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Eickelberg

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[54] **METHOD FOR POURING LIQUID METAL USING ELECTROMAGNETIC PUMP**

[75] Inventor: **Henry L. Eickelberg,** Port Washington, Wis.

[73] Assignee: **Modern Equipment Company,** Port Washington, Wis.

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[52] **U.S. Cl.** **222/1,** 222/383, 417/50

[51] **Int. Cl.** **B22d 37/00**

[58] **Field of Search** ... 222/1, 383, DIG. 2, DIG. 12, 222/DIG. 15; 164/337; 417/50

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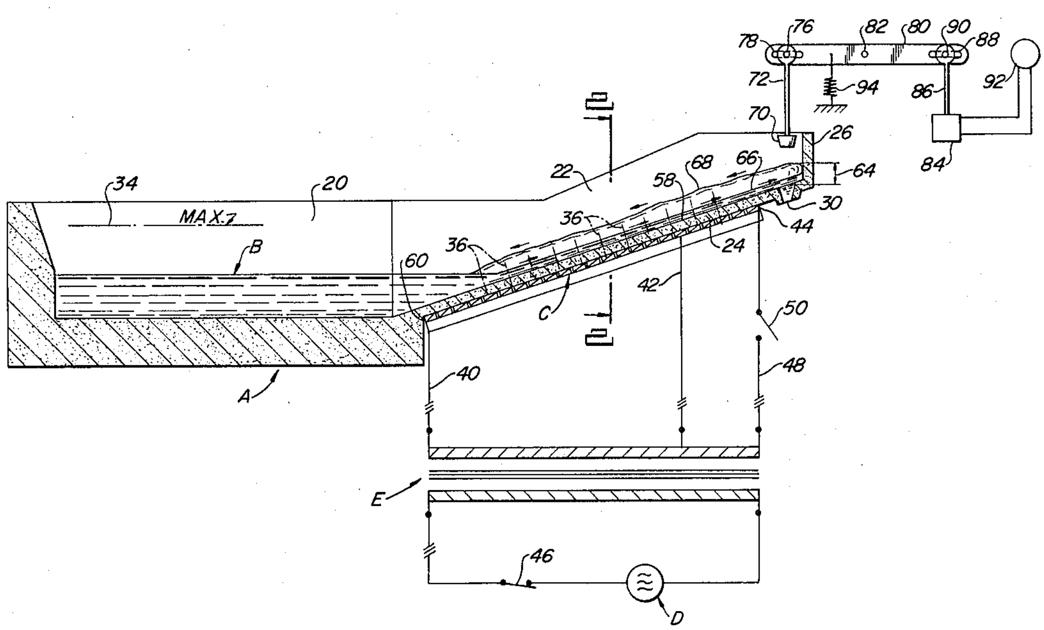
Primary Examiner—Robert B. Reeves
Assistant Examiner—David A. Scherbel
Attorney, Agent, or Firm—Meyer, Tilberry & Body

[57] **ABSTRACT**

Molten metal is poured from a receptacle through a discharge orifice at a substantially constant predetermined discharge rate. Metal is transferred from the receptacle to the orifice at a rate in excess of the predetermined discharge rate to completely cover the orifice with a predetermined head of liquid metal. Metal transferred to the orifice from the receptacle in excess of the predetermined discharge rate is returned to the receptacle so that the predetermined head is maintained substantially constant.

