No. 874,944. PATENTED DEC. 31, 1907.

F. CREELMAN.

ART OF ELECTRIC SMELTING.

APPLICATION FILED JAN. 5, 1904.

3 SHEETS—SHEET 1.

FIG. 1.

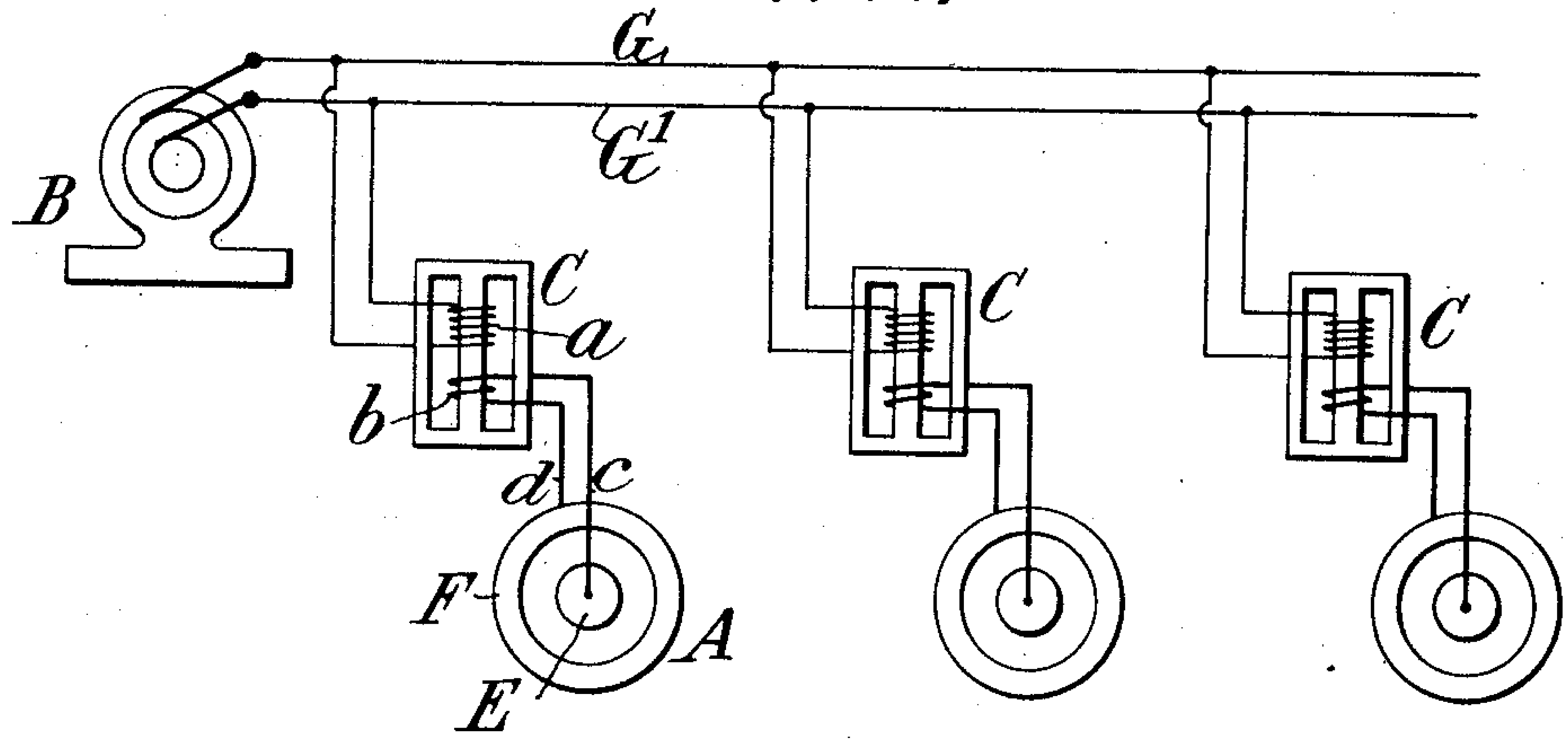


FIG. 2.

