into the pipes. The size and insulation of the mains in an electric light system is determined in almost exactly the same manner. Consideration is given (1) to the current, or number of "ampères," to be conveyed by the main; (2) to the pressure or tension at which the electricity is supplied—*i.e.*, its electro-motive force (E. M. F.) or number of volts.

These questions of quantity and tension not only determine the size and insulation of the main, but they come directly into play in overcoming the resistance of the carbon filaments, and making them white hot and light-giving.

The unit of resistance in electricity is the "*ohm,*" which is almost exactly equal to the resistance offered by 100 yards of ordinary telegraph wire. The electro-motive force of *one "volt"* [corresponding very closely to the E. M. F. of a single Daniell's cell], when applied to force electricity through a circuit whose resistance is *one ohm,* produces therein a current whose strength is *one ampère.*

The lamp on the table, containing a carbon filament with a resistance of 35 ohms, would require an E.M.F. of 35 volts to overcome such resistance and to feed it with one ampère current. But as this particular lamp requires $1\frac{1}{3}$ ampère current to give out a 20 candle-power light, it really requires, in order to perform its allotted task, ($1\frac{1}{3} \times 35$) $46\frac{2}{3}$ say 47 volts.

The mains themselves offer a certain resistance to the electric current, and therefore care has always to be taken, in an electric light installation, that the mains are of sufficient size, not only to allow the free passage of the current without becoming hot, but also not to offer such a resistance as would reduce the E. M. F., generated by the dynamo machine, below that amount required to feed each lamp with the requisite current.

These, however, are questions which more properly belong to the domain of the electric light engineer; but I mention them, because sound views upon them having, after an immense amount of thought and experiment, been arrived at, it has now become possible to bring the electric current to every one's door, by means of mains, and these will always, under a proper system, be charged with electricity, both by night and by day, at a pressure sufficient to supply the lamps on the circuit with the necessary current, be their number cut down to 2,000, or at any moment raised to 40,000.

A householder will only have to turn a switch in his hall to put his house-mains under pressure, when the various lights can be turned on and off at will all over the house.

From what has been said about the light resulting from the passage of the current through the carbon filaments in the lamps, it will be seen that no consumption of electric energy takes place if the lamps are not switched on.

Until the electricity has work to do, it may be regarded as lying dormant,—ready, however, at a moment's bidding to dart forward into the lamp to make the filament white hot and light-giving.

In order to make this point clearer, let me refer you again to Figures 24 and 25.* It has already been pointed out that, in the first circuit represented, the electric current has no path provided for it, because it cannot jump over the space between the ends of the hanging wires. If, however,

* See pages 39, 40.

a lamp be attached to one of the pair of wires, the electric current has one little path by which it can pass. Let us suppose that the filament constituting this little path, within the lamp, has a resistance of 35 ohms, then the electricity, with a "pressure" or E. M. F. of 47 volts, has sufficient pressure to overcome the 35 ohms resistance, and to feed the lamp with $1\frac{1}{3}$ ampères of current.

If another lamp, also with a resistance of 35 ohms, be joined on to the second set of hanging wires, then, a double path being afforded for the current, the total resistance is 35 ohms *divided* by 2. The electricity, therefore, in its endeavour to pass by these two paths, has only half the resistance offered to it, and double the current is thereby enabled to flow, just as, in a water supply, the addition of a second pipe to a cistern, providing a second path, lessens the resistance to the water by a half, and allows twice the amount of water to flow.

The amount of the current, therefore, passing through two lamps of equal resistance will be exactly twice the amount of the current passing through one; and, with a "pressure" or E. M. F. of 47 volts, these two lamps, with a total resistance of say 35 ohms divided by 2, will have in current $1\frac{1}{3}$ ampères multiplied by 2. And further, if the whole nine lamps, each of 35 ohms resistance, be fitted on, then their total resistance will be 35 ohms divided by 9, and the current which will then be possible to pass, supposing that the "pressure" or E. M. F. be kept constant at 47 volts, will be 9 times $1\frac{1}{3}$ ampères, *i.e.*, 12 ampères.

We are dealing, you will notice, with lamps each using, *in order to produce a 20-candle power light,* $1\frac{1}{3}$ ampère of current, with a tension or "pressure" of 47 volts, and the total amount of electric power so spent is arrived at thus:—

$$1\frac{1}{3} \text{ ampères} \times 47 \text{ volts} = 62{\cdot}6 \text{ volt-ampères.}$$

The unit so arrived at is known by the name of the "Watt."

This particular incandescent lamp absorbs, then, 62·6 (volt-ampères or) "Watts" to give out a 20-candle power light, and the great improvement which may be looked for in the electric light industry is not in the direction of raising the electrical efficiency of the dynamo machines (for it has been seen* that the latest type succeeds in giving out over 90 per cent. of the energy which, in the form of horse-power, is put into it by the steam-engine), but in the direction of obtaining more light in the incandescent lamp for a given power—for example, more than 20 candles from 62·6 "Watts."

At the present moment it is quite possible, by increasing the "pressure" of the electricity by 10 per cent. to produce a much greater increase of light; but this abnormal pres-

* Page 114.

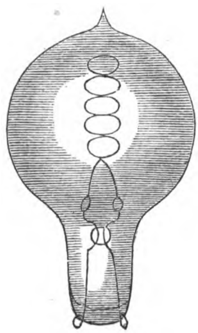
sure causes the filament to have a very much shorter life than the usual 1,500 hours, and therefore what has to be done by those who are working very hard at this problem is to produce a filament which will bear this extra strain without breaking.

At no distant date, then, we may expect that, even without any improvement whatever upon our best type of dynamo, 20 candles of light will be obtainable in the incandescent lamp by the expenditure of perhaps half the electric power that is at present used.

The householder will be at liberty, when a central supply station is started in his neighbourhood, to use any lamp he may choose, and if an improved lamp comes into the market, by which he can get, for instance, a 20-candle power light out of 30 "Watts" of electric power, instead of having to use 62·6 "Watts," he will be able, at exactly the same cost, without using one unit more, to double the illumination; or, keeping up an illumination of the same brilliancy, he will be able to reduce his electric light bill by one-half, because he will be charged by meter for the exact quantity of electrical energy used by him for lighting purposes.

He will, in fact, be in the same position as if, by the use of a greatly improved gas-burner, he could obtain 20 candles of light with the expenditure of only 3 feet of gas per hour, instead of being compelled, as in his present burner, to use 6 feet.

Having shown how, by means of our large dynamos working at a central station a mile or more from our houses, we shall produce the electric current, and having now demonstrated how easily it can be distributed, we will, to arrive at the same result, proceed to deal with the all-important question of cost.



CHAPTER X.

COST OF SUPPLY FROM HOUSE TO HOUSE.

Hitherto electricity made on retail scale—Comparison with price of gas only possible on supply on same scale—Capital for electric light works yet to be forthcoming—From capitalists or corporations—Electric light equal to 3*s.* 6*d.* per 1,000 feet for gas—Isolated installations.

On the question of the cost of the electric light much has been written, and the opponents of the new light have pointed out triumphantly how expensive has been, up to the present time, its application.

We must ask them, however, to bear in mind that England has not yet seen any attempt to grapple with the question of the cost of electric lighting upon a sufficiently broad basis; for, up to the present time, the electric current has been generated on an absurdly retail scale; and when addressing an audience of Englishmen, whose country holds its pre-eminence on account of its manufactures, and on account of the wholesale way in which these manufactures are carried on, one need hardly point out how materially the cost of an article may be decreased when the quantity produced is increased.

Of what weight, then, can be the argument that six electric arc lights, running from an engine in a back yard, cost more to illuminate a lecture hall than the gas which formerly lighted it? Or that 100 incandescent lamps in a draper's shop, the current for which is obtained from a dynamo machine working on the premises, cost very much more than the former 100 gas-jets, which were fed from a central supply in the town, where gas was being manufactured in sufficient quantity to supply 50,000 lights?

At the close of one of my lectures in London, a director of a gas company said he would like to ask me a test question:—

"Are you prepared to light the five street lamps in your grove with electricity, from the dynamo at your house, at the same price as the gas company is at present charging for gas?"

To which I replied,—"Yes; I am prepared to supply these five lights at the same price as that charged by the Gas Light and Coke Company, provided that the gas company allows me also to do the remaining 250,000 lights, by the supply of which they are enabled to keep the cost of five lights so low."

The leading point connected with the cost of supply of electricity is raised in this question and answer.

Comparisons are constantly being made between the cost of electricity, manufactured on the consumer's premises, with the cost of a number of gas-jets forming only a trifling part of a gigantic system.

The absurdity of such comparisons will, however, be acknowledged by those who have just heard my remarks with regard to the possibility of supplying and distributing the electric current on a large scale, and the real question at issue is whether, with all the advantages of 1,000-horse engines driving, with a minimum consumption of coal, 10,000, 20,000, or 40,000-light dynamos, the electric light can be obtained at a price placing it within the reach of all who value its immense advantages; and whether such price will leave a good margin of profit upon the capital invested.

On the latter point, it is well to understand that the capital has yet to be subscribed to start the first Electric Light Supply Company; and if, as a result of my lecture, you decided to give some electric light engineer a contract to light your town, he would probably ask you to provide the money to carry the work into effect.

