No. 825,359. PATENTED JULY 10, 1906.

F. T. SNYDER.

ELECTRIC FURNACE.

APPLICATION FILED JULY 15, 1904.

3 SHEETS—SHEET 1.

Fig. 1.

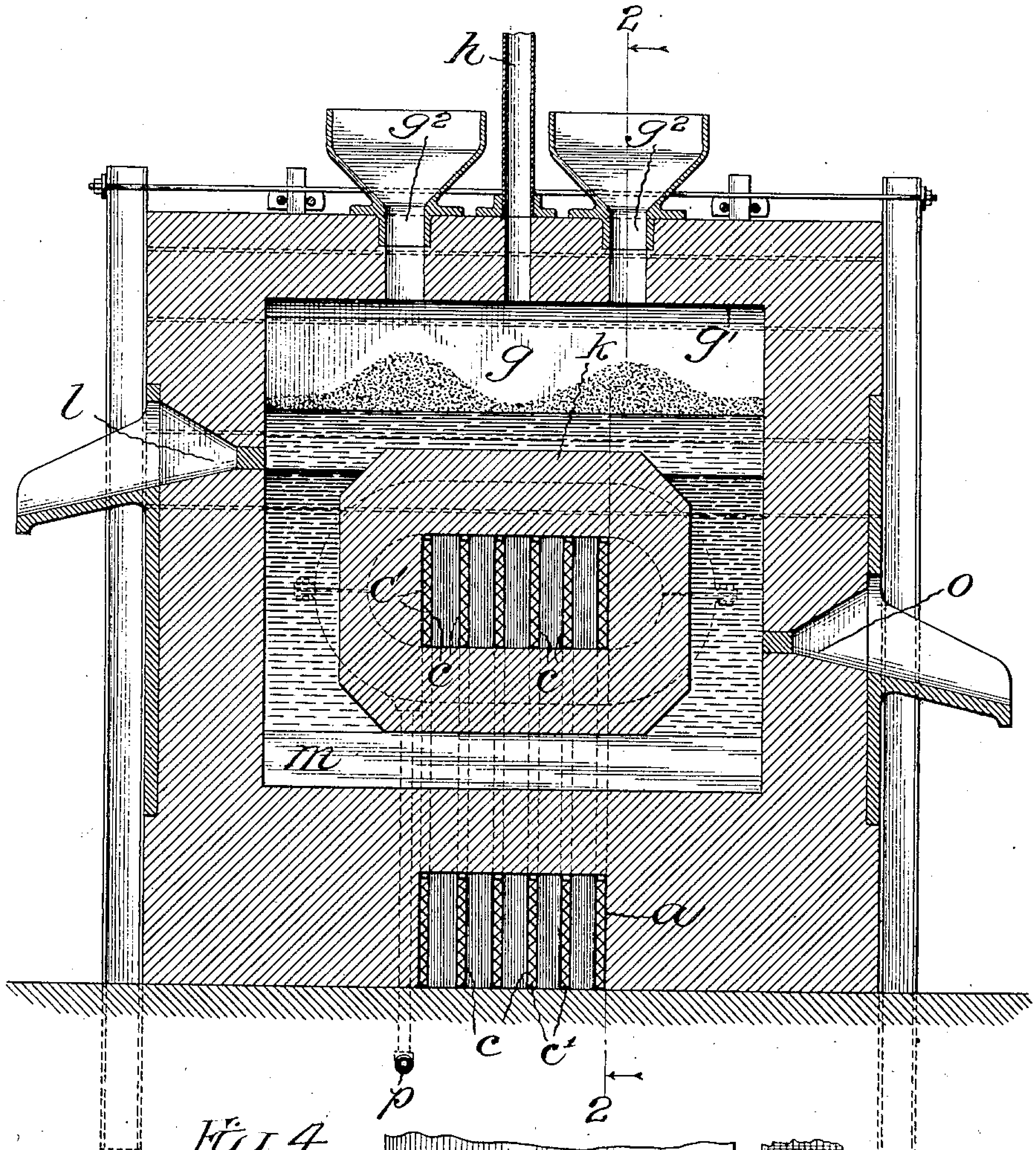


Fig. 4.

