(No Model.) 2 Sheets—Sheet 1.

T. L. WILLSON.

PROCESS OF MELTING OR REDUCING METALS BY ELECTRICITY.

No. 430,453. Patented June 17, 1890.

FIG. 1.

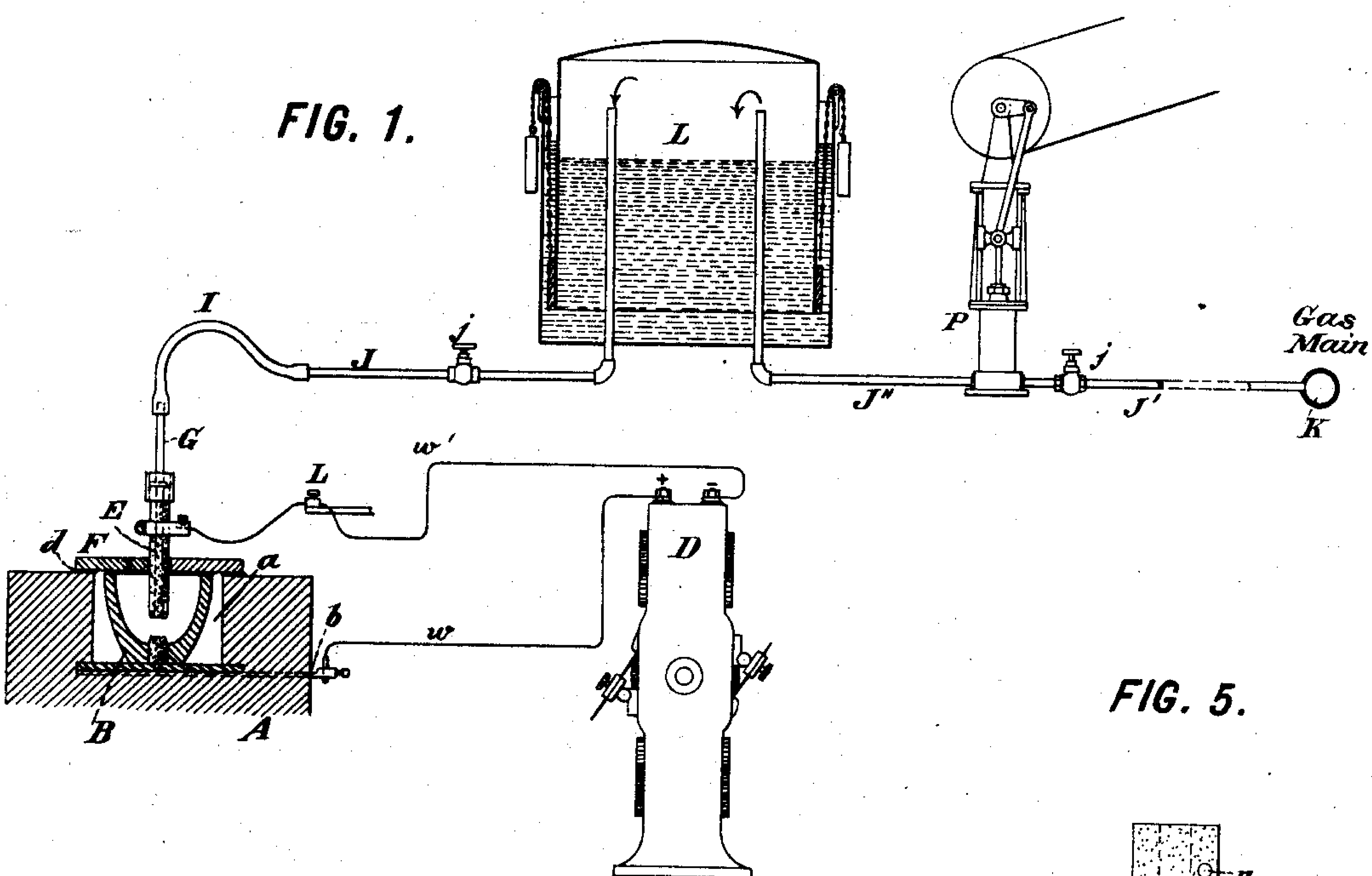


FIG. 5.

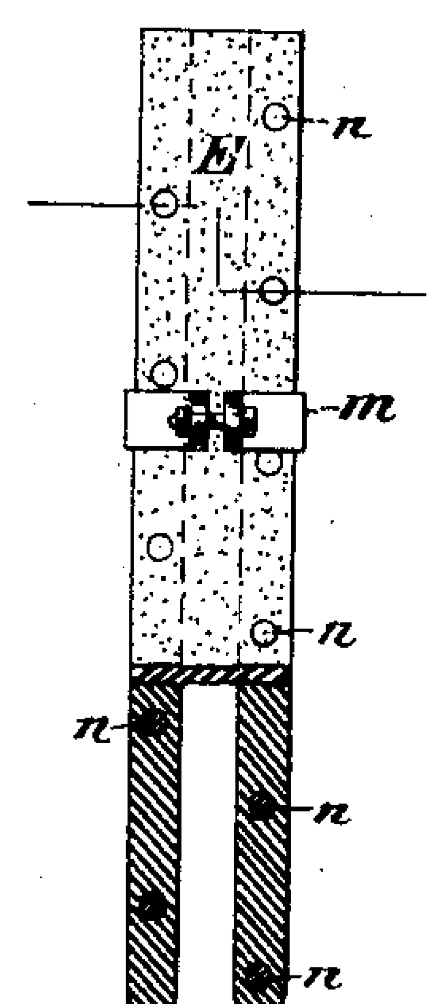


FIG. 2.