The very limited number of electric light companies at present in existence have spent large portions of their capital in obtaining patent rights, and some in equipping themselves for executing the contracts for electric light plant which may be given to them by corporations or by the future electric light supply companies.

Sufficient capital, no doubt, is in the hands of the best to carry out satisfactorily the contracts entrusted to them; but when they have executed their work, they will require to be paid for the same just as the contracting engineers in other branches, say for the building of bridges, the laying of water-pipes, or the erection of gas plant, are paid.

The raising of the necessary capital, then, either by private enterprise or by the corporation borrowing it to carry out the provisions of the Electric Lighting Act, 1882, is the first step towards the starting, in any particular town, of an undertaking for the supply of the electric current for lighting purposes.

Let us suppose this very important initial step taken, and £150,000 in hand. This amount, if spent prudently, will be more than sufficient to secure all the necessary plant, engines, dynamos, mains, &c., duly fixed and laid, for the lighting, over a large area, of 40,000 incandescent lamps of 20 candle-power, like those exhibited this evening.

Any householder in the district traversed by the mains would be able to avail himself of the system, by having his house wired, and electric lamps attached to his gas-fittings, which in every case would be found suitable for the purpose. He would, after paying the preliminary expense of wiring, or arranging with the electric light suppliers for paying a rental on the same, be charged

9

quarterly for the actual amount of energy used in his lamps.

It is fair to take as a basis of annual cost that if 50 lights were fixed in the house, 25 of them would, on the average, be burning from sunset to eleven o'clock in the evening all the year round. As a matter of fact, I am personally extravagant enough in my own house to have on an average 66 lights burning out of 73, because I look upon the light as a friend rather than as an enemy, and I know that it is not injuring one's health, nor spoiling one's house.

Some years may elapse, however, before the general public take this view of the matter, and meanwhile I am content to make my calculation of the cost of the electric light upon the basis that a plant, capable with ease on special occasions of working 40,000 lights, would, at the end of the year, only be found to have earned a revenue upon half that number, say 20,000.

After working out the revenue upon this basis, I have gone very carefully into the question of cost of production. The result of my calculations shows me that the Electric Light Supply Company, or the corporation owning the works, would be able, when the plant was being utilized in the manner indicated above, to supply electric light, equalling a given amount of gas-light, for a figure equivalent to that paid for gas at 3*s.* 6*d.* per 1,000 feet, after writing off a liberal amount for the depreciation of their works, and providing for a 10 per cent. dividend upon the capital invested.

We find therefore that electric light engineering has reached the stage of making it possible to supply electric light from a central station, when it is in general use, at a price no higher than that we are now paying in London for that article which you will begin to regard as the bugbear of your existence, viz., gas.

It may interest you to know the basis of the calculation from which it is gathered that electric light can be supplied at this low price.

I take, as I have said, for a basis, out of 40,000 lights, an average of 20,000 lights, burning 1,600 hours during the year; and giving the gas company the benefit of the liberal calculation that it only requires six feet per hour of ordinary coal-gas to produce a 20 candle-power light, we have the following:—

20,000 (average number of lights) × 1,600 (hours per annum) × 6 feet of gas = 192,000,000 feet of gas, which at 3*s*. 6*d*. per 1,000 feet = £33,600, an annual revenue which would yield the electric light supply company the handsome dividend referred to.

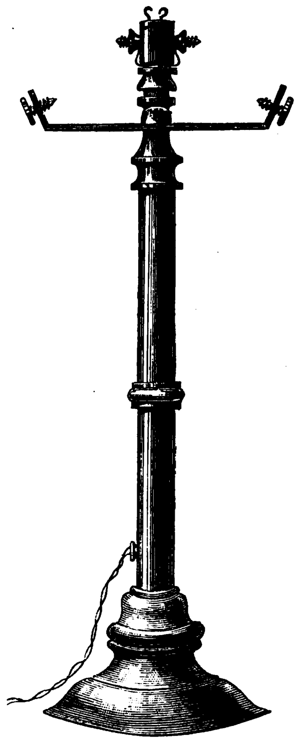
Though one hesitates to make public the details justifying my opinion of the cost of working an electric light station on this large scale, I shall be very happy indeed to supply them to *bonâ fide* inquirers, and in the meantime I content myself with assuring you that the *data* may be looked upon as strictly reliable, as there are responsible companies quite prepared to undertake the erection and working of a 40,000-light plant upon this basis of the annual revenue arising from the use of 20,000 lights, &c.

Though 3*s*. 6*d*. is about the average price of gas in London, it ranges in different parts of England from 1*s*. 9*d*. to 6*s*. per 1,000 feet, according to the price of coal, &c., in each locality. At the places where gas is cheapest, electric light would also be the cheapest, because the cost of coals is an important factor in the production of the electric current.

If, therefore, you are prepared to pay for the electric light—with all its immense advantages—a price equivalent to 3*s*. 6*d*. per 1,000 feet for gas, it can be placed within your reach by the establishment of an electric light supply station in your town or district; and you have it in your own hands, either as capitalist or citizen, to help forward the establishment of such a station.

No doubt the company at its start will have to charge a higher price than 3*s*. 6*d*., but as the use of the light extends in a town, the price will be gradually reduced to this or even a much lower figure.

Supposing, indeed, the price were fixed at first at a rate equal to 5*s*. per 1,000 feet of gas, I claim most distinctly that the householder would be a gainer by having the electric light on this basis, in place of gas, giving the same illumination, at 3*s.*; for when the annual cost of repairing the ravages of gas upon furniture, decorations, pictures, gilding, &c., be taken into account, the electric light at 5*s.*, regarded merely from a monetary point of view, is positively cheaper than gas at 3*s.*, irrespective of the increased cleanliness and comfort it affords.



If we weighed sufficiently the question of our healths and that of our children, we should discard gas from our dwellings, even though it were supplied at 1*s.* per thousand feet. No mother would be tempted to give the preference to a particular "children's food," on account of its cheapness, if she knew it to contain a modicum of poison; and the day will arrive when we shall feel the same reluctance to breathe, and allow our children to breathe, vitiated air.

Electric light supply stations are bound, therefore, in consequence of the unerring commercial instincts of our race, to be soon universally established in England; but, with the very strong feeling that there is throughout the country against the spread of monopolies like those connected with the water and gas supply, it will no doubt be found that gradually the electric light business will be undertaken in every town by the ratepayers themselves, especially when they see large profits on lighting going into the pockets of outside capitalists; and I shall, therefore, before I close, say a few words upon the recent Electric Lighting Act, under the provisions of which local authorities may become the suppliers of electric light in their respective localities.

As, however, there may be many present who are so impressed with the advantages of the electric light that they will be unwilling to wait till the general town scheme which has been foreshadowed is set on foot, I will first point out how it is possible, if you wish it, to have the electric light immediately installed upon your own premises.

CHAPTER XI.

SINGLE PRIVATE HOUSE INSTALLATIONS.

Some may not be content to wait till supply obtainable from central station—A single installation can be driven by:—Gas-engine—Water-power—Steam-engine—Comparative costs of same—Town houses—Country houses.

In spite of the overwhelming advantages of the electric light, the majority of householders will no doubt be content to wait until an electric light station is erected in their immediate neighbourhood, and until mains are laid down in front of their houses, from which they will be able to obtain the necessary supply of the electric current; but, on the other hand, there are, as I have just said, a large number unwilling to wait until the capital necessary to supply the whole of the country with electric light stations be forthcoming, and who would like the electric light immediately fitted into their houses. To these one is compelled to say that if they wish to enjoy before their fellows the advantages of the electric light, they will have to pay for the gratification of their wish, as it will be necessary to have a small electric light plant erected on their premises.

Owners of houses so isolated that the establishment of an electric light station in their immediate neighbourhood may be looked upon as a great improbability, will be especially anxious to know how they can enjoy the benefits of the new light.

It has already been explained that the electric current, as used for lighting purposes, is generated by the more or less rapid revolution of the armature of a dynamo machine; and, therefore, the first question to be considered, with regard to an isolated installation, is that relating to the most suitable power at hand for working a dynamo.

The quantity of power required depends upon the number of lights to be run. One-horse power is absorbed by every ten 20 candle-power incandescent lights, and if therefore an installation of 100 lights be made, and it is reckoned that an average number of 70 will be always in use, seven horse-power is necessary.

In central stations large steam-engines will be used; but where only a very limited horse-power is required, as in the present instance, gas or water-power will be found to be more convenient and more economical.

(*a*) The Gas-Engine.

By the use of the gas-engine the simplest method of obtaining the electric light is employed—a method which of course commends itself very strongly to the present holders of gas shares. Some of these gentlemen have gone so far as to say that it is rather mean of the electric light people to use gas for making their light; but there are others who, on the contrary, regard it as very important for the gas industry that one is able, by the use of gas as a motive power, to get a better light than by burning the gas direct through a gas-bracket. Of course it is true that in using a gas-engine a certain amount of oxygen is constantly being abstracted from the air; but it must be remembered that this abstraction occurs in an outhouse or in a cellar, instead of taking place, as in the case of the ordinary gas-jet, in our rooms.