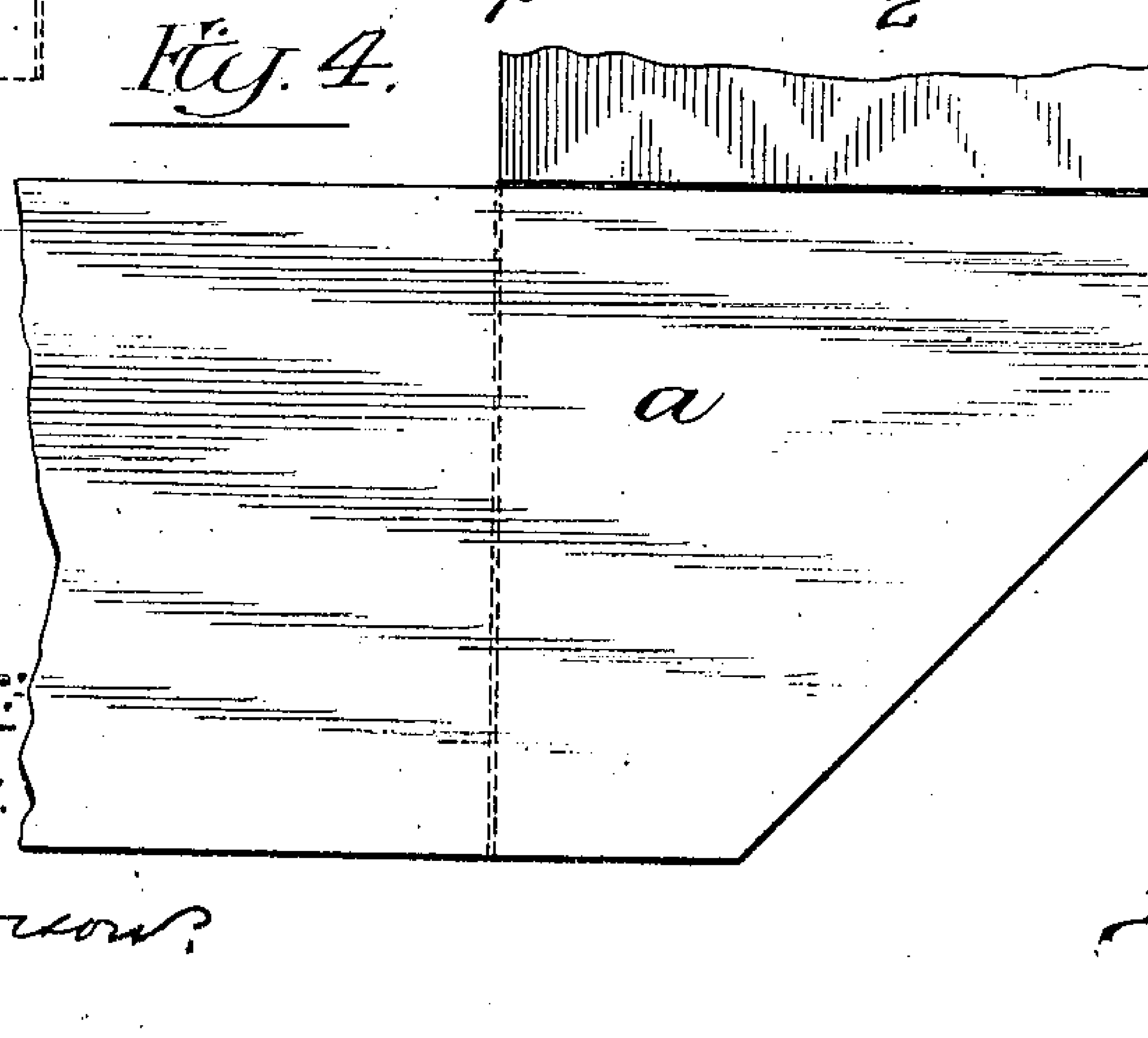
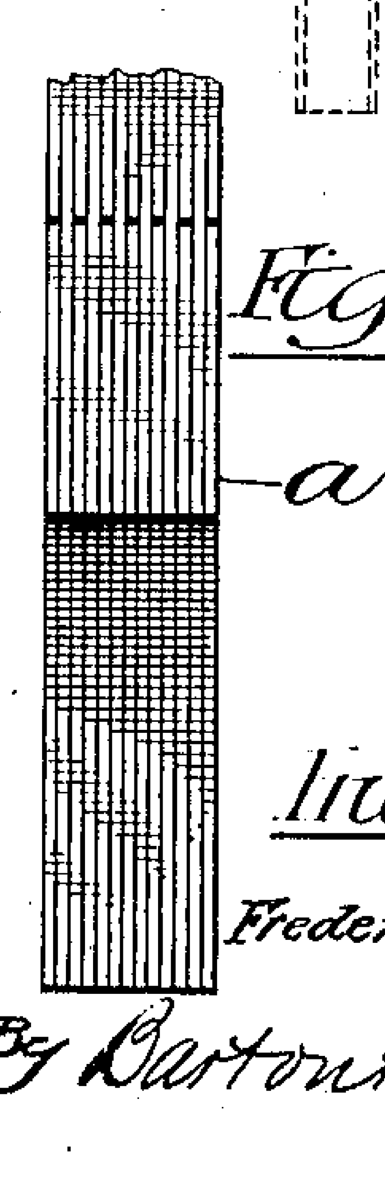


Fig. 5.



Witnesses:

Louis M. F. Whitehead.

Fred G. Dawson.

Inventor:

Frederick T. Snyder,

By Barton & Tanner

Att'ys.

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3 SHEETS—SHEET 2.

Fig. 2.

