containing 60,000 ohms and a box which contained resistances varying from one hundredth of an ohm to five thousand which were used to make a shunt around the galvanometer. The size of the resistances 60,000 ohms made it possible to measure electromotive force by placing various batteries of various strengths in the current and taking the deflection to represent the E.M.F. of the cell by neglecting its resistance. It also made the assumption true that if the ends of the circuit containing the high resistance galvanometer were placed at the extremities of a resistance where a strong current was flowing not enough would escape to make any practical difference in the flow. Thus the galvanometer readings would denote the difference of potential between the ends of the circuit containing it and for all practical uses in measuring currents may be considered as an electrometer. [N-79-02-15.1:199–201, Lab. (TAEM 31:756–57; TAED No28:99–100)]

10. These experiments continued on 24 August with Spiral No. 2, “A spiral wound very closely and kept in a vacuum over night without heating. The wire .007 in. in diam six inches long covered with Corundum.” Vacuum experiments with this spiral showed “the air escaping from the Pt.” After a full vacuum was obtained the laboratory staff tested the spiral and measured its resistance and the number of foot pounds required to heat it to different degrees of brightness. They also tested the spiral in the air. They also brought “a spiral size of grain wheat” to white heat in five hours and it gave “what was estimated as eight candles by means of a battery.” This spiral was taken to the AAAS meeting in Saratoga, presumably for use in connection with Edison’s paper on his process for treating platinum by heating it in a vacuum (see Doc. 1796). N-79-08-22:17–27, Lab. (TAEM 35:792–97; TAED No85:9–14).

[Saratoga, N.Y., c. August 28, 1879]

Some time ago in the course of my experiments upon the subject of E. Lighting I have developed some striking phenomena arising from the heating of metals especially of wires of pure a Platinum and on alloys of platinum and Iridium. These experiments are still in progress. b

The Lamp placed in My system of Electric Lighting is based upon the heating of spirals by of consists of several feet of The first phenomena observed was that loss of weight which platina wires lost weight in a flame of pure Hydrogen, that the metal colored the flame green and that these two results continued until the whole of the platina disappeared. That 306 miligrams of 4 thousandths platinum wires 4 thousands of an inch in diameter bunched together & suspended in a hydrogen flame lost a fraction less than 1 m.g. per hour for several hours, but no loss of weight occurred
when an equal weight amount of wire was suspended over the flame from a Bunson burner flame. If a straight piece of platinum wire is stretched between two supports and made to pass through a hydrogen flame, it will color it tinge the flame green, but if the temperature of the wire is raised above that of the flame by passing a current through it the flame is colored deep green to ascertain the loss of diminution in the weight of a platinum wire when heated by the electric current, I stretched between two clamping posts a wire five thousandth of an inch diameter weighing 296.66 mg. This wire after being brought to incandescence for 20 minutes by the electric current its weight was 293.265 mg showing a loss of one mg — The same wire was then raised to incandescence for 20 more minutes its weight was 262 mg shewing a further loss of weight of 3 mg or a total after 10 minutes additional its weight was 260 mg — in 20 minutes more 258 mg or a total loss of 8 mg in one hour and ten minutes after being kept incandescent for 40 minutes longer it loss 2 additional or a total loss of 7.8 mg in 1 hour & 50 minutes. Afterwards a wire strip of platinum offering large surface to the air was kept moderately incandescent by the current for 39 hours after which time it weighed 310 mg shewing a loss of 34.2 mg. A platinum wire 20 thousandths in diameter was wound in the form of a spiral 1⁄8 of an inch in diameter & about ½ an inch in diameter length. This was secured in clamping posts and covered with a glass shade 1½ inches in diameter & 3 inches high. upon passing the current through the spiral upon bringing the spiral to incandescence by the current for 20 minutes that part of the glass globe in line with the sides of the spiral become slightly darkened in 45 hours the deposit of platinum was so thick that the incandescent spiral could not be seen through it. This deposit was most perfect and I have no doubt but large plates of glass might be coated economically by being placed on each side of a sheet of platinum kept incandescent by a Dynamo Electric machine.

