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ZONE MELTING FURNACE AND METHOD OF ZONE MELTING

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Fig. 1.

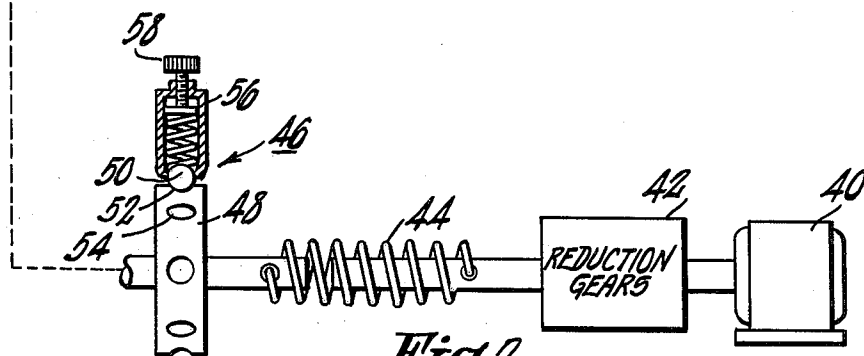
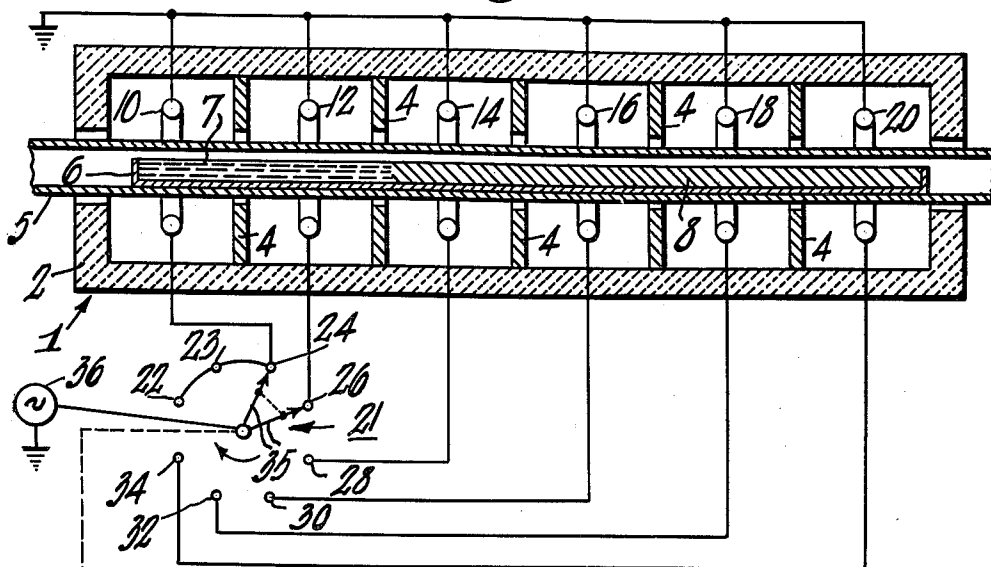
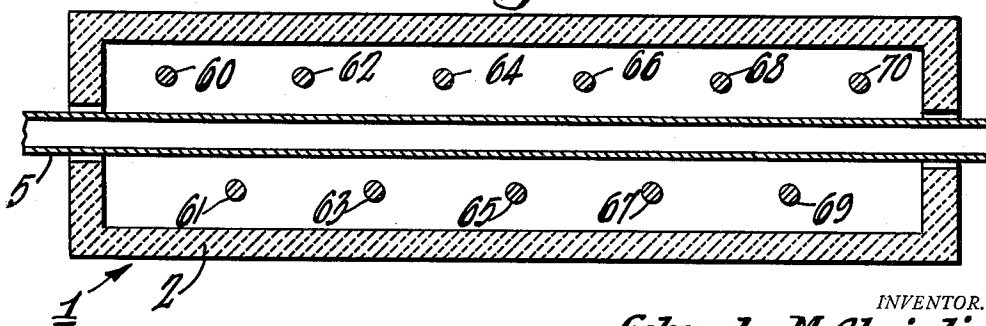


Fig. 2.



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This invention relates to an improved method for metallurgical zone-melting and to an improved apparatus for zone-melting.