The electric current used in my house is generated by a Ferranti dynamo, driven by an Otto gas-engine. The plant takes up a space of 16 feet by 5½ feet, and in most cases no difficulty would arise in finding a floor space of this size.

As so many visitors were likely to come to see my plant, a little machine-house was built in my garden, and in order to provide for twenty or thirty visitors being present together, I built it 23½ feet by 15½ feet.

This, however, is a piece of extravagance, which one can hardly recommend you to commit, if you can spare a suitable cellar or an outhouse.

The great advantage of a gas-engine is that, when once started, it can be left to itself for the remainder of the evening, and the constant attendance of a man is thereby rendered unnecessary.

My gardener is the only person that touches my engine and dynamo machine. When he first came to me, he had no experience whatever in this direction, and it is a point of great satisfaction to me to be able to state that the whole plant can be kept in order so easily, that under his unscientific care everything goes like clockwork.

He spends on the average two hours per day in cleaning the engine, and at sunset he turns on the gas, and sets the engine in motion. The lights immediately glow into existence, and he then leaves the engine to take care of itself for the remainder of the evening, dropping in for a few minutes only when he makes up his greenhouse fire for the night.

By my bedside there is a little switch, and on touching it the gas-engine stops instantly, and the lights go out.

In my explanation of the way this switch works, you may be reminded of the tale of the "House that Jack Built."

When one touches the switch an electric circuit is completed—which on its road passes through an electro-magnet —which attracts a catch—which drops a hook—which releases a chain—which allows a weight attached to the end of the gas-cock to fall—which turns off the gas—which robs the engine of its fuel—which stops the dynamo machine, and thereby puts out all the lights.

The lighting arrangements in my house have already been fully described, and it only now remains for me under this heading to tell you what it costs.

The number of 20-candle power lamps which we have lately had on the average alight at one time is 66; and, for the purpose of giving you reliable *data,* I have been careful during the last ten days to make a note of the exact number of hours that we have used these lights, and of the gas consumed.

It is the middle of winter, and the lighting hours are therefore long. From Thursday, the 8th, to Saturday the 17th, both inclusive, we used sixty-six 20 candle-power lights for 68½ hours; and if we had been using gas for the same period, and had had the same amount of light, we should have consumed, upon the basis of using six feet of gas per hour for every light—

66 (lights) × 68½ (hours) × 6 feet of gas = 27,126 feet,

which at 3*s.* 6*d.* per 1,000 feet = £4 15*s.* for ten winter's evening gas-lighting; and if it be, as it is generally acknowledged to be, correct to take 1,600 as the average number of hours in which artificial light is necessary for home use during the year, we have the following calculation:—

66 (average number of lights) × 1,600 (hours) × 6 feet of gas = 633,600 feet,

which at 3*s.* 6*d.* per 1,000 feet = £110 17*s.* 6*d.* for one year's gas lighting on the basis of my present illumination.

To turn to the cost of my electric lighting, I find that we actually consumed in the 68½ hours named 18,800 feet of gas, which at 3*s.* 6*d.* per 1,000 feet = £3 5*s.* 9*d.* for ten winter nights' electric lighting; and if we take the same average number of hours of lighting during the year as we did in the case of gas, we get an annual cost for gas in my gas-engine to produce the electric light,—

68½ hours = £3 5*s.* 9*d.*,—
1,600 hours = £76 15*s.* 9*d.*,

the cost of gas consumed in gas-engine for one year's electric lighting.

So we arrive at the very interesting conclusion that in actual production of light there is a gain of about 30 per cent. in passing the gas through the gas-engine to work a dynamo-electric machine, instead of burning it direct.

To make the comparison between the cost of gas and electric light complete, however, we must add the other expenses to which I am put, and the result is the following:—

Annual cost of electric light with Ferranti dynamo worked by an Otto gas-engine.

Average of sixty-six 20 candle-lights for 1,600 hours

	£	s.	d.
Gas used in gas-engine at 3*s.* 6*d.* per 1,000 feet (see above) - - - - - -	76	15	9
Share of gardener's wages, say 5*s.* per week -	13	0	0
Renewal of lamps, 100 at 3*s.* - - - -	15	0	0
Oil, sundries, and renewals of parts of machinery	4	10	0
	£109	5	9

As compared with—

Annual cost of the same amount of illumination by gas (see page 139) - - - - -	£110 17 6

We find, therefore, in actual practice that, manufacturing the electric current as I do upon a very retail scale, light is obtainable for almost exactly the same cost as if I had gas.

There will, no doubt, be some who will raise the objection that, in making up the electric light cost sheet, I have not added anything for interest upon the money sunk in my electric light machinery, which, for an installation of the size of mine, costs £650, the annual interest of which, at 5 per cent., amounts to £32 10*s*.

I have, however, purposely omitted this figure from the above calculation, and I will tell you the reason why.

Those to whom I am now appealing are presumably the wealthier among you, who, not being content to wait till the electric current is distributed from house to house, have special reasons for incurring the outlay for a separate plant for themselves, and this class know that when once the money be laid out it will produce an annual saving in their expenditure on renewals of painting, whitewashing, decorating, and regilding picture-frames, which saving will far outweigh the moderate £32 10*s*. interest upon the money sunk.

If, indeed, one approached this class solely with a scheme whereby a certain comparatively small capital outlay would minimize in future the ever-recurring onerous expenditure under these heads, they would, I feel certain, readily embrace the scheme, as one by which they would financially be great gainers; and when the plan, which I am at present putting before them, yields all these advantages, and gives them at the same time the most beautiful light that can be imagined, they will, I cannot help thinking, hail me as one offering them the cheapest bargain they have ever met with in their lives.

We must now leave the gas-engine, upon which we have dwelt at some length, because in town houses* it affords such a convenient mode of generating power to drive the dynamo, and pass on to the consideration of the means to be adopted in places distant from gas-works, or where the installation has to be such a large one that the use of a gas-engine would not be suitable.

We will first take the case of country houses, which are so often destroyed by fire, arising generally from defective means of lighting.

(*b*) Water Power.

In some places a good fall of water is available, and it can be very economically employed in turning a

* In country houses it may be found practicable to manufacture gas by the simple means employed in the "Dowson Gas Producer," and to use the gas so made, not of course for lighting purposes, but for working a gas-engine and dynamo machine to generate the electric current.

set of wheels to run the dynamo machine. The costs incidental to the application of water-power differ in almost every case, according to the volume, fall, and position of the water, and I am therefore unable to give an estimate which will invariably apply; but we may take the following as one not embracing very exceptional conditions.

Cost of electric light plant, vortex, turbine, pipes, &c., adapted for a fall of 70 feet, and designed to use, at the standard opening of the guide blades, 353 cubic feet of water per minute, the wheel being arranged to make about 540 revolutions per minute:—

Dynamo machine and exciter capable of maintaining 250 incandescent lights of 20 candle-power each, lamps, holders, cables, switches, and fuses, with cost of delivery and erection - - - - - - -	£800

The annual cost of working same would be as follows:—

150 lights on the average burning for 1,600 hours.

	£	s.	d.
Attendant—proportion of wages at the rate of 5*s*. per week - - - - - - -	13	0	0
Renewals of lamps - - - - - - -	37	10	0
Oil and sundries - - - - - - -	13	0	0
Keeping plant in perfect repair - - -	80	0	0
	£143	10	0

Let us compare this with the cost of a similar illumination by gas, and we find, taking the same basis, that the gas consumed would be—

150 (lights burning on an average) × 1,600 (the number of hours burnt) × 6 feet of gas = 1,440,000 feet of gas at 5*s*. per 1,000 feet, £360

Five shillings per 1,000 feet is taken as the cost of gas, that being the price in outlying country districts; but, instead of 5*s*., *the gas would have to be supplied at 2s. per* 1,000 *feet to make the illumination as cheap* as that obtained from the electric light by means of utilizing a good fall of water.

It must also be remembered that when once a turbine is erected and water-power utilized on an estate, it will be found available for many purposes besides the working of the electric plant.

That plant will only be in operation during the evening, and therefore during the day the "power" can be used for the pumping of water to the top storeys of the mansion, or for any of the farm purposes for which engines are often especially erected. Indeed, it may frequently be found practicable to drive the dynamo machine with an engine already fixed, and hitherto used in the directions indicated.

In London it will, I am glad to say, be soon possible to use hydraulic power in our residences, as a company is at the present moment laying down mains for the supply, to all houses *en route*, of water at a pressure of 700 lbs. to the square inch, sufficient to work a small installation of the electric light.

Where neither water-power nor gas can be applied for driving the engine, steam can, of course, always be utilized.

(*c*) The Steam-Engine.

A steam-engine of the semi-portable type, to work a 250-light installation, would cost, with necessary foundations, dynamo, leads, lamps, &c., £1,050, which is £250 beyond the estimated cost of the "water-power" plant to do the same work; and the annual cost of running a steam-engine plant is necessarily much larger than the cost of working a "water-power" plant, as the following estimate will show:—

Annual cost of working a 250-*light installation by steam-power.—Average,* 150 *lights, burning* 1,600 *hours.*

	£	s.	d.
Attendance - - - - - -	91	0	0
Fuel for engine - - - - -	54	0	0
Renewals of lamps - - -	37	10	0
Sundries - - - - - -	15	0	0
Keeping plant in perfect repair -	36	0	0
	£233	10	0

Here, again, it will be noticed that 1,600 hours and 150 lights burning on the average are taken as the basis, and the total is found *to be equal to a gas illumination at 3s. 3d. per* 1,000 *feet*; though in most isolated country houses a gas illumination is, of course, quite out of reach, unless the gas be made at very heavy cost on the premises.

