EUROPEAN QUALIFYING EXAMINATION 1990

PAPER A
ELECTRICITY / MECHANICS

This paper comprises:

INSTRUCTIONS TO CANDIDATES

You are to assume that you have received the annexed letter from your client including a description of an invention for which he wishes you to obtain an European patent together with references to the most pertinent prior art known to your client.

You should accept the facts given in the paper and base your answers upon such facts. Whether and to what extent these facts are used is your responsibility.

You should not use any special knowledge you may have of the subject-matter of the invention, but are to assume that the prior art given is in fact exhaustive.

Your task is to draft an independent claim (or claims) offering the applicant the broadest protection possible while at the same time having a good chance of succeeding before the EPO. In drafting your claim(s) you should bear in mind the need for inventive step over the prior art indicated, the requirements of the Convention as to the form of claims, other requirements of the Convention and the recommendations made in the Guidelines for Examination in the EPO. Dependent claims should be kept to a reasonable number and so drafted as to enable you to fall back upon them should the independent claim(s) fail.

You are also expected to draft an introduction, i.e. that part of the description which precedes the examples or the explanation of the drawings. The introduction should begin with an appropriate title and be sufficient to provide support for all claims. In particular, you should consider the advisability of mentioning advantages of the invention in the introduction.

You are expected to draft claims and an introduction for one European patent application only. If you find that the requirements of the Convention as to unity would in practice cause you to make any of these claims the subject of a separate patent application, you should indicate that separately without further elaboration in this respect.

In addition to your elaborated solution, you may - but this is not mandatory - give, on a separate sheet of paper, the reasons for your choice of solution, for example, why you selected a particular form of claim, a particular feature for an independent claim, a particular piece of prior art as starting point or why you rejected or preferred some piece of prior art. Any such statement should however be brief.

It is assumed that you have studied the examination paper in the language in which you have given your answer. If this is not so, please indicate on the front page of your answer in which language you have studied the examination paper. This always applies to candidates who - after having filed such a request when enrolling for the examination - give their answer in a language other than German, English or French.

Client's Letter

Your client writes:-

For many years we have manufactured zinc coating baths which are used in industry for zinc-coating items as diverse as fence posts and car bodies by dipping them in the bath.

The traditional zinc bath 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. We have in the past sold a bath which successfully overcomes this disadvantage; this known bath is shown in Document I and makes use of induction heating.

In induction heating the zinc is exposed to an intense alternating magnetic field by passing a current through an electromagnet winding surrounding a portion of the bath; this field induces circulating electrical currents in the zinc which heat it up. The electromagnet winding can be considered as the primary winding of a transformer, the molten metal constituting a short-circuited secondary winding. The "secondary winding" has a finite resistance and is heated by the current.

By means of an induction heater the metal is heated directly and its temperature can therefore accurately be controlled. Since the induction heater of Document I is mounted on the side of the hearth the impurities are largely left undisturbed.

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.

Our engineers have therefore designed a bath which makes use of induction heating, but which does not suffer from the above-mentioned disadvantages of the Document I bath.

Moreover, two mutually conflicting requirements had to be reconciled: the need on the one hand to keep convection to a minimum, so that impurities are kept away from the dipping zone, and the need on the other hand to maximise convection to ensure melting of all the zinc and maintenance of an even temperature distribution throughout the dipping zone. Thus, the convection must be kept under close control. We have found that a particularly advantageous manner of controlling the speed of convection uses a rotating magnetic field. By arranging induction heater windings to overlap in a predetermined manner, a rotating magnetic field can be generated which can regulate the speed of flow through the heater in accordance with the working parameters of the hearth. The rotating field is analogous to the field generated within an electric motor and which causes a part of the motor to rotate; the manner in which windings must be arranged in order to generate such a motor field will be well known to the skilled engineer.

In the course of working on the convection problem our engineers also found solutions to a problem which arises in induction heaters, the so-called magnetic pinch effect. Whenever current flows in a conductor, the magnetic field which is set up exerts a compressive effect on the conductor, perpendicular to the current direction; in a liquid conductor this may be great enough to cut the conductor and break the continuity of the circuit. This can be disastrous in a bath, as the result is to send a series of shock waves through the molten metal as the circuit through the metal is interrupted and the current collapses; once the current has collapsed the pinch effect ceases and the circuit is re-established so that the process repeats itself. The resultant shock waves can damage the sensitive refractory lining of the furnace and can be dangerous to the operating personnel.