The principles of zone-melting are well known. See, for example, an article entitled "Principles of Zone-Melting" by W. G. Pfann, in the Journal of Metals for July 1952, at page 747. In zone-melting a small molten zone or zones traverse a long charge of alloy or impure metal. Either purification of an impure metal or a more even solute distribution in an alloy may be accomplished by the process of zone melting.

Previous methods for accomplishing zone-melting have relied on mechanical motion of a heating element and the material being treated relative to each other. Due to the temperatures necessarily involved in a zone-melting process, mechanical movement often presents considerable difficulty. For example, it has been found that in one method including moving a heating element along a stationary chamber, the chamber sagged slightly when heated and jammed against the heating element so that it could not be removed without destroying it. Also, in another method comprising drawing an elongated crucible through a refractory tube considerable inconvenience has been caused by the breaking of a silica rod and hook used to drag the crucible through the tube.

In zone-melting according to the present invention, a molten zone is caused to pass along the length of a solid frozen charge without any mechanical movement. This is accomplished through the use of separate heating elements spaced in sequence along the length of the charge and individually controlled to produce the effect desired.

An object of the invention is to provide an improved method for zone-melting.

Another object of the invention is to provide an improved apparatus for use in the process of zone-melting.

Another object of the invention is to provide an improved zone-melting apparatus for zone-melting without mechanical movement.

Still another object of the invention is to provide an improved method for controlling a zone-melting process.

These and other objects will be more readily apparent and the invention more easily understood by reference to the following detailed description and to the drawings, of which:

Figure 1 is a partially schematic and sectional elevational view of a zone-melting apparatus in accordance with a first embodiment of the invention.

Figure 2 is a partial sectional elevational view of another apparatus illustrating a second embodiment of the invention. Similar reference characters are applied to similar elements throughout the drawings.

According to the invention the material to be subjected to zone-melting is placed in a crucible, boat or other container within an insulated furnace which may be arranged either as a straight line or in any other elongated shape. The furnace is heated by a number of elements spaced in sequence along the length of the crucible.

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These elements are individually controllable so that any part of the furnace may be heated above the melting point of the substance being treated at any time. By proper control of the heating elements either manually or automatically, a molten zone is caused to travel along the length of the charge.

Figure 1 illustrates a preferred embodiment of the invention. A furnace 1 of insulating refractory material 2 contains and supports a refractory tube 5 and a plurality of insulating refractory panels 4. The furnace is heated by carbide or other suitable electric heating elements 10, 12, 14, 16, 18, and 20. Within the refractory tube 5 is disposed a metallurgical boat, or crucible 6 containing an impure metal charge 8 of germanium. The heating elements 10, 12, 14, 16, 18 and 20 are individually connected to respective contacts 24, 26, 28, 30, 32, and 34, of a switch 21. The switch arms 35 are driven by a motor 40 through a reduction gear assembly 42, spring coupling 44, and detent 46. An electric power source 36 is connected between the switch arms 35 of the switch and the common leads of heating elements 10, 12, 14, 16, 18 and 20.

Generally in zone-melting germanium it is desirable to provide an inert atmosphere such as pure nitrogen or argon within the refractory chamber. This is not shown in the drawing since it is not essential in the production of a moving melted zone, but has to do only with preventing oxidation of the charge. Such an atmosphere may readily be provided, however, by connecting a source of inert gas to one end of the refractory tube 5 and permitting a stream of the inert gas to flow through the tube during the melting process.

In operation, after the boat 6 containing the charge 8 has been placed within tube 5, switch 21 is set at its beginning position so as to connect electrically the switch arms 35 to contacts 22 and 23, and the motor is started. It will be seen that heating element 10 is now the only heating element in operation, and remains the only heating element in operation during the time the switch remains in its initial and in its second positions. When the switch is driven to its third position, heating element 10 remains energized and heating element 12 is also energized. In the next position of the switch, heating element 10 is deenergized and heating elements 12 and 14 are energized. It will be seen thus that after an initial warm-up period restricted to heating element 10, a series of two adjacent elements is in operation at all times and that this series changes progressively as switch 21 is driven from step to step at about 10 to 15 minute intervals. This progressive action of the heating elements 10, 12, 14, 16, 18, and 20 melts a progressively moving zone 7 of the charge 8 from one end of the boat 6 to the other.