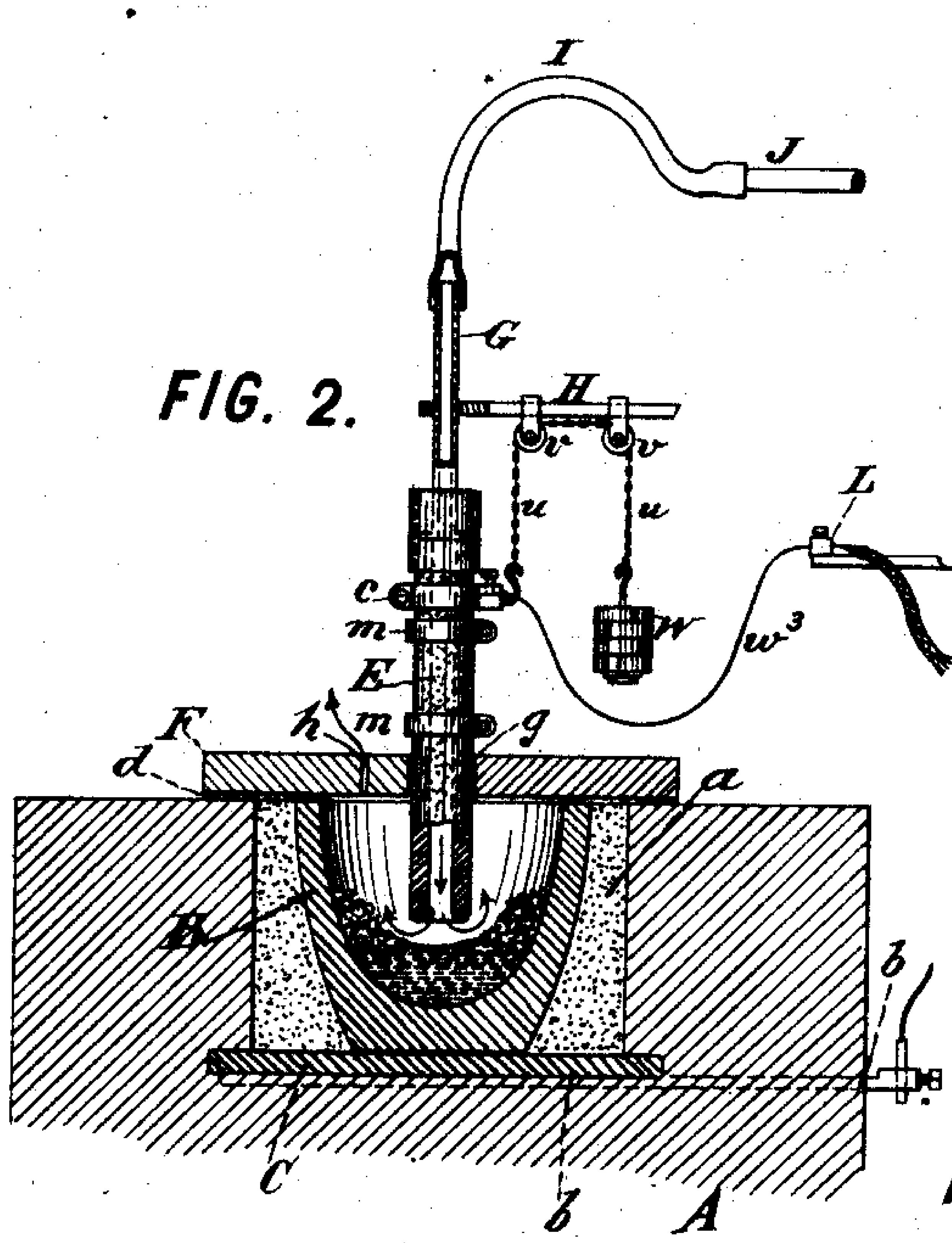


FIG. 3.