The solution we have used in the past has been to limit the maximum power which is applied to the windings. However, in seeking to control convection our engineers found that the cross-sectional shape of the channel adjacent the windings has a major influence not only on convection but also on the pinch effect and that choice of a suitable cross-section enables a higher power input to the heater.

A detailed explanation of the invention can be found in the accompanying description and drawings.

In the drawings:-

Fig. 1 is a part sectional view of a first zinc coating bath according to the invention;

Fig. 2 is a part sectional view of a second zinc coating bath according to the invention;

Fig. 3 shows the use of a rotating magnetic field to control flow speed and direction in the Fig. 1 embodiment;

Fig. 4 shows the use of two magnetic fields rotating in opposite directions to control flow in the Fig. 2 embodiment; and

Fig. 5 shows in section a modification of the Fig. 1 bath, whilst Figs. 5a and 5b respectively show a section taken on the line V-V in Fig. 5 and cross-sections of the channel at differing locations.

The zinc coating bath shown in Fig. 1 comprises a cylindrical hearth 1 whose walls are made in known manner of a refractory layer of substantial thickness. The refractory layer has a flat bottom 1a to which a channel

2 with refractory walls 3 is mounted, the channel forming a loop in a vertical plane and communicating with diametrically opposite sides of the hearth bottom. The channel has a constant circular cross-section over most of its length but at its ends flares outwardly towards the hearth, the hearth and channel walls co-operating to minimise turbulence in the flow of the molten zinc. The refractory walls of the hearth and channel can be formed in known manner of, for example, refractory bricks, the rigidity of the assembly being assured by rings of concrete 5 with an additional outer metal casing 4 adjacent the channel.

An induction heater is located below the hearth. The heater includes a transformer core 6 of circular cross-section passing through the middle of the loop formed by channel 2. Transformer yokes 8,9 extend around the exterior of the channel assembly and, together with the core 6, form a closed magnetic circuit for the magnetic flux generated by induction windings 10 mounted on the core. Cooling means (not shown) surround the windings and serve to prevent the build-up of excessive heat.

The windings serve to generate an axial magnetic field which permeates the transformer core and yokes; this axial field penetrates the molten metal and in known manner induces heating currents in it. The windings also generate a rotating magnetic field which serves to regulate the circulation of the molten zinc inside the channel. Referring to Fig. 3, it will be seen that the rotating field is analogous to that of a bar magnet rotating about the axis of the core 6. This rotating field exerts a force F on the molten metal in the channel 2 analogous to that exerted on the armature of an electric motor. By controlling the speed of rotation of the rotating field the speed of the molten metal can be controlled.

The rotating and axial fields can in principle be generated by two independent sets of windings but it has been found convenient in practice to provide a single set of windings for both. In consequence, the rotating field rotates at a predetermined fixed speed which is a function of the supply frequency and the winding configuration. The manner of winding to provide a rotating field component, and the necessary control circuitry, are well known in the electrical motor art and will not be described further.

In use, the channel is charged with a sufficient quantity of molten zinc to fill it completely and power is gradually applied to the heater. The power applied in the warm-up phase is controlled to avoid the pinch effect and to prevent overheating of the zinc, which circulates poorly until the entire hearth contents are fully molten. Zinc is continuously added either in molten or powdered form until the hearth is fully charged, at which time full power can be applied. The molten zinc is thereafter maintained at a predetermined operating temperature by means of a thermostatic control loop of known kind (not shown). The rotating field ensures that the flow of zinc in the channel is unidirectional and of predetermined speed. The speed is kept sufficiently low to ensure that impurities are not carried into the dipping zone at the top of the hearth, but sink back under their own weight before reaching this zone, whilst nevertheless maintaining a constant temperature throughout the dipping zone.