It should be noted also that the "overlap" provided between successively melted segments of the charge is essential in the practice of the invention. As may be seen by reference to the article referred to above, it is important in zone-melting to maintain a constantly melted moving zone and not to permit one segment of the charge to freeze before the next has been melted. In the practice of the invention this is accomplished by melting each segment first in conjunction with the segment immediately preceding it and next in conjunction with the segment immediately following it. There is thus provided an overlap that insures a constantly melted moving zone.

Switch contacts 22, 23, and 24 are connected together to provide an initial warm-up period required in starting a cold furnace. If a second zone is to be propagated along the length of the charge before the charge has cooled appreciably, the initial warm-up period may be shortened or omitted and the process may be repeated by

starting with the switch set at its second or its third position.

Switch 21 is driven through the spring coupling 44 and detent 46 for the purpose of providing minimum delay time between switch positions in the operation of the device. Without the spring and detent arrangement, considerable time elapses between the deenergization of one set of heating elements and the energization of the next following pair. With the detent 46, the spring 44 is wound by motor 40 through reduction gear 42 until sufficient torque is exerted upon a notched wheel 48 to dislodge the metal ball 50 from the notch 52 into which it is pressed by a spring 56 and adjusting screw 58. After the ball has been dislodged from the notch 52, the spring continues to exert sufficient torque on the wheel to cause it to rotate rapidly until the ball falls into the next succeeding notch 54, thus providing a rapid switching action.

It should be understood, however, that the invention is not limited to the particular switching arrangement described and illustrated. Other arrangements are also suitable, and may be easily devised by one skilled in the practice of electric control circuits.

When using an electric furnace, the type of electric heating element employed is not critical. For example, although carbide type heating elements have been described, nichrome elements are also satisfactory. Further, other types of furnaces may be adapted to the practice of the invention such as, for example, an induction type furnace.

It should further be understood that the invention is not limited to a furnace built in a straight line but that furnaces built in other shapes may also be used.

It should also be understood that the number of heating elements employed in the practice of the invention is limited chiefly by a practical consideration of the relative sizes of the furnace and of the heating elements selected, and not only one zone but two, three or any desired number of zones may be caused to travel the length of the charge. It is also practicable to arrange for moving melted zones of different length.

Figure 2 illustrates another of the many possible embodiments of the invention. In Figure 2 a furnace 1 of insulating refractory material 2 contains a refractory tube 5 heated by separate heating elements 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, which may be controlled in the same manner as the heating elements shown in Figure 1. In particular, the sequence of heating in the arrangement as shown in Figure 2 provides an initial warm-up period during which heating elements 60, 61, and 62 are energized, subsequent to which a progressively changing series of elements is energized in accordance with the following table:

1st step—	60—61—62
2nd step—	61—62—63
3rd step—	62—63—64
4th step—	63—64—65
5th step—	64—65—66
6th step—	65—66—67
7th step—	66—67—68
8th step—	67—68—69
9th step—	68—69—70

It will be seen that this type of arrangement even as shown without the use of insulating panels between the heating elements to confine heat to a narrow zone may be made to provide a molten zone of comparatively short length.

By techniques well known in the art it is also possible to provide for differential heating of separate segments of the moving zone. By these techniques one or more segments of the molten zone may be maintained at a lower temperature than another segment.

It should be understood that the practice of the invention is not limited to the particular modes of operation illustrated by Figures 1 and 2. It is also sometimes desirable to cause a molten zone to travel not only from one end of a charge within a furnace to the other but also back and forth along the length of the charge.

There has thus been described an improved method and apparatus for zone melting, which method and apparatus operate without any mechanical movement of the furnace, heating elements or charge relative to each other.

What is claimed is:

1. A furnace comprising a chamber, a plurality of heating elements arranged sequentially along said chamber, control means to increase and decrease the heating effect of said elements individually and means cooperative with said control means for establishing a plurality of overlapping heating zones along said chamber, said control means being operative to maintain the energization of a particular heating element during the energization of a first succeeding and adjacent heating element and to interrupt the energization of said particular heating element only after the energization of a second succeeding heating element, whereby successive portions of a charge being melted in said chamber are melted before a preceding portion is frozen.

2. A furnace according to claim 1 in which said heating elements comprise electric resistance elements.

3. The method of zone-melting a charge of material in a furnace comprising forming said charge into a volume of substantially greater length in one dimension than in its other dimensions, establishing a plurality of overlapping heating zones along said charge, successively melting and freezing the respective portions of said charge in successive zones while maintaining said charge stationary in said furnace, each successive portion being melted before the preceding portion is frozen.

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