For instance:—

Cost of gas manufactured on the premises—150 (lights burning on an average at one time) × 1,600 (hours of illumination) × 6 feet of gas

= 1,440,000 feet of gas,

which, at 7*s.* per 1,000 feet, equals £504. The cost of an equal illumination over the same period by the electric light being, as it has been calculated, £233 10*s.*

The remarks under this head will, of course, have most weight with owners of isolated country mansions;* but I am

* The following letter from a well-known and highly esteemed Member of Parliament, completely confirming my calculations, appeared in the *Times* of January 29th, 1884, as a Letter to the Editor, a day or two after the printing of the first edition of this work.

ELECTRICITY v. GAS.

Sir,—On the 16th of January last year you were good enough to insert in the *Times* a long letter from me under the above title, believing it would be of interest to the public, in which I described in detail the manner I lighted up by electricity a house (Berechurch Hall) I had lately built, the way I set about it, and the result up to the end of the year 1882.

The letter has been so often quoted and referred to since, and has entailed so much correspondence, that I think it but right on my part to describe how the lighting has been behaving during the twelve months that have elapsed, together with its cost. I must therefore beg permission of you to kindly spare me space for this communication, which to my mind is of a still more important nature than the previous one; for, though the public are getting fully alive to the beauty and great advantages of

anxious that those who live in towns should see the desirability of at once applying the electric light to their premises,

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the electric light when first installed, yet grave uncertainty exists in the minds of many, not only as to the amount of expenditure necessary to keep it up to its pristine excellence, but also as to what its lasting power may be. * * * * * *

The total cost of the electric light, every item of which I gave, including buildings, electroliers, fittings, &c., came to £1,470 8s., against £1,333 18s. for gas. But to the cost of the electric light I ought to have added £20 for stores, which will bring the amount to £1,490 8s., showing that the first outlay was somewhat in excess of what gas would have been. At the time I wrote my letter, the electric light had been running about three months, and upon that working I supplied an estimate of the probable annual expense. * * * *

And now, before giving the actual cost for the year 1883, I must state that during the whole of the twelve months there has been no mishap of any kind, with the exception of the belt slipping three times, which caused five minutes' delay at the outside; and a little temporary trouble was occasioned by the drunkenness of the engine-driver, who had to be summarily dismissed. The lights have been steadier than gas, and they are as beautiful and brilliant as when the installation was first put up; nay, they are if possible more so, for instead of 18 candle-power being given out, they are now working up to 20 candle-power each, an increase of over 10 per cent. in the original contemplated illumination.

When the installation was first put up it was intended that the lights should run about the same number of hours per annum that they do here—viz., 1,150; but altered arrangements have required that the lights should be run for a very much longer period than previously determined upon; the actual working hours of the lights during the last twelve months having amounted to 1,823.

I will now give the cost:—Coals (small, at 13s. 6d. per ton, mixed with coke at 18s. per ton), £90; wages (engine-driver and lad), £79 14s.; renewal of lamps (300 at 5s.), £75; oil, cotton-waste, &c., £20; repairs, £5 8s. 1d.; sundry small items and expenses, £7 16s. 8d.; depreciation, 10 per cent. on cost of machinery, £78; ditto, 5 per cent. on conductors, £4; total, £359 18s. 9d., which is just under a farthing per 20 candle-power lamp per hour (the exact figure being ·95 of a farthing).

even if there be a prospect of an electric light supply company starting a distributing station in their immediate neighbourhood in the course of the next few years.

It will be seen, therefore, that in the estimate contained in my letter of last year, I overstated the probable expense. I have not only kept the installation in repair, but I have actually placed a sum by of £82, which annual amount will enable me in less than nine years to entirely renew the engine and electrical machinery, taking advantage of any improvements that may have been made in the meantime; or, in the event of the machinery still being in good working order, to entirely recoup myself for its expenses. My engine does a large amount of pumping, and I calculate that on this head alone it is saving me at the very least £60 per year.

The renewal of lamps—300—may seem large, but there is little doubt that the late engine-driver by his carelessness weakened the carbon filaments of many of these, and caused them to break sooner than they would otherwise have done. However, this is an item I hope to see reduced this forthcoming year, and as time goes on to shrink into a very insignificant amount. I am also hoping to reduce the fuel charge, but it must be remembered that Berechurch Hall is about four miles from the nearest railway station, which is at Colchester. Speaking of the lighting in my letter of last January, I said, "The result has been a success that has exceeded my anticipations. The light is quite as easy to manage as gas, while the softness, the purity, and the agreeableness are such that a return to any other method of illumination would be now quite out of the question. The pictures, books, and decorations have no chance of injury; the ceilings and walls remain unsoiled; while the difference in health felt after sitting an evening in a room electrically illuminated, and another lighted with gas, must be experienced before it can be appreciated." The whole of which a year's further experience enables me to most emphatically reassert.

To those who are about lighting their houses, perhaps a few words concerning the manner I have distributed the lights, so as to get the greatest possible illumination at the least possible cost, may be of interest. Upon going into the matter, I perceived that the electric light was so very different from gas that it would be most wasteful to lay it out on

The money to be spent covers: (1) putting the wires in the house; (2) erecting the fittings; (3) buying an engine and a dynamo.

the same lines. I therefore determined to have no "bunching" of the lights, but to keep each one as much as possible apart from the other. In no part of Berechurch Hall are there more than three grouped together, except over the billiard-table. The majority of the lights are single, and in the hall and dining-room they are simply suspended from the ceilings by silk cords, producing a charming effect, the lights appearing as if floating in the air.

In some installations it is not unusual to see a great cluster of lights attached to heavy massive electroliers. Having thus succeeded in producing such a dazzling effect as to be positively hurtful to look at, ingenious devices have been resorted to so that a portion of the light may again be destroyed, which is generally accomplished by toning the whole down again by means of semi-opaque or coloured globes, thereby losing 50 per cent. of the light at least. I venture to say that had this system been followed at Berechurch Hall the installation would have cost thrice the sum it has, and not have been half so satisfactory.

And now with regard to the great question of accumulators. Though great improvements have been effected within the twelve months, I must own that I have not yet sufficient confidence to adopt them, but intend waiting to see what time will do, with regard to still further improving and cheapening, before I employ them.

In conclusion, I may mention that neither directly nor indirectly am I interested in or connected with any electric light company or electrical system whatever; neither do I hold a single gas share. My sole object has been to try and solve the question as to whether the electric light has reached the stage that it can be successfully used in country houses. And I resolved to do this independently, but to apply to the matter that care which to my mind is absolutely requisite to insure the success of an electrical installation, which, without due precautions, is very likely to result in a disappointing failure. Yours faithfully,

OCTAVIUS E. COOPE.

ROCHETTS, BRENTWOOD,
January 24th, 1884.

Now, one is able to urge that whether you apply the electric light to your residences sooner or later, you will have to incur the expenses under headings 1 and 2; and if your house be properly wired and fitted up now, the wires will be available for the passage of the current as soon as an electric light station is started in your vicinity; so that, come what may, the expenditure under these headings would never be rendered fruitless.

The only part of the plant that you will be able to dispense with, if you are fortunate enough within two or three years to have the electric current brought to your front door, is the engine and dynamo, and even here you need have no fear of a total loss, for good plant of this description will always be realizable at a fair figure.

Indeed, I may confess, in passing, that, in the opinion of many, one thing which will delay the application of the electric light from house to house in its earlier stages will be the difficulty that the engine-builders of the world will at first experience in keeping pace with the heavy contracts which will be crowded upon them.

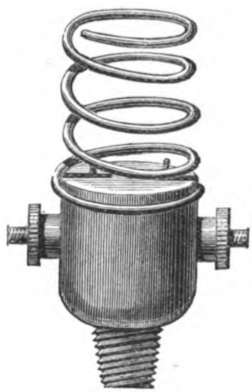
In ship-building one finds, from decade to decade, instances in which an excess of demand for such universally recognized necessities as steamships occasions ship-builders to refuse to accept orders except for very extended dates of delivery, varying often from nine months to two years; and one may look for the same law of supply and demand affecting the engine-works of the country when orders for plant—the certainty of the demand for which only comparatively few recognize—are poured in upon them.

