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Nov. 22, 1966 N. F. EATON 3,287,107

ELECTRON BEAM FURNACES

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Fig. 1.

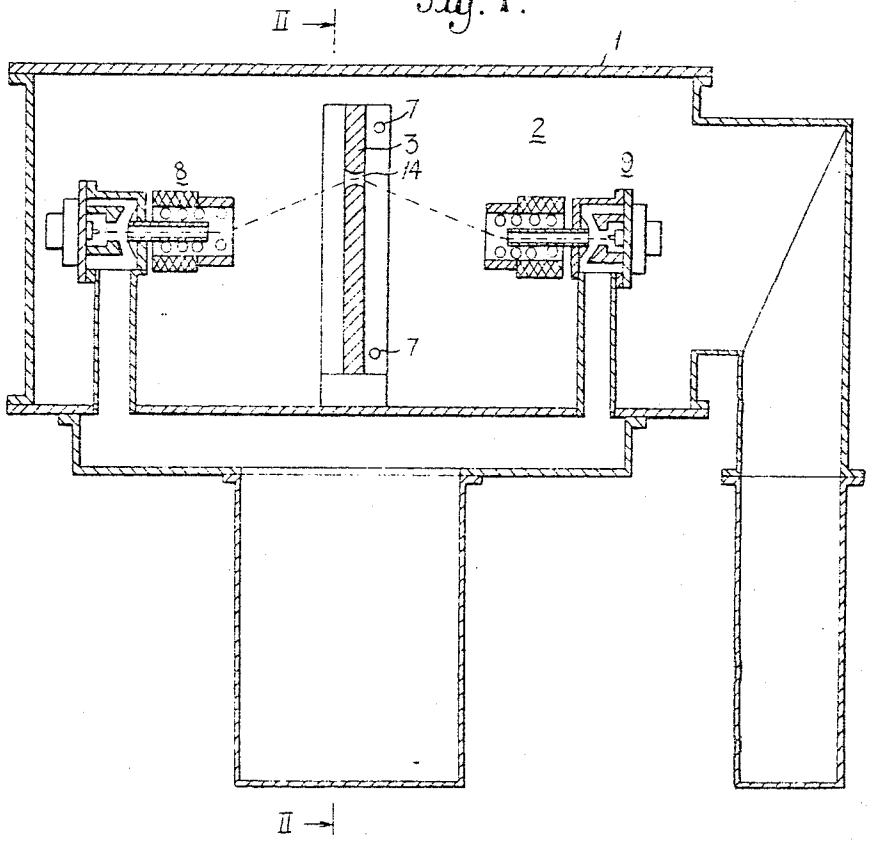
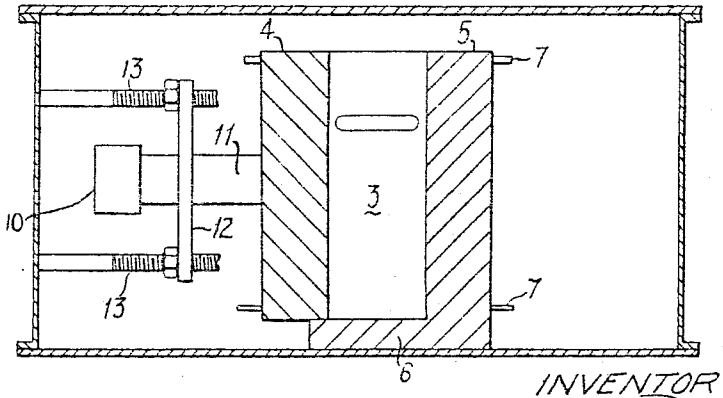


Fig. 2.