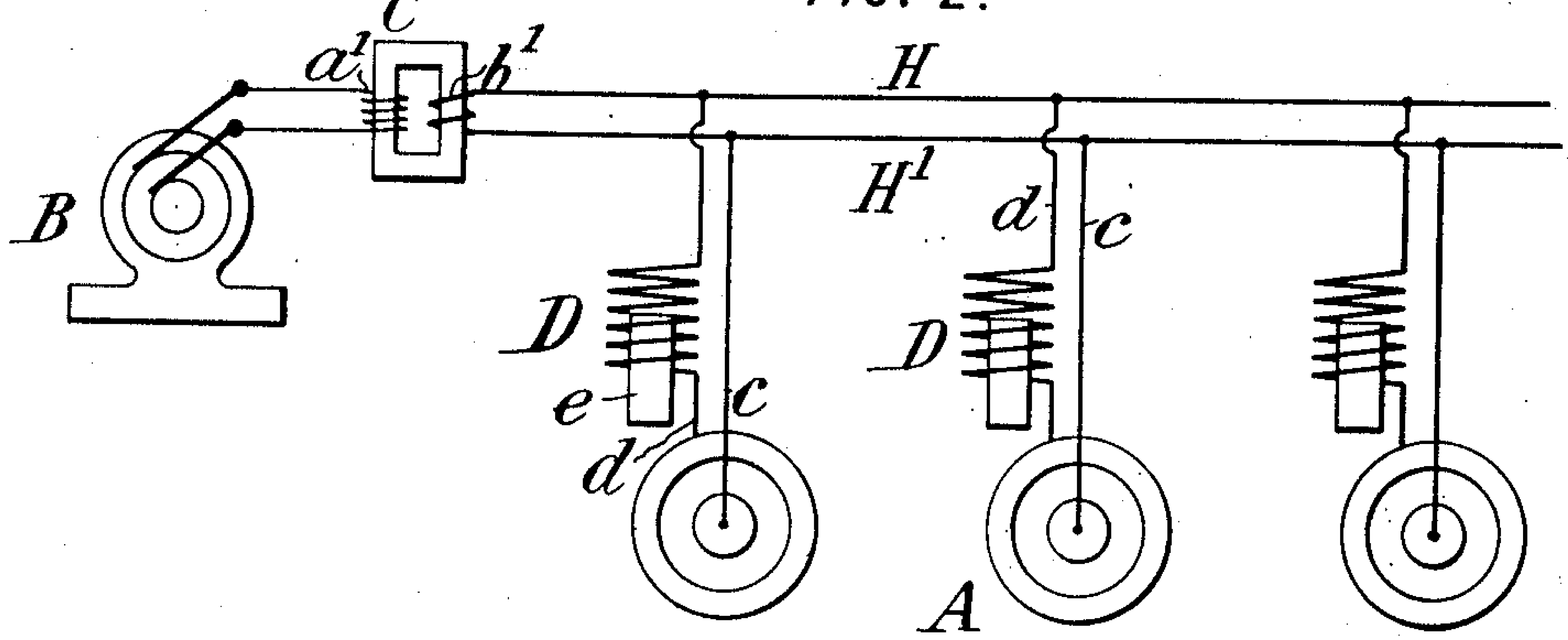
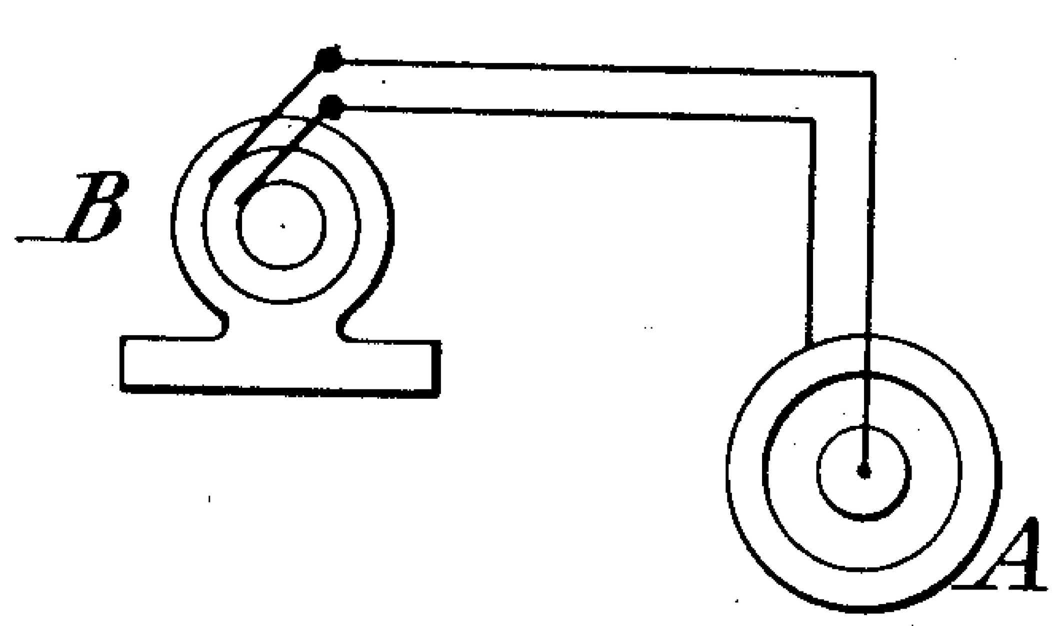


FIG. 3.



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3 SHEETS—SHEET 2.