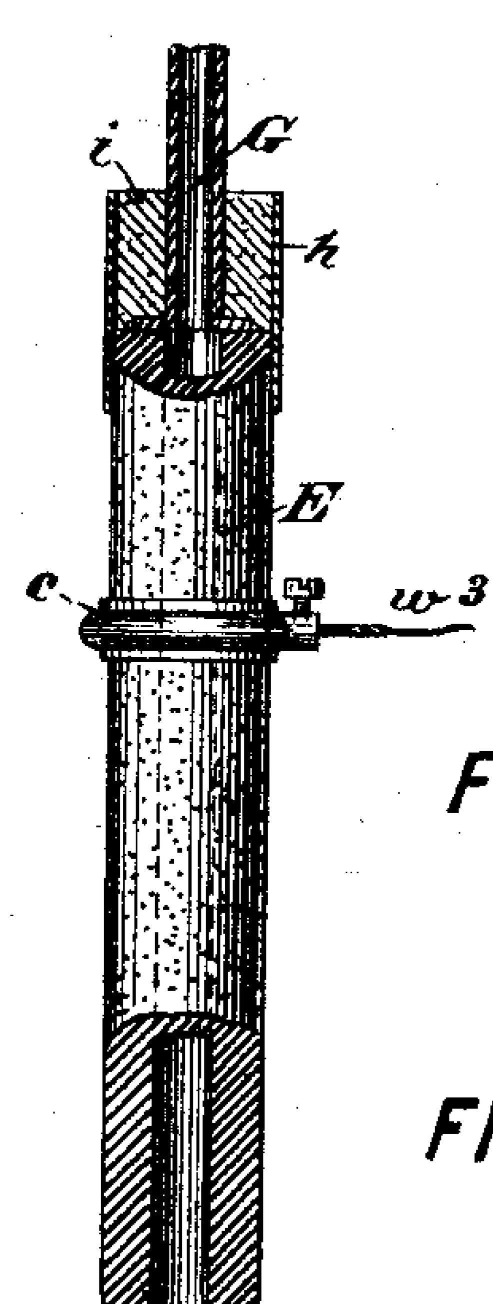


FIG. 4.

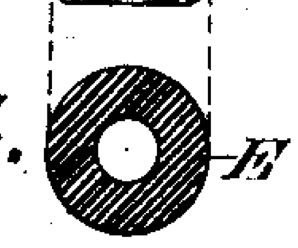


FIG. 6.

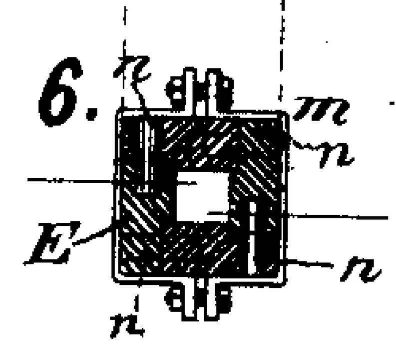
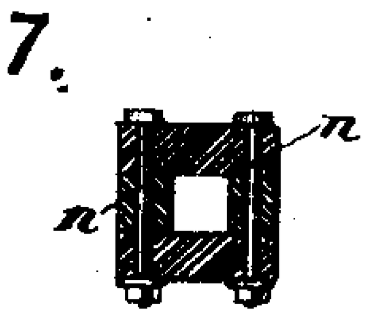


FIG 7.



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C. K. Fraser.

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(No Model.)

2 Sheets—Sheet 2.

T. L. WILLSON.

PROCESS OF MELTING OR REDUCING METALS BY ELECTRICITY.

No. 430,453. Patented June 17, 1890.

FIG. 8.