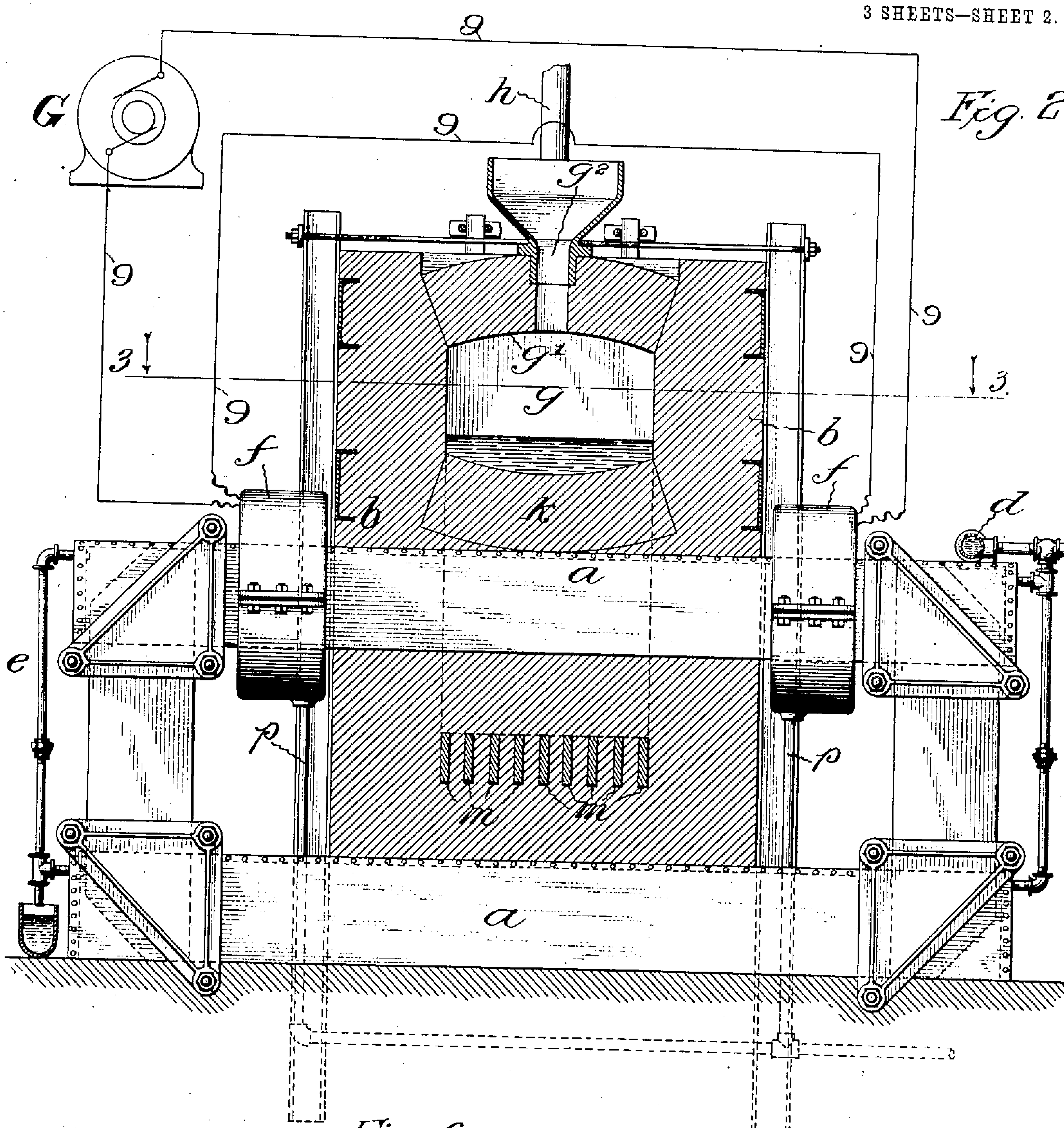


Fig. 6.