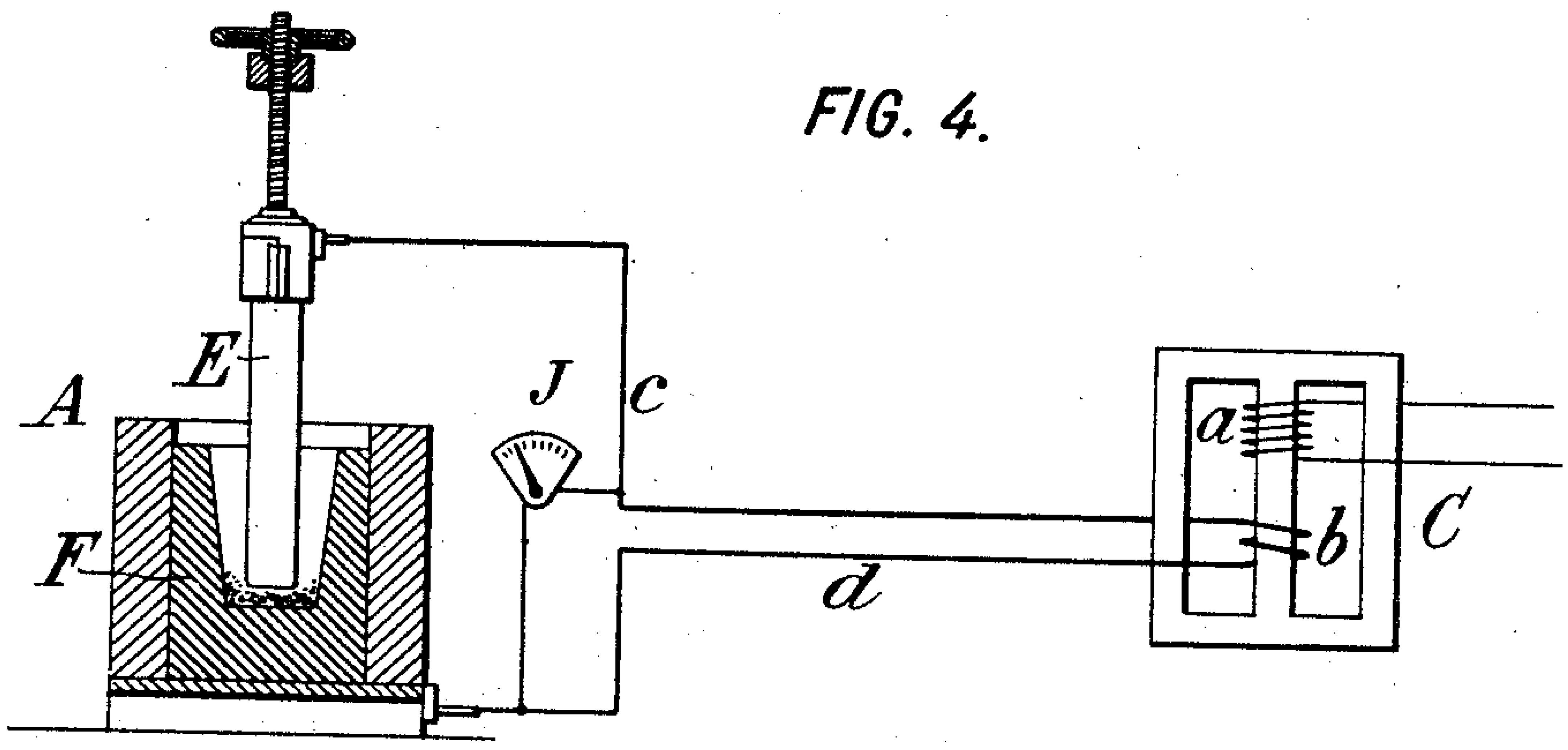

FIG. 4.

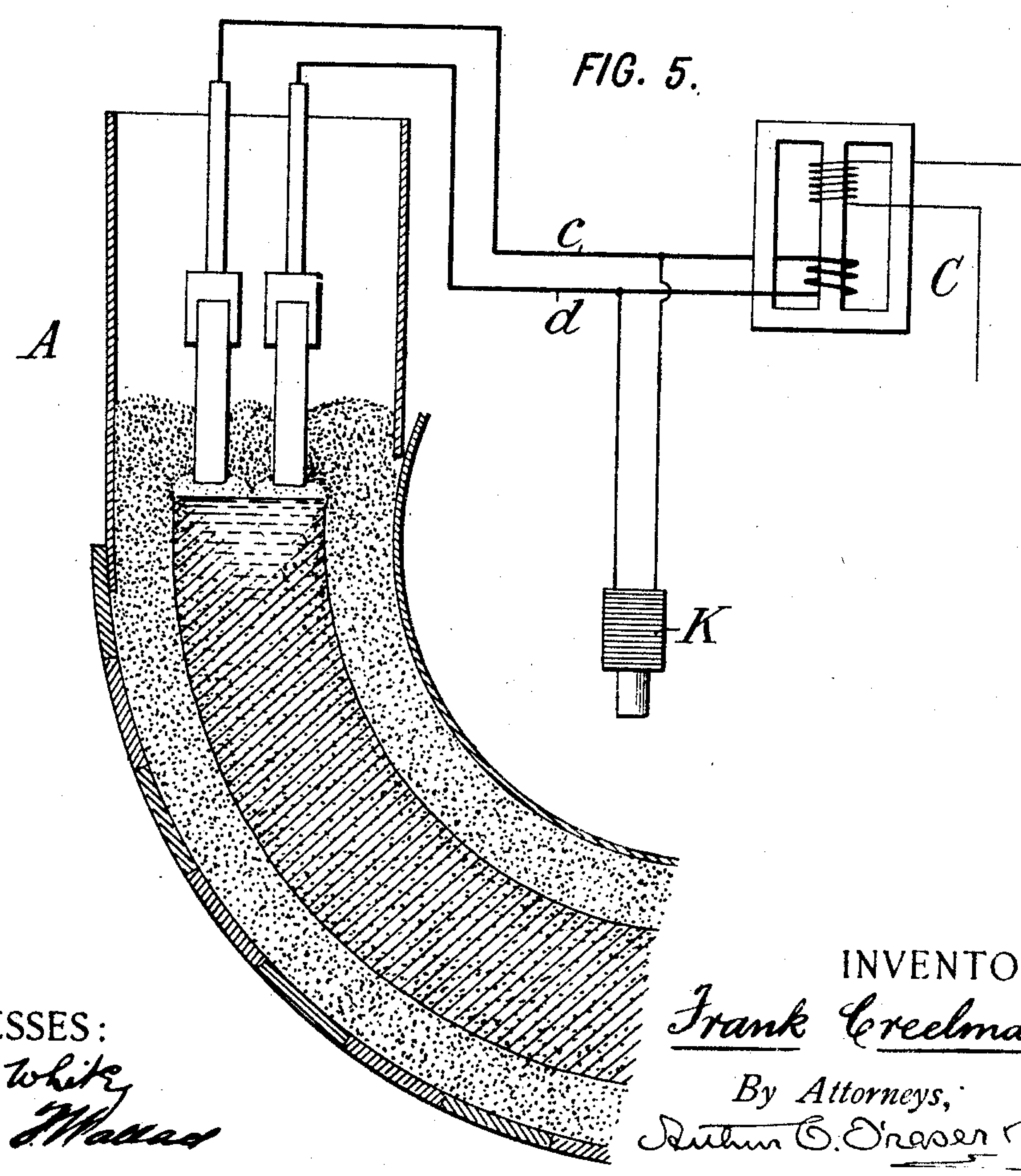

FIG. 5.

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3 SHEETS—SHEET 3.

FIG. 6.