5 Claims, 4 Drawing Figures



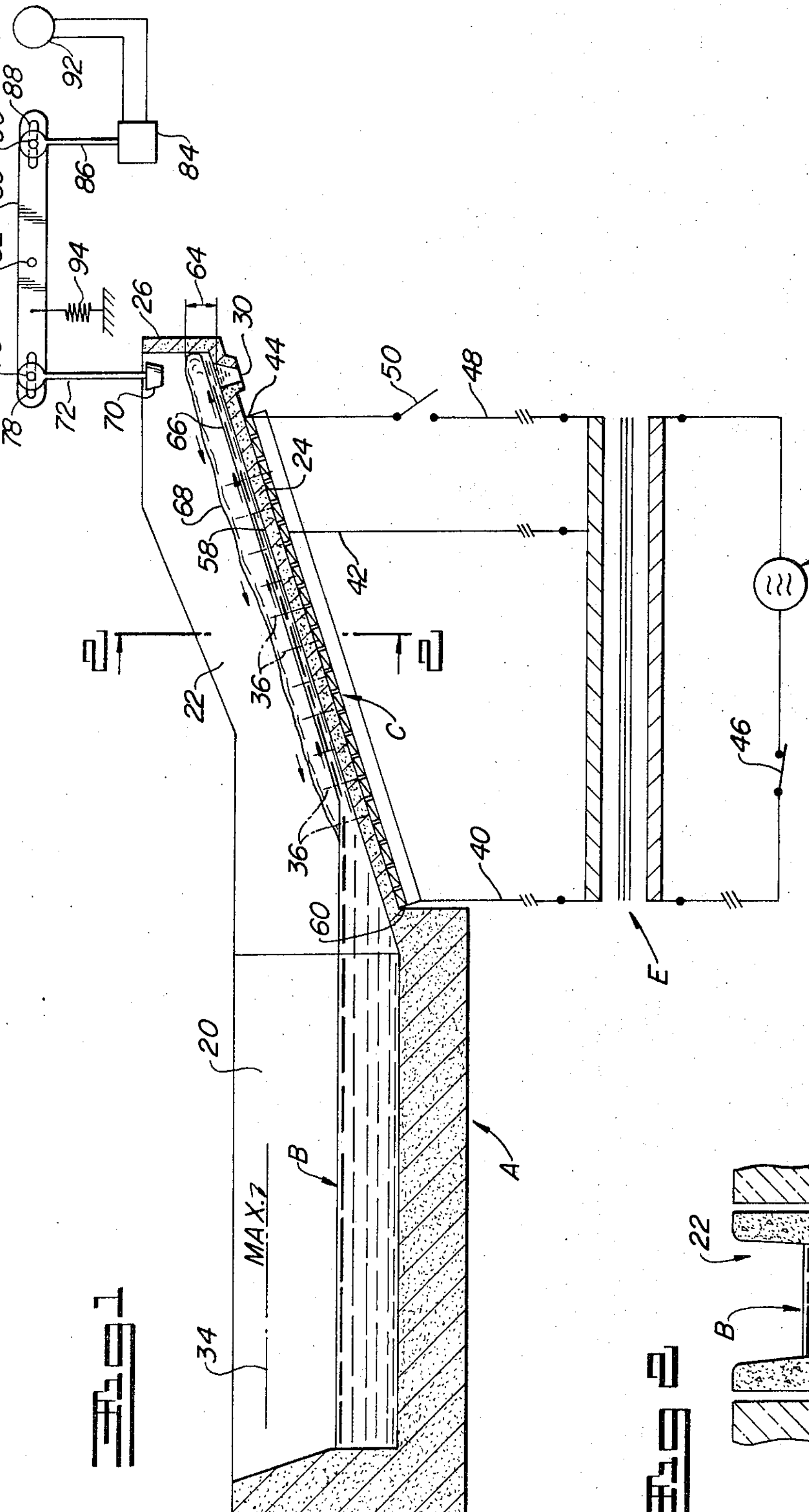

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Fig. 1

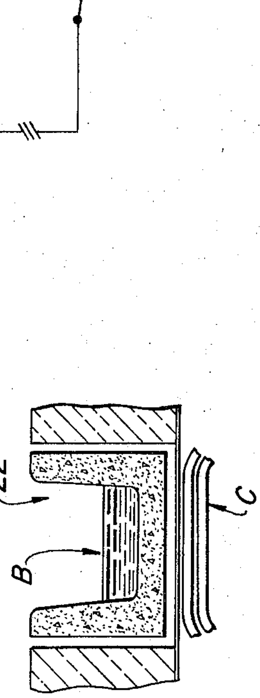
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Fig. 2

