current be heated, less electricity flows through it than before. If two such wires, carrying equal currents from a powerful battery, meet in a recording apparatus (the galvanometer) the index of the instrument—pushed in two opposite ways by exactly equal forces—will remain at rest. If one current be diminished by warming ever so little the wire which conveys it, the other current gets the upper hand, and the index swings with a force due, not directly to the feeble heat which warmed the wire, but to the power of the battery which this feeble heat controls. The application of this principle is thus made: Iron or steel is rolled into sheets of extreme thinness. The speaker said he had succeeded in rolling sheets of steel made at the works of Miller & Parkin, Pittsburg, Penn., until it took 8,000 of them to make the thickness of an inch. Specimens of these sheets were exhibited, together with platinum, rolled at the United States Mint in Philadelphia, even thinner. Of these sheets fifty laid one on another did not together equal the thickness of light tissue paper. Minute strips, 1-32 of an inch wide and $\frac{1}{4}$ of an inch long, cut from this were united so as to form a prominent part of the circuit, through which a current of a powerful battery passes to the galvanometer. Experiments proved that an almost inconceivable minute warming of a set of these strips would reduce the passage of the electricity, so as to produce very large indications on the registering instrument. Professor Langley had in the course of his experiments thus far, he said, found iron the most advantageous, though other metals were still under trial. The instrument thus formed was from ten to thirty times more sensitive than the most delicate thermopile; but this was almost a secondary advantage, compared with its great precision and the readiness with which it is used. The thermopile is very slow in its action. This new instrument, the thermal-balance, takes up the heat and parts with it again in a single second. It is almost as prompt as the human eye itself. To show its accuracy, Professor Langley gave experiments which proved that the probable error of a single measurement made with the instrument could be reduced within one per cent. of the amount to be measured. To show its sensitiveness, the statement was made that it would register a change in the temperature of the iron strips, just described, which did not exceed one-fifty thousandth part of a Fahrenheit degree. When mounted in a reflecting telescope it would record the heat of a man or other animal in a distant field. It would do this equally well in the night, and might be said, in a certain sense, to give the power of seeing in the dark. A more valuable proof of its efficiency was shown in a series of measurements of the heat of the moon, made under varied circumstances, to guard against error, but each made in a few seconds. All agreed in showing that the almost immeasurably minute amount of heat from the moon could be certainly measured by it, even with a common refracting telescope.

TRACING THE PENDULUM.

At the last session of the American Association, Professor Mayer said: Last year, in the month of October, I mounted in the physical laboratory of the Stevens Institute of Technology a Foucault pendulum formed of a cannon ball suspended by a steel wire. By floating the ball in mercury I determined the point on the ball to which the wire should be attached, so that this point and the center of gravity of the ball should be in the same vertical line. This line, having been prolonged as a diameter of the ball, determined the spot into which I screwed a pointed index. The point of this index, when the ball was stationary, was about $\frac{1}{40}$ of an inch above a piece of smoked paper placed on a plate of metal which had been carefully brought into a horizontal plane. The pendulum was now drawn from the vertical by the tension of a delicate cord, one end of which was attached to the ball, the other fastened to a fixed support. The pendulum was started in the usual manner by burning this string. After a few oscillations a current of electric sparks from an induction coil was passed through the suspending wire, and from the point of the index of the pendulum through the smoked paper to the metal plate, and thus was obtained a trace of the path of oscillation of the pendulum. At successive and known intervals of time I obtained similar traces, which were rendered permanent by passing the smoked paper through spirit varnish.

Last May I described this experiment to Professor Cross, of the Massachusetts Institute of Technology, and he then informed me that the same idea had occurred to him, though he had not put it in practice, and also that he had recently mentioned this plan of experimenting before the American Academy of Arts and Sciences in Boston; therefore his name and mine should be always associated in designating this method of obtaining a permanent trace from the Foucault pendulum.

NEW AIR THERMOMETER.

By M. MILLER.