In Fig. 1 the bath is provided with a single channel; however a plurality of channels with respective windings may be provided. Such an arrangement is useful in zinc coating because it has the advantage that for a given throughput of molten zinc the speed of flow and thus the convection is slower. Fig. 2 shows an example of such an arrangement, elements which have the same construction or function as in Fig. 1 bearing the same reference numerals. In this embodiment two outer channels 2a,2b are located in a common plane and share an inner channel 2c. The channels have respective cores 6 and windings 10, the cores being joined by yokes 8 to form a common magnetic circuit. The windings 10 are arranged in such a way as to generate magnetic fields rotating in opposite senses, as shown in Fig. 4, such that the molten metal enters through the outer channels 2a,2b and flows back to the hearth by way of the common inner channel 2c. The Fig. 2 bath is used in a similar manner to that of Fig. 1. Because two channels are provided the speed of flow in each channel can be reduced in comparison with the Fig. 1 embodiment, thereby reducing the danger of impurities entering the dipping zone.

It will be understood that numerous modifications of the above-described zinc coating baths are feasible. For example, considerable simplification of the induction heater windings is possible if the rotating field component is not required. Although full control of zinc flow in the channel(s) is thereby sacrificed, stability of flow both as regards speed of flow and the pinch effect can be provided by mechanical means as described below.

Figs. 5 shows a modification of the Fig. 1 arrangement in which a winding is used which does not give rise to the rotating field component. Like parts are designated by the same reference numerals as in Figs. 1 and 2. A channel is provided which has a constant cross-sectional area over its length but, as shown in Fig. 5a, has a width measured parallel to the core axis which decreases linearly from the hearth bottom to the lowest point of the channel, such that at the lowest point, see Fig. 5b, the channel cross-section is square whilst towards the hearth it is elongate. This channel has about half the cross-sectional area of that of the Fig.1 embodiment in order to reduce the flow rate; it has been found that the reduced flow rate and channel geometry serve to maintain convection at acceptable levels.

Because of the square cross-section the pinch force is strongest at the lowest point of the channel, at which point however the hydrostatic pressure exerted by the molten metal is also at a maximum. Closer to the hearth the pinch effect is reduced by reason of the elongate channel cross-section, which is balanced by the lower hydrostatic pressure. Thus, more power can be applied to the bath than if the channel were of the same cross-section throughout. The Fig. 5 channel arrangement can moreover be used with a plurality of channels, as in Fig. 2, and can be combined with the induction heater of Fig. 1, so as to provide a rotating field component, thereby enabling more power to be applied whilst maintaining flow control and avoiding the pinch effect.

In a further modification, not shown in Fig. 5, the cross-sectional area increases linearly from one channel end to the other. This ensures unidirectional circulation in the channel.

As shown in Fig. 5 a plug 25 is preferably provided at the lowest point of the channel to enable drainage of molten metal and/or impurities. By turning off the power to the induction heater at regular intervals, the impurities can be allowed to settle and be tapped off. It will be understood that in the absence of such a plug impurities will tend to collect in the channel and obstruct the flow.

