Candidate's examination paper
(Examination paper A/1990 Electricity/Mechanics)

Refractory Bath

The present invention relates to a refractory bath. Such baths are used typically, but not exclusively, for holding molten metal in which items to be coated are dipped. One known bath used for zinc coating consists of a general purpose furnace for melting metal, for example a refractory pot or hearth in which the solid metal is heated up from cold by a gas heater, usually mounted below the pot; once the zinc is liquid and the bath is ready for use the gas must be switched off as the coating process produces dross, oxide and other impurities which sink to the bottom of the bath. If the bath were heated during dipping these impurities would rise by convection into the dipping zone. It is therefore important to keep the bottom portion of the bath undisturbed so that impurities may settle there.

The traditional bath has the disadvantage that coating has to be interrupted at regular intervals, firstly to reheat the zinc, which of course cools with time, and secondly to allow the impurities to be removed or to resettle after the heating.

A known bath which solves these problems has previously been developed by the present applicants and is described in DI. In this bath convection channels are provided which join the hearth towards its top. When the bath is fully charged these channels are in fluid communication with the hearth. Heat is applied to the molten metal or other fluid in the channels and convection then takes place in the channels so that impurities are left largely undisturbed. An induction heater is used to heat the metal. Although overcoming many of the disadvantages of the traditional bath, there still remains a number of problems to be solved.

The Document I bath, although a major advance on the traditional bath, does have certain disadvantages in the start-up phase. The position and construction of the heater are such that it cannot easily melt solid zinc from cold; the hearth must first be charged with molten zinc, up to and including the heater channels, and even then cannot melt subsequently added solid zinc within a reasonable time because of the slow convection in the relatively long channels joining the heater with the hearth. It is therefore necessary to provide a separate furnace to melt the zinc before charging the entire bath. The channels must initially be kept free of solid zinc which could slow down convection during start-up and after use the molten zinc must be drained by means of the plugs shown in Fig 2 of Document I as otherwise restarting would be slowed by the solidified zinc. Since heated zinc is supplied by the heater to the top of the bath and there is little convection, a substantial temperature gradient exists which can adversely affect the quality of coated products.

It is an object of the present invention to provide a refractory bath which overcomes at least some of these disadvantages.

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According to the present invention there is provided ... [WORD as claim 1, without reference numerals].

The present invention by providing a bath in which the convection channels extend down from the bottom of the bath overcomes the problems associated with the bath disclosed in D I while retaining all that bath's advantages over the traditional bath. Since the channels join the hearth at the bottom of the hearth fluid communication is established without it being fully necessary to pre-charge the bath with fluid. Moreover, since the heated fluid from the channels joins the hearth at the bottom the characteristics of the temperature gradient are improved. Since the channels can be substantially vertical, less problems are encountered with blocking of the channels. The bath can be used without a separate furnace.

Preferably the bath further comprises means to control the speed of convection in the at least one convection channel.

It is found that by controlling the speed of convection in the channel it is possible to meet the otherwise conflicting requirements of keeping convection to a minimum, so that impurities are kept away from the main body of the hearth, and the need on the other hand to maximise convection to maintain an even temperature distribution.

Preferably the means to control the speed of convection comprise an electromagnetic coil extending around at least part of the at least one convection channel and arranged to generate a rotating magnetic field in a conductive fluid substance in the at least one convection channel.

Where the fluid in the channels is conductive - typically a molten metal - precise and effective control over speed can be realised using a rotating magnetic field. Preferably in this case the means to heat comprise an inductive heater and an electromagnetic coil of the inductive heater is arranged both to generate heating currents and to generate the rotating magnetic field.

Preferably the bath includes two convection channels arranged as adjacent loops having a common central arm. The use of two channels has the advantage of reducing the speed of convection for a given throughput. Where two such channels are used, preferably the means to control the speed of convection are arranged to generate fields rotating in opposite senses in the adjacent loops, such that the fluid substance flows back to the hearth via the common central arm.

Preferably the or each convection channel is flowed in the regions where it joins the hearth. The provision of flows minimises turbulence in the flow of the fluid.

Preferably the cross-section of the or each convection channel varies along its length so as to reduce the flow rate in the channels. The cross-sectioned area and/or shape may be varied as appropriate.

.../...

Preferably the or each convection channel is of substantially constant cross-sectional area along its length, is of substanti square cross-section towards its bottom and has a cross-section which uniformly diminishes in width towards the regions where it joins the hearth.

It is found that a channel which is square towards the bottom and thins towards its ends is particularly effective in both reducing flow rate and avoiding the pinch effect which otherwise tends to disrupt fluid electrodes in induction heaters when operated beyond certain powers.

Alternatively the or each convection channel may increase in cross-sectional area from one end to the other, so as to ensure unidirectional circulation in the channel.

Claims

1. A refractory bath comprising a hearth (1), arranged to hold a fluid substance for heating, at least one convection channel (2) in fluid communication with the hearth (1), and means to heat the fluid substance in the at least one convection channel (2), characterised in that the at least one convection channel (2) extends downwardly from the bottom of the hearth (1).

2. A refractory bath according to claim 1, further comprising means (10) to control the speed of convection in the at least one convection channel (2).

3. A refractory bath according to claim 2, in which the means (10) to control the speed of convection comprise an electromagnetic coil extending around at least part of the at least one convection channel (2) and arranged to generate a rotating magnetic field in a conductive fluid substance in the at least one convection channel (2).

4. A refractory bath according to claim 3, in which the means to heat comprise an inductive heater and an electromagnetic coil of the inductive heater is arranged both to generate heating currents in the fluid substance, and to generate the rotating magnetic field.

5. A refractory bath according to any one of the preceding claims, including two convection channels arranged as adjacent loops (2a, 2b) having a common central arm (2c).

6. A refractory bath according to claim 5 when dependent on claim 3 or 4, in which the means (10) to control the speed of convection are arranged to generate fields rotating in opposite senses in the adjacent loops (2a, 2b) such that the fluid substance flows back to the hearth (1) via the common central arm (2c).

7. A refractory bath according to any one of the preceding claims, in which the or each convection channel (2) is flowed in the regions where it joins the hearth (1).

.../...

8. A refractory bath according to any one of the preceding claims, in which the cross-section of the or each convecti channel (2) varies along its length so as to reduce the flo rate in the channel (2).

9. A refractory bath according to claim 8 in which the or each convection channel (2) is of substantially constant cross-sectional area along its length, is of substantially square cross-section towards its bottom, and has a cross-section which uniformly diminishes in width towards the regions where it joins the hearth (1).

10. A refractory bath according to any one of claims 1 to 7, in which the or each convection channel 2 increases in cross-sectional area from one end to the other, so as to ensure unidirectional circulation in the channel.

Note to the Examiner

I would consider filing separate applications directed to the inventions of:

(1) an induction heater including a channel of square section at its bottom (c.f. claim 9),

(2) an induction heater in which the speed of convection in a fluid electrode was controlled by a rotating magnetic field (c.f. claim 3).

Claim 1 is framed on the assumption that fluid in the channels might be heated by means other than induction heating - I would seek the client's technical input on this.