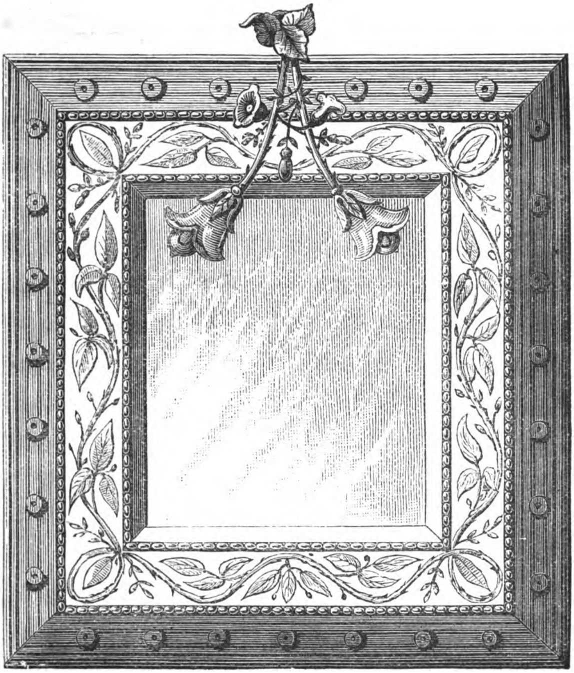
This, however, in a parenthesis; what one wishes to convince you of at the moment is that, if a resident in town, your risk of monetary loss in immediately installing the electric light is a very small one, and is amply counterbalanced by the material gain the electric light would be to you in your residence.

To the dweller in the country one can speak with even greater confidence, for he is shown how there is brought within his reach, at a comparatively small outlay, the luxury of bright light, which hitherto has only been possible to those in towns.

In glancing through the calculations of cost that we have made, it must be borne in mind that the expenditure of "power" to drive the dynamo machine is almost exactly proportional to the number of lights burning from time to time. If, for instance, in our 250-light installation the whole of the lights be burning, on the occasion of a ball or some gala night, the full 25 horse-power will be consumed; but if 150 of the lights be turned out all at once, or room by room, the horse-power required to drive the dynamo to supply the current for the remaining 100 lamps will be automatically decreased from 25 horse-power to 10 horse-power, and when almost all the lights are turned out, till out of the 250 only 10 are lighted, the horse-power consumed will be enconomized in almost direct proportion to the number of lights burning.

If it be thought desirable only to provide for a maximum number of 50, 100, or 150 lights in a house, the cost of the plant will be lessened somewhat in proportion to the size, and the expenses of running will decrease in like proportion.





CHAPTER XII.

HOTEL AND THEATRE INSTALLATIONS.

Advantages of the electric light in hotels—No damage to decorations, &c.—A "1,000-lighter" on the premises a cheap source of supply of electric current—First Avenue Hotel, Holborn, London—Duplicate sets of boilers, engines, and dynamos—Each capable of supplying 1,000 lights, or any lesser number—Cost of plant—Cost of working —Comparison with gas.

We may seem to be digressing from the subject of the electric light in our homes, if we touch upon the question of the lighting of hotels; but since there is always a large floating population making their homes in hotels, I venture to think that it may be considered to come within our limits this evening.

All that has been said on the importance of having the electric light in our homes can be also urged, and with much greater force, in reference to hotels, whether one considers the desirability of keeping the rooms as free from bad air as possible, or the immense damage that gas and candle-light do to the interior decorations.

In a new hotel an almost incredible sum is paid to decorators, and while the proprietors feel that their business will very largely depend upon the clean, attractive appearance of their public rooms and halls, they have hitherto had the mortification of knowing that the beautiful, fairylike palace handed over to them by their architects, will gradually lose all its pristine freshness, and so be a constant source of expense to them.

By the introduction of the electric light, however, all these drawbacks are banished, and the money which has hitherto gone to repair the ravages of gas will in future be distributed in the form of handsome dividends to shareholders.

No private person, then, can possibly be as anxious as the hotel proprietor to see the establishment in his neighbourhood of an electric light supply station; but perhaps no one should be more anxious than he to anticipate that date by putting up his own plant.

Again, one may point out that, sooner or later, he will have to face the expense of "wiring" his building, and indeed the majority of architects are now recommending their clients, in the case of all new buildings, to fit in the electric light wires, the work in connection with which can so easily be done when the place is in course of erection, provided the wires are not embedded in the walls.

As this expenditure must therefore be incurred sooner or later, the only thing the hotel proprietor has to consider is the question of the advisability of purchasing and putting down in the basement an electric light plant; and if the hotel be a large one, involving, say, the use of 1,000 or 1,500 lights, he will probably find that *he can manufacture the electric current upon this large scale at a cheaper rate than it can be supplied to him from a central station, where a handsome dividend is being set aside for shareholders, and where provision has to be made for interest, &c., on money sunk in the ramification of mains leading from the station to his hotel.*

To take an example. The only hotel in the country at the present moment which is lighted in every part with the electric light, supplied from engines on the premises, is the First Avenue Hotel, London.

Those who have stayed at that hotel know how well it deserves the title of a fairy palace, and how excellently the electric light fulfils its mission there. I will therefore confine myself to pointing out the means by which, during the course of the evening, 800 to 1,000 lights, and a smaller number during the whole of the night, are kept supplied with the electric current.

The engine-room is sunk in a space dug out from the back yard, and the plant is in duplicate, each set consisting of—

(a) *Boiler.*
(b) *Steam-engine.*
(c) *Dynamo machine (Ferranti) capable of producing sufficient current for* 1,000 *twenty candle-power incandescent lamps.*

Arrangements are made by which the steam can be drawn from either boiler, the power from either steam-engine, and the current from either machine; so that it is almost inconceivable that a break-down of the lighting can occur.

In the large iron-works of the North, where duplicate engines are in use, there are cases where no stoppage of the work has taken place since first they began their work ten or fifteen years ago; and with high-class Adamson boilers and Gwynne's engines, like those at the First Avenue Hotel, one may look for a similar result with absolute certainty.

By an inherent feature in its construction, the Ferranti dynamo machine always maintains in the circuit that amount of electric pressure which is requisite to feed the lamps with the current necessary to enable them to give out light, so that in any part of the hotel, lights are extinguishable at will, and as the machinery runs all night, it is possible to turn on any number of lights at any time.

Now for the question of cost.

The value of the electrical plant, including the erection of the duplicate boilers, engines, dynamo machines, mains, and conductors thoughout the building may be fixed at £7,500, and the cost of running the plant is as follows:—

1.—*Cost of running electric light plant at First Avenue Hotel, London.*

Average of 230 lights per hour throughout the whole year.

	£	s.	d.
Wages - - - - - -	450	0	0
Coals - - - - - - -	400	0	0
Renewals of lamps - - -	200	0	0
Sundries - - - - - -	200	0	0
Keeping plant in perfect repair -	600	0	0
	£1,850	0	0

2.—*Cost of same illumination in gas.*

230 (average number of lights per hour throughout the year) × 24 (hours) × 365 (days) × 6 feet of gas = 12,088,800 cubic feet of gas at 3*s.* per 1,000 = £1,813 6 4

In making the comparison between the cost of the electric light and gas, we again omit the item of interest on the money sunk in plant, as the saving to the decorations, &c., will much more than counterbalance this.

All that has been said with regard to hotel lighting applies to theatre lighting, and also in some degree to the lighting of a block of private houses in a square. An isolated installation, when it embraces over 1,000 lights, as in the case of the First Avenue Hotel, can be erected on an absolutely reliable and economical basis.

CHAPTER XIII.

ACCUMULATORS.

Advantages of storage — Chemical phenomena — Must be capable of rough handling — And be cheap — Disadvantages of their use — Secondary generators.

The storage of gas in gasometers, and the assurance which this storage gives of an unbroken supply, have induced many to hold the opinion that unless analogous storage arrangements can be introduced into an electric current-distributing system, it will never be able to keep up a steady house-to-house supply.

I have already given my reasons for directly dissenting from this opinion, in holding that, if ample provision be made at the central stations, in the way of extra engines connected with the same shafting as those working to their full power, and by the use of spare dynamos, also ready to come into work at a moment's notice, break-downs will be impossible; but even if accumulators have no place in the future central supply systems, they may, *when sufficiently improved,* very usefully figure as an aid to electric lighting in other directions.

The current, which has been in use for the experiments this evening and for the lamps which have illuminated this room, was generated, as I have already mentioned, by means of a dynamo machine. But I must go on to explain to you that the dynamo did its work in London, and that the electric energy was stored up in these boxes in a convenient form for transit, so saving me the expense and trouble of bringing with me an engine and a dynamo, to produce, for the very short space of time necessary, the small amount of current required by me.

These boxes are known by the name of *accumulators, or secondary batteries;* and I am able to state, that though I have used different sets at varying intervals for about twenty lectures, they have only once failed to give out the same quantity of current as that which has done its work so well this evening.

It is a matter of great surprise that in each of these small boxes (Figs. 11 and 26),* measuring 8¼ inches long by 4¼ inches wide by 7½ deep, there can be stored up energy equivalent to that given off by an engine of half a horse-power working for one hour, or 990,000 foot-pounds.

That is to say, there is sufficient energy in one of these little cells, when fully charged, to raise 100 lbs. 9,900 feet high, or to raise 1,000 lbs. 990 feet high.

The energy contained in this box is stored up in it by

* Pages 23, 53.

the passage through it of an electric current generated by a dynamo machine.

This current, acting for a certain time and representing a fixed amount of energy, produces inside the accumulator certain chemical actions, and, when required, the accumulator reproduces this energy in the form of an electric current, by reversing these chemical actions.