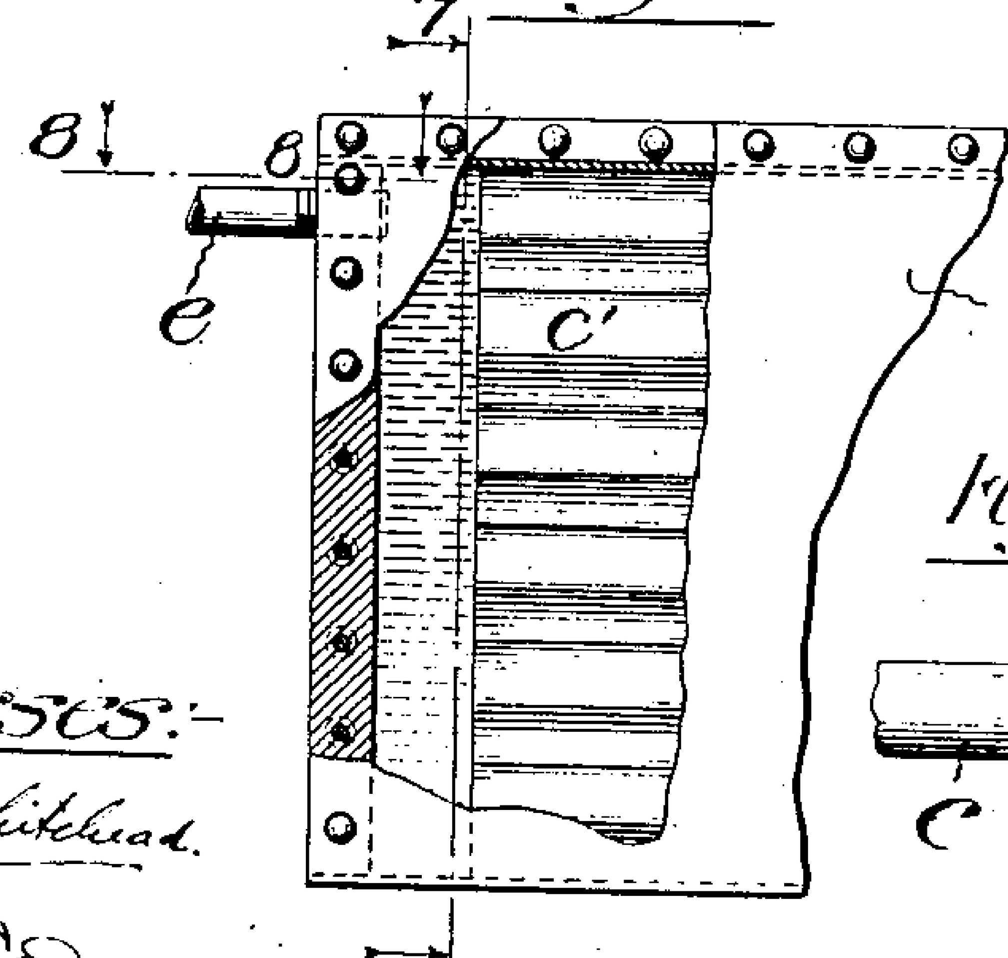


Fig. 8.

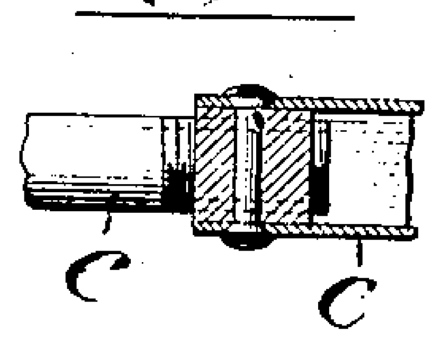
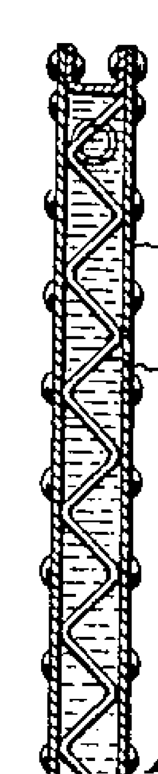


Fig. 7.



Witnesses:-
Louis M. F. Whitehead.
Geo. C. Dorson

Inventor:
Frederick T. Snyder,
By Barton & Tanner
Att'ys.

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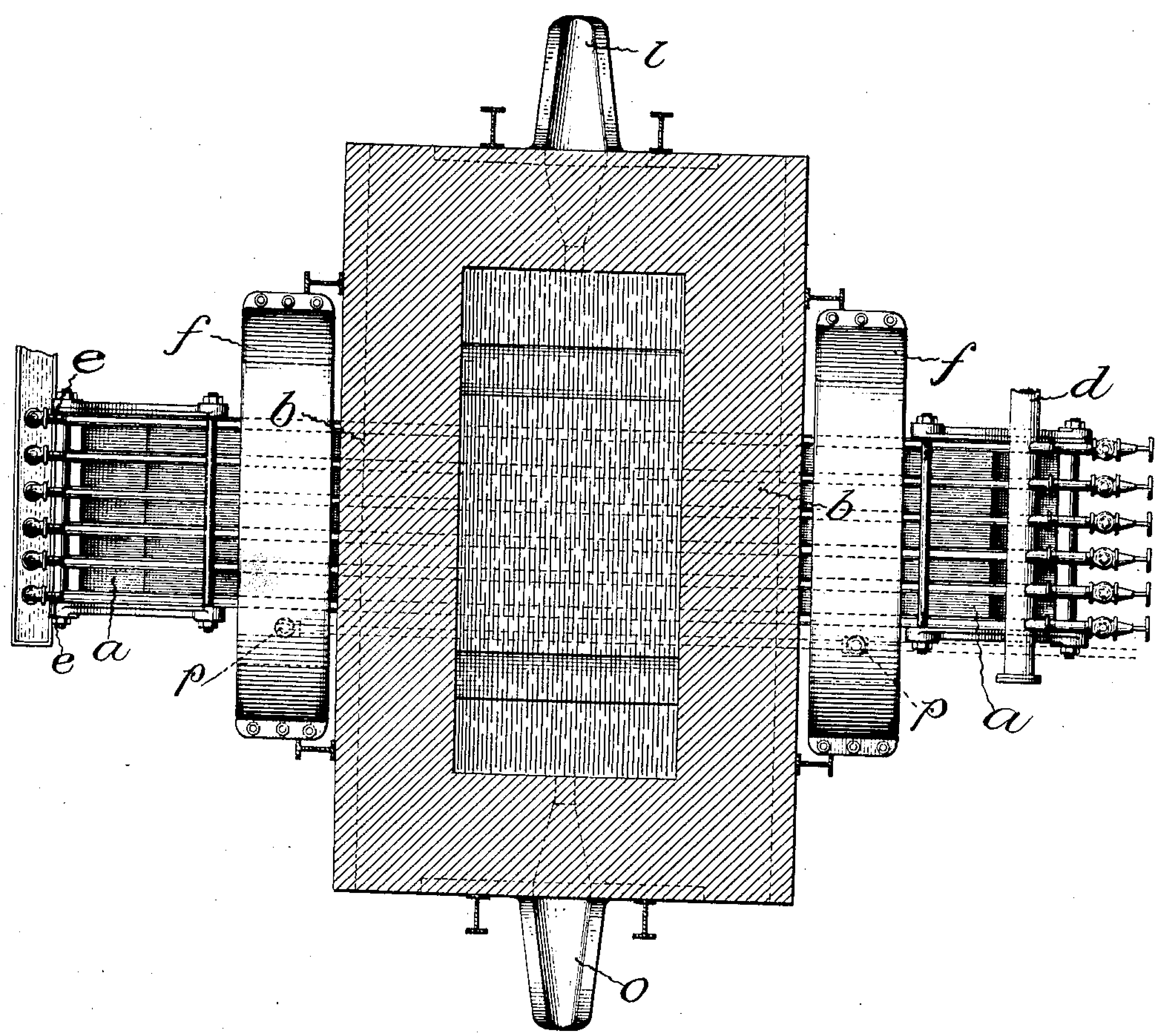
3 SHEETS—SHEET 3.