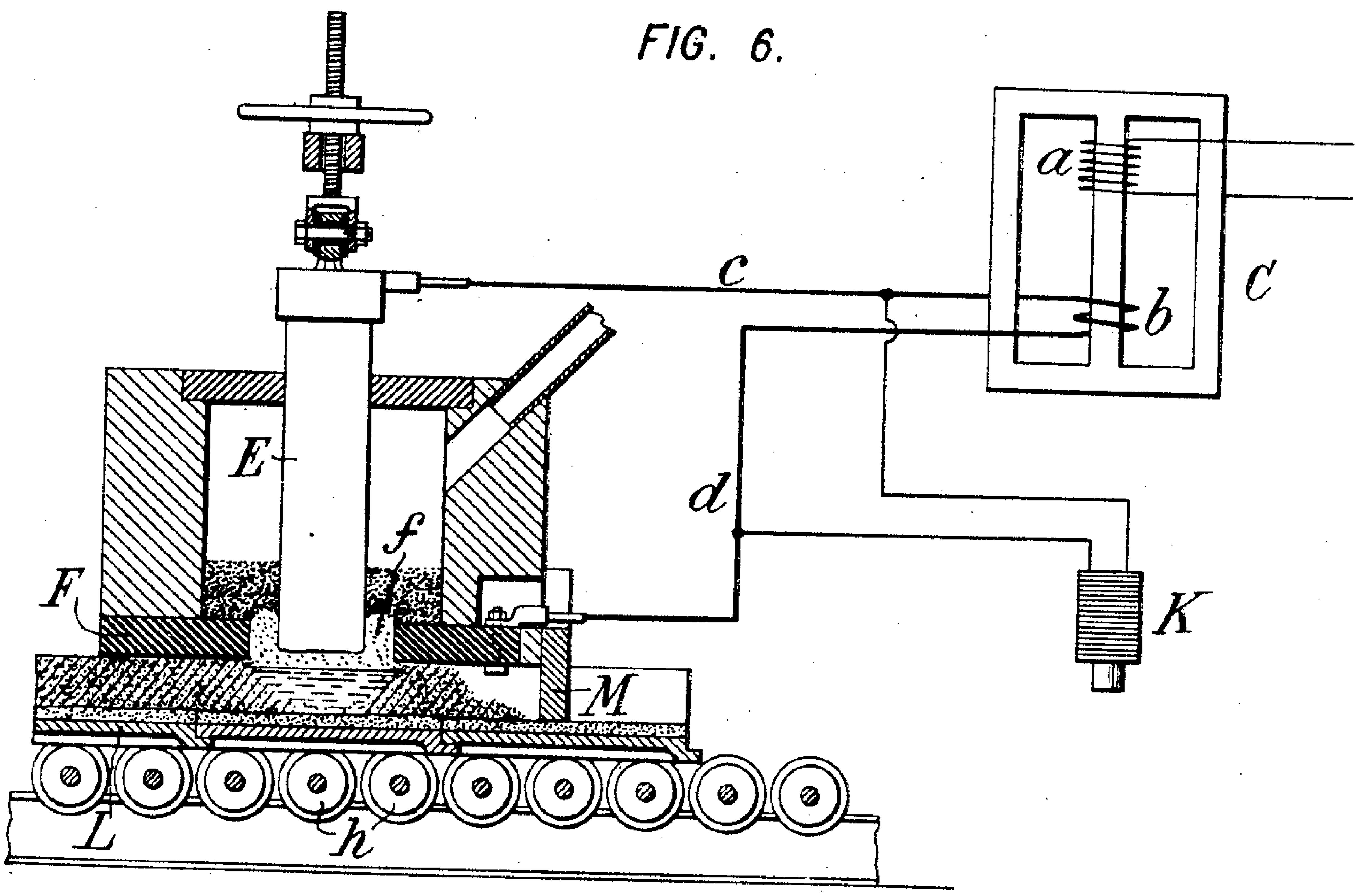


FIG. 7.

