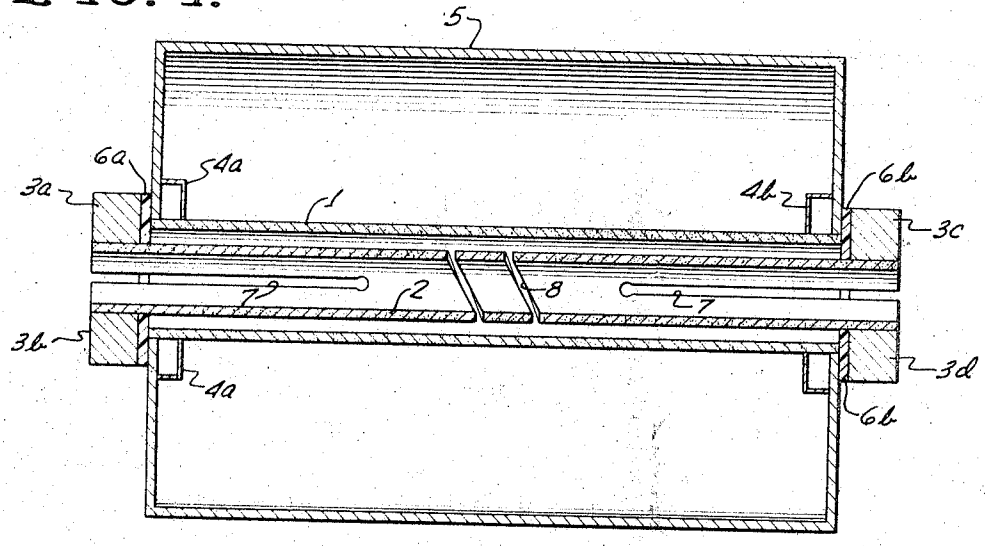
Aug. 15, 1967 R. H. BIDDULPH 3,336,431

ELECTRIC FURNACE

Filed March 22, 1965

FIG. 1.



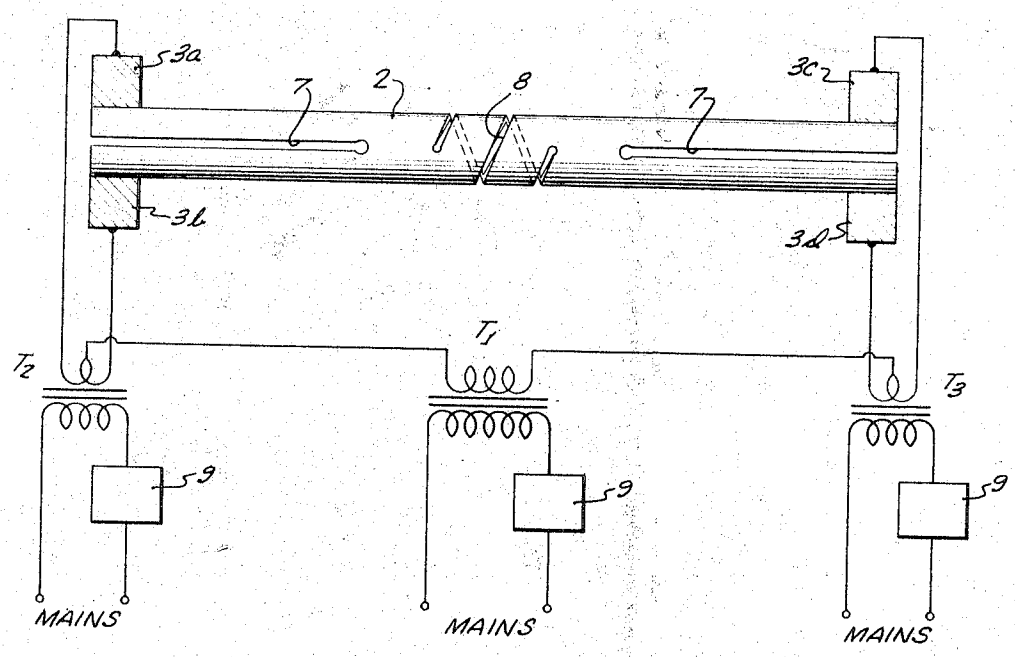


FIG. 2.