The apparatus is constructed of an iron support fitted at its upper part with two tubules, in which are fixed the two tubes of the manometer. The closed branch bears a thread of opaque glass, soldered in its side at the point where the large tube joins the connecting tube.

LIGHTNING RODS ON WAR SHIPS.

The Lords Commissioners of the Admiralty direct that in future the captains and commanding officers of Her Majesty's ships and vessels are to be held responsible for ascertaining that the continuity of the lightning conductors on board the ships and vessels under their command is complete, and also for maintaining such lightning conductors in a state of efficiency. In ships which have galvanometers on board the conductors are to be tested periodically, and in ships which are not supplied with such instruments the commanding officer is to apply for the conductors to be tested, when an opportunity offers, at a dockyard.

IMPROVEMENT OF THE BUNSEN BATTERY.

This improvement, made by Mr. Azapis, consists chiefly in replacing the acidulated water in which the zinc is immersed by a solution of about fifteen per cent. of cyanuret, either of potassium, of caustic potash, of sea salt, or of ammonia salts. The liquid in the porous vessel which contains the carbon plate remains the same as usual. This improvement has the advantage that, while the intensity of the current is the same as in the Bunsen element, the zinc plates do not need to be amalgamated, and the consumption of zinc is considerably less, while the constancy and the durability of the current are remarkable. A battery improved in such a manner, which consisted of twenty-five elements, and in which ordinary ammonia salts were employed, was used

without interruption for four days in succession, and during the evening for the purpose of producing an electric light. Another advantage of the battery is that it gives out very little odor.

ELECTRIC LIGHTING.*

ALMOST two years ago I had the honor of delivering a lecture in this place on electric light. To-night I have undertaken to report the progress which has been made since then in connection with the subject. At the time of my last lecture the public mind was greatly perturbed by the question whether or not gas lighting was about to be superseded by electric lighting. It was generally believed that a revolution-working discovery had been made, and you may remember, as a consequence, gas stock was much depressed in value. After a while, when the supposed wonderful discovery dwindled and paled in the daylight of scientific examination, the panic subsided, and then the current of feeling drove the other way, and in place of the hasty credulity which at first took possession of the public mind, there is now, I think, an equally unreasonable unbelief in the possibilities of electric lighting—the idea now widely prevailing that electric light, as a substitute for gas, is after all a delusion.

[A brief résumé of the general principles was here given, and the development of the dynamo machine shown.]

On the whole the cost of producing electricity by mechanical means has been diminished.

It is practicable to develop 1 horse power by the combustion of 2 lb. of coal per hour, and to produce with this amount of motive power a current of electricity sufficient to give a light of over 1,000 standard candles; that is to say, we can maintain for one hour an electric light more than equal to 1,000 standard candles, or 66 large gas burners, by the combustion of 2 lb. of coal. That is a much more economical result than can be obtained by the voltaic battery or any other means of generating an electric current at present known. [Reference was made to the voltaic cell, and the question of storage was discussed as exemplified in the secondary battery of M. Planté.] M. Planté was, I believe, the first to put the idea of a secondary battery into practice. The secondary battery of M. Planté consists of plates of lead placed opposite each other and very near together, but not touching. Here is a Planté cell. It consists simply of two pieces of sheet lead rolled up together, and separated by the space of about one-eighth of an inch. You observe that in this combination we have two plates of the same metal, viz., lead; and in this respect the combination differs from an ordinary voltaic battery, inasmuch as the very essence—so to speak—of the voltaic battery is the dissimilarity of the two plates which in part constitute it. It is zinc and copper, or zinc and platinum, or some dissimilar combination of that sort that we are all familiar with as characteristic of the voltaic battery. Here, in the secondary battery, the two plates are alike, therefore of themselves they cannot generate a current of electricity like the ordinary voltaic battery. But if these two lead plates are for a time connected by wires with a generator of electricity, no matter of what kind (it may be a dynamo-electric machine which supplies the primary current) one of the lead plates is changed on its surface—it becomes oxidized—and after undergoing this change, it is, when detached from the generator, in such a condition as to be able to give out, at any future time, a current of electricity on its own account; and when the charge has been expended the plates are, like an empty gasometer, just in the same condition they were before receiving the charge, and ready to be charged afresh. The secondary battery is, therefore, an instrument of very great interest at the present moment, and it is much to be hoped that it may be improved, because, in the simple form which I have described, it does not quite do all that would be required of a secondary battery, applied as a store of electricity on a large scale for extensive practical electric lighting. I have here a modified form of a secondary battery, which, if it does not give us all that could be desired, makes a very considerable contribution toward it. This battery was charged this morning; before being charged it was nearly inert. I will join the poles together by this platinum wire, and if the charge has been retained the wire will become hot. [The wire is, you see, white hot.] The want of a means of storing electricity is a newly felt want; as yet it cannot be said to have been fully supplied, but, as I have shown you, it has been supplied to a certain extent, and research is still busy at work seeking its complete fulfillment. There can be no doubt that what is wanted will be found, and with the perfecting of the secondary battery that great objection to electric lighting—that you cannot store the power which produces it as you can store gas—will be completely met.

