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R. D. HALL

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ELECTRIC FURNACE

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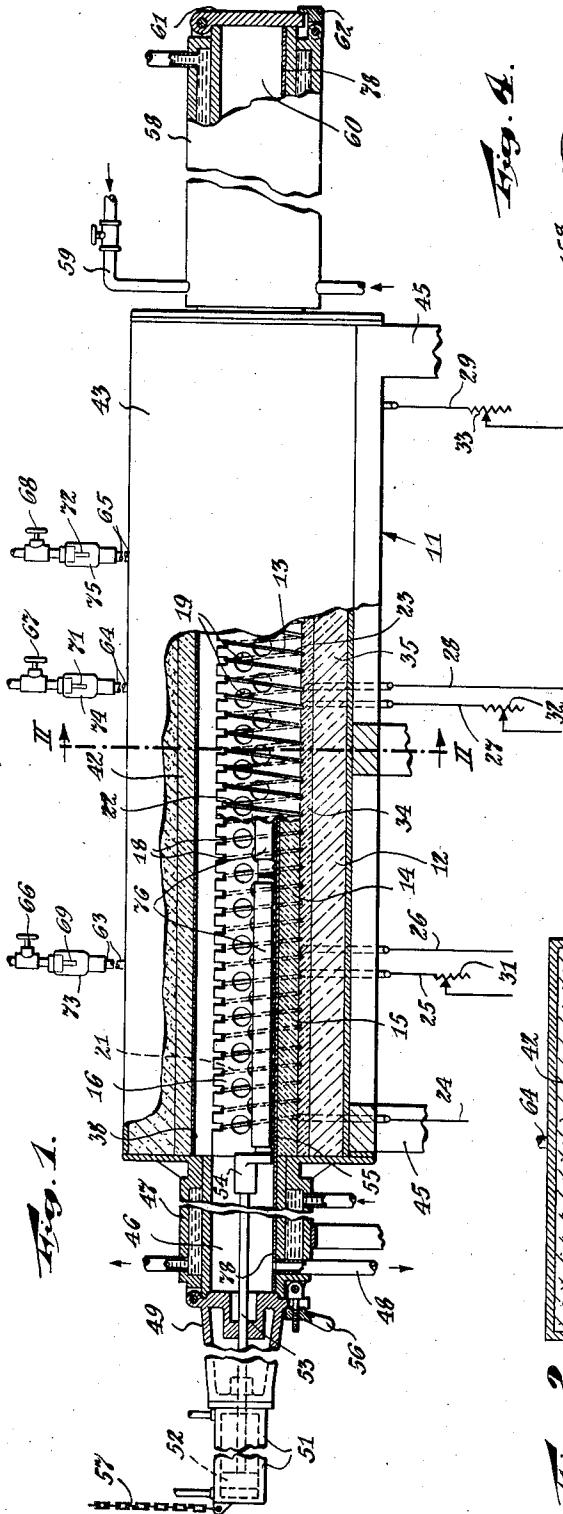


Fig. 4.

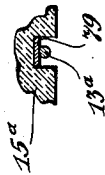


Fig. 3.

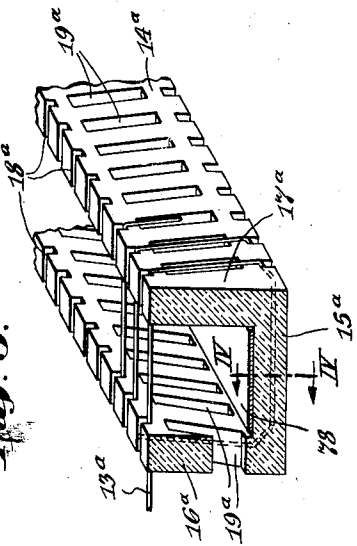


Fig. 5.

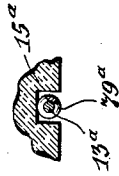
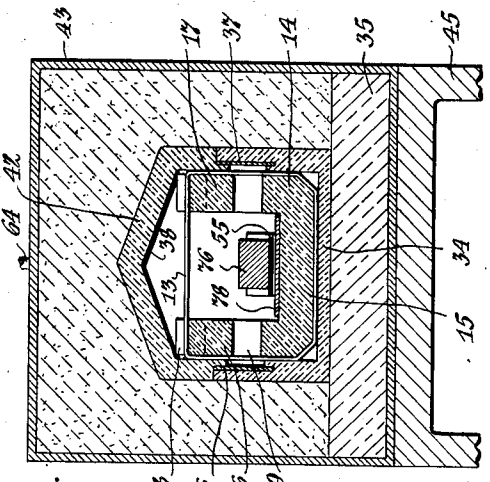


Fig. 2.