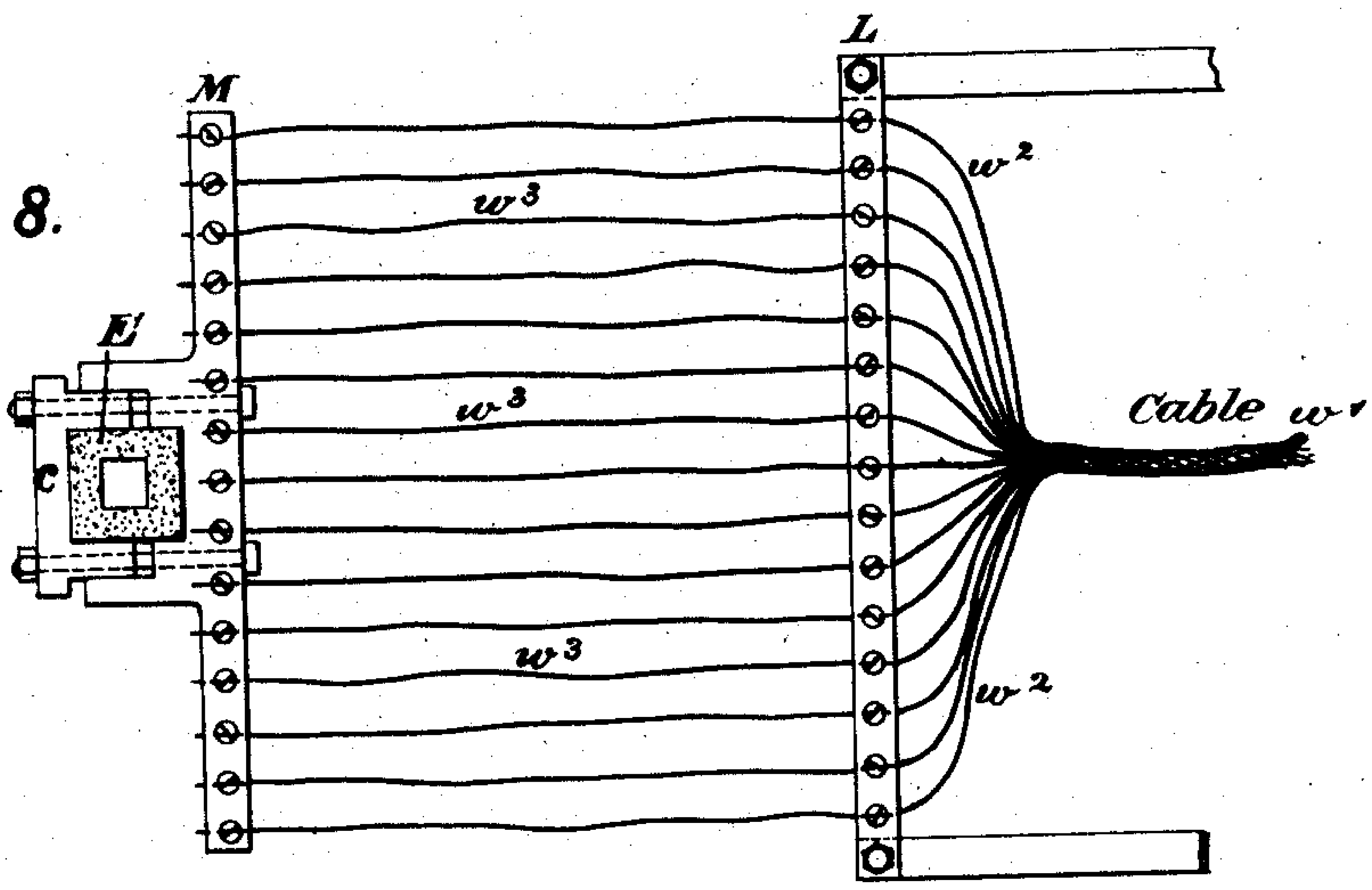
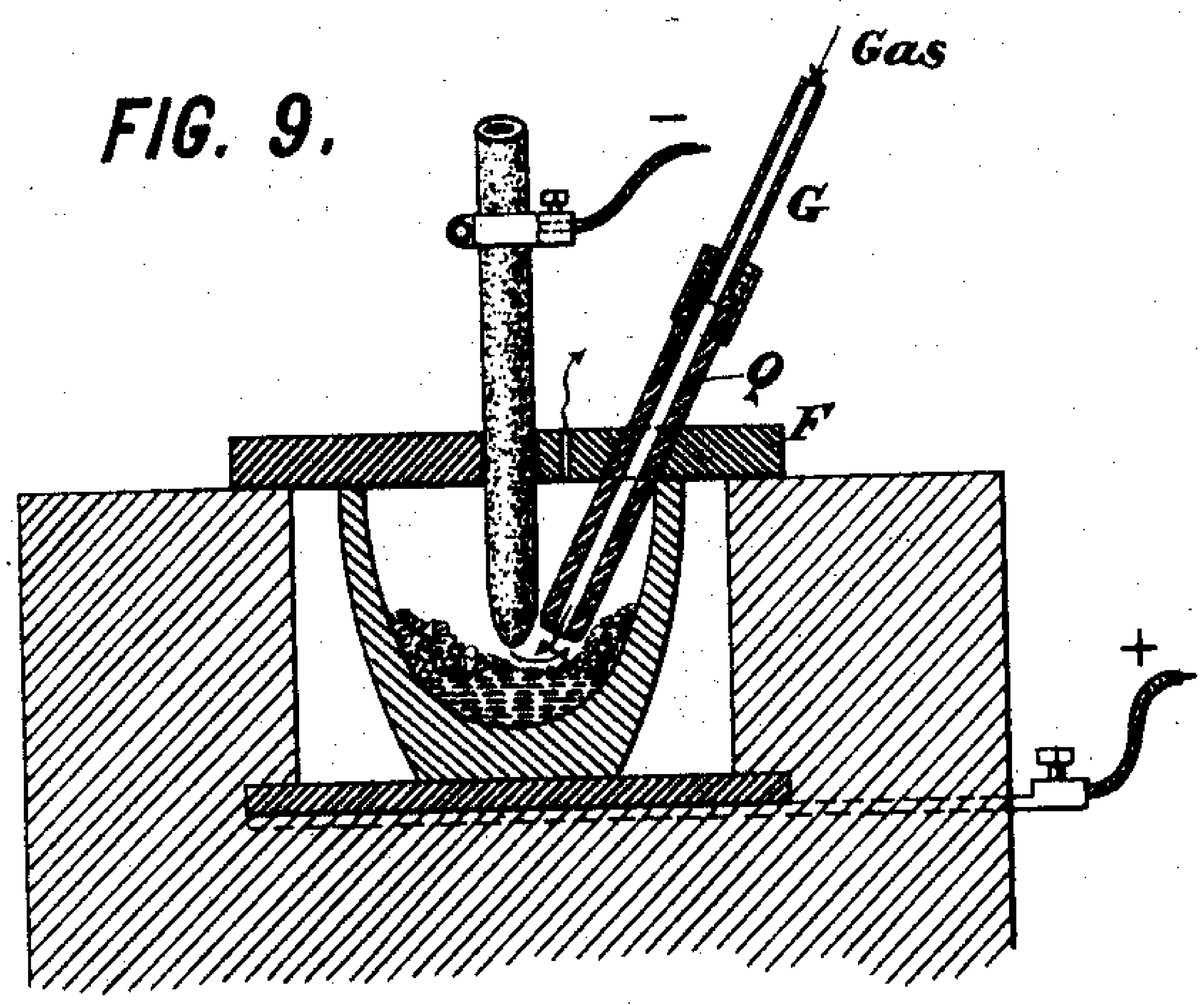


FIG. 9.



INVENTOR:
Thomas L. Willson,
By his Attorneys,
Arthur C. Fraser & Co

WITNESSES:
John Becker
C. K. Fraser.

UNITED STATES PATENT OFFICE.

THOMAS L. WILLSON, OF BROOKLYN, NEW YORK.

PROCESS OF MELTING OR REDUCING METALS BY ELECTRICITY.

SPECIFICATION forming part of Letters Patent No. 430,453, dated June 17, 1890.