[The thermopile was here briefly referred to.]

All the various means of producing light by electricity that can make any pretension to practicability are divisible into two classes, namely:

- 1st.—Lighting by the electric arc.
- 2d.—Lighting by incandescence.

In lighting by the electric arc there is a break or gap in the circuit which has to be bridged over by a sort of electric flame. In lighting by incandescence there is no break or gap at the point where light is produced, but a thin, highly infusible, and badly conducting solid substance is there interposed which becomes white hot, and emits a light, bright in proportion to the degree of heat produced in it.

Now, to fix in your mind precisely what I am talking about, I will first show you what I mean by the electric arc. This will enable you more easily to follow my remarks on the question of electric lighting by this method.

Here is an enlarged view of the electric arc—here are the two carbon points, and here—between them—is formed the electric arc.

A powerful electric current, produced by a gas engine and dynamo-electric machine, is supplied to these two pencils of carbon through thick copper conducting wires, and you see that a stream of flame is flowing or rushing between them. If the points are too much separated, the light is lessened; by increasing the air space between the points resistance to the passage of the current is increased, and the current is consequently diminished, and when this diminution of current passes a certain limit the light is lessened. On the other hand, when the points are made to approach too closely to each other, the light becomes less for the opposite reason.

A certain amount of difficulty or resistance must be offered to the passage of the current in order to produce light, and to get the best effect the resistance must neither be too much nor too little.

When the points are made to touch there is no longer the

resistance of the air space to be struggled through, the light consequently goes out.

Observe the alteration in the points; they burn away, and one faster than the other. Now, as the production of a steady light demands that the points should be maintained at a constant distance apart, it is evident that under the complicated conditions of the case, a nice regulation of the distance of the points to each other is a matter of extreme difficulty.

I will now ask for the current to be turned on to a lamp hung up aloft, in order that you may see how very nearly the difficulties of producing a steady arc light have been surmounted.

The particular lamp I am using for the purpose of my illustration is Crompton's lamp, of which here is a diagram. Properly regulated it feeds the pencils together almost continuously and with great precision.

That, then, ladies and gentlemen, is *par excellence* the electric light. That is the form and style of electric light that inventors have for the last forty years struggled and battled with difficulty upon difficulty to render serviceable to the wants of man.

From the nature of the electric arc light you will readily perceive that it is a kind of light not suited to the lighting of dwelling houses, nor shops, nor streets.

It does not lend itself kindly to division nor extensive distribution. It will give you either a great deal of light or none.

For certain exceptional uses it is excellent. If you want a very brilliant illumination all centered in one focus, for a lighthouse, or signal, for example, or for a high-roofed railway station, or very large workshop, or open space, it is unquestionably the most economical and the best of all artificial lights.