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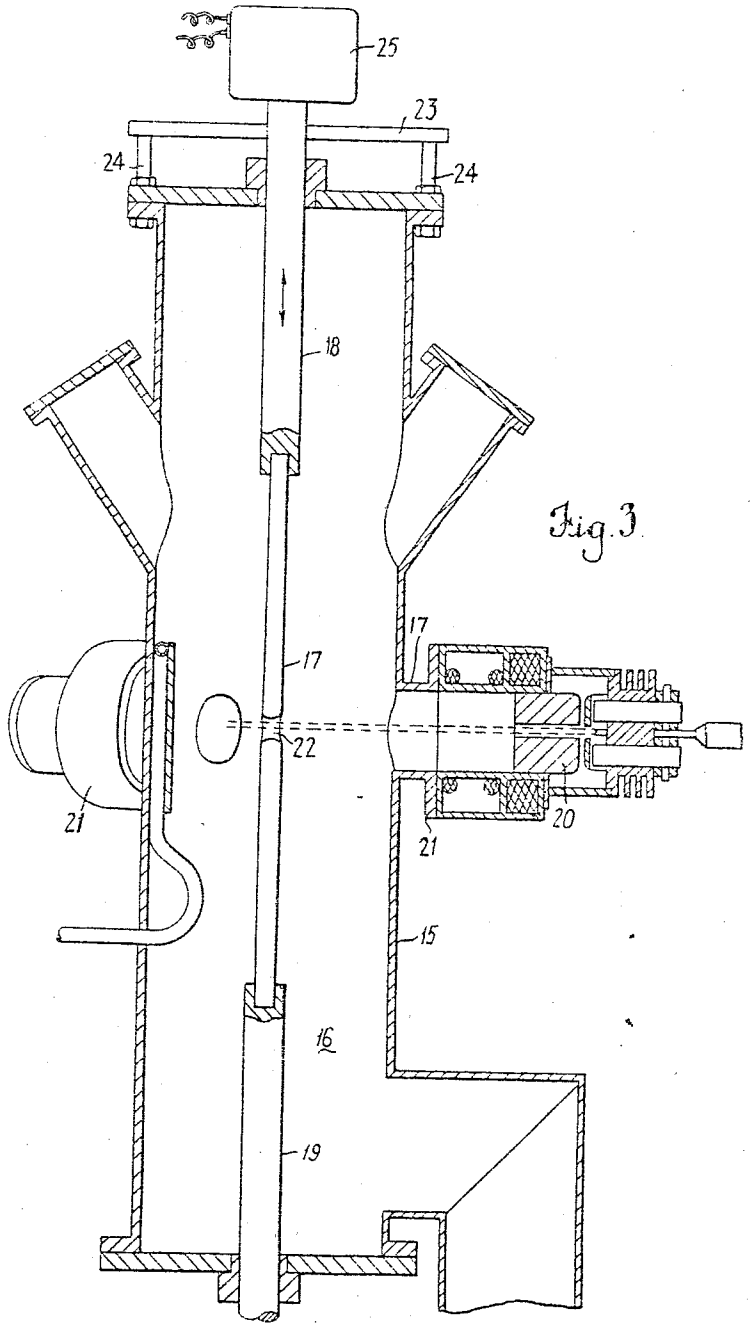


Fig. 3

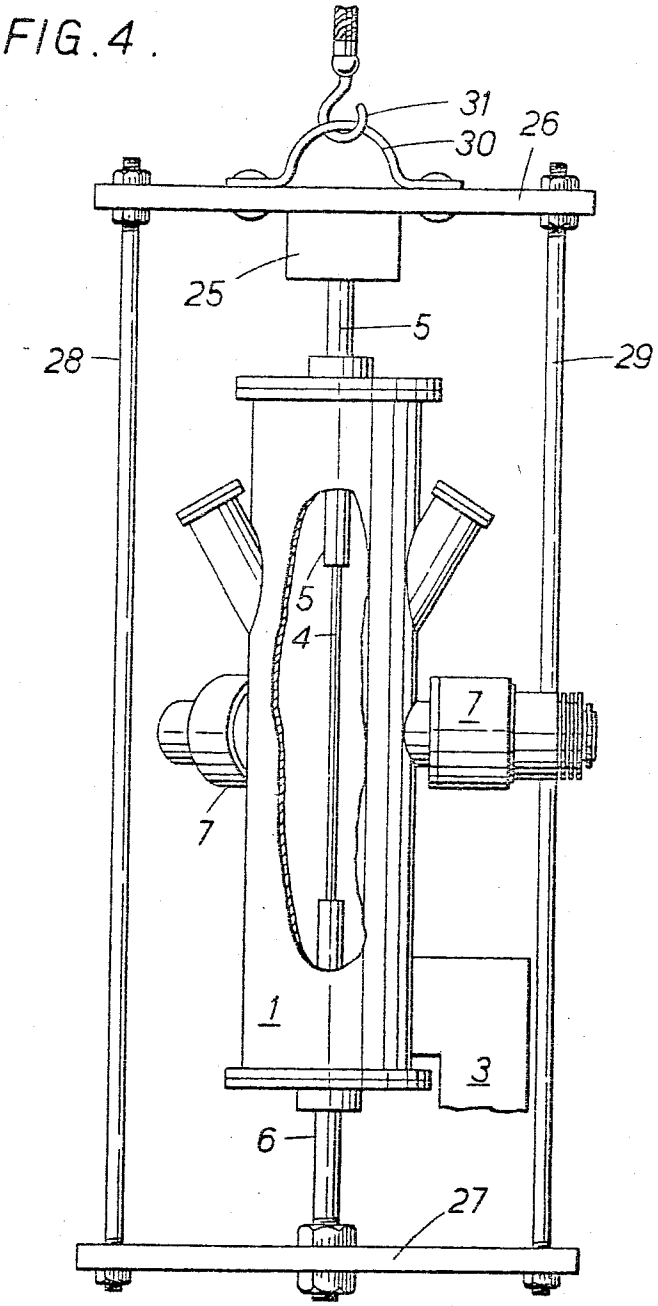
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FIG. 4.