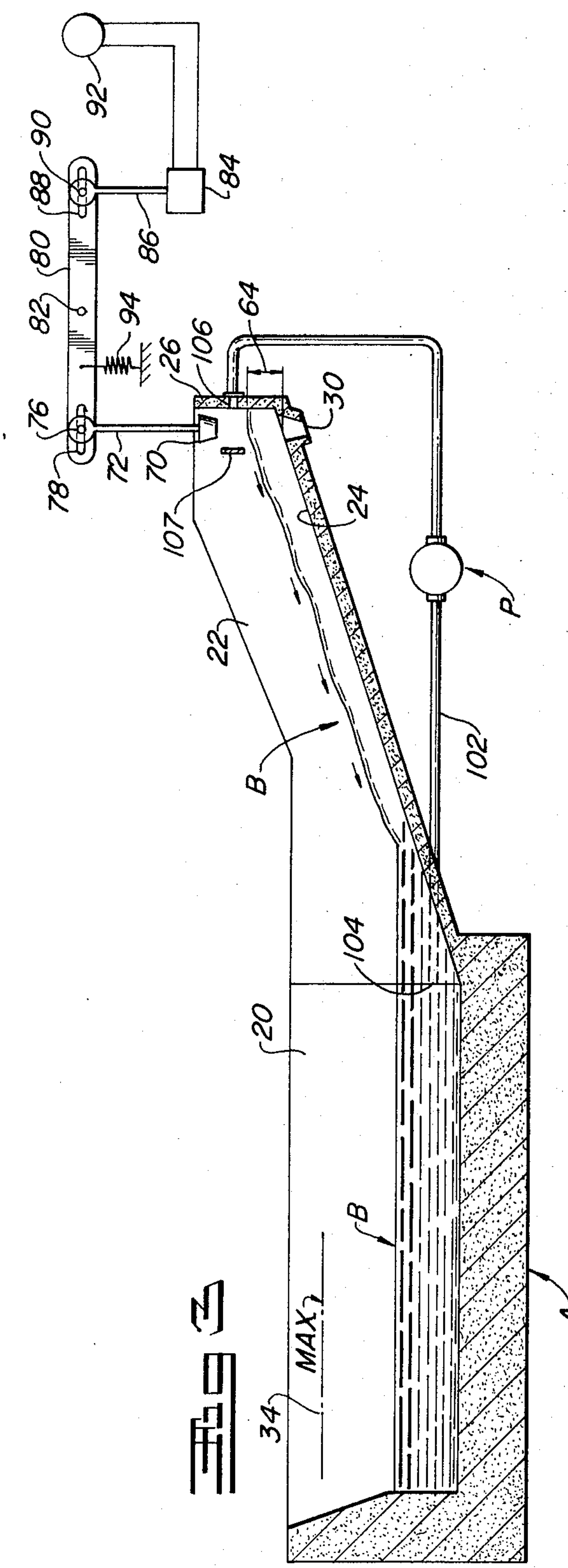
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FIG. 3

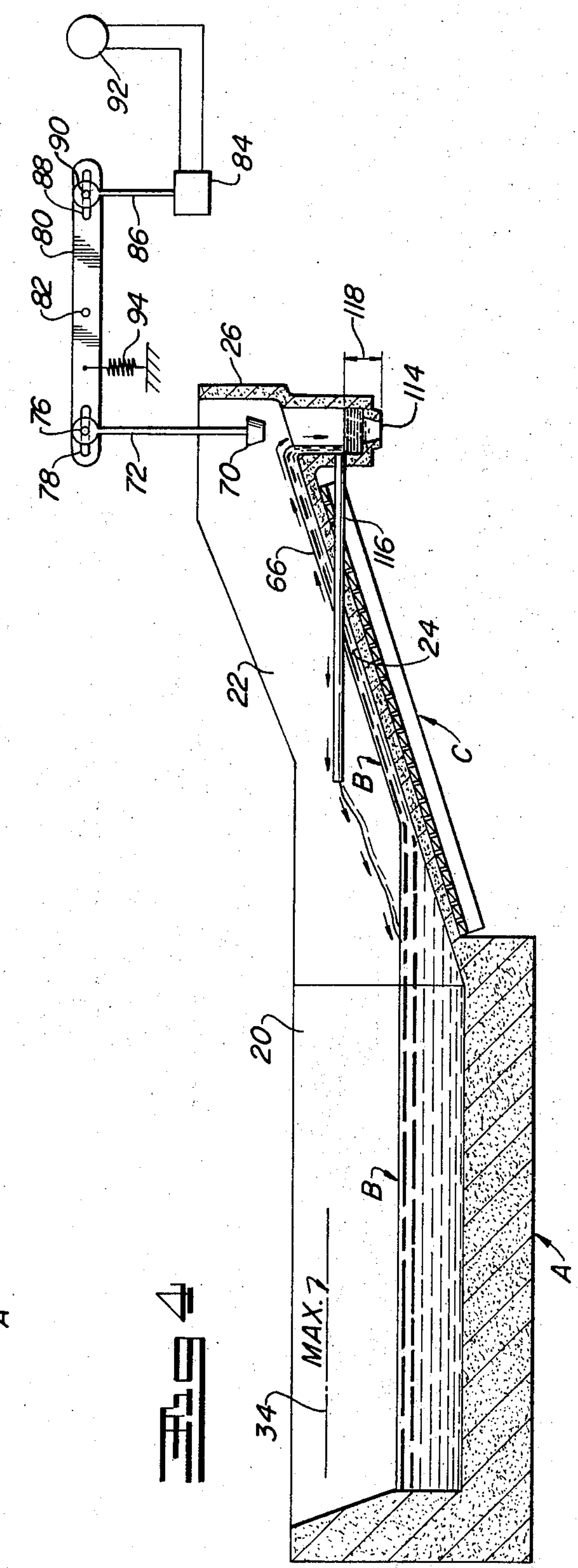
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FIG. 4