It has already found for itself in England over two hundred appropriate applications. Its use is continued and increased on the Thames Embankment. It is used in the reading room of the British Museum; in the Picton Library, Liverpool; in a portion of the South Kensington Museum; at the Liverpool Street Railway Station; the Barrow Ship-building Works; the St. Enoch Railway Station, Glasgow; on the Promenade at Blackpool; and at the New Albert Docks, where, by means of Siemens lamps, three miles of wharves and quays are made almost as light by night as by day, and at a very moderate cost.

As an illustration of the economy of lighting by means of the electric arc under conditions suited to its use, I instance the case of the Alexandra Palace, where 2,000 gas lights, which consumed 2½s. worth of gas per hour, are replaced by six of Mr. Crompton's lamps, giving a greater aggregate amount of light than the 2,000 gas burners, at a cost of 6s. per hour. In some instances the economy of the electric arc light is greater by half than in the case I have mentioned. Not only is it economical in such a case as that of the Alexandra Palace, but it produces an effect of general illumination overhead as well as upon the ground not producible by any other means.

But the interest which attaches to electric arc lighting is much lessened by the fact that the purposes to which that mode of lighting is suited are exceptional. We do not, as a rule, want the light of 1,000 candles or more all in one place. What we do generally want is a number of small and steady lights, spread about in different rooms, and in different parts of those rooms. For electric light of this description we must search in another direction.

I said that there is another way of producing electric light: namely, by incandescence.

Lighting by incandescence is a branch of the subject which has a special charm for me, because I have bestowed upon it much thought and labor; and it is, I believe, the branch which will yield the largest crop of fruit. Electric lighting by incandescence is just as simple as arc lighting is difficult; all that is required is a material which is not a very good conductor of electricity, highly infusible, and which can be formed into a wire or lamina, and is either non-combustible in air, or, if combustible, does not undergo change in a vacuum. There are, so far as I know, just two substances that possess, in any sufficient degree for the purpose in question, the qualities I have specified.

The two substances are: Platinum, or an alloy of platinum with iridium and carbon. Platinum has the advantage over carbon that it is not combustible in air; it does not, like carbon, burn away if you make it white hot; but it is very inferior to carbon in the degree of heat it will bear without fusion; and for producing light by incandescence it is essential to economy that the incandescent material should be capable of enduring an extremely high temperature, because the amount of light emitted by an incandescent substance increases in a more rapid ratio than the temperature.

When, for example, you have a piece of platinum wire or carbon red hot, it emits almost no light, but double its temperature by sending a double quantity of current through it, and it will yield much more than twice the light it did before.

It is, therefore, evident that the hotter the incandescent material can be made the less the light will cost per unit of power expended.

Iridio-platinum, comparatively with other metals, may be called extremely infusible, but compared with carbon it is nowhere. Carbon has, in fact, resisted without fusion the very highest degree of heat brought to bear upon it, and what that degree of heat is I can hardly estimate, it is so enormous.

But carbon has been found so difficult to deal with on account of its ready combustibility (and some other troublesome properties which I will mention afterward), that experimenters have bestowed much attention upon platinum and iridio-platinum as the incandescent material for electric lamps.

Mr. Edison was, I think, the last who attempted to utilize platinum in an electric lamp, and I think there can be no doubt that he obtained better results with platinum, and came nearer making a useful platinum than lamp, any experimenter in the same track who had gone before him.

Here is a view of Edison's platinum lamp.

This is the lamp of which so much was promised and expected in October, 1878, and which led, you remember, to the panic in gas shares. This lamp did not realize the hopes of the inventor.

(I will not rekindle Mr. Crompton's electric sun, because I hope presently to show you some small lamps, whose light would be absolutely drowned in that fierce radiance, as stars are by the light of day.)

While Mr. Edison was endeavoring to produce a useful incandescent lamp by means of platinum, I was endeavoring to obtain the same end by means of carbon.

It had appeared to me for many years that if ever electric light was to become generally useful, it would, most probably, be by means of the incandescence of carbon. I had,

* Abstract of a lecture delivered by J. W. Swan, at the Literary and Philosophical Society, Newcastle-on-Tyne, October 20, 1880.