Fig. 3.



Witnesses:-
Louis M. F. Whitehead
Fred. C. Dawson.

Inventor:
Frederick T. Snyder,
By Barton & Tanner.
Att'ys.

UNITED STATES PATENT OFFICE.

FREDERICK T. SNYDER, OF OAK PARK, ILLINOIS.

ELECTRIC FURNACE.

No. 825,359. Specification of Letters Patent. Patented July 10, 1906.

Application filed July 15, 1904. Serial No. 216,662.

To all whom it may concern:

Be it known that I, Frederick T. Snyder, a citizen of the United States, residing at Oak Park, in the county of Cook and State of Illinois, have invented a certain new and useful Improvement in Electric Furnaces, of which the following is a full, clear, concise, and exact description.

My invention relates to an electric furnace of the induction type in which the metal to be heated is placed in inductive relation to a magnetic core having a primary winding included in circuit with a source of alternating current. The metal to be heated, in other words, forms the whole or a portion of the secondary element of a transformer. By this means a very intense current may be directly induced in the material forming the secondary circuit, the energy of which current is transformed into heat.

It is my object to produce an improved furnace of this type which will be suitable for commercial smelting of metals upon a large scale, my intention being to improve both the electrical and mechanical design to make possible an increased efficiency of the apparatus, to provide for the regulation of the temperature of the furnace, both automatically and also by varying the quantity or disposition of the materials therein, and more particularly to provide a construction in which the heat developed in the secondary circuit will be localized at the particular places where it is most desired, while keeping the remainder of the furnace, including the core, comparatively cool.

I will describe my invention particularly by reference to the accompanying drawings, which illustrate the preferred form in which my furnace is constructed, it being understood, of course, that this form may be varied to a considerable extent without departing from the general principles herein set forth. The description of the particular form shown is not, therefore, to be taken as defining the limits of my invention; but the parts, improvements, or combinations which I regard as novel will be pointed out in the concluding claims.

Figure 1 is a vertical cross-section of the furnace. Fig. 2 is a sectional elevation on line 2 2 of Fig. 1, also showing the electrical connections in diagram. Fig. 3 is a sectional plan view on line 3 3 of Fig. 2. Figs. 4 and 5 are detail views showing the manner of assembling the laminated core. Fig. 6 is a detail view of the end of one of the water-troughs which are provided between the laminations of the core, a portion of the side of the trough being broken away. Fig. 7 is a detail sectional view on line 7 7 of Fig. 6, and Fig. 8 is a detail sectional view on line 8 8 of Fig. 6.

The same reference characters designate the same parts wherever they are shown.