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ELECTRIC FURNACE

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12 Claims. (Cl. 13—25)

This invention relates to electric furnaces of the resistance type.

It has been proposed in copending application Ser. No. 193,793 filed May 10, 1962, by A. A. R. Wood and B. P. Long, now Patent No. 3,246,956, to employ as the heating element of an electric-resistance furnace a cylindrical graphite tube having two diametrically opposed longitudinal slits extending from one end almost to the other. Current is led to the element by two metal contact blocks, one on each limb of the slotted end of the element. While the temperature profile within such a furnace can be varied to some extent by altering the applied E.M.F. or by shaping the element, the possible variation is very limited and difficult to control.

I have now devised a new electric furnace which enables considerable variation of the temperature profile therein conveniently to be obtained and which, in certain constructions, is especially suitable for use in the hot-pressing of refractory particulate materials.

The electric furnace of this invention comprises an electric-resistance heating element of generally tubular shape, the wall of the element being interrupted at one or both ends by at least two longitudinal gaps (hereinafter referred to as "slots") extending part way toward the unslotted end of the element or part way toward the inner end of the slots running from the other end of the element, each limb of the slotted end or ends of the element and any unslotted end being provided with an electrical contact. While the resistance element may be slotted at only one end, preferably both ends are slotted. Elements slotted at both ends not only enable a greater variation in temperature profile to be obtained than when only one end is slotted, but also are particularly suitable for use in the method of hot-pressing refractory powders described in detail below.

The temperature profile within the element can be conveniently varied by superimposing local heating currents on the main heating current. The electrical resistance of the element between contacts on different limbs of the same end of the element is desirably lower than the resistance between contacts at opposite ends of the element. Preferably one or more sections of the wall of the element are thinned or completely cut away. In the case of elements slotted at both ends, an intermediate section of the element between the inner ends of the slots is desirably pierced by a continuous spiral cut or other gap around the periphery of the element. Instead of the spiral cut, a number of longitudinal or transverse slots may be cut in the intermediate section.

The element is desirably made of graphite, although other conducting materials capable of withstanding the intended operating temperature of the furnace may be used. Generally, the element will be circular in cross-section, although this is not essential. The slots at one or both ends of the element are preferably symmetrical but they may be unsymmetrically arranged and are conveniently parallel to the axis of the element.

Aluminum, copper or other metal blocks are suitable for use as the contacts. Desirably they are cooled, as by cooling jackets through which water or another fluid is passed.

Furnaces according to the invention in which both ends of the element are slotted and the resistance from end to end is higher than the resistance across each slotted end are especially suitable for use in the hot-pressing of powders of refractory materials, such as the refractory carbides, silicides, and borides, for example titanium diboride.

It has been found, according to a further aspect of the invention, that it is advantageous when hot-pressing particulate refractory materials by means of relatively movable pressure surfaces acting upon the ends of a mass of the material which is laterally confined, as in a graphite or other heat resistant die, to apply heat at first so that only a zone of the mass between the ends is at a temperature at which bonding of individual particles occurs and then so that each longitudinal boundary of the zone moves gradually outwards to the end of the mass. The furnace herein described is particularly adapted to carrying out this process. This process enables compacts of excellent density to be obtained with relatively short pressing times.

The invention is illustrated in the accompanying drawing in which FIGURE 1 is a sectional side view of one form of furnace according to the invention and FIGURE 2 is an overall view of the furnace and diagram of a circuit suitable for operating this furnace.

Referring to FIG. 1 of the drawing, the furnace comprises an outer graphite tube 1, a tubular graphite resistance heating element 2 and contacts 3*a*, 3*b*, 3*c* and 3*d* in the form of metal blocks in electrical contact with the ends of the resistance element. At the ends of the element each limb is in contact with one of the contact blocks 3*a*, 3*b*, 3*c* and 3*d*. Water cooling rings 4*a* and 4*b* are provided for supporting the ends of the outer graphite tube. A tubular casing 5 encloses the outer graphite tube 1. The free space within the casing is packed with carbon black (not shown) for heat insulating purposes. The contact blocks (3*a*, 3*b*, 3*c* and 3*d*) are separated from the casing by an insulating washer at each end of the furnace (6*a* and 6*b*).