Application filed August 3, 1889. Serial No. 319,632. (No model.)

To all whom it may concern:

Be it known that I, THOMAS L. WILLSON, a citizen of the United States, residing in Brooklyn, in the county of Kings and State of New York, have invented certain new and useful Improvements in the Process of Melting or Reducing Metals by Electricity, of which the following is a specification.

This invention relates to smelting or reduction by the agency of heat derived from the passage of an electric current for producing aluminium or its alloys or other metals or alloys of more or less refractory character—such as boron, silicon, calcium, chromium, titanium, &c., as well as iron or steel. In such electric smelting of refractory ores, usually oxides, the ore is fused and decomposed by the heat generated, and the oxygen thus liberated attacks the vessel or crucible inclosing the material acted upon and the electrodes through which the electric current is introduced, which are usually of carbon, and which are thus rapidly wasted away. The material of the electrodes and crucible thus is made to serve as a reducing or deoxidizing agent, and as such electrodes and crucibles are of somewhat expensive material and are more costly than other equally effective deoxidizing substances their consumption is attended with loss and the process of electric smelting or reduction is rendered expensive and uneconomical.

It is the object of my present invention to economize expense in electric smelting by the avoidance of the loss referred to. To this end my invention contemplates the introduction of a deoxidizing or otherwise reducing agent in gaseous form and in such manner that it shall be interposed between the liberated oxygen or other agent requiring elimination and the surfaces of the crucible and electrodes, which would otherwise be exposed to the destructive action of the oxygen, so that the oxygen is caused to unite with the gaseous agent thus introduced before it can gain access to the surfaces of the electrodes and crucible, so that the latter are protected from oxidation and their wasting away is almost entirely prevented.

In the preferred practice of my invention I employ an electric furnace consisting of a crucible for holding the material to be reduced, an electrode or electric connection with such crucible for the passage of the current to its contents, and a separate electrode in the form of a tubular carbon-rod thrust into the crucible and connected to the opposite terminal of the electric circuit, and a source of gas connected through a suitable pipe or duct with the said tubular electrode. When the current passes, the upper electrode is lifted sufficiently to form an electric arc between it and the surface of the metal or ore in the crucible, and the gas is injected through the tubular electrode into the electric arc, and hence into the hottest portion of the molten or vaporized mass. In the case of reduction of a metal from an oxide the gas is hydrogen gas or a hydrocarbon, preferably the latter, ordinary illuminating-gas being suitable. The oxygen liberated by the decomposition of the ore unites with the carbon and hydrogen of the gas, producing water, carbonic acid, and carbonic oxide, which escape from the furnace through a suitable vent.

My invention is applicable to the reduction of other ores than oxides, it being only necessary in such case to inject a gas of different character—that is to say, one having an affinity for the substance that is liberated by the decomposition of the ore in order that this substance may enter into a new combination with the gas and be carried away from the furnace, or reduced to such form as to be readily separable from the reduced metal.

In the accompanying drawings, Figure 1 is a sectional elevation showing in general the preferred apparatus for the practice of my invention. Fig. 2 is a sectional elevation, on a larger scale, showing the furnace and electrodes more in detail. Fig. 3 is an enlarged fragmentary view of one form of the upper or tubular electrode and its connections. Fig. 4 is a transverse section thereof. Fig. 5 is a similar view to Fig. 3, showing another and preferable construction of the electrode. Fig. 6 is a transverse section of Fig. 5. Fig. 7 is a transverse section showing a different construction. Fig. 8 is a plan view showing the means for making electrical connection with the upper electrode, the latter being shown in transverse section. Fig. 9 is a vertical longitudinal section of a modified form of furnace.

I will first describe the construction shown in Figs. 1 to 8 of the drawings.

Let A designate a suitable hearth or bench of brick-work constructed with an opening or recess *a* of suitable size and shape, within which is set a crucible B. A carbon plate C is built into the bench A, and forms the bottom or floor of the opening *a*, so that the crucible rests on this plate. The brick-work immediately surrounding the opening *a* should be constructed of fire-brick or other highly-refractory material.

D designates the dynamo, which of course may be of any suitable type adapted to generate a current of the requisite volume under suitable electro-motive force, and the positive and negative terminals of which are connected, respectively, with the carbon plate C and with a carbon pencil or electrode E. The connection with the carbon plate is made, preferably, through the medium of a bar of metal *b*, fastened by bolts to one edge of the carbon plate, and its end projecting beyond the brick-work is provided with a socket and set-screw, constituting it a binding-post into which the positive terminal of the wire *w* is fastened. The connection of the carbon pencil E may be made by a clamp *c*, fastened on it at its upper portion and formed with a binding-post into which the end of the other wire *w'* is fastened. The crucible B having been placed in the opening *a*, it is covered by placing over it a cover F, which may rest either on top of the crucible or on top of the brick-work A. A luting of fire-clay *d* should be placed under this cover in order to prevent access of air to the crucible. A suitable hole *g* is formed vertically through the middle of the cover F, and also a vent-opening *h*, which is preferably distinct from the hole *g*. The hole *g* is made of such size as to admit the passage of the carbon pencil E through it with just sufficient friction to hold the carbon pencil at any height at which it may be placed.