The loss of weight in together with the deposit upon the glass became a very serious obstacle in the way of its use for producing the Electric light by the incandescence, but it was easily surmounted when the cause was ascertained. I coated a spiral wire with the wire forming a the spiral by passing with the oxide of Magnesium by dusting powdered acetate of magnesia on the wire while incandescent. The salt was decomposed by the heat and left a strongly adherent coating of the oxide of magnesia upon the wire. This spiral placed in the
glass shade was brought to incandescence and allowed to remain in that state 20 minutes an opalescent for some time but no deposit instead of a deposit of platinum there was a deposit on the glass of the oxide of magnesia, proving that the effect was due entirely to the molecular attrition— or the attrition of the rapidly circulating air in the glass receiver globe and produced by the rapid movement of gaseous molecule when in proximity to the highly incandescent was washing the that the loss of weight & coloration of the hydrogen flame was also due to the wearing away of the surface of the platina by the attrition produced by the impact of the stream of gases upon its highly incandescent surface, and not to volatilization as I understand it, and I venture to say although I have not tried the experiment that sodium cannot be volatilized in high vacua by the heat derived from incandescent platinum, and if any effects are obtained they will be produced by the action of the residual gases. After being satisfied that the deposit & loss of weight was due to the attrition of the air, I placed a spiral of platinum in a glass receiver of a common air pump arranged so that the current could pass through it while the receiver was exhausted, at exhaustion of 2 millimeters it took the spiral was kept incandescent for over 2 hours before the deposit was sufficiently thick to become noticeable.

by another experiment & at a higher exhaustion it required 5 hours before a tint was observed, in a sealed bulb exhausted by a sprengel mercury pump to a point where a ¼ inch induction coil spark from an induction coil will not pass between wires 2 mm apart I have not detected any deposit whatever although the spiral contained therein had been kept incandescent for many hours, and I feel certain that I shall be able to produce. I will now describe the most important phenomena which I have observed. If a piece of platinum wire 1 thousandth of an inch in diameter be held in the flame of a bunsen burner at some point it turns a sharp angle, and under the microscope shews a globule formed at the point where it is bent. in some cases the effect of the heating is to throw the wire into a zig zag shape & melting in many places. with a wire 4 thousandths of an inch in diameter this effect does not take place as it temperature cannot be raised to equal that of the small wire, but if thise wire be examined under a powerful microscope that part of its surface which has been incandescent will be found to be covered with innumerable cracks. If a piece of wire be stretched between clamping posts and is brought to
incandescence for 20 minutes by the passage of the electric current, this effect will be greatly magnified and the wire will present these cracks may be seen with the naked eye. The wire under the microscope will present the same appearance as a stick of moistened pipe clay after drying. If the current be continued for several hours—the whole wire will become so cracked & shrunk that it will fall to peices. This disintegration has been noticed by Prof. John W Draper. and it was also the cause of the failure of the process of lighting devised by the eminent French chemist Tessie Du Motay who caused raised platinum to incandescence by the combustion of hydrogen on its surface. Now I have discovered that I have discovered the cause of this phenomena an in eliminating this and have succeeded in bringing platinum wire and have succeeded in eliminating that which produces it, and in doing so have produced a metal in a state hitherto unknown, a metal which stands absolutely stable at which temperature where nearly all substances melt or are disintegrated, a metal which is a homogenous as glass and nearly as brittle, as hard as steel wire, in the form of a spiral is as springy and elastic when dazzling incandescent as when cold, and which cannot be annealed, by any process generally known to me. The method cause of the cracking & shrinking of the wire is entirely due entirely to the sudden expansion of the air in the mechanical & physical pores of the platinum wire and the subsequent contraction of the metal when the air has escaped. Platinum wire as delivered from the manufacturers may be compared to a piece of sandstone, it being made up of innumerable particles seperated at places by air spaces. The sandstone on being melted becomes homogenous & no air spaces exists while with the platinum the air spaces may be eliminated and the wires made homogenous by a simple process. If a This process I will now describe. I made a large number of platinum spirals all of the same size a presenting to the air a radiating surface of \( \frac{3}{16} \) of an inch. 5 of these spirals were brought to incandescence by the electric current, and had their temperatures slowly increased by the current until thes melted, the lights which they gave off being measured by a photometer up to the melting point—This varied from 3 to 4 candles, the melting point of the metal being determined by the depth of the large crack in the wire wire due to the \(-\) flaws produced by by sudden heating one of the same kind of spirals was then placed in the receiver of an air pump and the air exhausted to two mm. a very weak current was then passed through the wire to
slightly warm it. For the purpose of assisting the passage of the air from the pores of the metal into the vacuum, the temperature of the wire was then gradually augmented at intervals of 10 minutes until it became red. The object of slowly increasing the temperature so as to was to allow the air to pass out of the metal gradually without disrupting it. Afterwards the current was increased at intervals of fifteen minutes each time before increasing the current the wire was allowed to cool this expansion & contraction of the wire caused it to melt together at the points previously containing air. In one hour and forty minutes this spiral had reached such a temperature without melting that it was giving a light of twenty-five standard candles, whereas it would undoubtedly have melted before it gave a light of five candles had it not been put through the above process. Several more spirals were afterwards tried with the same result. One spiral, which had been brought to these high temperatures more slowly, gave a light equal to thirty standard candles. In the open air this spiral gave nearly the same light, although it required more current to keep it at the same temperature.