Fig. 1

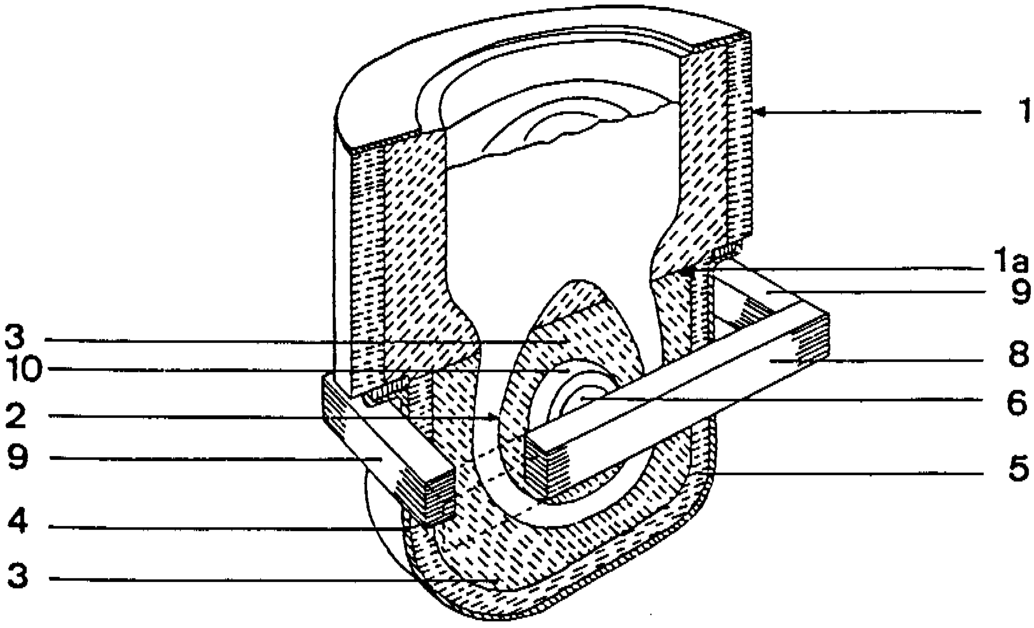


Fig. 2

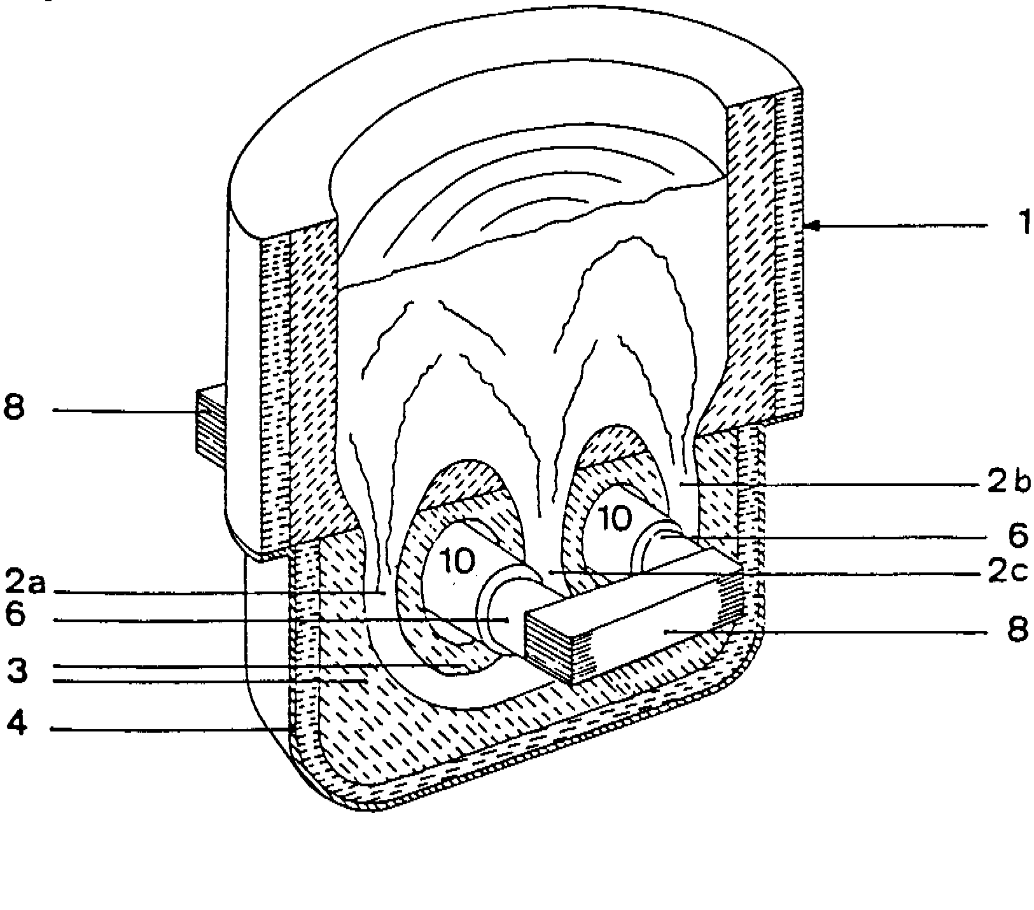


Fig.3

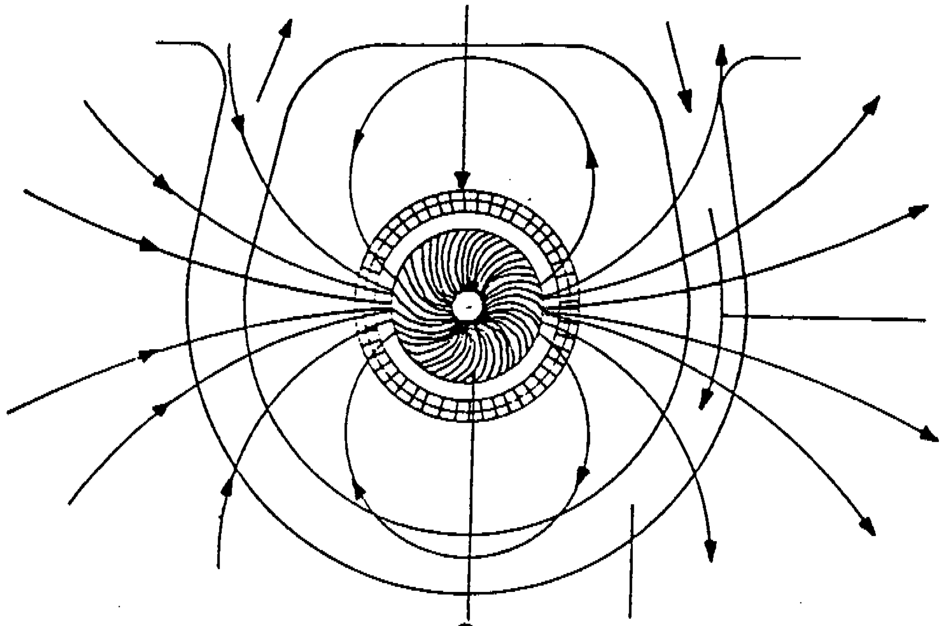


Fig.4

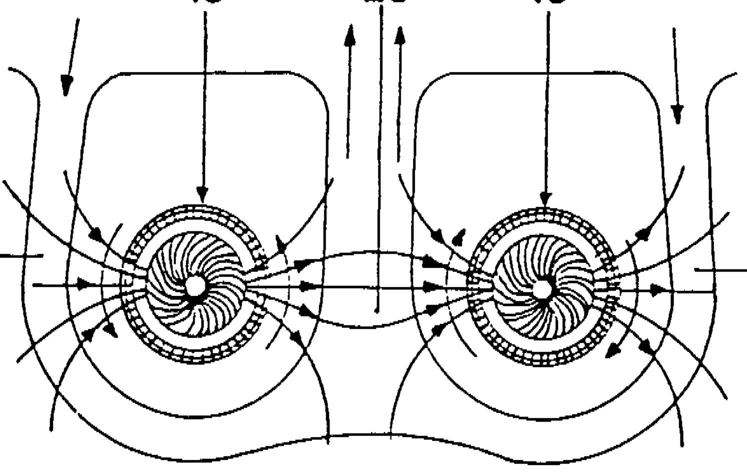


Fig. 5

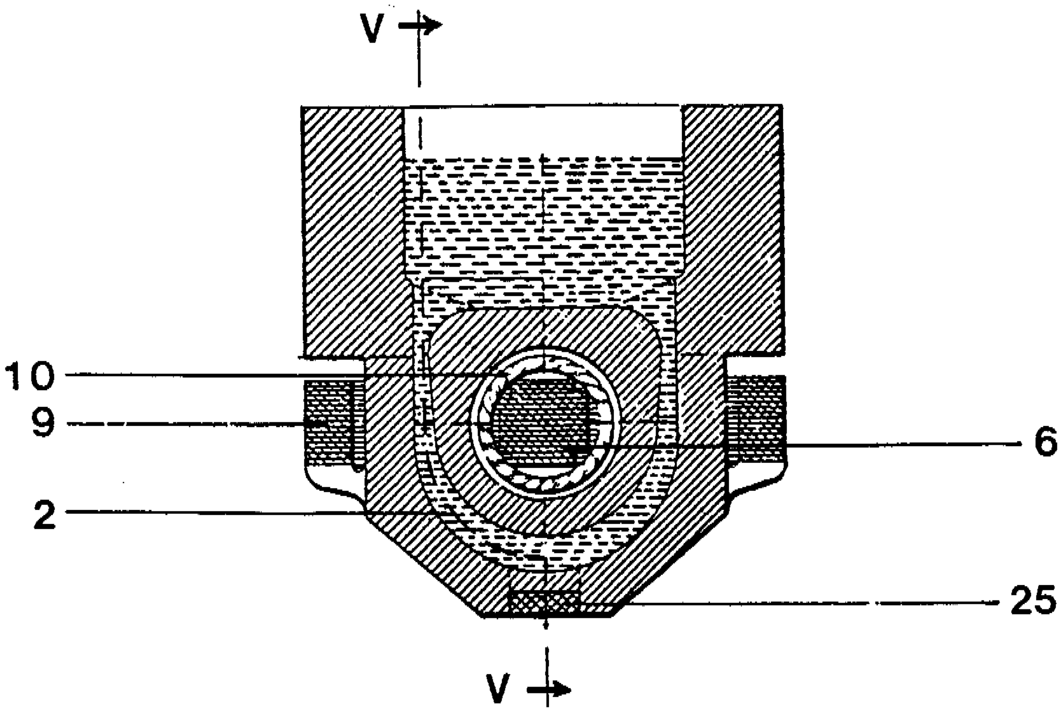
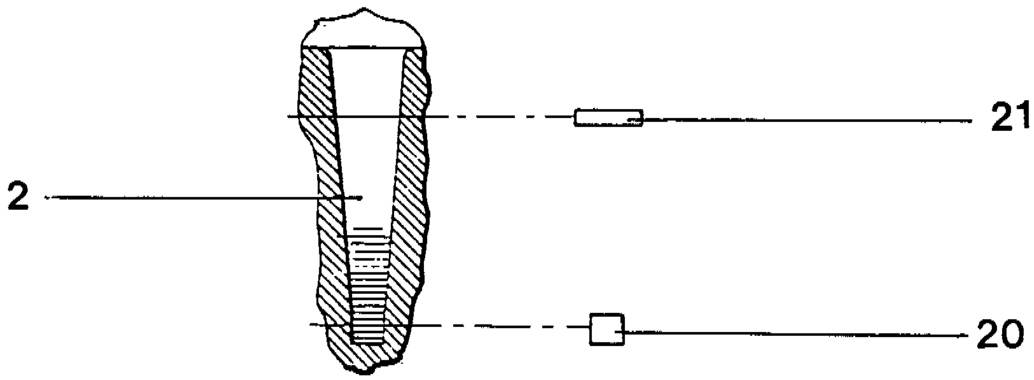


Fig.5a Fig.5b



DOCUMENT I (State of the Art)

In the drawings:-

Fig. 1 is a sectional view of a metal coating bath; and

Fig. 2 is a sectional view on line II-II of Fig. 1.

The bath 1 consists of a steel casing 2 which is provided with a refractory lining 3 enclosing the hearth 12; an inclined opening or passage 5 is provided in the side wall 7, the passage 5 flaring out into the upper portion of the bath space.

A double-coil inductor unit 11 is attached to the wall 7 in such a manner that the inclination of the melting channels 8, 9, 10 is in