The core *a*, which is made of iron laminations or strips clamped together at the corners, is arranged to pass horizontally through the wall *b* of the furnace. As shown, this core is in the shape of a rectangle set on edge, and the two horizontal arms which pass through the furnace are provided with a series of water-troughs *c c*, set at intervals between the laminations. These troughs may be formed, as shown in Figs. 6, 7, and 8, with a stiffened web *c'* throughout the central portion to withstand the compression of the clamps which hold the laminations in assembled position and to reduce convection-currents in the water, whereby a better circulation of water from end to end of the trough is secured. An inlet-pipe *d* is connected with the series of troughs at one end of the core, while at the other end of the core discharge-pipes *e* are led from said troughs. A continuous circulation of water for cooling purposes is thus provided for. This water serves both to carry away the heat produced by the magnetic action of the core and to preserve the furnace structure by preventing the overheating of the furnace-walls, the heat in the walls being conducted away through the core and the water flowing through the same. Primary coils *f f* are wound upon the core *a* on either side of the furnace and are electrically connected in a circuit 9, leading from the poles of an alternating-current generator G. This generator is provided with means such as are well known in the art for maintaining the current delivered thereby at a constant potential, and the transformer of the furnace should be so designed that approximately constant current will be maintained in the secondary circuit under constant-potential conditions in the primary. The electrical design of transformers to produce such results is well understood by those skilled in the art.

In practice the conducting-wires leading to the primary windings will be inclosed in metallic pipes *p*. (Shown in Fig. 2.) The drawings, however, indicate the circuit connections of the primary diagrammatically.

The furnace is built up around the magnetic core in such a way as to provide a chamber *g*, adapted to receive the material to be melted. This chamber is provided with a reverberatory roof *g'*, having openings g^2 g^2 therein, through which the ore to be smelted may be fed into the furnace, and a vent *h*, through which the gases produced in the furnace may escape. A bridge *k* is built across the central portion of the furnace from wall to wall immediately surrounding the horizontal core *a* and dividing the vertical chamber into two vertical wells on either side of said bridge. A number of bars of copper *m m* are set in the furnace, crossing from one well to the other underneath said bridge and transversely thereto. When molten material is introduced into the furnace to fill the chamber *g* above the level of the bridge, it will be seen that a complete secondary circuit is thus formed around the core *a* and in inductive relation thereto, said secondary circuit being totally inclosed by the walls of the furnace.

A tap-hole *l* is provided in the furnace at a point slightly below the level of the bridge, with a spout to guide the material tapped out. This tap-hole will be for the purpose of drawing off the slag and is normally closed by a clay plug. A second tap-hole will also be provided at a point nearer the bottom of the chamber for the purpose of drawing off the metal which is derived from the smelted ore, and a suitable spout is also provided to receive the metal from this tap, which is also normally closed by a clay plug.

The vertical wells on either side of the bridge *k* will be filled with molten metal, preferably the same metal as that in the ore being smelted. These vertical wells will be filled only to a point slightly below the top of the bridge and will form molten electrodes united at the bottom by the copper bars *m m*. Slag is provided in the chamber resting upon the surface of the molten metal in the vertical wells and filling the chamber to a level above the surface of the bridge, so that the two wells are electrically united above the bridge by the molten slag, which is electrically conducting, but of comparatively high resistance. The material to be smelted is fed through the openings g^2 g^2 upon the surface of the molten slag and is gradually reduced, the metal which is liberated sinking into the wells on either side of the central bridge. As the metal accumulates in these wells it can be gradually drawn off through the tap *o*. As the slag accumulates it can be drawn off through the tap *l*. The taps for the slag and for the metal also serve as a means for regulating the resistance of the secondary circuit, since when the level of the molten material above the bridge *k* is lowered the cross-section of the secondary circuit is reduced at this point, increasing the resistance.

The secondary circuit, which is arranged in a vertical plane, as shown, is composed of conducting materials having different conductivity and correspondingly-different specific gravity—that is to say, the heavier material at the bottom should be a good conductor, while the lighter material at the top should be of comparatively high resistance. Since the heating effect of an electric current increases in proportion to the resistance of the conductor through which the current is passed, it will be seen that in my furnace the maximum heating effect of the current in the secondary circuit will be developed at the top—that is to say, in the slag upon which the ore to be smelted is fed. The maximum heat is thus produced at the particular point desired. The lower portion of the secondary circuit, which is made up of the massive copper conductors *m*, will be heated to a very much less extent. It is well understood that in conductors carrying alternating current the electrical effect is manifested chiefly at the surface of the conductor, no great amount of current being conveyed by the interior mass of the metal. In my furnace, therefore, I increase the conductivity of a portion of the secondary circuit by laminating the same, the lower portion of the furnace-chamber crossing underneath the bridge being divided into a number of channels, in each of which a copper bar *m* may be placed. A portion of the secondary circuit is thus composed of separate laminæ *m*, as shown in Fig. 2. If the heat should be sufficient to melt the copper, the molten conductor will still be laminated or divided between the several channels. The metal of the molten electrodes is a comparatively good conductor, but not so good as the copper bars at the bottom, so that said electrodes will be heated to a sufficient extent to keep them molten. As before stated, however, the maximum heating effect is developed in the slag.

In the smelting of iron the copper at the bottom may be molten, if desired. It will remain at the bottom by virtue of its specific gravity. The slag, on the other hand, will always be light enough to remain at the top, the ore to be smelted in turn floating upon the surface of the slag.