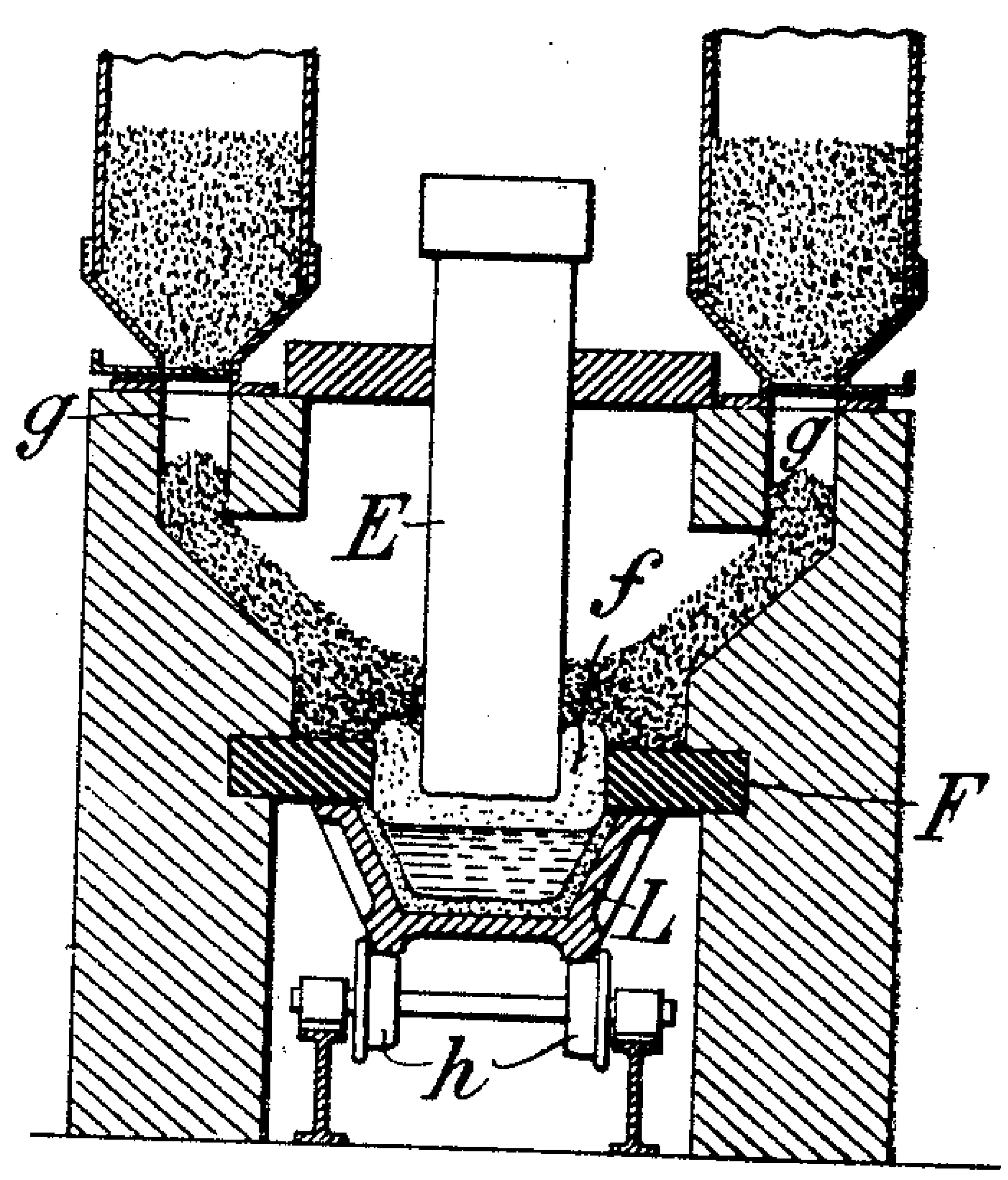
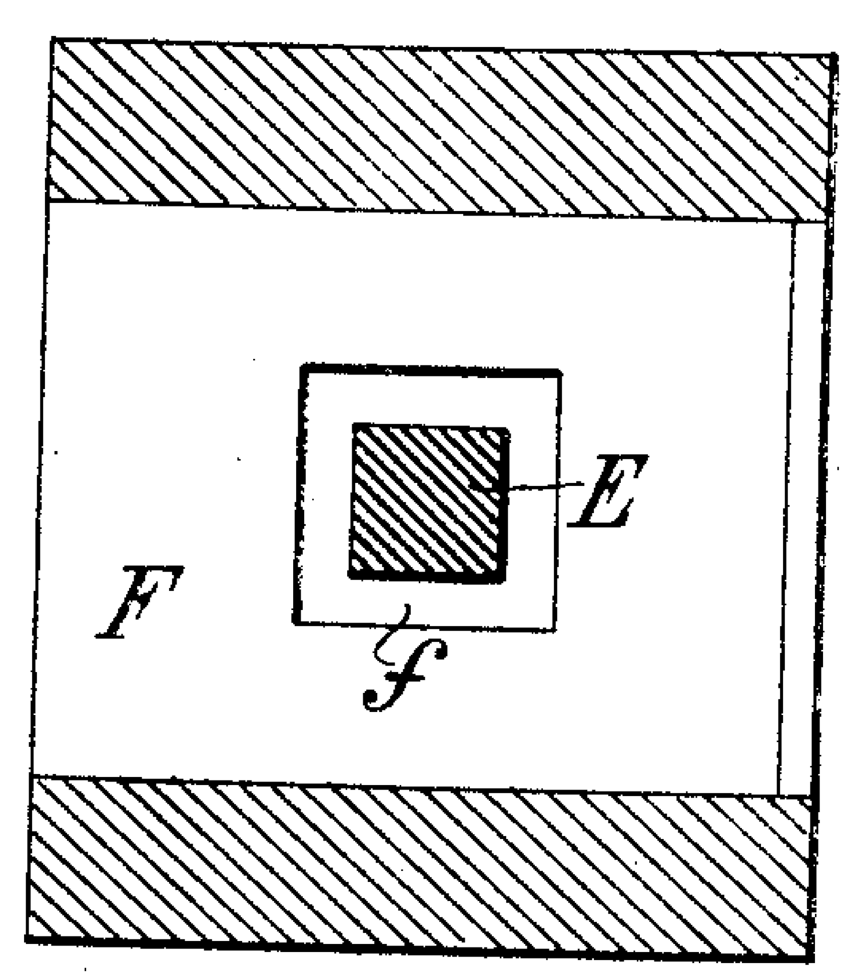


FIG. 8.



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UNITED STATES PATENT OFFICE.

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ART OF ELECTRIC SMELTING.

No. 874,944. Specification of Letters Patent. Patented Dec. 31, 1907.

Application filed January 5, 1904. Serial No. 187,794.

To all whom it may concern:

Be it known that I, FRANK CREELMAN, a citizen of the United States, residing in the borough of Manhattan, city, county, and State of New York, have invented certain new and useful Improvements in the Art of Electric Smelting, of which the following is a specification.

This invention relates to the smelting or reduction of refractory substances in the electric furnace, and particularly to the smelting of a mixture of lime (or limestone) and carbon to form calcium carbid.

In existing electric smelting processes, it is customary to provide an electric generator adapted to maintain an approximately constant or uniform electro-motive force, and the effort is made to maintain an approximation to uniformity of current or volume in each furnace by so manipulating the furnace as to maintain an approximation to a uniform internal resistance. The realization of these conditions in actual practice is extremely difficult, because of the liability of the formation of a short-circuit within the furnace by the melting down of the material undergoing treatment, or from other cause, so that a heavy rush of current occurs which is liable to injure the generating or transforming elements, and the furnace, and makes the smelting operation proceed in an irregular and fluctuating manner. An excessive rush of current can be limited to some extent by special windings, choke-coils, or the like, with the accompaniment, however, of loss of energy.