METHOD FOR POURING LIQUID METAL USING ELECTROMAGNETIC PUMP

BACKGROUND OF THE INVENTION

This application relates to the art of pouring liquid metal, and more particularly to pouring molten metal from a receptacle through an orifice. The invention is particularly applicable to an apparatus wherein an electromagnetic induction field is used to move the metal and will be described with particular reference thereto. However, it will be appreciated that the invention may be carried out with other transfer means for transferring metal from the receptacle to the orifice.

There are many known arrangements for attempting to successively transfer substantially equal volumes of molten metal from a receptacle to successive molds. One known arrangement for accomplishing this includes a pressurized receptacle. The pressure in the receptacle is successively raised and lowered in order to successively pour substantially equal volumes of metal. Variations in the amount of metal in the receptacle, and small variations in pressure, make it very difficult to successively pour substantially equal volumes of metal with great accuracy.

Other arrangements include a mechanical pump driven by an electric motor. With certain molten metals at high temperatures, mechanical pumps rapidly deteriorate. Fluctuations in voltage applied to the driving motor cause the pump to operate at varying speeds so that it is difficult to make successive pours of equal volume with great accuracy.

Other known arrangements for pouring molten metal include a receptacle having an upwardly inclined discharge passage. An electromagnetic induction field is used for moving the metal up the discharge passage. Known apparatus of this type is disclosed in U.S. Pat. Nos. 3,515,898 issued June 2, 1970; 3,534,886 issued Oct. 20, 1970; and 3,554,670 issued Jan. 12, 1971. In apparatus of this type, the upwardly inclined discharge passage terminates at a discharge weir. There are many different formulae for determining the rate of flow over a weir. In general, a somewhat different formula is used for each different shape of weir. Regardless of the shape of the weir, the rate of flow over a weir is proportional to the metal depth over the lip or crest of the weir raised to a power greater than one. Therefore, a small change in the depth of liquid flowing over the weir greatly changes the flow rate.

In electromagnetic apparatus of the type described, it is extremely difficult to adjust the electromagnetic induction field for moving metal from the receptacle up the discharge passage at such a rate that the depth of metal over the weir will remain substantially constant. In practice, variations in the depth of metal flowing over the weir will vary and this greatly changes the flow rate. In apparatus of the type described, it is desirable to discharge metal at a substantially constant rate for a predetermined period of time so that equal volumes of metal may be discharged into a mold or the like in successive pours. Small variations in the depth of metal flowing over the weir causes a major change in the flow rate due to the fact that the flow rate is proportional to the metal depth raised to a power greater than one. This makes it practically inpossible to make successive accurate pours of predetermined volumes of metal over substantially equal periods of time.

SUMMARY OF THE INVENTION

Metal is poured from a receptacle through a discharge orifice at a substantially constant predetermined discharge rate. Metal is transferred from the receptacle at a rate in excess of the predetermined discharge rate in order to completely cover the orifice with a predetermined head of liquid metal. Flow of metal through the orifice at the predetermined discharge rate is then proportional to the predetermined head of liquid metal. Metal transferred from the receptacle to the orifice in excess of the predetermined discharge rate is returned to the receptacle so that the predetermined head is maintained substantially constant.

The improved apparatus and method of the present invention may be used with a mechanical pump or with pressure to define the transfer means for transferring the metal from the receptacle to the discharge orifice.