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ELECTRON BEAM FURNACES

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Claims priority, application Great Britain, Aug. 20, 1960, 28,990/60

10 Claims. (Cl. 75—10)

This invention relates to zone melting of materials in which the molten zone traverses the length of the material vertically, as for example in zone refining and zone levelling.

The invention has an important application in zone melting by electron bombardment.

Zone refining depends upon the differing solubility of impurities in the solid and liquid phases of the material being zone refined. Thus a diffusion process occurs across between the solid/liquid phases. Under steady conditions concentration gradients are set up which minimise the rate of diffusion of impurities in the liquid phase. Attempts have been made to remove this concentration gradient by stirring mechanically, i.e., by rotating the rod. Such an arrangement is however undesirable. In zone levelling which is similar to zone refining excepting that the speed of traverse is higher so that the impurities tend to be distributed throughout the material uniformly instead of being removed from the material. However, as in zone refining, there is a liability for undesirable concentration gradients to be set up.

The present invention comprises a method of treating metals by zone melting consisting in applying mechanical vibrations to a solid material during said zone melting.

The invention also comprises apparatus for treating materials by zone melting including means for supporting a specimen in an evacuated chamber so as to extend vertically, means for directing a plurality of electron beams on to the same horizontal zone of the specimen, means for effecting relative vertical movement between the specimen and the electron beams and means for vibrating said specimen during the zone melting.

According to one form of the invention, mechanical vibrations are applied to the solid material specimen by means of an electromechanical transducer.

Arrangements embodying the invention have the advantage that the concentration gradients referred to above tend to be eliminated so that more effective refining or levelling is obtained.

Moreover the specimen may be properly supported as it is not moved but only vibrated.

The vibration may be a low frequency but preferably the vibration is an ultrasonic frequency and is produced by a suitable electromechanical transducer such as a piezo-electric crystal or a magneto-strictive device.

The invention is especially applicable to zone melting of metals but is applicable to other materials such as semiconductors.

In order that the invention may be more clearly understood reference will now be made to the accompanying drawings, in which:

FIG. 1 is a vertical sectional view showing one form of electron beam zone melting apparatus,

FIG. 2 is a section on the line II—II of FIG. 1 showing how the invention may be applied,

FIG. 3 is a vertical sectional view of another form of furnace embodying the invention, and

FIG. 4 is an external elevation of the apparatus shown in FIG. 1 showing the carrier for vertical movement.

The apparatus shown in FIGS. 1 and 2 comprises a casing 1 enclosing a melting chamber 2 in which the specimen

of material is in the form of a vertical slab 3. This is supported at its vertical edges between two support pillars 4 and 5. The support pillar 5 extends upwardly from a base member 6 and the pillar 4 is coupled to it by rods 7 which permit relative horizontal movement. The specimen slab 3 is bombarded from opposite sides by two electron guns 8 and 9 respectively, details of which are described in copending U.S. Serial No. 846,306, now Patent No. 3,034,012.

Whilst the support pillar 5 is mounted rigidly the pillar 4 is not mounted rigidly and means are provided to vibrate the pillar 4 and hence apply vibrations to the specimen 3.

In the arrangement shown in FIG. 2 an electro-mechanical transducer 10 is connected through a rod 11 to the pillar 4, the rod 11 being slidable through an apertured support 12 mounted on studs 13. The transducer 10 may for example be a piezo-electric crystal or alternatively it could be a magneto-strictive device.

FIG. 3 shows another form of electron gun melting furnace in which a vertical cylindrical casing 15 encloses a melting chamber 16 for a rod-type specimen 17 which is held between clamps 18 and 19.