It will thus be seen that one of the most important features of this invention lies in the formation of the secondary circuit from a number of materials of different resistance arranged in series relation, and this series relation where the materials are molten is obtained by arranging the secondary circuit in such a way that the varying specific gravity of the different materials is utilized to cause these metals to take of themselves the desired relative positions in the circuit. One advantage of a furnace constructed as above described is that the furnace can be made gas-tight, no openings being required in the furnace for the introduction of electrodes, as is necessary in most smelting-furnaces heretofore devised. Another advantage is that when the secondary circuit is totally inclosed by refractory walls the waste of heat by conduction will be minimized. Still another advantage is that the furnace may be provided with a reverberatory roof immediately above the point where the maximum heat is developed. A further feature of my invention lies in the means for regulating the temperature of the furnace. As before described, this may be accomplished by adjusting the level of the slag or of the molten electrodes to change either the relative proportions of the different resistance metals serially included in the circuit or to vary the cross-section of the circuit where it crosses above the bridge. If the furnace begins to cool off, the resistance of that portion of the working circuit which is composed of slag will increase, as slag contains a large proportion of silica and is, in fact, a sort of glass which is electrically conducting when molten, but of very low conductivity when cold. The resistance of the metal portions of the secondary circuit will decrease as the temperature of these metal portions is lowered; but the increase in resistance of the slag will more than balance the decrease due to the cooling of the metal, so that the total resistance of the circuit will increase as the temperature falls. By properly proportioning the slag and metal portions of the circuit any desired conditions of regulation may be obtained. Under constant-current conditions as the furnace cools off more energy is put into the furnace as the resistance increases, and the temperature will thus be automatically brought back to normal. If, on the other hand, the temperature of the furnace rises above normal, the resistance decreases and less energy will be put into the furnace under constant-current conditions, so that the furnace will be brought back to the normal temperature required. The temperature is automatically regulated by so proportioning the inductive portions of the furnace that constant-current conditions will obtain in the secondary circuit—that is, there will be a constant volume of current flowing in the secondary, and the electromotive force will vary with the resistance of the secondary. By proper design this constant-current condition in the secondary may be secured with either constant-potential or constant-current conditions in the primary.

In the furnace illustrated the primary winding is mounted concentrically with the secondary upon the same arm of the core, but is relatively displaced along the core, so the secondary a distance sufficient to permit that said primary winding is separated from considerable magnetic leakage from said core between the primary winding and the secondary. Under these conditions with constant potential applied to the primary winding the current in the secondary will be maintained substantially constant.

I claim—

1. In an electric furnace of the induction type, the combination with a core, and a primary winding thereon, of a chamber about said core and molten conducting materials of different conductivity and different specific gravity in said chamber the material offering the highest resistance also possessing the lowest specific gravity, said materials being serially arranged in a closed secondary circuit around said core, whereby the maximum heating effect of the current in said secondary circuit is developed at the upper part of said secondary circuit.

2. In an electric furnace of the induction type, the combination with a core and a primary winding thereon, of a chamber and a plurality of molten conducting materials contained in said chamber in series in an electric circuit around said core, said materials being of different resistance, whereby the greater heating effect of the current is localized in the higher-resistance material.

3. In an electric furnace, the combination with a magnet-core and a primary induction-coil winding upon the same, of non-conducting material disposed about an arm of said core to form a vertically-disposed annular chamber surrounding said core, low-resistance conducting material in the lower portion of said chamber, higher-resistance material in the upper portion of the chamber completing a secondary circuit about said core, and means for feeding material to be smelted into the upper portion of said chamber; whereby a complete secondary circuit is formed, in which the greater heating effect of the current is localized in the material to be smelted.

4. In an electric furnace, the combination with a core, and a primary winding thereon, of a secondary circuit interlinked with said core, said secondary circuit comprising a low-resistance conductor, molten electrodes of the metal being smelted in contact with the terminals of said low-resistance conductor, a slag supported on and electrically uniting said molten electrodes, and ore of the material to be smelted lying upon the surface of said slag, a bridge of refractory material below the surface of the slag and separating said electrodes, and walls of non-conducting material inclosing said secondary circuit, all substantially as set forth.

5. In an electric furnace, the combination with a chamber adapted to contain molten materials, of a bridge extending across the

chamber in the central portion thereof, a laminated-iron core within said bridge, and a primary induction-coil winding on said core, said chamber being continuous around and under said bridge, whereby the material in said chamber forms a closed secondary circuit about said core.

6. In an electric furnace, the combination with the chamber formed of non-conducting material, of a bridge extending across said chamber, a laminated-iron core in said bridge, a primary winding on said core, molten conducting materials of different specific gravity and resistance contained in said chamber forming a complete secondary circuit around said core, in which circuit the different materials are in series relation, and means for adjusting the level of the materials in said chamber to vary the resistance of the secondary circuit.