The carbon pencil or electrode E is made tubular, as clearly shown in Figs. 3 and 4, the duct through it constituting a gas-passage. The upper end of the carbon-rod has united to it preferably an iron or other suitable metallic pipe G, which extends upward in line with the carbon-rod, being preferably guided by passing through a hole *e* in a guiding or supporting arm H, as shown in Fig. 2. The joint between the pipe G and carbon-rod E may be made, as shown in Fig. 3, by fitting a short piece of tube *k* over the upper end of the carbon and filling plaster-of-paris or other cement *i* into this tube and around the pipe G, the latter being preferably flanged at its lower end. Thus a sufficiently strong joint is made, which is not liable to be affected by any heat which can reach it in practice. The upper end of the pipe G is connected by a flexible tube I with a fixed pipe J, through which the gas is conducted, a valve *j* being provided to regulate the flow.

The gas, which will ordinarily be the usual hydrocarbon illuminating or heating gas served in the city mains, or which may be natural gas, will be drawn usually from a main designated at K in Fig. 1, passing through a pipe J', controlled by a valve *j'*. In the case of natural gas under high pressure it will usually be necessary to reduce this pressure by resorting to the usual reducing valves. Ordinarily, however, in the use of common illuminating-gas, the pressure will be insufficient for the purpose, and I therefore provide a pump P, driven by suitable power, which draws the gas from the pipe J' and forces it through a pipe J'', whence it enters the pipe J and flows to the furnace. The action of such pumps, however, being somewhat irregular, and it being desirable to introduce the gas at a uniform pressure and free from any puffing or pulsating, I provide a gas holder or reservoir L between the pump J and furnace, into which the gas is delivered from the pump, and from which it flows out through the pipe J to the furnace. This gas-holder is of usual construction, consisting of an inverted box or tank with its lower edge submerged in water or other liquid, and with its weight so nearly counterbalanced that the gas under suitable pressure will raise it, and it will rise and fall as the volume of gas varies, and thereby largely compensate for any variations of pressure occasioned by the irregular operation of the pump. The pressure at the furnace may be still further reduced or regulated by the valve *j*.

The operation may now be understood. I will describe the operation in furnaces used for the reduction of aluminium from its ore and the production of aluminium bronze, that being the principal use to which my invention has thus far been applied. I place in the bottom of the crucible a suitable quantity of copper suitably broken up or of copper wire twisted or compacted into a mass of convenient shape, and on top of this a layer of suitable quantity of alumina in the form of a nearly-pure corundum. I have found the best proportions to be two parts, by weight, of copper to one part, by weight, of corundum. The cover F is then placed over the crucible and luted down and the carbon pencil E thrust through it and pressed down through the layer of corundum until its tip touches the copper. The circuit-connections being completed, an electric current is passed through the electrodes B and E, which, in a crucible containing about four or five pounds of materials, I have used at two hundred ampères under an electro-motive force of fifty volts. The carbon pencil E is then lifted slightly to strike the arc, and as the copper fuses it is lifted still higher until the maximum arc is formed.

This arc is then to be maintained stationary. At the same time the gas is turned on by opening the valve j, the gas-holder L, having been previously supplied with a charge of gas, and during the operation the pump P is kept running at sufficient speed to supply the desired quantity of gas at the proper pressure. This pressure should be sufficient to overcome any pressure existing in the furnace and to cause a slight blowing out of the gaseous products of combustion through the blow hole or vent h. If inflammable gases are blown out through this vent, it may be known that the pressure is in excess, and it should be reduced by slowing down the pump or partly closing the valve j or the valve j'. The heat of the arc first fuses the copper and sets it into ebullition, partially vaporizing it. As the heat becomes more intense the alumina is also fused and is decomposed, its oxygen being set free and immediately combining with the hydrocarbon gas and forming carbonic acid, carbonic oxide, and steam, which escape through the vent. The aluminium, which is freed from its combination with oxygen, at once combines with the copper, forming an aluminium bronze. Throughout the operation the copper is vaporized by the intense heat and the copper vapors circulate within the crucible, becoming condensed against the comparatively cool sides thereof and streaming down as liquid copper through the mass of corundum, whereby a circulation is created through the latter, and as rapidly as the corundum is fused and its oxygen driven off the copper combines with the aluminium. The operation consumes from fifteen minutes to two hours, depending upon the character of the corundum, the proportions of the ingredients, and the strength of the current. When the corundum has been wholly fused and melted down and its oxygen eliminated, there remains in the crucible a bath of molten aluminium bronze. The operation is then discontinued by stopping the current and shutting off the stream of gas, and the molten metal is poured or tapped out of the crucible. With the construction of furnace shown in Figs. 1 and 2, the furnace is discharged by first lifting out the carbon pencil, then pushing off the cover, and then lifting out the crucible and pouring the molten bronze from it, preferably into a mold to form an ingot. The aluminium alloys I have made in this manner have varied between three per cent. and eighteen per cent. of aluminium.