Between the action and the reaction there is naturally a loss of work, which has been variously estimated to range from 10 to 40 per cent. as compared with the amount of electric energy given out by the dynamo machine.

To describe minutely to you the chemical action and reaction which take place in an accumulator would cause me to be so technical that I fear I should weary you, and I will therefore content myself by saying that the electric current, when passing through the secondary battery, tears asunder the oxygen and hydrogen composing the water present in dilute sulphuric acid contained in it, and the thereby compels them to act respectively on the two sets of lead plates. When the so-called charging process is completed, and the positive and negative poles of the battery are joined to an outside circuit, to which of course lamps may be attached, then the oxygen and hydrogen recombine to form water; but in the work of recombination they throw out a portion of that electric energy which formerly tore them asunder.

I do not go on to describe what may or may not be the function played by the sulphate of lead, &c., in these cells, as this and other details of the process are yet subject of dispute among recognized authorities.

I look forward with great interest to the gradual improvements in the construction of accumulators, and hope that they will some day be of such a simple character that, like the dynamo at my house, they can be placed under the care of the class of men who will have for better or worse to superintend the isolated country house installations of electric light of the future.

Hitherto, when a set of accumulators has been turned over to the care of unskilled hands, they have usually ceased to perform their functions; though it is certain that only secondary batteries suitable for very rough-and-ready usage, and capable of being supplied at very much more reduced prices than those now current, will be of widespread commercial value. A set of these accumulators could then be employed in connection with a dynamo machine used in a private installation, so that during the day sufficient electric energy could be stored to tide over any casualties, should such from unforeseen causes arise.

In my own installation you will notice, however, that I dispense with accumulators entirely; but if the day comes when accumulators are produced which fulfil the conditions laid down by me, I shall be very glad to add a small set to my installation. At the present time, however, it is, I consider, much more economical to provide spare power than to use accumulators.

A gentleman whom I met in the railway train the other day, laid it down as a canon that electric light supply stations would not be thoroughly successful until huge accumulators for storing up the current were invented; but I pointed out to him that, meanwhile, under my plan he might, if he chose, regard the electricity as stored up in an immense accumulator, *i.e.*, *the universe*, and the engines and dynamos merely as the means by which a constant and exact pressure was kept up through the mains, just as, in the case of a water supply, the water is held in a large reservoir, and forced through the mains at a certain pressure by means of the pumping engines.

Some, however, urge that, even if this constant pressure of electricity can be maintained without break, it would be possible, by the use of accumulators in every house, to largely decrease not only the size of the mains, but also the dimensions, and consequent cost, of the engines and dynamos, as the latter could be worked without interruption night and day.

Those who argue in this way do not, in my opinion, sufficiently take into account (1) the heavy prime cost of the accumulators; (2) the waste of energy entailed by their use; (3) the expenditure upon the devices for automatically working them; (4) their very rapid destruction, and (5) the great wear and tear entailed by keeping the same set of engines constantly at work day and night. If they went sufficiently into the figures, they would have to acknowledge that these items would not only completely counterbalance the alleged saving in other directions, but that the use of accumulators would introduce into the system apparatus almost certain from time to time to get out of order, which apparatus, distributed over a large area, many of the houses being a mile or two distant from the central station, would be beyond the immediate supervision of the electricians in charge there.

Their use, therefore, would create an element of increased cost, and risk of break-down, far outweighing the supposed advantages, and would, in the present state of the industry, make central stations for large areas an impossibility; while absolutely other reliable means, perfected during the past few years and lying ready at our command, can be immediately employed, with a certainty of giving good and continuous results, upon a sound commercial basis.

If you think that I am wrong in supposing that the advocates of accumulators would not distribute them from house to house, but would have a huge "reservoir" of electric energy at their central station, I must point out that no one with any commercial instincts would recommend this course to be pursued, as under this system the mains would not be decreased in size, and there would be no advantages to counterbalance the heavy expenditure on the accumulators, and the daily loss of energy entailed by their use.

The same remarks would apply to the use of "*secondary generators,*" as an improved form of induction coil has recently been named.

The advocates of the employment, in town installations, of these secondary generators, urge that only a very small wire, instead of a heavy main, need be used for a current with an electro-motive force of say 20,000 volts, and that if the wire carrying this *primary* current be brought into close proximity, on its course (say of twenty miles) to a series of sets of secondary generators, a *secondary* current will be generated within them, which will be capable of use in the incandescent lamps.

There is absolutely nothing new in all this, though one would suppose, from what has recently appeared in the public prints, that these *secondary* currents had hitherto been completely wasted, *and that they can be used for lighting purposes without robbing the primary current of any power.*

The opposite is, of course, the case, and if the *secondary* current instead of the *primary* one is tapped, as it were, for lighting purposes, a proportional amount of power has to be generated at the central station to supply what is used up in giving light in the lamps; with this important difference, however, that for every 100 units of electric energy, which could be obtained by the utilization direct of the primary current, only about 50 units can be rendered serviceable in the secondary current.

To state the matter from a commercial standpoint, one may say that if an amount of electricity which has cost, during the year, £30,000 to manufacture, be delivered to the consumers direct by means of primary currents, they will give you, say £40,000 for it; but if you handicap the electricity by passing it through secondary generators *en route*, half of it will be lost, and your revenue will drop from £40,000 to £20,000.

If the fact be once clearly grasped that electrical energy can only be obtained in direct proportion to the consumption of some other form of energy, it will be seen how much more economical is the utilization *direct* of the energy generated on the cheapest basis, that is to say, by dynamo machines, &c., than by the use of expensive and roundabout devices.

CHAPTER XIV.

THE ELECTRIC LIGHTING ACT, 1882.

The private Bills of 1882—The Electric Lighting Bill of Mr. Chamberlain—The Select Committee—The Electric Lighting Act—Licences—Provisional orders—Value of the same—Basis of solid companies—Private Acts.

In my remarks upon the establishment of electric light supply stations, and the attitude of corporations in relation to them, I referred to the Electric Lighting Act, 1882, and you may like to have a slight sketch of the provisions of that Act.

We have seen that the distribution of the electric current on a large scale will necessitate the laying in the public streets of certain mains; and two years ago the leading Electric Light Companies found themselves face to face with the grave difficulty that, while there is no bar to private persons giving permission for the carrying of electric light wires across their houses, or of electric light mains through their property, the local authorities have no power whatever to grant permission to an electric light company to break up the public streets.

It is true that in almost every case the local authorities have power to take up the public streets themselves for the purpose of repairing the roads; but their power to permit others to touch the streets for other purposes is extremely limited, and in fact generally only extends to water companies and gas companies holding Parliamentary powers.

Certain electric light companies therefore felt it desirable to promote Bills in Parliament giving the local authorities throughout the United Kingdom power, when they deemed it prudent, to allow these electric light companies to make use of the highways for their mains.

The result of this application to Parliament was that an Electric Lighting Bill was prepared, by which the privileges sought by these eight companies might become general under certain conditions, and introduced by Mr. Chamberlain and Mr. Ashley; and this Electric Lighting Bill, as well as the private bills, were submitted to a Select Committee.

At the first meeting of this Committee, on Wednesday, 25th April, 1882, Mr. Edward Stanhope was elected to the chair. After many meetings, and after carefully hearing evidence on all the points of the Bill, a report upon it was laid on the table of the House on the 12th June, 1882; and it finally became the Electric Lighting Act, 1882.

By it no special privileges whatever were given to the eight companies which had promoted the private Bills, which were, of course, withdrawn; and it became open to any who might be so desirous to apply for the privileges granted by the Act. These privileges cover power to break up streets for the purpose of laying mains for supplying electricity in any particular town or district, and the Act provides for these privileges being granted in three different ways:—

(1) By a licence granted by the Board of Trade, and for a period of seven years.

(2) By a provisional order, also granted by the Board of Trade, and for such a period as may be specified in the order; and

(3) By a private Act of Parliament which must include certain provisions mentioned in the Act.

1.—*A licence,* it will be noticed, only lasts for seven years, and it can not be applied for except with the consent of the local authorities of the place sought to be covered by the licence.

In the Act it is provided that *the Board of Trade may* grant such licence, and the following letter on the subject, issued by the Board of Trade in August last, is extremely interesting.

"BOARD OF TRADE, LONDON, S.W.
"*17th August,* 1883.

"ELECTRIC LIGHTING ACT, 1882.

"SIR,—The Board of Trade have had under considera-
" tion the application for licences which have been made to

"them under the Electric Lighting Act. Some of these "applications are made by electric lighting companies, and "extend over large areas, involving a large expenditure of "time and money. According to the terms of the Electric "Lighting Act, such licences can only be granted for seven "years, and at the end of that time the undertakers, and "all the capital they may have expended, are subject to "the decision of the local authority and the Board of "Trade as to whether the licence should be renewed, and "if so, on what terms and conditions. It must be some "time from the date of the licence—probably two or three "years—before such an undertaking can be brought into "full operation, and there would then remain not more "than four or five years during which the undertakers "could expect to reap the fruits of their enterprise. During "this period, moreover, they would be exposed to severe "competition with gas. It is difficult to believe that under "such circumstances prudent and capable investors will be "found able and willing to provide the capital necessary "for so large and so hazardous an undertaking; and that "which is unsafe and imprudent for investors can seldom "be for the ultimate good of the public.