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UNITED STATES PATENT OFFICE

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ELECTRIC FURNACE

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13 Claims. (Cl. 13—22)

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This invention relates to electric furnaces and, more particularly, to one adapted for sintering such materials as molybdenum, alloys thereof with tungsten and other metals, as well as for the reduction of such metals from the oxides.

The principal object of my invention, generally considered, is to provide an electric furnace of the resistance type in which a large proportion of the energy is radiated directly from the resistance elements to the material to be heated.

Another object of my invention is to provide an electric furnace of the resistance type in which considerable advantage is taken of the direct radiation from the resistance elements, while still retaining an efficient insulating material, and not interfering with the utilization for continuous movement of the product through the furnace.

A further object of my invention is the provision of an electric resistance furnace which may utilize a large proportion of the energy directly radiated from a filament of refractory material such as tungsten, whereby it may be utilized for sintering tungsten or the like which could not be sintered in furnaces in which the heat developed in a resistance element has to pass through the wall of a refractory tube or other container.

A still further object of my invention is to construct an electric furnace of the resistance type in which the temperature on the inside thereof may be caused to approach the maximum temperature that the available refractory will stand, that is, probably about 1800° C. when using alumina as the refractory.

Other objects and advantages of the invention will become apparent as the description proceeds.

Referring to the drawing:

Fig. 1 is a vertical longitudinal sectional view, with parts in elevation and parts shown diagrammatically, of a furnace and associated apparatus embodying my invention.

Fig. 2 is a transverse sectional view on the line II—II of Fig. 1, in the direction of the arrows.

Fig. 3 is a perspective view of a modified form of heating frame for such a furnace.

Fig. 4 is a detailed sectional view on the line IV—IV of Fig. 3, in the direction of the arrows.

Fig. 5 is a detailed sectional view corresponding to Fig. 4, but showing a modification.

Resistance furnaces employed prior to my invention were constructed substantially as follows:

A tube or muffle of highly refractory material, preferably alumina, was wound with a wire or ribbon of molybdenum or tungsten as the resistance element. This element was then embedded

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in an insulating powdered oxide, such as alumina, and operated in a protective atmosphere preferably hydrogen.

Since the furnace refractory must have considerable thickness in order to give it the necessary mechanical strength at the high temperature of operation, such operating temperature of the furnace was limited, in part, by the thermal conductivity of the tube or muffle, the outside of which is necessarily considerably higher in temperature where it contacts the resistance wire, than is the interior surface which furnishes the radiant heat available to the material being treated in the furnace. This differential in temperature may well be of the order of 150° to 200° C. This limits to from 1600° to 1650° C. as the temperature to which furnaces of this type can be successfully operated.

It has been proposed to mount the resistance wires on the inside of the refractory tube, but for general operations this is impractical, especially where heavy loads or tracks of molybdenum are used in the furnace.

In accordance with my invention I take advantage of the direct radiation from the resistance elements, still retain powdered or other efficient insulation, and do not interfere with the utilization of the furnace for continuous horizontal movement of the product therethrough.

Referring now to the drawing in detail, like parts being designated by like reference characters, and first considering the embodiment of my invention illustrated in Figs. 1 and 2, there is shown a furnace 11 which comprises a middle or intermediate hot zone part 12 maintained at a desired temperature by a heating element 13 which, if the furnace is to be used for maximum temperatures, or those up to about 1800° C., is desirably a tungsten wire or filament. If the furnace is to be operated at a lower temperature, the filament may be of molybdenum or some other material which will stand the temperature of furnace operation.

In the present embodiment, the refractory filament 13 is supported by being wound on a refractory insulating inside box or frame 14, desirably formed of alumina and comprising a floor or bottom portion 15 and sides 16 and 17, forming a trough-shaped object extending the full length of the furnace, and opening upwardly. The filament 13 is wound helically around the frame 14 and desirably received in grooves or notches 18 at its lines of engagement therewith. On account of the shape of the frame, the filament is bare or unobstructed at the top to radiate direct-

ly on material being treated. In order to further increase the amount of direct radiation received from the filament, the sides of the frame may be apertured, as indicated at 19, where the filament passes thereover, so that a large proportion of the heat of said filament when incandescent is received directly by radiation by the material being treated.

Suitable connections are provided for introducing the desired electric current to the filament 13. If it is desired to maintain portions of the furnace at different temperatures from other portions, said filament may be formed as sections, respectively designated at 21, 22 and 23, each section having lead-in conductors such as those numbered 24, 25, 26, 27, 28 and 29, suitable rheostats 31, 32 and 33 being provided for the respective sections 21, 22 and 23 for regulating the heat of the furnace.