The nearest approximation to uniformity of current volume heretofore attained has been by the application of automatic regulating mechanisms governed by the variations of current and adapted to control the internal resistance of the furnace, by restoring the normal resistance when any change of conditions has disturbed it, and thereby to bring about either an approximately constant volume (or amperage), or the expenditure within the furnace of an approximately constant energy (or wattage). These expedients, however, have only ameliorated the difficulties, since such automatic regulators cannot act instantly, because they control the movements of heavy masses which require time to start or stop them. For example, in an ordinary calcium carbid furnace, the resistance is controlled by moving the carbon pencil or pencils in a crucible furnace, or by moving the mass of reduced carbid in a continuous (or rotary) furnace. In some other types of furnaces used in electric smelting, the control of the internal resistance is even more difficult.

In practicing my improved process I provide an electric furnace of any suitable or known kind, preferably one which will permit a continuous infeed of material to the arc and a continuous outfeed of the reduced product; I provide for supplying electrical energy from a source thereof which is adapted to maintain in the practical operation of the furnace a constant flow or volume, that is to say, within narrow limits a constant number of amperes under an electro-motive force varying in proportion to the internal resistance of the furnace; and I so regulate the furnace (by hand or automatically) as to restore the normal internal resistance when varied from, and hence to maintain an approximately uniform internal resistance, to thereby maintain an approximately uniform expenditure of energy or generation of heat. Thus in practical operation whenever the internal resistance varies, the current, instead of varying in inverse proportion, remains constant, and a variation in voltage alone takes place, the normal voltage being soon restored by the regulation of the furnace, which restores the normal resistance. By the regulation of the furnace I mean the manipulation of such moving parts as control its internal resistance; that is to say, in a crucible furnace the lifting of the carbon pencil or pencils; in a rotary furnace the advancement of the shell carrying the reduced product, commonly in the form of a pig or ingot; or in a horizontal incandescent furnace the separation of the conducting pencils.

My new process enables the smelting operation to be conducted with great precision and uniformity both in the rate at which the reduction proceeds and in the consumption of electrical energy, and results in a high degree of economy, while avoiding the deterioration of the furnace elements and the liability to injury of the electrical generating or transforming elements, which have been incidental to the violently fluctuating action heretofore encountered in electric smelting operations.

According to a further feature of my invention I utilize, the constant current system hereinbefore set forth for the production of calcium carbid in a crustless pig. In the ordinary production of calcium carbid in the form of a pig or ingot, only the central portion of the powdered or broken mixture of lime (or limestone) and carbon is reduced, and immediately surrounding the reduced product or pure carbid in the pig is a crust of the partially fused and unreduced or but partly reduced mixture, which is very low in carbid and hence practically worthless; and outside of this crust is a layer of the mixture which is entirely unfused and practically unaltered. It is customary to chip off the crust from the pig, an operation which involves considerable expense. It is also customary to return the outer layer of mixture to the furnace to be resmelted. The formation of crust and the necessity of re-handling the hot unreduced mixture, are serious difficulties in the manufacture of calcium carbid. Efforts have been made to produce a crustless carbid by tapping the liquid product from the furnace at intervals, but this tapping process has been successful only with comparatively low grade carbid, which will not compete in the market with the ingot carbid. One serious difficulty with the tapping process is that the molten carbid is liable to congeal in the tap-hole; to avoid this it is necessary before tapping to force the pencil or pencils deep into the mass and heat it to a high temperature to insure the requisite fluidity, which is not only wasteful of energy, but results in dissociation of the elements, producing burned carbid of low gas-producing power.

According to my invention I produce calcium carbid (or analogous material) in a crustless pig or ingot by a process differing from that practiced in the ordinary pig or ingot furnaces, and differing from that practiced in the tapping furnaces. My process may be said to be a continuous tapping process in which the zone of fusion is maintained in the tap-hole itself, the fused material being supported immediately beneath the tap-hole to uphold therein the material undergoing fusion. In practicing this process I feed or pass the entire mixture through the zone of fusion and reduction maintained between two electrodes, the interspace between the electrodes constituting the outlet or tap-hole of the furnace, and also constituting the zone of reduction. Preferably one electrode is formed as a pencil projecting into and through an opening formed in the other or annular electrode, the annular space between the two forming the interspace or tap-hole. Since none of the mixture can pass through this interspace or zone of reduction without being reduced, no crust is formed, and no unreduced mixture is discharged from the furnace. The molten carbid is formed into a pig or ingot in a suitably shaped conveyer or trough beneath the outlet from the furnace. The application of a constant current is practically important to the success of this process, since in this process the electrodes are normally stationary or are readjusted only at long intervals as they wear away, and wide but momentary fluctuations of resistance are liable to occur due to variations in the condition of the material filling the interspace or zone of reduction.

I will proceed to describe the practical application of my process and suitable apparatus for practicing it in connection with the accompanying drawings, wherein,

Figure 1 is an electric circuit diagram illustrating three furnaces fed by an alternating current dynamo through transformers; Fig. 2 is a similar diagram showing three furnaces fed by an alternating current dynamo through a single transformer; Fig. 3 is a similar diagram showing a furnace fed directly from a dynamo; Fig. 4 shows in sectional elevation a vertical type of furnace, the electric connections being shown in diagram; Fig. 5 shows in vertical section a form of double-pencil continuous furnace with its electrical connections; Fig. 6 is a vertical section of the form of furnace for making a crustless carbid according to my complete invention, with its electrical connections; Fig. 7 is a transverse section of the furnace shown in Fig. 6; Fig. 8 is a plan showing the arrangement of the electrodes.