"But this is not all. The grant of a licence, when "approved by a local authority and adopted by the Board "of Trade, is final, and there is not, as in the case of a "Provisional Order, any means of preventing or modifying "it by an appeal to Parliament. If, therefore, as has "lately been the case in more than one instance, consumers "should be dissatisfied with the action of the local authority "and of the Board of Trade, they will, in the case of a "licence, have no remedy.

"Under these circumstances the Board of Trade have "come to the conclusion that they will grant no licences "to electric lighting companies for wide areas, such as the "whole of a provincial town, or of a London parish.

"This does not apply to smaller areas, containing, for "instance, a limited number of streets, squares, or public "buildings, which a company may well be willing to light "by way of experiment or otherwise. Nor does it apply "to cases in which local authorities themselves are the "applicants for the licence.

"I am to add that the Board of Trade, whilst adopting "the above conclusion and making it known for the con-"venience of applicants, do not propose to proceed with any "of the licences now before them until October.

"I am, Sir,

"Your obedient servant,

"HENRY G. CALCRAFT."

I may say that, in my opinion, this part of the Act is valueless, because no electric light supply station that is not laid down upon a permanent basis can possibly stand a chance of making profit, and no capitalists that I know of would be willing to embark in the establishment of solid works which at the end of seven years might be put a stop to. It is true that a second seven years' tenure can be obtained, if the local authority be willing, at the end of the first seven years, to give the same consent which it gave at the beginning.

With, however, all England to choose from, and towns in every part anxious to have the electric light, I cannot understand why any company should apply for a licence when a provisional order, with at least twenty-one years' tenure, is open to it.

2.—*The provisional order* is obtainable by application to the Board of Trade, and Parliament, in making this provision in the Act, has sanctioned a divergence from its ordinary rule, and inaugurated an important change with regard to local legislation, for it thereby invests a department of the Government with powers to go through the details of a scheme coming before it.

The provisional order may be granted for an unlimited period, and, under the rules laid down by the Board of Trade, an electric lighting company obtaining a provisional order for a certain district has to comply with the following conditions:—

(*a*) To deposit within six months from the granting of the order, a certain sum in cash with the Board of Trade, as guarantee that the work proposed will be executed in due course.

(*b*) To put up all the plant necessary to light a certain section of the district granted to the electric lighting company under the provisional order. This portion of the district has been named in the provisional orders "Section A," leaving the remainder of the district to be gradually lighted, as applications from householders are made, from time to time, for the electric light.

(*c*) That a certain maximum price for electricity, fixed by the Board of Trade, shall be charged by the company. This price enables the electric light companies to charge for light upon a basis which, as compared with gas, would equal 5*s*. to 7*s*. 6*d*. per 1,000 feet.

The provisional orders granted by the Board of Trade were presented to Parliament for confirmation last session in the following form:—

Names of Districts.		Undertakers.
No. 1 Bill	Cambridge	Provincial Brush Co.
	Canterbury	South-Eastern Brush Co.
	Chelsea	Metropolitan Brush Co.
	Finchley	Metropolitan Brush Co.
	Folkestone	South-Eastern Brush Co.
	Gravesend	„ „ „
	Greenock	Board of Police.
	Greenwich	Metropolitan Brush Co.
	High Wycombe	Provincial Brush Co.
	Ipswich	„ „ „
	Maidstone	South-Eastern Brush Co.
	Sunderland	N.-East. Electric Light Co.
No. 2 Bill	Aston	South Staffordshire Co.
	Birkdale	Local Board.
	Dudley	South Staffordshire Co.
	Saltley	„ „ „
	Ulverstone	Local Board.
	West Bromwich	South Staffordshire Co.
	Wolverhampton	„ „ „
No. 3 Bill	Balsall Heath	„ „ „
	Birmingham	Incandescent Light Co.
	Redditch	„ „ „
	Walsall	„ „ „
No. 4 Bill	Barton, Eccles, Winton, and Monton	Local Board.

	Names of Districts.	Undertakers.
No. 4 Bill	Carlisle	Corporation.
	Croydon	South-Eastern Brush Co.
	Luton	Provincial Brush Co.
	Margate	South-Eastern Brush Co.
	Nelson	Local Board.
	Rochester	South-Eastern Brush Co.
	Scarborough	Corporation.
	Sudbury	Provincial Brush Co.
No. 5 Bill	Bermondsey	Metropolitan Brush Co.
	Clerkenwell	,, ,, ,,
	Hampstead	Ferranti-Hammond Co.
	Holborn	Metropolitan Brush Co.
	Hornsey	,, ,, ,,
	St. George's-in-the-East	,, ,, ,,
	St. Giles's	,, ,, ,,
	St. James & St. Martin's	Edison Company.
	St. Luke's	Metropolitan Brush Co.
	Wandsworth	,, ,, ,,
No. 6 Bill	Limehouse	,, ,, ,,
	Poplar	,, ,, ,,
	Richmond	Vestry.
	Rotherhithe	Metropolitan Brush Co.
	St. Giles	Pilsen-Joel Company.
	St. Olave	Metropolitan Brush Co.
	St. Saviour's	,, ,, ,,
	Shoreditch	,, ,, ,,
	Wednesbury & Darleston	South Staffordshire Co.
No. 7 Bill	Barnes and Mortlake	Metropolitan Brush Co.
	Hackney	,, ,, ,,
	Islington	,, ,, ,,
	St. Pancras	Vestry.
	Whitechapel	Metropolitan Brush Co.
No. 8 Bill	Bradford	Corporation.
	Brighton	,,
	Hanover Square	Swan Company.
	Norwich	Corporation.
	South Kensington	Swan Company.

Names of Districts.		Undertakers.
No. 8 Bill	Strand	Swan Company.
	Victoria	" "
No. 9 Bill	Bristol	Corporation.
	Grantham	"
	Lowestoft	Provincial Brush Co.
No. 10 Bill	Chiswick	Metropolitan Brush Co.
	St. George Martyr	" " "
No. 11 Bill	Dundee	Gas Commissioners.

It will be noticed that in some cases corporations have taken advantage of the provisions in the Act enabling them to become purveyors of the electric current; but in the case of the other orders there is a very important provision in the Act, by which, *at the end of twenty-one years, the local authority of the district can, if it so choose, become the purchaser of the electric light undertaking* in its district "at its fair market value, without any addition in respect of compulsory purchase, or of goodwill, or of any profits, which may, or might have been, or be made from the undertaking, or of any similar consideration."

So that the local authorities find themselves in the very advantageous position of being able to prevent a monopoly of electric lighting in their town or district beyond a period of twenty-one years, and as at the present moment, there is practically not a tithe of the money in the hands of the electric light companies, to carry out the above orders, if the works are to be set on foot under them, an appeal will have to be made to capitalists.

It will be a point which investors will very properly consider whether it be worth their while to invest in undertakings which, if profitable, will be taken out of their hands in the course of twenty-one years.

For my part, I hold that while the seven years' tenure proposed to be guaranteed by the *licences* would be perfectly useless for the formation of a sound undertaking, the clause in the provisional order giving the local authority power to purchase at the end of twenty-one years should be no bar whatever to the employment of capital in a dividend-paying *electric light supply* undertaking.

On the contrary, I am convinced that in no direction is there, at the present time, any investment so favourable as that of taking up, and working in a *bonâ fide* manner, one of these provisional orders, and I consider that those capitalists who have secured orders thus early from the Board of Trade, will be some day remembered as very "canny" individuals.

If such an Electric Light Supply Company as I am foreshadowing be started in this town, pray take care (1) that no money be paid for patent rights; (2) that all the money subscribed shall be used exclusively for the establishment of electrical works; (3) that the company shall be bound to no particular system, but shall be at liberty, as the gas companies are, to make use from time to time of the best means known to carry out the lighting under its care.

It is well known that the gas companies throughout the country, especially those started in the early days of the gas industry, have earned and still continue to earn very large dividends, and I feel certain that an Electric Light Supply Company based upon these lines, holding exactly the same position towards the lighting as a Gas Company, will earn good dividends from the supply of the electric current for lighting purposes.

The provisional orders, when granted by the Board of Trade, are incorporated in Acts of Parliament.

3.—The third method of obtaining Parliamentary powers for the supply of the electric current in a town or district is by means of a private Act of Parliament, which must be applied for in the usual way by petition to Parliament, and which, if opposed, will be fought out in Committee, with the usual attendant heavy expenses; and as the provisional order offers a very much easier method of obtaining all the privileges under the Act, no one, at all events at the present moment, will think of applying for powers in this way.

It will be seen that the great feature of the Electric Lighting Act, 1882, is to give power to companies in particular districts to break up the roads, and that no bar is put upon the working of electric light plants upon private premises, as the Act does not give the undertakers under the Act exclusive privileges for a particular town or district. Nor does it in any way interfere with the formation of an electric light station, the wires from which do not touch the public highways, but pass through private property.

