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Andersson

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[54] **CHANNEL TYPE INDUCTION FURNACE**

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[52] **U.S. Cl.** **13/29**
[51] **Int. Cl.** **F27d 11/06,** H05b 5/12
[58] **Field of Search** 13/29, 30

[56] **References Cited**

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Primary Examiner—Roy N. Envall, Jr.

[57] **ABSTRACT**

A channel type induction furnace with a furnace body having a hearth and an inductor arranged below the hearth has melt channels opening into the hearth below the normal surface of the bath. The melt channels are vertically directed. At least two disc cores of substantially greater height than thickness are provided with their windings located substantially parallel to the plane of the channel and positioned on both sides of all the channels except the outermost one.

12 Claims, 12 Drawing Figures

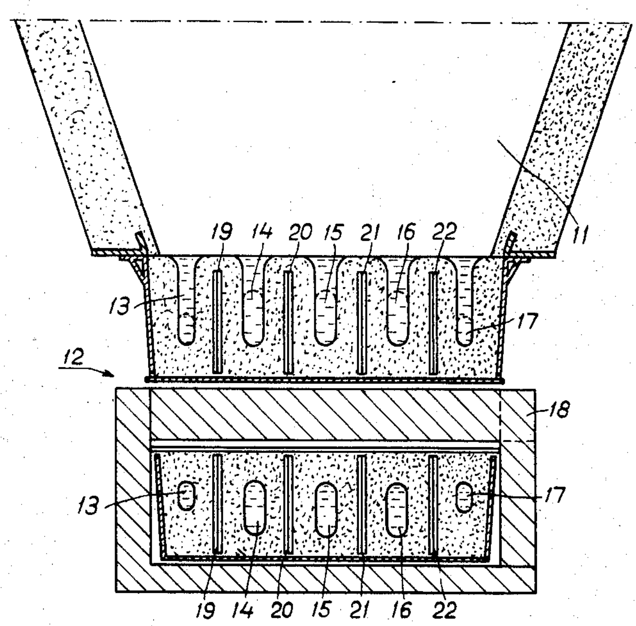

Fig.1

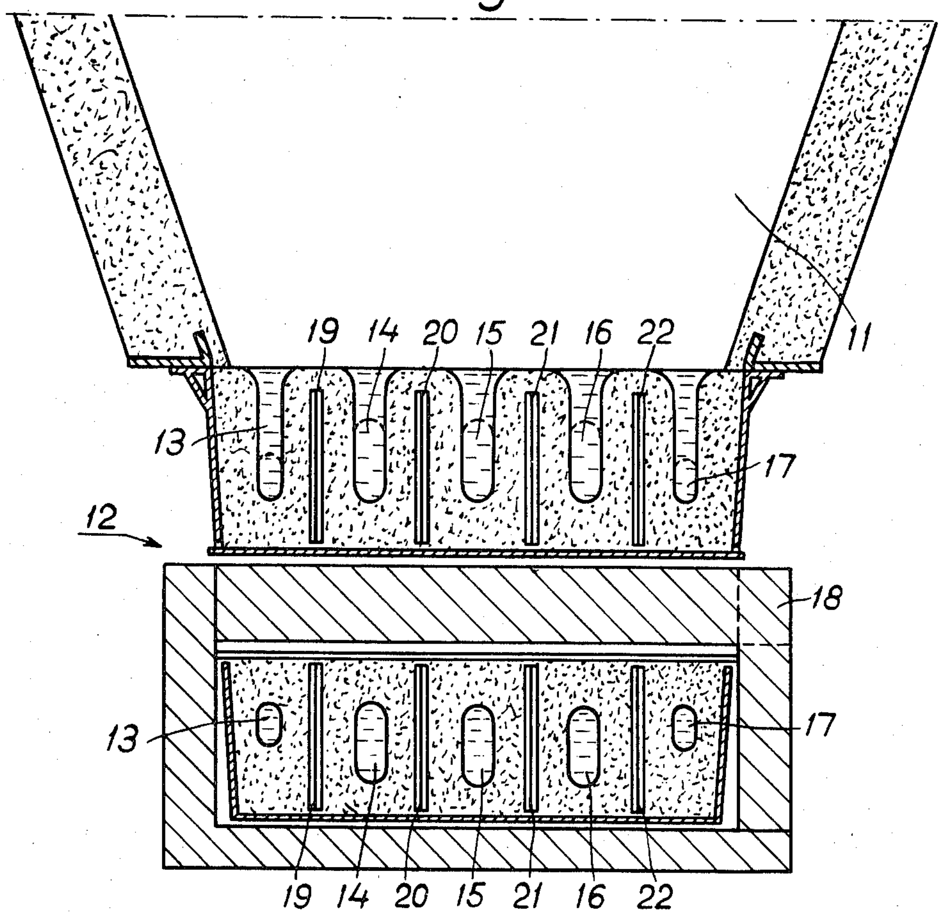
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Fig.2