In FIG. 2, the wall of the heating element 2 is interrupted at each end by two diametrically opposed longitudinal slots 7 extending part way towards the inner ends of the slots running from the distant end of the element. The intermediate section of the element inwards of the slots contains a peripheral continuous spiral cut 8.

The circuit shown in FIG. 2 includes three transformers T_1, T_2 and T_3 with low-voltage secondary windings, used to supply power to the furnace. One end of the secondary winding of T_1 is connected to contact blocks 3*a* and 3*b* via a center tap on the secondary winding of transformer T_2, and the other end to the blocks 3*c* and 3*d* via a center tap on the secondary winding of transformer T_3. The ends of the secondary winding of T_2 are connected across the contact blocks 3*a* and 3*b* and the ends of the secondary winding of T_3 are connected across the contact blocks 3*c* and 3*d* at the other end of the element. The ends of the primary windings of transformers T_1, T_2 and T_3 are connected across the mains through variable transformers 9 to act as controllers. (Saturable reactors are also suitable for use as controllers.) The output voltage of T_1 is several times the separate output voltages of T_2 and T_3, and the output voltages of T_2 and T_3 are substantially equal.

The intermediate section of the element containing the spiral cut 8 has a much higher resistance than either outer section. Consequently, if at first transformer T_1 alone is used to supply power to the furance, the temperatures, attained in the center section are much higher than those attained in the outer sections. If then power is also supplied by transformers T_2 and T_3, the temperatures of outer sections rise and the boundaries of the high temperature zone in the furnace each move gradually towards

the ends. This mode of operation of the furnace is satisfactory for hot-pressing refractory particulate materials according to the procedure described above. Other variations of the temperature profile within the furnace may be achieved by appropriate switching-in, switching-out or alteration of the power input to the three sections of the furnace.

Various changes and modifications of the invention can be made and, to the extent that such variations incorporate the spirit of this invention, they are intended to be included within the scope of the appended claims.

I claim:

1. A furnace comprising an electric-resistance heating element of substantially tubular shape, the wall of said element being provided with at least two longitudinal slots in at least one end of said element extending inwardly about one-third the length of said element, the intermediate section of the wall being thinned, a non-slotted end of said element and each limb of said slotted end being provided with electrical contacts, the resistance of said element between electrical contacts on different limbs of the same end of said element being lower than the resistance between electrical contacts at opposite ends of said element.

2. The furnace according to claim **1** in which means for superimposing local heating currents on the main heating current are connected to said electrical contacts.

3. The furnace according to claim **1** in which said electric-resistance heating element is a cylindrical graphite tube.

4. A furnace comprising an electric-resistance heating element of substantially tubular shape, the wall of said element being provided with at least two longitudinal slots extending inwardly about one-third of the distance from each end of said element, each limb of said slotted ends being provided with electrical contacts, the resistance of said element between electrical contacts on different limbs of the same end of said element being lower than the resistance between contacts at opposite ends of said element.

5. The furnace according to claim **4** in which means for superimposing local heating currents on the main heating current are connected to said electrical contacts.

6. The furnace according to claim **4** in which an intermediate section of the wall of said heating element between the inner ends of said slots is thinned.

7. The furnace according to claim **4** in which an intermediate section of the element between the inner ends of said slots is pierced by a continuous spiral cut around the periphery of said element.

8. The furnace according to claim **4** in which said heating element is a cylindrical graphite tube.

9. In an electric furnace comprising an electric-resistance heating element of substantially tubular shape having at least two longitudinal slots extending inwardly from each end of said heating element, the improvement which consists of a continuous spiral cut around the periphery of said heating element in the intermediate section of said element between the inner ends of said slots, whereby the resistance from end to end of said heating element is higher than the resistance across each slotted end.

10. A furnace comprising an electric-resistance heating element of substantially tubular shape, the wall of said element being provided with at least two longitudinal slots in at least one end of said element extending inwardly about one-third of the length of said element, the intermediate section of the element having a continuous spiral cut around the periphery of said element, any non-slotted end of said element and each limb of said slotted ends being provided with electrical contacts, the resistance of said element between electrical contacts on different limbs of the same end said element being lower than the resistance between electrical contacts at opposite ends of said element.

11. The furnace according to claim **10** in which means for superimposing local heating currents on the main heating current are connected to said electrial contacts.

12. The furnace according to claim **10** in which said electric-resistance heating element is a cylindrical graphite tube.

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