alignment with the wall opening or passage 5 and the metal flow only reaches the upper portion of the bath. The refractory lining 3 of the bath has an extension 6 for attachment to the inductor unit.

This replaceable inductor unit consists of a refractory block 13 which is surrounded by a steel casing 14. The unit contains two copper coils 15 on opposing sides of an iron core 16 which forms a closed magnetic path. The magnetic flux generated by the coils intersects the melting loop, which is formed of a bottom channel 21 and the three melting channels, 8, 9, 10 connecting at their lower ends with the bottom channel and at their upper ends with passage 5. Channel 21 is closed by refractory plugs 17, see Fig. 2.

The melting channels 8, 9, 10 of the inductor unit extend, as stated above, in the same inclined direction as the wall passage 5; the inclination of the channels permits convective flow of hot molten metal from the inductor unit to the hearth and return of cooler metal in the opposite direction.

The metal, for example zinc or any other metal for which the impurities settle, is constantly heated in the inductor unit and enters into the upper portion of the bath; the bottom section therefore remains undisturbed. Contamination of the metal in the upper portion of the bath is eliminated; the settling of dross, metal oxides and other impurities on the bottom of the bath is undisturbed. Because the centre axes 20 of the inclined channels extend towards the open top of the furnace and refractory plugs 17 are provided in the bottom channel 21, the melting channels of the inductor unit can be cleared of metal and can easily be reached and cleaned with cleaning tools.