This mode of distributing the electric light will be possible, as hitherto, without Parliamentary powers; but as already pointed out, it will probably be found that in every town where an electric current-distributing station is formed with large engines, large dynamos, &c., the supply company will be able to purvey the current at a cheaper price than it could be generated by the householder himself, except in those cases where the premises are so large that they require a very large supply of current for a large number of lamps.

As long as the supply company copes satisfactorily with the requirements of its district, it will be left in undisturbed possession of it.

CHAPTER XV.

FAILURES OF THE ELECTRIC LIGHT.

No failure of the electric light when it is properly installed—The experience in the past a safeguard against failures in the future—Cockermouth—York.

THERE will, I feel certain, be some among the audience who will say that I have confined myself, this evening, to painting the rosy side of electric lighting, and have ignored the fact that on more than one occasion in the past the application of the electric light has proved a failure.

As I am very anxious that you should be in a position to view this question from all sides, I think it well to say a few words to explain how it is that things have not always gone on so satisfactorily as we might have desired.

You will notice in the first place that I have insisted that all the electric light installations of the future should be put down upon a safe and solid basis; and, as in the First Avenue Hotel, where as many as 1,000 lights are being run from one single plant, the boilers, engines, and dynamos *should be in duplicate*.

I have also insisted that in the case of the establishment of central electric light stations, an excess of power, ready to counterbalance any break-down that might occur, should be provided, and be capable of use at a minute's notice.

When, however, I look back upon the history of electric lighting, I am, unfortunately, confronted with a state of things in which no attention whatever was paid to the laying down of the dynamo machines, &c., on the complete and necessary scale which I have indicated.

In a discussion which recently took place upon the advisability of applying the sum of £60,000 to electric light works in Brighton, a town councillor stated that the electric light had proved a failure elsewhere; but, from my point of view, I feel justified in urging that *the electric light has not yet been tried* on the basis upon which it is desired to introduce it into Brighton and elsewhere, and therefore it would be wrong to say that upon that basis it had proved a failure.

On the contrary, I am able most distinctly to state that in every case in which the electric light has proved a failure, it has been due to the fact that, while electricians have known perfectly that no installation of the electric light, put down otherwise than in a solid manner, was likely to be successful, they have generally been compelled, by the exigencies of the case, to erect the plant in a temporary manner, and in a way in which success could not be absolutely assured.

For instance, over and over again during the last two years, the proprietors of public places, the town council of a borough, or the organizers of a fête, have determined to have the electric light for a week or a fortnight, and, through the competition in the electric light business, have found some electric light company (and I confess myself to have been a sinner in this respect) to undertake the work for the mere costs out of pocket, in order that it might serve as an advertisement.

Well, you are aware that it is a weakness of human nature that when one is only going to receive £100 for a contract, to take care that £120 shall not be spent, and, shortsighted as the policy has been, many an electric light company has, in its endeavour to avoid a loss, executed a temporary piece of work in a very different manner from that which would characterise a permanent installation.

In listening to the debates of town councils upon the electric light question, you may expect to hear some member say,—"We do not want the electric light in this town, because it has been tried in other places and has failed. It failed in Cockermouth, in York, in Barnsley, in Scarborough, in Chesterfield, and in Middlesborough. Wherever it is put up, it always 'bobs' out; and whenever it is used, people are in an agony of suspense as to what trick it will play next."

I admit, you notice, that *no proper trial has yet been made of house-to-house lighting;* and in reference to isolated plants I feel perfect confidence in declaring *that during the* *past two years the electric light has never failed in one single instance where it has been properly installed.* In support of my view I could give you the most amusing accounts of the cause of every failure that has occurred in England; failures in no case due to the electric light system, but due entirely to some wretched incident connected with the fitting up of the installation; and I am glad to be able to say that the result of the failures which have occurred in the past has been to train up among us a set of electrical engineers, who know exactly what mistakes to avoid, and how to do their work in a thoroughly efficient manner.

Think for one moment of the position which was occupied by the electric light companies some two years ago. They found themselves face to face with a general desire, on the part of works managers, town councils, proprietors of public places, &c., &c., to try the electric light. The college that has since been formed by us for training young men as electric light engineers was not then in existence, and in order to get through the work the electric light companies were compelled to press into their employ almost every man who came to them and called himself an electrician. I should weary you if I were to detail the experiences that I have had with the so-called "electrician," and I begin to wish that some other word could be invented to designate the electrical engineer.

To take, however, a case to which the gas companies are very fond of alluding—that of Cockermouth, a small town, as you know, in Cumberland, but one a long way ahead of its fellows, in that it adopted the electric light some three years ago. In the pressure of business this installation was left in the hands of a gentleman, who is still remembered in that enlightened town as one who went away and never paid any of his bills, and who actually tried to run the electric light with an engine which was one of the best-known features of Cumberland country-side life; for this engine had, in the course of its existence, acted as a threshing machine, it had also assisted in dragging about a circus, and having passed through many vicissitudes, was chosen as the particular piece of apparatus which would suit admirably for running a dynamo machine to give light to Cockermouth!

This so-called electrician, who, I veritably believe, did not know how to switch an arc lamp on and off, telegraphed enthusiastically, at intervals of a few hours, that everything was progressing beautifully; and, on the eventful evening when Cockermouth expected to be bathed in the effulgence of the electric light, special excursion trains were run from all parts of Cumberland to see the great sight, and a fair lady was chosen to turn on the switch, at the end of one or two inaugural speeches. The lady performed her task extremely well; but when the switch was turned on no light came, the bulk of the lamps being short-circuited. That electrician had to make good his exit from the back-door of his hotel, or I believe he would have been roughly handled by the excursionists.

It is in vain to try to explain to the holders of gas-shares that electric lighting under the conditions tried in Cockermouth was almost an impossibility. They still point to that failure; and though Cockermouth has, during the last two years, had steady and good light, the memory of that failure is treasured up as something to score against the electric light.

I could give you half a dozen such instances as these.

In York, for instance, at the meeting of the British Association, in 1881, the whole town was illuminated with the electric light, and Sir John Lubbock, the chairman of the Edison Company, will probably have a very sad recollection of the unsteady working of those arc lights, when he was giving his presidential address.

What took place at York was this. Two days before the meeting opened, some one discovered that the steam-engine, which was to run the dynamo machine, was in too close proximity to the hall of meeting, and must, at all hazards, be removed; and, incredible as it may appear, the whole of the plant had to be moved and fresh foundations put down in a place about half a mile off, and the whole of the work executed within thirty-six hours.

I could go on explaining every failure of the electric light, but I will ask you to take it for granted that no failure has occurred from causes which would surprise a single engineer among you; and I feel perfectly confident that, with the experience gained in the past, there are now those who, with the perfected means now at their command, are justified in guaranteeing to carry out electric light work in an efficient manner, and who are prepared to give weight to their opinion by risking substantial sums, to be forfeited if the work does not fulfil in every way the conditions that the most stringent engineer can lay down.

CHAPTER XVI.

CONCLUSION.

My task is done, and I have to thank you for the very kind attention which you have granted me. I hope that I have succeeded in giving you a clear idea of how the electric light is produced, and have imbued you with a warm appreciation of it.

Kindly allow me to indulge in a few words of recapitulation:—(1) I have shown that the failures of the electric light are not likely to recur. (2) I have explained how recent legislation provides for the proper regulation of the conditions of supply, either by private companies or by corporations, and on how solid a basis Electric Light Supply Companies may now be started. (3) I have touched upon the most recent forms of accumulators, and have shown you how fallacious is the notion that they are a necessity to central supply stations. (4) I have indicated how practicable it is for the owners of the large hotels, theatres, public buildings, &c., of the country to avail themselves immediately of the benefits of the electric light upon a reliable and economical basis. (5) I have pointed out the means whereby you in your respective residences can have, if you wish it, single installations of the electric light. (6) I have proved that if in spite of its manifest advantages you prefer to wait until mains are laid down in your neighbourhood, the cost of your electric light will be on a par with the present price of gas, and, even at that figure, will yield a good dividend to the suppliers. (7) I have gone fully into the means by which the electric current will be brought, through large mains or conductors, from central electric current supply stations, where large engines and dynamos will work at a minimum of cost and consumption of fuel. (8) I have, I hope, proved to you, by the illustration of what is going on at my house, and by what you have seen around me this evening, (*a*) that the electric light is under perfect control; (*b*) that it is a pleasing and not a glaring light; (*c*) that it is an element of safety rather than of danger in a house; and that while (*d*) it adds no noxious fumes to the air and is the cause of no ravages to be repaired at heavy cost, (*e*) it does not absorb the life-giving oxygen which surrounds us, and which is so essential to health.

If my arguments have had weight with you, I look forward on my return to your town six months hence to find works connected with an electric light supply station in full progress of erection; and when I visit you a year hence, I hope to find that installation in full work, and to be able to congratulate you on having completed a step in the progress of your town greater than any which has hitherto been taken in its history, and one securing you profits which have hitherto gone into the pockets of strangers. If my hopes in this respect be realised, I shall look back with redoubled satisfaction to the time when I first had the pleasure of bringing prominently before you the advantages and the possibility of the immediate application of **THE ELECTRIC LIGHT IN OUR HOMES.**

"Lux et Felicitas."

DALZIEL BROTHERS, CAMDEN PRESS, N.W