In all the figures A designates an electric furnace and B a dynamo or generator, C C being transformers, and D D (in Fig. 2) being current regulating coils.

In the diagrams Figs. 1, 2 and 3, the furnace A is assumed to be of the single carbon crucible type shown in Fig. 4, E being the central carbon pencil, and F the pot or crucible, which constitute respectively the electrodes. This is a well understood type of furnace, the pencil E being vertically adjustable to cause it to recede from the pool of reduced material which accumulates in the crucible.

In the preferred circuit arrangement shown in Fig. 1, the dynamo B is an alternating current generator, which may be adapted to maintain a normal constant potential or electro-motive force upon the main wires or leads G G′. For each furnace A is provided a separate transformer C, of which *a* is the primary coil and *b* is the secondary. The primary coils are connected in multiple with the main circuit leads. Each transformer C is of any construction adapted to maintain a constant current in its secondary coil *b* which feeds the circuit *c d* leading to the furnace. One suitable construction for these transformers is that in which the primary or secondary coil is made movable along the core, and so counterbalanced that as the secondary current increases it causes the movable coil to recede from the fixed coil and thereby diminish the induction in such proportion as to maintain a constant current. Such a transformer suitably fed by an alternating dynamo, becomes a source of constant current for its special furnace. Whenever from any cause the resistance in its furnace falls, the transformer by proportionally reducing the voltage at the terminals of its secondary, maintains the current constant and prevents any rise or rush of current such as would otherwise occur.

As examples of the conditions under which my process may be practically applied, I will state that each furnace may receive a normal current of 2,000 amperes under normally 75 volts difference of potentials at the furnace terminals, this voltage however varying constantly from time to time. I contemplate also feeding a series of furnaces from a single dynamo which may have a uniform voltage of 2,200, and maintaining a mean or normal total current of 650 amperes, divided among the primaries of any suitable number of transformers, said primaries being arranged in parallel, for example ten, each receiving 65 amperes; the secondaries of these transformers being each in a separate circuit including one furnace, and delivering thereto a substantially uniform current approximating 1,000 amperes under a varying electro-motive force. By this arrangement the variations of load upon individual furnaces to some extent offset one another, so that the load upon the generator is the sum of the loads upon the respective furnaces.

With the arrangement shown in Fig. 2, the alternating dynamo B feeds the primary a' of the transformer C′, the secondary b' of which feeds the main leads H H′. In this case the transformer is not necessarily a constant current transformer, but will normally be adapted to maintain substantially constant voltage. The furnaces are fed by branch circuits *c d* derived from the main leads H H′, and in each of these branch circuits is introduced a current regulating coil D of any suitable kind adapted to maintain a constant current within its own branch circuit. The coil D may be of that character wherein a core *e* is drawn more or less into the coil to introduce more or less self-induction or impedance, and thereby to prevent any rise of current above the normal, and hence within narrow practical limits to keep the current constant. This arrangement, however, is less desirable than that first described.

In Fig. 3 is shown a dynamo B, which may be either an alternating current or direct current generator connected directly to a furnace A. In this case the dynamo is itself constructed to maintain a constant current according to any known system.

In Figs. 4 and 5 two types of furnace are shown, in each case the furnace being energized by a constant current transformer C in the manner shown in Fig. 1. With either type of furnace the regulating operation is performed either manually or mechanically, and is determined by the variations of voltage or electro-motive force at the furnace terminals. That is to say, if a variation in resistance occurs within the furnace, instead of causing a change in current, it causes a change in voltage; and the ensuing regulating movement which restores the normal internal resistance, instead of restoring the current to the normal, acts to restore the normal voltage. Preferably the regulating operation is made automatic under direct control of the variations in voltage. In Fig. 4 a voltmeter J is shown connected between the leads *c d* to show the variations in voltage at the furnace terminals by which an operator may be guided in manually regulating the furnace, that is, with this type of furnace in raising or lowering its pencil E. In Fig. 5 a regulating shunt magnet K is shown adapted to control the rate of feed of the furnace body, (which in a furnace of this type moves the ingot or pool of reduced material away from the fixed carbon pencils). The magnet K may actuate any suitable regulating mechanism; for example, it may operate or control the regulating mechanism commonly applied in rotary furnaces. An example of suitable mechanism is contained in my application filed January 7, 1904, Serial No. 188,038, the movable member or core of the magnet K being substituted for the part E in Fig. 1 of said application.

When the proper rate of passage of the material through the zone of fusion is determined for a given current, this rate of feed may be maintained approximately constant, and it is not necessary to vary it continually to correct trifling fluctuations in internal resistance, because if fusion takes place too rapidly at any moment the reduction in resistance reduces the voltage and reduces the rapidity of fusion so as to automatically check itself; or if the rate of fusion should be retarded for a short time for any reason the resistance and the voltage and consequently the energy (or watts, or heating effect) would increase so as to tend to make up for the loss. Thus the irregularities of action tend to be self-compensating. The regulator may be controlled by a governor of any suitable sort which responds to variations in the internal resistance, and which operates to rectify after a certain interval of time any departure which has occurred from normal conditions within the furnace. The self-compensating action referred to being instantaneous, precedes the necessarily slow action of a regulator, which, even if automatic and very sensitive, requires an appreciable time to restore the normal internal resistance.

An important advantage of my invention is that it protects the electrodes from injury by excessive heat. In the ordinary furnaces, when the current becomes excessive, the heat due to the resistance of the electrodes increases with the square of the current, and as the resistance is greatest at the contact between the iron carbon holders and the carbon pencils, the holders are liable to be fused at this point, which would result in the dropping of the pencils. Since with my invention the increase of the current beyond the normal is impossible, such injury to the holders and destruction of the pencils is avoided. My invention also avoids heat loss (or C^2 R loss) in the carbons due to an excessive current, which with carbons of high resistance becomes an appreciable waste.