Upon examination of these spirals which had passed through the vacuum process, by the aid of a microscope, no cracks were visible, the wire had become as white as silver and had a polish which could not be given it by any other means. The wire had a less diameter than before treatment, and it was exceedingly difficult to melt in the oxyhydrogen blow pipe as compared to untreated platinum, that it was as hard as the steel wire used by pianoforte makers and could not be annealed at any temperature, and my experiments with many metals treated by the process has proved to my satisfaction and I have no hesitation in stating that what is known as annealing of a wire by heating to make it soft and pliable is nothing but cracking of the metal as in every case when a hard wire has been annealed a powerful microscope shows myriads of cracks. Since these experiments above, Since these experiments I have by the use of sprengel pumps produced higher exhaustions, and have succeeded by consuming 5 hours in excluding the air from the wire & in intermitting the current by obtaining a light of eight candles from radiating surface of 3 hundreds of an inch, which is equal to 26.4 candles per inch of radiating surface, divided upon 33 parts. The utmost average quantity of light obtainable from a surface of \( \frac{3}{100} \) of an inch without passing through this process is 1 standard candle.

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Thus I am enabled to by the increased capacity of platinum to withstand high temperatures to employ small radiating surfaces, and consequently require less energy to give per candle light than if I were compelled to use a radiating surface several times greater in consequence of lower melting points, and I can thus enabled obtain eight separate lights each giving a light of sixteen candles by the expenditure of 33 000 ft lbs of energy notwithstanding all the losses which occur in the passage from the engine to the belt lamp, but all that is required and as to the impossibility of subdividing the Electric light with economy as has been asserted by some scientific men a result which is quite sufficient to make the Electric Light a commercial success. As a matter of curiosity I have made spirals of other metals and passed them and excluded the air from them in the manner described. Common iron wire may be made to give a light greater than that obtainable from platinum not treated its becomes as hard as steel Nickel is far more refractory than Iron. Steel wires used in piano becomes decarbonized remains hard and very as white as silver. Aluminum melts only at a white heat. Magnesium melts only at a bright red The color of the arc at the moment of melting an iron wire in high vacua is deep violet. In conclusion it may be interesting to state that the melting points of many oxides is dependent upon the manner of applying the heat. For instance, pure Z oxide of Zirconium does not fuse in the flame of the oxyhydrogen blow pipe, while it melts like wax on an incandescent platinum spiral, at a which is at a far lower temperature, on the other hand alumina the oxide of aluminum easily melts in the flame of the oxyhydrogen blow pipe, while it only becomes vitrous at the melting point of platinum.

ADf, NjWOE, Miller (TAEM 86:72; TAED HM790088a). “Interlined above. “Obscured overwritten text. “Canceled. ““4 . . . diameter” interlined above. ““the flame from a” interlined above. ““above that of the flame” interlined above. ““diminution in the” interlined above. ““66” interlined above. ““This wire” interlined above. ““brought to” interlined above. ““by the electric current” interlined above. ““offering . . . air &” interlined above. ““[] moderately” interlined above. ““301 mg” interlined above. ““the wire” interlined above. ““with the oxide of Magnesium by” interlined above. ““gases” overwrites “gaseous.” ““produced by . . . washing o the” interlined above; “washing o the” interlined separately. ““are obtained they” interlined above. ““from an induction coil” interlined above. ““in diameter” interlined above. ““for several hours—” interlined above. ““of lighting” interlined above. ““the combustion of” interlined above. ““temperature where nearly” interlined above. ““by
any . . . me" interlined above. ""piece of"" interlined above. ""by the current"" interlined above. "by a photometer"" interlined above. "by heating"" interlined above. ""The temperature of the"" interlined above. ""The object . . . disrupting it—"" interlined above; ""was to allow"" interlined above that. Page missing, text taken from published paper. ""& in intermitting the current"" interlined above. ""average amount"" quantity of"" interlined above. ""am thus enabled to"" interlined above. "the . . . energy"" interlined above. ""result . . . success."" interlined above. "its . . . steel"" interlined above. "remains hard"" interlined above. "as silver"" interlined above. ""flame of the"" interlined above. "which is at a"" interlined above.