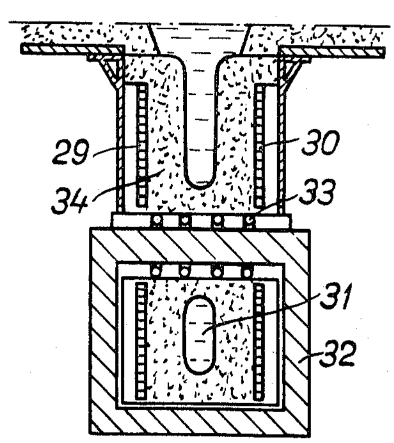
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Fig.3

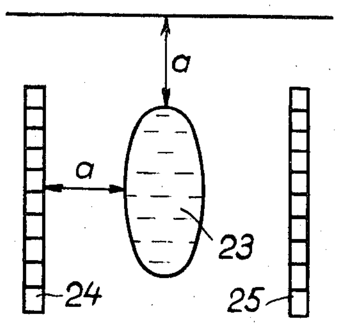


Fig.4

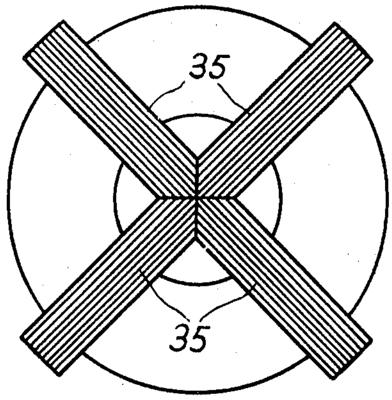


Fig.5

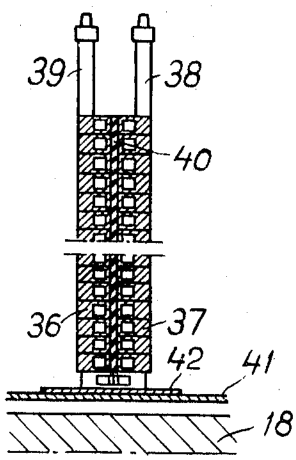


Fig.5A

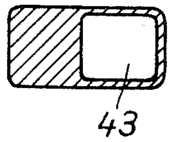


Fig.6

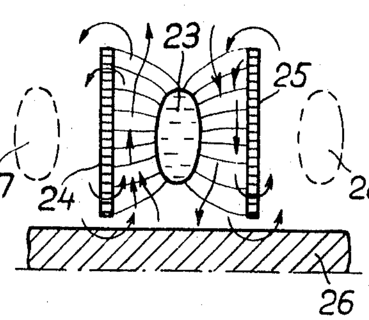


Fig.7

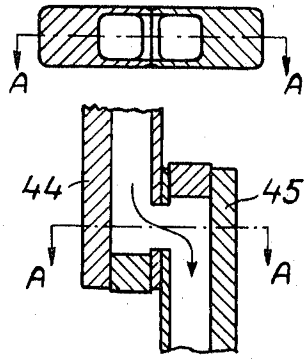


Fig. 8

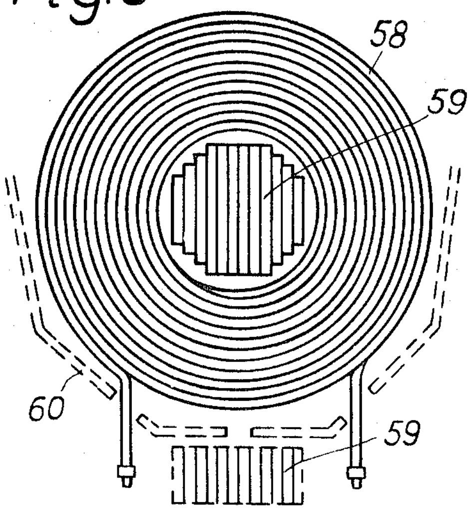


Fig. 9

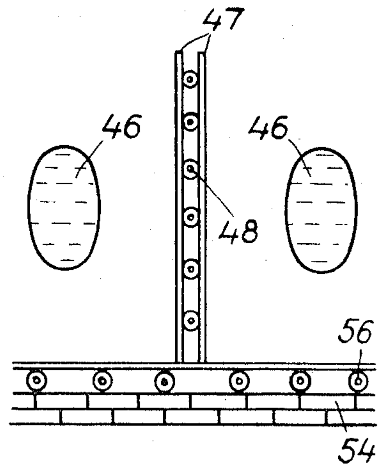


Fig. 10

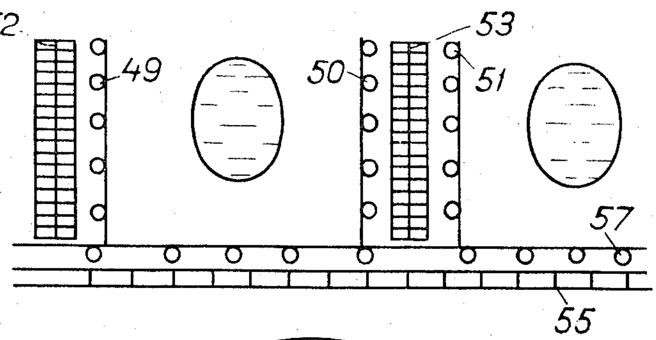
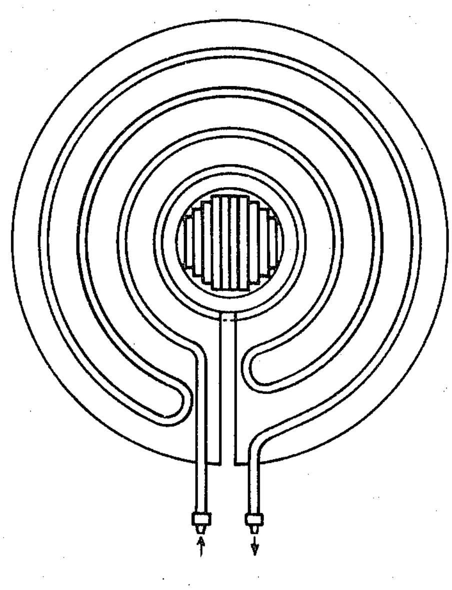


Fig. 11



CHANNEL TYPE INDUCTION FURNACE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a channel-type induction furnace having a furnace body with a hearth and at least one inductor arranged below the hearth, the inductor having one or more melt channels which open out into the hearth below the normal surface of the bath, as well as at least one primary coil.

2. The Prior Art

In such furnaces, among other things, eddy current heating should be reduced as much as possible in the structural components. Furthermore, the need for reactive power should be as small as possible, that is, the power factor should be increased. It should also be possible to supply considerable power in relation to the inductor volume and to enlarge a furnace for even greater power.

SUMMARY OF THE INVENTION

These and associated problems are solved by means of the invention which is characterised in that at least two primary coils are in the form of disc coils with their winding planes located substantially parallel to the plane of the channel(s) and positioned one on each side of at least one channel.