I will now describe the furnace shown in Figs. 6, 7 and 8. The electrode E is in the form of an upright pencil, having means for vertically adjusting it to compensate for wear. The electrode F is in the form of a plate or slab having a hole or opening *f* forming the interspace in which the arc or zone of fusion is maintained. The furnace chamber above this lower electrode is fed with the mixture to be smelted through chutes *g g* in the ordinary manner. Beneath the lower electrode is placed a receptacle L, preferably in the form of a trough made up of sections as shown, these sections being movable in a direct line and horizontally, or down a suitable incline, as preferred, either by constructing them as cars running on a suitable track, or as slides moving on suitable slideways, or preferably by providing a succession of anti-friction wheels *h h* for carrying the trough sections. In Fig. 6 the trough sections travel from right to left, their left hand or outgoing end being closed by the solidified carbid within the trough, while their entering or right hand end is closed by a plate M, which serves primarily to prevent ingress of air, which would oxidize the electrodes, and also serves to limit any outflow of the molten carbid. Any suitable regulating mechanism serves to slowly or intermittently push forward the trough sections, a new section being supplied from time to time. This regulating mechanism is controlled by a magnet or other electromotive device K adapted to respond to fluctuations in voltage. A suitable regulating mechanism is set forth in detail in another application executed by me coincidently herewith, namely, Serial No. 188,038 filed January 7, 1904.

In starting the furnace, the trough section beneath is filled with a pile of suitable heat resistant material, coarse carbon or coke being introduced into the interspace between the electrodes to complete the circuit, and the current being turned on, the zone of fusion is immediately instituted in this interspace; the raw material is then fed into the furnace chamber above, and a portion thereof falls into the interspace, where it is fused and reduced, the fused carbid flowing down through the zone of fusion and resting upon the material in the trough beneath. As the reduction proceeds, fresh material falls into the arc or zone of fusion. As the fluid product descends below the zone of fusion, it eventually cools and hardens, forming a pig or ingot of carbid the shape of which is determined by the shape of the trough. Whenever the fluid material accumulates too close to the inter-space so that it reduces the resistance between the electrodes, the consequent reduced voltage causes the regulating mechanism to act and push forward the trough sections, so that the molten product is permitted to overflow and restore the normal resistance. In this furnace there is no control of or readjustment of the electrodes by means of a regulating mechanism to maintain a constant resistance, and therefore as in the ordinary furnaces an approximately constant current; but on the contrary the resistance in the interspace between the electrodes is subject to wide fluctuations accompanied by corresponding fluctuations in voltage, the current remaining constant within the capacity of the generating and transforming apparatus. Such relatively fixed electrodes would be inadmissible in a furnace energized by the usual source of approximately constant potential.

Heretofore (except in tapping furnaces) it has been practically necessary in order to produce a high grade carbid, to employ as the raw material an intimate mixture of pulverized lime and carbon, the latter being usually in the form of coke or anthracite coal. My invention enables considerable economy to be attained as compared with other ingot furnaces by using limestone instead of lime, and by using the materials in granulated or lump form instead of pulverized.

My invention is not necessarily limited to the production of calcium carbid, but is applicable so far as concerns the use of a constant current, to electric smelting generally, and so far as concerns the complete process whereby a crustless product is produced by a continuous tapping operation, to any product presenting difficulties analogous to those encountered with calcium carbid.

I do not claim to be the first inventor of the process whereby calcium carbid or analogous product is produced in a crustless pig, or is produced by passing the entire mixture of raw material through a zone of fusion and reduction from which the reduced material is discharged as a crustless pig.

My invention may be greatly varied or modified in its application to varying types or kinds of electric furnaces, and in its application to the production of different products, without departing from its essential features or characteristics.

I do not herein claim the electric furnace and appurtenances shown in the accompanying drawings, the same being claimed in my aforesaid application No. 188,038.

I claim as my invention:—

1. The process of electric smelting which consists in subjecting the material to be smelted to the heat of an electric current of substantially uniform amperage notwithstanding variations in the internal resistance of the furnace, and regulating the furnace to restore the normal internal voltage and maintain an approximately uniform expenditure of energy.

2. The process of electric smelting which consists in subjecting the material to be smelted to the heat of an electric arc maintained by electric energy of substantially uniform amperage notwithstanding variations in the internal resistance of the furnace, and regulating the furnace to restore the normal internal resistance and thereby maintain an approximately uniform expenditure of energy.

3. The process of electric smelting which consists in subjecting the material to be smelted to electric energy of substantially uniform amperage notwithstanding variations in the internal resistance of the furnace, and regulating the furnace by means of the variations in electromotive force occurring at its terminals to restore the normal internal resistance.

4. The production of calcium carbid by subjecting the mixture to the heat produced by a current of electricity of substantially uniform amperage notwithstanding variations in the internal resistance of the furnace, and regulating the furnace to restore the normal internal resistance and thereby restore the normal voltage and maintain an approximately uniform expenditure of energy.

5. The production of calcium carbid by fusing the entire mixture in a zone of fusion produced by an electric arc maintained by a source of energy of substantially uniform amperage notwithstanding variations in the internal resistance of the furnace, and discharging the fused carbid as a crustless pig.

6. The production of calcium carbid by fusing the mixture in a zone of fusion formed by an electric arc, and discharging the molten carbid therefrom into a mass of carbid beneath the outlet from the furnace, which mass is held so closely adjacent to the zone of fusion that it is maintained molten.

7. Electric smelting by passing the material to be smelted through a zone of fusion maintained in an interspace between electrodes, from which the fused material may freely flow, and continuously discharging the fused and reduced material therefrom into a receptacle beneath the outlet from the furnace, this receptacle being located so closely adjacent to the zone of fusion that the material is maintained molten.

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

FRANK CREELMAN.

Witnesses:
Arthur C. Fraser,
Fred White.