The specimen is melted by three electron guns 20 mounted on ducts 21 extending radially outwards from the casing 15 and arranged at 120° intervals around the casing.

The electron beams are arranged to form a molten zone 22 on the rod 17. The zone may be caused to traverse the rod 17 either by moving the rod vertically or by deflecting the beams in unison.

For a fuller description of the furnace reference may be made to co-pending application No. 133,203, Gasson and Eaton, entitled, Electron Beam Furnaces, filed August 22, 1961.

The invention consists in mounting an electro-mechanical transducer on the holder 18 so as to vibrate the rod 17 during the melting treatment.

The holder 18 may extend through a guide 23 mounted on pillars 24 and the transducer may be constructed to have sufficient mass to provide the reaction for the vibration.

As above-mentioned an ultrasonic frequency is desirable since in such case any vibration emitter will be inaudible and will not cause annoyance. At the same time the invention is not limited to ultrasonic frequencies and lower frequencies may be employed. In the arrangement shown the beams emitted by the two guns form a melted layer indicated at 22 which is caused to traverse the height of the specimen. By applying vibrations in this manner it is possible to minimise concentration gradients of impurities in the melt.

FIG. 4, which is an elevation of the apparatus shown in FIG. 1 with the casing partly broken away, shows how the specimen is arranged for vertical movement.

The upper specimen holder 5 is secured to an upper cross bar 26 and the lower specimen holder 6 is attached to a lower cross bar 27. The cross bars 26 and 27 are coupled together by rods 28, 29 to form a composite structure.

The upper cross bar 26 has a loop 30 which is engaged by a hook 31 of hoisting mechanism by means of which the structure, and hence the specimen 4, can be raised and lowered.

It will be appreciated that the apparatus shows only two examples of the application of the invention and the invention is by no means limited to these particular types of electron beam melting apparatus.

What I claim is:

1. A method of treating solid materials by zone melting consisting in applying electron bombardment from an

electron gun means to produce a horizontal molten zone, effecting relative vertical movement between the layer of impact of the electrons and the material to cause the molten zone to move vertically to traverse the height of the material and simultaneously vibrating the material mechanically at ultra sonic frequency.

2. A method of treating solid materials by zone melting comprising the steps of positioning a specimen vertically, applying horizontal electron bombardment from a plurality of directions simultaneously by means of a plurality of electron guns spaced from the specimen and distributed equiangularly, effecting relative vertical movement between the layer of impact of the electrons and the specimen to cause the molten zone to traverse the specimen vertically and vibrating the specimen mechanically at ultra sonic frequency during the traversal of the molten zone.

3. A method of treating solid materials by zone melting comprising the steps of positioning a rod specimen vertically in an evacuated chamber, applying horizontal electron bombardment from a plurality of directions simultaneously by means of a plurality of electron guns spaced from the specimen and distributed equiangularly, effecting relative vertical movement between the layer of impact of the electrons and the specimen to cause the molten zone to traverse the specimen vertically, applying longitudinal mechanical vibrations at ultra sonic frequency to an end of the rod during the traversal of the molten zone.

4. A method of treating solid materials by zone melting comprising the steps of positioning a slab specimen vertically in an evacuated chamber, applying horizontal electron bombardment from opposite directions simultaneously by means of electron guns located respectively on opposite sides of the specimen, effecting relative vertical movement between the layer of impact of the electrons and the specimen to cause the molten zone to traverse the specimen vertically and applying mechanical vibrations at ultra sonic frequency to an edge of the specimen during the traversal of the molten zone.

5. Apparatus for treatnig solid materials by zone refining comprising means for supporting a solid specimen in an evacuated chamber so as to extend substantially vertically, means for directing at least one electron beam on to the same horizontal zone of the specimen, means for effecting relative vertical movement between the specimen and the electron beams and means for vibrating the specimen mechanically at ultra sonic frequency during the zone melting.

6. The apparatus of claim 5, wherein said electron beam directing means comprises a plurality of electron guns positioned horizontally and spaced from said specimen.

7. The combination of claim 6, wherein said horizontally positioned electron guns are spaced equiangularly around said specimen.

8. The combination of claim 5, wherein said vibrating means consists of a piezo-electric crystal transducer.

9. The combination of claim 5, wherein said vibrating means consists of a magneto-strictive transducer.

10. The combination of claim 5, wherein said supporting means consists of a reciprocable holder for said specimen and wherein said vibrating means are mechanically connected to said holder means.

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