Such a furnace will require low reactive power, often about half that required by a conventional furnace. The leakage flux is reduced in comparison with that of a conventional furnace and better inductive connection is obtained between the coils and the channel(s). The working flow will be slight and a relatively small iron core can therefore be used. The space requirement is low and the furnace can easily be enlarged for higher power. Only conventional methods are necessary. The construction of the furnace makes replacement of the lining a relatively simple operation.

BRIEF DESCRIPTION OF THE DRAWINGS

The channel-type induction furnace according to the invention is exemplified in FIG. 1 of the drawings which shows in section a channel-type induction furnace with a multi-channel inductor. FIG. 2 shows the same type of furnace with a single-channel inductor. FIG. 3 is a diagrammatic sketch. FIG. 4 an alternative embodiment of the iron core. FIG. 5 is a two-layer coil shown in section and FIG. 5A is a conductor within this coil. FIG. 6 shows the magnetic flow in a single-channel inductor. FIG. 7A shows a conductor joint in sections on the line A—A of FIG. 7A. FIG. 7B is a section on the line B—B of FIG. 7A. FIGS. 8 and 11 show an embodiment of a disc coil and cooling lining, respectively. FIG. 9 shows cooling members in a multi-channel inductor and FIG. 10 an alternative arrangement of the cooling members.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 shows a channel-type induction furnace having a hearth **11** and one (or more) inductor(s) **12** fitted detachably (or permanently) to the hearth. By channel-type induction furnace is meant here and in the following an induction furnace having one or more primary coils, the melt in the channels acting as a secondary circuit, currents being induced in this circuit which heat the melt. The following equation applies to the power in a single-channel inductor:

$$P=\frac{U^2}{X\left[\frac{R}{X}+\frac{X}{R}\right]}$$

where U = voltage, R = resistance and X = reactance. In order to increase the power (at cos $\phi < 0.7$) there are four possibilities:

1 Increase the voltage
2 Increase the resistance
3 Decrease the reactance
4 Increase the number of channels per inductor unit.