In my experiments I have used both the crucible as an anode and the carbon pencil as a cathode by passing the current upwardly, and the crucible as a cathode and the carbon pencil as an anode by passing the current downwardly through the furnace. I have found the reducing effect to be the same in either case, there being ordinarily no perceptible difference in the rapidity of operation and little or no difference in the product. There is, however, a considerable difference in the rapidity with which the electrodes are consumed, since when a current is passed downwardly the upper electrode or carbon pencil is consumed more rapidly than when the current is passed upwardly. The reasons for this, as I understand them, are fully set forth in my previous application, Serial No. 307,337, filed April 15, 1889. I therefore prefer in practice to pass the current upwardly, making the carbon pencil the cathode or negative electrode. In either case an extended arc is formed between the upper electrode or pencil and the surface of the molten metal, and the latter assumes the form of a deep hollow or crater partly surrounding the end of the carbon pencil. It is within this crater that the most violent action and the most intense heat exist, and hence it is within this crater that the greater portion of the oxygen is liberated from the ore. This circumstance is availed of in my present invention in order to effect a union between the liberated oxygen and the injected reducing or deoxidizing gas before the oxygen can gain access to the exposed surfaces of the electrodes—that is, the carbon pencil and the crucible. This union is effected, according to the best means of applying my present invention, by the use of the tubular carbon pencil G as a duct through which to inject the gas, as described, whereby the gas is introduced into the crater above referred to, and hence into the arc itself, in such manner that it flows around the exposed and incandescent tip of the carbon pencil. The injected gas thus interposes itself between the liberated oxygen and the portion of the carbon pencil which is most exposed to oxidation, while at the same time the gas is heated to incandescence, and is thus in such condition as to afford the utmost possible affinity for the oxygen, so that the oxygen is caused to unite with it in preference to passing through the stream of hydrocarbon gas and attacking the incandescent carbon. Thus the wasting away of the carbon pencil by oxidation is almost or quite entirely prevented. The copper fumes or vapors circulate from the crater upwardly within the crucible and are condensed against the comparatively cool sides thereof, and by steaming down the latter protect it from oxidation. There is also, but to a less degree, a condensation of liquid copper against the upper portion of the carbon pencil, whereby it also is shielded from the action of any uncombined oxygen that may be circulating within the crucible. In practice, however, when the reducing gas is introduced into the crater, as described, there will be, as I believe, little or no uncombined oxygen that can escape beyond the crater, and hence little or no liability of a wasting away of the crucible or the upper portion of the carbon pencil by oxidation.

When the current is passed upwardly, the surface of the crucible from which the current passes being entirely covered by the bath of molten metal, is protected thereby from the action of the electric arc in tearing off particles from the positive electrode and projecting them against the negative electrode, this action being confined to the surface of the molten bath, which hence becomes essentially the positive electrode, and this projecting action thus assists the ebullition and vaporization of the copper and promotes its circulation. By passing the current in this direction, in connection with the introduction of gas around the tip of the carbon pencil E, the wasting away of the latter is almost entirely provided against, being reduced to the slow disintegration occasioned by the intense heat; hence there is little or no necessity for feeding the pencil E downwardly as the operation proceeds, in order to maintain the arc of uniform length, the very gradual increase in the length of the arc being easily corrected from time to time by the attendant, who will very slightly lower the pencil whenever he observes that the arc is becoming too long. For this purpose an ammeter or voltmeter may be advantageously introduced into the circuit, by which from time to time the resistance of the arc may be ascertained. Thus it is one advantage of my invention, in addition to the economy which it effects, that all complication of automatic feeding or regulating mechanism for moving the carbon pencil is eliminated. If desired, the carbon pencil may be counterpoised in the manner shown in Fig. 2—that is, by hanging a weight W from one end of a chain *u*, which passes over pulleys *v v*, and the other end of which is connected to the carbon pencil.

By altering the weight W so that it just counterbalances the weight of the carbon pencil and its accessories the latter may be made to stand at any height at which the attendant may set it. Even this refinement, however, is not necessary, since the hole *g* may be made so close a fit for the carbon pencil that the latter will be held frictionally in any position in which it may be placed.

I have made numerous experiments with different quantities and proportions of ingredients and different ores of aluminium, the best results having been obtained by the use of pure corundum with copper in the proportions stated, and with a current of the character named. By the partial melting down of the fire-clay used for the cover F, I have produced a bronze of aluminium and copper with silicon. I have also used iron ore (oxide of iron) in connection with corundum, and by smelting the two together have produced an aluminium steel of fine quality. I have also smelted iron ore or fragments of iron with a very small quantity of aluninium ore used as a flux, and have made a fine quality of steel by passing the current through the furnace for a period of five minutes.