1. In Doc. 1810 George Barker indicated that Edison wrote this paper while in Saratoga. Edison arrived there on 27 August and left on the evening of 30 August, leaving Francis Upton to "read the paper from the writer's exquisite manuscript" on 2 September ("Mr. Edison's Discoveries," New York Tribune, 3 Sept. 1879, Cat. 1241, item 1322, Batchelor [TAEM 94:511; TAED MBSB21322X]). This draft is essentially the same as Edison 1880a with some changes in wording and different paragraphing; text from the published version has been used to replace the text from the missing page nine of the draft. The paper was reprinted within days by three New York newspapers. One of these, the New York Times, also reported George Barker's enthusiastic remarks on Edison's electric light and the paper itself, which he praised "as one of the highest importance" ("Giving Metals New Properties. Some of the Wonderful Results of Prof. Edison's Experiments," New York Times, 3 Sept. 1879; "Mr. Edison's Experiments," New York Sun, 3 Sept. 1879; "Mr. Edison's Discoveries," New York Tribune, 3 Sept. 1879; Cat. 1241, items 1314, 1318, and 1322, Batchelor [TAEM 94:506, 509, 511; TAED MBSB21314X, MBSB21318, MBSB21322X]). The paper was also reprinted in the technical press ("On the Phenomena of heating Metals in Vacuo by means of an Electric Current," Sci. Am. Supp. 194:3098; "The Action of Heat in Vacuo on Metals," Chemical News 40:152–54; "The Action of Heat in Vacuo on Metals," Nature 20:545–46; "Heating Metals in Vacuo by the Electric Current," Teleg. J. and Elec. Rev. 7:320–21).

2. On the wire experiments described in the first part of this document see Docs. 1665, 1666, 1669, 1670, 1672, 1675, and 1678; see also Docs. 1676 and 1735.

3. Edison apparently had with him the notebook containing the notes of experiments he had conducted during the last two weeks of January as the precise weights and times given here are found in that book (Doc. 1665). The final paper has some differences. The first twenty minute loss of 1 mg. is incorrectly omitted but the total loss is correctly summed as 8 milligrams after one hour and ten minutes.

4. This statement regarding sodium is not contained in the final paper.

5. See Docs. 1679 and 1735.

6. The work in which John Draper's observation appears has not been identified.

7. Nothing is known of this particular apparatus. Cyprien Tessié du Motay was a French industrial chemist noted for inventing a system of producing pure oxygen with which he planned to modify carbureted gas...
systems in Paris and New York. More recently he had experimented with incandescent lighting and, with a partner, filed for a U.S. patent in January 1879 for an electric lamp employing a “pencil formed of earthy material in combination with a metal or metallic oxide.” The Patent Office declared an interference with Edison’s Case 164 and rejected a related application from Edison (Case 172). The interference was decided in Edison’s favor in June; Case 164 issued as U.S. Patent 218,866 and Edison subsequently abandoned the other application. “Death of a Noted Chemist,” New York Times, 7 June 1880, 2; Gde. Ency., s.v. “Oxygène”; Ency. Brit., s.v. “Gas and Gas-Lighting”; Lemuel Serrell to TAE, 7 Feb., 14 Mar., 9 and 15 Apr., and 14 June 1879, DF (TAEM 51:407, 435, 402, 470, 507; TAED D7929M, D7929ZAL, D7929ZBF, D7929ZBL, D7929ZCT); TAE to Serrell, 16 Apr. 1879, Lbk. 4:283 (TAEM 80:74; TAED LB004283A); see also Doc. 1802 n. 1.

8. In the final paper Edison states that these were platinum-iridium spirals of the same quality.

9. In the final paper Edison states that the intervals were fifteen minutes.

10. See Doc. 1670 n. 3.

11. In the final version Edison noted that “it was also scarcely attacked by boiling aqua regia.”

12. In the final paper Edison states that the spiral of wire had a “total radiating surface of one-thirty second of an inch, or a surface about equal to a grain of buckwheat.” To the side of this statement he wrote the calculation $\frac{33}{8} = 264$.

13. In the final paper the discussion of economy ends after Edison states the figure of 30,000 foot pounds, which he notes is “less than one horse power”; the rest of the sentence is omitted.

14. In the final paper Edison also noted that common wire became as elastic as steel.

15. The statements about magnesium and the color of the arc when melting iron wire in vacua are omitted from the final paper.

16. See Doc. 1787.

Menlo Park NJ Sept 1st 1879

My dear Johnson,

We have just got your gratifying information that you have “tumbled” to the beauty of the ‘new design.’ Also received yours of Aug 9th and short one, day before.\(^2\) We are now making thirty telephones, which we shall send you next week direct to London, and we shall endeavour to give you thirty per week thereafter; the parts are being made by different parties, some by Bergman and some down East; but the whole thing\(^3\) is put together by us, so as to make sure of your getting them all alike.

We shall send you the chalk cylinders all pure, without any phosphate of Soda in at all, and you must wet them with a so-

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Charles Batchelor to Edward Johnson

July–September 1879