If the voltage is increased, the leakage flux will also increase resulting in problems with eddy-current heating in structural parts. If the resistance is increased, the temperature in the channel increases and it must be noted that the temperature which the ceramic lining material will stand limits the extent to which the resistance can be increased. Lowering of the reactance can be achieved according to the invention by improving the inductive connection, reducing the distance between the channel and the coil, making the channel "flatter" (across the channel plane), and so on. The strength of the ceramic lining material, the space requirements, and other things are the factors which will set the lower limit of the reactance.

The channels **13, 14, 15, 16, 17** (FIG. **1**) are located below the normal level of the melt surface in the hearth **11** and their orifices are located at the bottom of the hearth (in FIG. **1** the channel plane is substantially vertical). Between these channels in the inductor, primary coils (**19, 20, 21, 22**) are arranged having at least one winding plane. An iron core **18** (or several) which is completely or substantially closed extends through the centre of the disc coils (**19 – 22**). The supply to the primary coils is normally single-phase but it may also be multi-phase. The frequency is normal frequency of 50–60 Hz. The coil or coils may operate with substantially the same turn voltages as in conventional channel-type induction furnaces. The iron core can be made small and the problems with eddy currents will be slight.

FIG. **3** shows a diagrammatic sketch of a channel section **23** having two disc coils **24, 25,** one on each side of the channel. This arrangement allows the channel to be narrow (in the direction of the coils **24, 25**) in relation to the height which, combined with the shape of the coil, gives good induction connection between the coil and the channel. The distance a in FIG. **3** can be made small, the "flatness" of the channel great. This increases the freedom of choice for the thickness of the lining and give greater flexibility in the choice of cross section for the channel.

FIG. **6** shows a flux diagram for a two coil furnace. A channel cross-section **23** is shown between the coils **24, 25.** The core is shown at **26.** The flux lines are shown as small arrows in FIG. **6** and it can be seen that the field strength is approximately halved in comparison with earlier, conventional constructions. Since the coil covers two sides of the channel instead of only one, the requirement of reactive power is reduced to approximately half and the power factor (cosϕ) can be increased to about **0.7**, for example. The power per channel increases while the voltage remains unchanged. Because of the location of the coils, several channels **27, 28** can be placed around the same iron core 26 (cooling between the channels can be arranged by means of cooling members and/or cooled coils, see below). As mentioned previously, the distance between the channel and the coil (lower "*a*" in FIG. 3) can be reduced because of the positioning of the coils (less risk of penetration) and possibly a cooling lining between the coil and the channel can be omitted. The reactive effect is therefore decreased, as well as the space requirement.

Cos ϕ=0.7, that is, R=X, may be selected as the optimal operating point, thus giving maximum effect at a given voltage and reactance. With cos ϕ—0.7 the inductor is affected least by the gradual wear and clogging of the channel, thus permitting longer operating time for the inductor. Since the side of the channel towards the coil can be made flat, the total flatness of the channel can also be increased without risk of melt penetration. The reactive effect will be lower.

The principle of two radial coils **29–30** (FIG. **2**) can also be applied to single-channel inductors. The channel **31** is shown here with vertically flattened section and iron core **32.** Cooling members are shown at **33** and conventional lining compound at **34.** Because of the high value of the power factor the leakage flux will be less, among other things.

The iron core **18, 32** can be divided into several parallel-connected circuits **35** (FIG. **4**), thus reducing the leakage flux and its effects.

The construction of the coil is exemplified in FIG. **5** where the disc coil has two layers **36–37** located axially adjacent each other. **38** is an inlet for current and coolant and **39** the outlet. An insulating layer **40** is arranged between the layers and cooling lining **41** and spacers **42** are arranged between the coil and the iron core **18.** The conductor section with a channel **43** for cooling water is shown in FIG. **5**A.