In practicing my invention on a large scale it is desirable to provide electrodes which present a large surface, in order that the zone of fusion may be as extended as possible, thereby rendering the process rapid and subjecting the entire mass under treatment to as nearly as possible simultaneous action. This increase of surface in the lower electrode or crucible results, as a matter of course, from the employment of larger crucibles. To secure this increased surface in the case of the upper electrode or carbon pencil, my invention provides the construction shown in Figs. 5 to 7. In the present state of the art it is impracticable or unduly expensive to construct tubular carbon pencils, such as shown in Figs. 3 and 4, of sufficiently large diameter for the purpose. I therefore build up the carbon pencil of separate sections or plates suitably united together. I employ by preference four plates united in the manner best shown in Fig. 6, so as to leave an inclosed space or duct between them, each plate being set with its edge against the face of the next plate. Preferably the plates are rabbeted or shouldered, as shown in Fig. 6, to prevent their collapsing. At the upper part of the pencil they are held together through the medium of metal clamps, one of which is shown at *m* in Figs. 5 and 6. The lower portion of the pencil, which is destined eventually to enter the crucible, where it is exposed to heat that would melt any known metal, is necessarily secured together by other means. For this purpose I prefer to use dowel-pins *n n* of carbon driven tightly into holes in the respective plates, as clearly shown in Fig. 6. The joints between the plates may be made tight by luting them during the operation of fitting the plates together with a paste of carbon-dust and molasses or other carbonaceous cement. Fig. 7 shows a modified construction of the pencil, wherein instead of four like plates being employed two opposite wide plates and two intervening narrow plates are fastened together by pins *n n* passing through from side to side. Since currents of great volume will be used with these large electrodes, it is necessary to provide electrical connections, which shall afford at once very great conductivity with perfect flexibility, in order to conduct the current to the electrode without danger of melting the connections, and to admit of the free up-and-down movement of the carbon pencil. To this end the wire or conductor w', Fig. 1, is made adjacent to the carbon pencil in the form of a cable consisting of a great many fine wires of sufficient number to provide ample conductivity, and this cable is opened or spread out near the carbon pencil in the manner shown in plan view, Fig. 8, its separate wires or groups or strands of wire w^2 being passed through holes in a horizontal bar L, which is fixed in place at a suitable distance from the electrode, and fastened in said holes by screws, and extending thence in the form of freely suspended or pendent loops w^3 to another bar M, into holes in which their ends are thrust and fastened by set-screws constituting binding connections. This bar M is fastened to the carbon pencil E by means of a clamping-jaw *c* and clamping-screws in such a manner as to secure an extended surface of contact with the carbon pencil. The numerous parallel wires or strands w^3 are hung between the bars L and M with sufficient slack to permit of any desired movement of the pencil E in up-and-down direction, both to permit the new pencil of greatest length to be lifted entirely out of the furnace, and to permit the pencil as it becomes shorter in the course of time to be fed downwardly into the furnace and until it is consumed to the shortest length that may be used.

My invention is susceptible of considerable modification without departing from its essential features. The constructions and operation hereinbefore described are those which I consider preferable; but they are not in all respects essential.

Instead of introducing the gas through a tubular electrode, it may be introduced through a separate tube of refractory material, provided this tube is so arranged within the furnace as to discharge the gas into or closely adjacent to the arc—that is to say, into the crater formed by the arc. One such construction is shown in Fig. 9, where Q is a tube of refractory carbon passing through the cover F, receiving gas from a pipe G and terminating at its lower end in the crater.

I am aware that it has been suggested by several patentees to introduce hydrogen and hydrocarbon gases into an electric furnace. In such cases, however, the gas has been simply introduced through a hole in the exterior of the furnace so as to pass into the chamber or vessel thereof, and in no instance, so far as I am aware, has any attempt been made to utilize this gas to the best advantage for the protection of the electrodes from waste or destruction by oxidation by so directing the gas into the furnace that its union with the liberated oxygen is assured—that is to say, by introducing it between the source of oxygen and the most exposed portions or surfaces of the electrodes.

My invention is by no means confined to the introduction of gas in the nature of hydrogen or hydrocarbon, since any other deoxidizing gas may be sustituted in cases where the metal or other substance to be reduced contains oxygen to be eliminated. In case the metal or ore contains other materials than oxygen the reducing-gas should be of such character as to present a chemical affinity with such other materials. In such cases the particular constitution of the gas will be determined in accordance with the known components of the ore or other material which are to be eliminated. For example, in making aluminium bronze an alumina and an ore of copper, in combination with sulphur, (as redruthite or other cuprous sulphide,) may be put in the crucible and the eliminated oxygen and sulphur, both of which are corrosive of the carbon electrode, may be combined with an introduced gas—such as a hydrocarbon gas—which has an affinity for both, thereby protecting the electrode. The gas may also be of such a character as to present some constituent having an affinity for the reduced metal or other material which is derived from the ore in order to produce special alloys. This characteristic will be especially useful in the treatment of iron or steel. I contemplate, also, by a further development of my invention the utilization of the electric furnace simultaneously for the reduction of metals, &c., from their ores or for the melting or other metallurgical treatment of metals, and for the production of various chemical substances requiring a high degree of heat.

I claim as my invention the following defined novel features and improvements, substantially as hereinbefore specified, namely—

1. The herein-described process of reducing metals or ores, which consists in heating them to fusion by means of an electric arc between an electrode above and the metal or ore beneath and injecting a reducing-gas into the crater formed in the molten mass by the arc in such manner that the gas is introduced between the point of liberation of oxygen or other corrosive agent and the exposed incandescent surface of the electrode, whereby the latter is protected from corrosion.

2. The herein-described process of reducing metals or ores, which consists in heating them to fusion by means of an electric arc between an electrode above and the metal or ore beneath and injecting a reducing-gas downwardly into the arc through the said electrode, whereby the gas is delivered uniformly around the incandescent tip thereof and ascends in a protecting stream around all sides of the electrode.

3. The herein-described process of reducing metals or ores, which consists in subjecting them to the heat of an electric arc passing between a positive electrode beneath the metal or ore and a negative electrode above it and introducing a reducing-gas into the arc through said negative electrode, whereby the gas is caused to pass across the current of gases projected toward the negative electrode from the positive bath beneath and thereby protects the electrode from corrosion.

In witness whereof I have hereunto signed my name in the presence of two subscribing witnesses.

THOMAS L. WILLSON.

Witnesses:
ARTHUR C. FRASER,
JNO. E. GAVIN.