7. In an electric furnace of the induction type, the combination with a horizontal core and a primary winding thereon, non-conducting walls built around said core to form a chamber adapted to receive metal to form a vertically-arranged secondary circuit, a reverberatory roof over the top of said chamber, a metal conductor of low resistance in the bottom of said chamber, molten metallic electrodes in the vertical sides or risers, and a slag-bath at the top containing the material to be smelted, said slag-bath being of comparatively high resistance; whereby the entire mass of metal in the chamber is directly heated by the passage of the induced current therein, and the heating effect is developed to a maximum extent in the upper portion containing the slag.

8. The combination with the laminated-iron core of an induction-furnace, and means for clamping the laminations together, of a closed trough between the laminations of said core, adapted to contain water, said trough having a transverse web, substantially as and for the purpose specified.

9. In an electric furnace of the induction type, the combination with a chamber of non-conducting material and a laminated-iron core through said chamber, of a primary winding on said core, material in the chamber constituting a closed secondary circuit around said core, and means for circulating cooling fluid between said core and said chamber.

10. In an electric furnace of the induction type, the combination with a chamber of non-conducting material, of a bridge across said chamber, a horizontal iron core within said bridge, said core passing through and projecting outside the wall of said chamber, a primary coil upon the projecting portion of said core, molten electrodes of the metal being smelted on either side of said bridge, a slag containing said metal filling said chamber from the level of said electrodes to a level above the upper surface of said bridge, and conductors electrically uniting the lower ends of said molten electrodes.

11. In an electric furnace, the combination with a horizontal core carrying a primary winding, of a chamber having a central bridge built around said core, dividing said chamber into two vertical wells on either side of said bridge, multiple bars of copper passing under said core from one well to the other, and molten conducting material in said chamber, filling the same above the level of said bridge; whereby a complete secondary circuit is formed around said core, and a reverberatory roof for said chamber, said roof having an opening through which ore may be fed upon the surface of the molten material in the furnace.

12. The combination with an electric furnace having a pair of molten electrodes, of metal being smelted in the furnace, with slag completing the circuit between said electrodes, of a source of current for said circuit, and automatic means for maintaining the volume of current in said circuit constant under varying resistance, whereby the temperature of the furnace is maintained substantially constant.

13. The combination in an electric furnace arranged to heat material by the passage of an electric current, of a chamber adapted to contain said material and thereby to form a closed circuit in said furnace, means for maintaining a constant current in said circuit under varying resistance thereof, and means for varying the quantity of material in the path of the current, whereby the temperature in the furnace may be adjusted, and when adjusted will be automatically maintained at the degree to which adjusted.

14. The combination with an electric furnace, of a transformer, the secondary of said transformer being composed in part of a metal whose resistance increases with a rise in temperature and in part of a material whose resistance decreases with a rise in temperature, said material being within said furnace, the relative resistance of said metal and said material being so proportioned that the resistance of said secondary will increase with a fall of temperature in said furnace.

15. An electric furnace of the transformer type, comprising a core, a primary winding about said core and a chamber adapted to contain material to form a secondary circuit around said core, said chamber being provided with an opening through which the quantity of material in the secondary circuit may be varied to vary the resistance in said secondary, in combination with a source of constant - potential current connected with said primary winding; the furnace - transformer being proportioned to maintain substantially constant current in the secondary under constant-potential conditions in the

primary; whereby the temperature of the furnace may be adjusted and automatically maintained substantially constant at the degree to which said temperature is adjusted.

16. An electric furnace adapted to be heated by the passage of alternating current, said furnace having a chamber divided by partitions into a plurality of channels, and conducting material in said channels forming a conductor of separated laminæ included in the electric circuit, substantially as and for the purpose set forth.

17. An electric furnace of the transformer type comprising a horizontal core, a primary winding and a chamber adapted to contain conducting material to form a closed secondary circuit around said core, the lower portion of said chamber being divided by partitions into a number of channels, the material in said channels forming a laminated conductor; whereby a high conductivity of the lower portion of the secondary circuit relative to the mass of material therein, is obtained.

18. An electric furnace of the induction type, comprising a core and a chamber adapted to contain material to form a secondary circuit about said core, the transformer thus constituted being proportioned to maintain substantially constant current in the secondary upon application of constant potential to the primary, whereby the temperature in the furnace may be automatically regulated.

19. An electric furnace of the induction type, comprising a core, a chamber adapted to contain material to form a secondary circuit about said core, and a primary winding about said core, said primary winding being so located upon said core with reference to said secondary as to permit a considerable magnetic leakage from said core between said primary winding and said secondary, in combination with a source of constant-potential alternating current connected to said primary winding, whereby the current in the secondary is maintained substantially constant.

20. An electric furnace of the induction type, comprising a core, a chamber adapted to contain material to form a secondary circuit about said core, a primary winding about said core, said primary winding being substantially concentric with said secondary but relatively displaced along said core such a distance as to allow sufficient magnetic leakage between said primary and said secondary to maintain substantially constant current in said secondary upon the application of constant potential to said primary winding.

In witness whereof I hereunto subscribe my name this 13th day of July, A. D. 1904.

FREDERICK T. SNYDER.

Witnesses:
ALFRED H. MOORE,
DE WITT C. TANNER.