The two inner turns of the coil are soldered together and recessed so that current and water can pass down into one layer **44** and up into the other **45** (see FIG. **7**). The upper part of FIG. **7** is a section along the line A—A in the lower part. The coils may be combined in parallel or in series.

Cooling can be arranged in many ways. For example, cooling members with a cooling lining **47** without coils may be arranged between channels **46** in accordance with FIG. **9.** Coolant conductors are arranged between the cooling linings **47.**

FIG. **10** shows similar cooling members (cooling lining) **49, 50, 51** arranged close to coils **52, 53** between channels.

The cooling members are often constructed to extend so far that they limit individual channel planes (in the case of multi-channel furnaces).

The channel-type induction furnaces may also be provided with conventional cylindrical primary coils **54, 55** (FIGS. **9** and **10**) with or without cooling members **56, 57.**

The cooling linings **47** are made of copper sheeting, for example, with cooling loops **48** running longitudinally inside which together form the cooling members. The linings can be pinched together and removed before the inductor is dismantled. If the iron core is cooled the cooling lining may be omitted altogether.

FIG. **8** shows a coil with helically wound conductors **58,** through which a coolant flows, about an iron core **59.** Conventional lining compound is arranged around the coil and the lining.

FIG. **11** shows one embodiment of a cooling member, the intention being to increase the cooling required by the lining compound between the channels.

During casting, the coils, together with the cooling lining (if such is provided) are fixed in positioned by means of the terminal ends **38, 39.** The flat shape of the coils (one, two, or multi-layered) decreases the risk of cracks and melt penetration.

Upon dismantling, the core and cooling lining are removed first. The inductor is then turned upside down. When the lining compound falls out of the inductor, the coils fall out with it and can then easily be separated from the compound.

The cooling members are designed to prevent penetration of molten metal to adjacent coils. The iron core(s) is (are) designed to act as a support for the disc coils and other parts of the inductor.

The disc coils are designed completely or partially to support the lining of the inductor, possibly with the help of the cooling members.

In certain cases cooling members may replace coils as support members between the channels and, because of their cooling action with or without adjacent coils, the capacity of the inductor can be increased. The cooling action may also be obtained completely or partially from conductors, cooled by coolant, in the coil.

The term "disc coil" here also applies to a "part coil" in disc shape, together with other part coils forming a primary coil which may have a cross-section which is V-shaped, square U-shaped, consists of two parallel, electrically connected part coils, or the like. The main thing is that at least one part coil is substantially parallel to the plane of the channel.

"Part coil" may also refer to a primary coil constructed partially in flat disc shape, the part coil being parallel to the plane of the channel.

Normal, separate disc coils may also be included in a primary coil system with V-shaped section, U-shape (rounded or square), several in parallel, and so on.

Disc coils or part-disc coils may also be included in primary coils together with coils having a different shape.

The invention can be varied in many ways within the scope of the following claims.

I claim:

1. Channel-type induction furnace having a furnace body with hearth and at least one inductor with at least one substantially vertically extending melt channel arranged below the hearth of the furnace, the primary windings comprising at least two disc coils of substantially greater height than thickness with their windings located substantially parallel to the plane of the channel and positioned one on each side of at least one channel.

2. Channel-type induction furnace in accordance with claim **1**, in which at least one disc-wound primary coil is located between all adjacent channels.

3. Channel-type induction furnace according to claim **1,** having flat cooling members close to at least one disc coil.

4. Channel-type induction furnace according to claim **3**, in which the cooling members limit radial segments through the inductor, each segment containing at least one channel.

5. Channel-type induction furnace according to claim **3**, in which the cooling members include means to prevent molten metal from penetrating adjacent coils.

6. Channel-type induction furnace according to claim **1**, in which a flat cooling member is arranged between two channels where there is no side coil.

7. Channel-type induction furnace according to claim **1**, in which a cylindrical primary coil is arranged axially in relation to the channels.

8. Channel-type induction furnace according to claim **1**, in which at least one closed iron core extends through the centre of the disc coils.

9. Channel-type induction furnace according to claim **7**, in which the iron circuit is constituted of several branches operating in parallel for reducing leakage flux.

10. Channel-type induction furnace according to claim **1**, in which at least one of the primary coils includes hollow conductors through which coolant flows.

11. Channel-type induction furnace according to claim **1**, in which at least one of the primary coils has at least two disc-shaped conducting layers.

12. Channel-type induction furnace according to claim **1**, in which the disc coils support the lining in the inductor.

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