In use of the bath, the lining 3 is pre-heated in a suitable manner. Molten metal is charged into the hearth 12 until the metal overflows into and fills the melting loop of the inductor unit; the current is gradually switched on until full power is reached and the hearth is filled to the level 18. The metal is continuously heated in the melting loop, from where it circulates into the upper working zone of the bath. Fresh metal may be charged into the hearth 12 as required. The articles to be coated are introduced from above in the usual manner.

The inductor unit 11 is detachable and can be easily replaced, if necessary. Since the furnace can be operated within an exactly controlled narrow temperature range wear is greatly reduced.

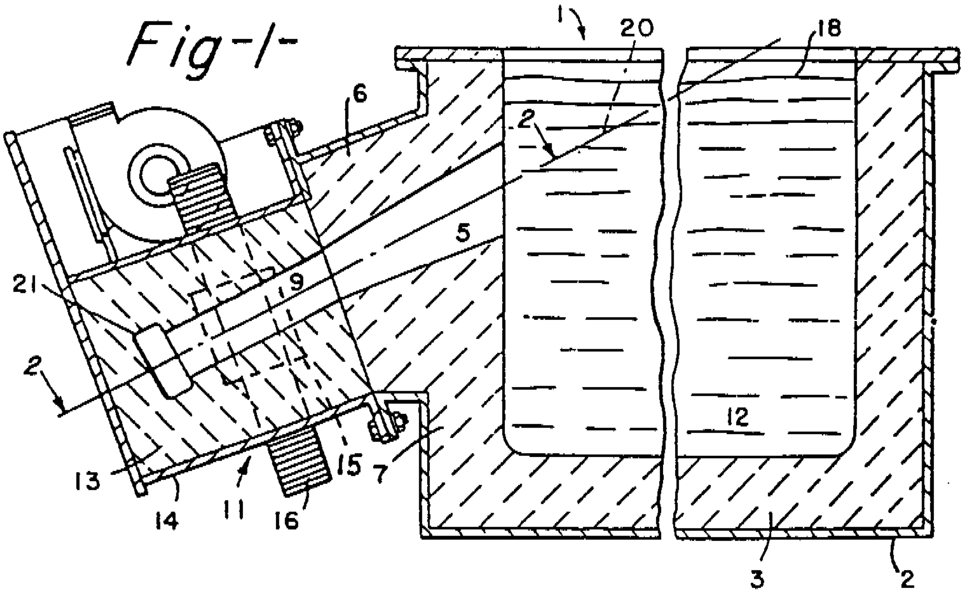

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Fig-1-

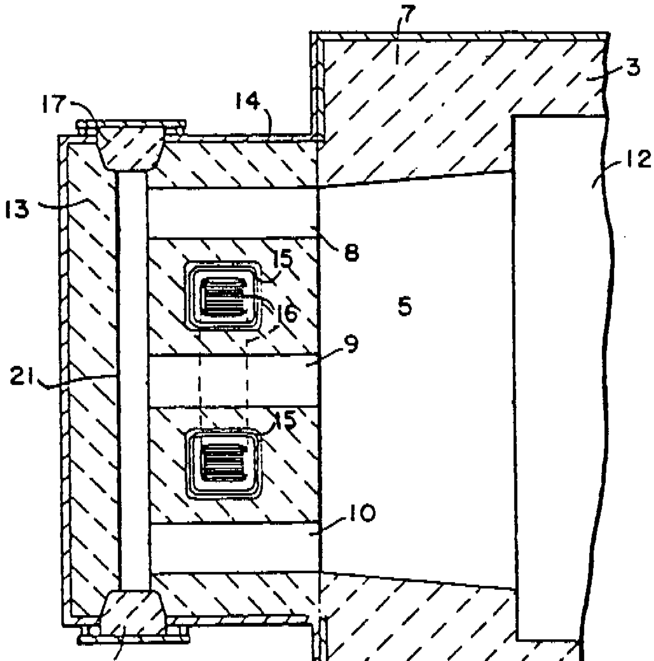
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Fig-2-