The frame carrying the resistance winding, or windings, is enclosed in a suitable insulating housing which is illustrated as comprising a bottom insulating, preferably alumina, member 34, tightly closed by a refractory insulating, preferably alumina, top or cover member 42, desirably arched for strength. The assembly rests on a refractory insulating preferably alumina, block 35 and is otherwise desirably surrounded by powdered refractory, such as alumina, and the whole held in a suitable outer air-tight metal housing 43, and supported on a suitable table or stand 45. Reflector plates 36 and 37, desirably of polished high-melting-point metal, such as molybdenum, may be positioned outwardly of the apertures 19, and spaced from the filament sections spanning said apertures, to reflect filament heat to the furnace interior. The cover 42 is also desirably lined with similar reflector means 38.

At the front end of the furnace is a vestibule portion 46, desirably cooled by a water jacket 47 and provided with an outlet 48 for excess hydrogen, steam and/or ammonia or other reagent used during the process. The portion 46 is closed by a hinged door or cap 49, desirably including power means for pushing the material treated through the furnace, such as an air or water cylinder 51 and piston 52, for operating a rod 53 and associated pusher element 54. This or other suitable means may be used for moving containers or boats 55 through the furnace at desired speed, from the left hand or inlet end to the right hand or outlet end of the furnace. The door or cap 49 may be secured in place by locking means 56 and provided with a chain 57 for a counterweight or lifting apparatus, not shown.

The outlet end of the furnace is desirably provided with a section 60 cooled by a water jacket or like means 58, and provided with a pipe 59 for introducing a supply of the reagent, such as hydrogen, wet hydrogen, or other gas or mixture thereof. The extreme end of the cooled section 60 is desirably closed by a hinged lid or door 61, provided with a suitable latch or locking device 62.

If used for the reduction of molybdenum trioxide, in accordance with the Rennie application, Ser. No. 471,604, filed January 7, 1943, for "Continuous reduction of molybdenum compounds," and owned by the assignee of the present application, means are preferably provided for introducing desired amounts of water or other diluting agent along the length of the furnace, said means in the present embodiment comprising pipes 63, 64 and 65. The diluting agent for

these pipes is desirably supplied from a reservoir (not shown) kept at a desired level in a conventional manner. A flow of the agent from the reservoir to the pipes is controlled by valves 66, 67 and 68, respectively, and admitting it through gaged capillary tubes 69, 71 and 72, and transparent connections 73, 74 and 75 permitting observation. The hydrogen, or other reagent, which is necessarily reducing or protective if the furnace is operated at high temperature and the heating element is oxidizable material such as tungsten or molybdenum, passes to the hot portion at a desirably continuous rate, being, however, naturally steadily attenuated, if the furnace is used for reduction of oxides or if water is admitted along its length, the excess of said reagent being withdrawn from the pipe 48, for reclamation if desired.

If used for the sintering of molybdenum or other refractory metals or alloys, the slugs or ingots 76 are desirably supported on corrugated plates of similar material, said plates being covered with a film of inert refractory powder to prevent sticking, in accordance with the disclosure of the Newman application, Ser. No. 526,153, filed March 13, 1944, and owned by the assignee of the present application.

At the temperature that it is desired to operate the furnace for the sintering of molybdenum powder to coherent metal, which is about 1600° C. for molybdenum, and especially at about 1800° C., practically all ceramics tend to wear rapidly if boats or slabs, used to hold material or pressed slugs to be fired, are slid thereover. I therefore find it preferable to use a track 78 of molybdenum or tungsten through the furnace, including the entrance vestibule 46. Such a track may be made in one piece or several pieces riveted or otherwise suitably secured together.

Referring to the embodiment illustrated in Fig. 3, there is shown a heating filament or wire 13^a wound on a frame 14^a, formed like the frame 14 of the first embodiment except that the apertures 19^a in the sides 16^a and 17^a are formed as slots, or elongated so that they extend a major proportion of the length of the side or nearly vertical sections of the filament 13^a, so as to allow for a maximum amount of direct radiation from said side sections to the interior of the furnace.

In order to operate the filament, especially if formed of tungsten, in a furnace for sintering refractory metal powder at a high-enough temperature for that purpose, without fusing the refractory material of the frame 14^a, the bottom of each slot 18^a which receives a portion of the filament is desirably lined with a plate 79 of material which corresponds with that of the filament, that is, tungsten if the filament is tungsten, and molybdenum if the filament is molybdenum. This plate is either in close contact with or welded or brazed to the filament, so that it protects the refractory from excessive heating and deterioration, protects the filament from deterioration and embrittlement, and carries part of the current, so that the sections of the filament engaging said plates run at lower temperatures than that of the remainder of the filament, whereby the power employed for heating is more efficiently used in that it is concentrated at the points where direct radiation from the heating filament is obtainable and minimized at points where the heat has to pass through a relatively thick mass of refractory.

Fig. 5 is a view corresponding to Fig. 4, except that instead of using a plate of metal, the latter

is wound about the filament as a coil 79^a, in close contact with the filament or brazed or welded thereto like the plate 79 of the preceding embodiment.

From the foregoing disclosure, it will be seen that I have developed a furnace of the electrical-resistance type in which higher temperatures than heretofore are obtainable because of using direct radiation from the heating filament, rather than receiving the heat therefrom after passing through a tube or muffle. Although preferred embodiments of my invention have been disclosed, it will be understood that modifications may be made within the spirit and scope of the appended claims.

I claim:

1. In an electric furnace, in combination, an insulating housing, a refractory insulating frame enclosed therein, and a refractory heating element carried on the exterior of said frame and comprising sections above, at the sides of, and below said frame, said frame being formed to allow radiant heat to pass directly from at least some of all but the last-mentioned sections of the heating element to the interior.

2. In an electric furnace, in combination, an insulating housing, a refractory insulating frame enclosed therein, and a refractory heating element carried on the exterior of said frame and comprising straight sections above, at the sides of, and below said frame, said frame being provided with openings through which radiant heat passes directly from all but the bottom sections of the heating element to the interior.

3. In an electric furnace, in combination, an insulating housing, a refractory U-shaped insulating frame enclosed therein, and a refractory heating element carried on said frame, said heating element spanning the distance between the upper portions of the sides of said frame so as to radiate heat directly to the interior.

4. In an electric furnace, in combination, an insulating housing, a refractory insulating frame enclosed therein and U-shaped in section, a refractory heating element on said frame and spanning the distance between the upper portions of the sides thereof, the sides of said frame being formed with openings through which radiant heat passes directly from the heating element to the interior.

5. In an electric furnace, in combination, an insulating housing, a refractory U-shaped insulating frame enclosed therein and a refractory heating element wound on said frame, said heating element spanning the distance between the upper portions of the sides of said frame, and a major portion of the height of said sides, adjacent the side sections of said element, being slotted to allow heat to radiate directly from the side sections of the element, as well as directly from the upper sections of said element, to the interior.

6. In an electric furnace, in combination, an insulating housing, a refractory insulating flat-sided frame enclosed therein and formed with notches at the edges of said sides, and a refractory heating element wound on said frame and received in said notches, said frame being provided with openings between said notches through which radiant heat passes directly from the heating element to the furnace interior.

7. In an electric furnace, in combination, an insulating housing, a refractory insulating frame

enclosed therein and formed with notches, a refractory heating element wound on said frame and received in said notches, said notches being lined with plates of material similar to and closely engaged by said heating element in said notches, so as to cause said element to run at a lower temperature in said notches than therebetween.

8. In an electric furnace, in combination, an insulating housing, a refractory insulating frame enclosed therein and formed with notches, a refractory heating element wound on said frame and received in said notches, the parts of said heating element in said notches being covered with material similar thereto, so as to cause said element to run at a lower temperature in said notches than therebetween.

9. In an electric furnace, in combination, an insulating housing, a refractory insulating frame enclosed therein, U-shaped in section, and provided with notches, a refractory heating element wound on said frame, received in said notches, and spanning the distance between the upper portions of the frame sides, the sides of said frame being formed with openings between said notches through which radiant heat passes directly from the heating element to the furnace interior.

10. In an electric furnace, in combination, an insulating housing, a refractory insulating frame enclosed therein, U-shaped in section, and formed with notches, a refractory heating element wound on said frame, received in said notches, and spanning the distance between the upper portions of the frame sides, said notches being lined with plates of material similar to and closely engaged by said heating element in said notches, so as to cause said element to run at a lower temperature in said notches than therebetween.

11. In an electric furnace, in combination, an insulating housing, a refractory insulating frame enclosed therein, U-shaped in section, and formed with notches, a refractory heating element wound on said frame, received in said notches, and spanning the distance between the upper portions of the frame sides, the parts of said heating element in said notches being covered with material similar thereto, so as to cause said element to run at a lower temperature in said notches than therebetween.

12. In an electric furnace, in combination, an insulating housing, a refractory insulating frame enclosed therein, a refractory heating element wound on said frame, said frame being formed with openings to allow radiant heat to pass directly from the heating element to the interior, and metal reflector elements set in said housing directly outside of the sections of heating element at said openings, to reflect heat inwardly therefrom directly to the furnace interior.

13. In an electric furnace, in combination, an insulating housing, a refractory insulating frame enclosed therein, and U-shaped in section, a refractory heating element wound on said frame and spanning the distance between the upper portions of the sides thereof, the inner surface of the upper portion of said housing being covered with a refractory lining for causing the heat radiated upwardly from said element to be reflected downwardly to the interior of the furnace.

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