In accordance with a preferred arrangement, apparatus of the type described has an upwardly inclined discharge passage which terminates at a discharge orifice instead of a weir. Flow through an orifice is proportional to the square root of liquid depth over the orifice. Therefofore, small variations in the depth of metal over the orifice vary the flow rate in a more insignificant manner proportional to the square root of the variation in depth.

In accordance with the preferred arrangement, the electromagnetic induction field is operated to move metal from the receptacle up the discharge passage at a sufficient rate for completely covering the discharge orifice with a predetermined head of liquid metal. This predetermined head is maintained substantially constant so that metal flows through the orifice at a substantially constant predetermined rate.

In the preferred arrangement, the induction field is operated to move metal up the discharge passage at a rate in excess of that required to maintain metal flowing through the orifice at the desired predetermined rate. Metal in the discharge passage then includes a lower level moving upward under influence of the induction field and an upper level moving downward under influence of gravity. The predetermined head over the discharge orifice is then maintained by having excess metal moved up the discharge passsage under influence of the induction field flow back down in an upper level under influence of gravity.

In accordance with another aspect of the device, the induction field is alternately energized and deenergized at predetermined intervals of time for successively discharging substantially equal predetermined quantities of metal through the discharge orifice.

In accordance with another aspect of the device, the discharge orifice is provided with a selectively openable and closable stopper. Selectively opening and closing the stopper at predetermined intervals of time successively discharges substantially equal predetermined quantities of metal through the discharge orifice. The induction field may then be maintained in operation at all times.

It is a principle object of the present invention to provide an improved apparatus and method for pouring liquid metal.

It is another object of the present invention to pour molten metal at a substantially constant rate through a discharge orifice by transferring metal to the orifice at a rate in excess of the discharge rate so that a substantially constant head is maintained over the orifice and excess metal is returned to a receptacle.

It is also an object of the present invention to provide an improved apparatus and method for pouring liquid metal at substantially constant rate while using an electro-magnetic induction field to move the metal.

It is an additional object of the present invention to provide an improved apparatus and method for pouring liquid metal by using an electromagnetic induction field, and without requiring accurate energization of the induction field to pour metal at a constant rate.

It is a further object of the present invention to provide an apparatus and method for pouring liquid metal in a more accurate manner than was heretofore possible.

BRIEF DESCRIPTION OF THE DRAWING

The invention may take form in certain parts and arrangements of parts, a preferred embodiment of which will be described in detail in this specification and illustrated in the accompanying drawing which forms a part hereof;

FIG. 1 is a side, elevational cross-sectional view showing the metal pouring appparatus having the improvement of the present invention incorporated therein;

FIG. 2 is a cross-sectional elevational view looking generally in the direction of arrows 2—2 of FIG. 1;

FIG. 3 is a view similar to FIG. 1 showing an alternative arrangement; and

FIG. 4 is a view similar to FIGS. 1 and 3 showing another alternative arrangement.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawing, wherein the showings are for purposes of illustrating a preferred embodiment of the invention only and not for purposes of limiting same, there is shown a receptacle A in which liquid or molten metal B is contained. Receptacle A may be heated in a known manner for maintaining metal B in a liquid or molten state. A removable cover may be provided for receptacle A if so desired to minimize heat losses from metal B due to radiation.

Receptacle A includes an outlet **20** communicating with an upwardly inclined channel or discharge passage **22** having an upwardly inclined bottom wall **24**. Discharge passage **22** is closed at its outer end by wall **26**. Bottom wall **24** of discharge passage **22** terminates at a vertical discharge orifice **30** having a substantially circular cross-sectional configuration. It will be recognized that a discharge orifice having other cross-sectional shapes may also be used, and it will be further recognized that orifice **30** could extend horizontally through end wall **26** adjacent bottom wall **24. 68**

In one arrangement, an electromagnetic inductor C, which is shown only schematically, is positioned directly beneath bottom wall **24** of discharge passage **22.** The necessary voltage to energize inductor C may be produced by generator D which is connected with inductor C through transformer E. Although generator D and transformer E are illustrated only schematically for simplicity, it will be recognized that these are three-phase devices.

In the arrangement shown, receptacle A contains molten metal B having its upper surface at a level somewhat higher than the bottom portion of outlet **20.** However, it will be recognized that receptacle A is capable of holding sufficient molten metal to bring the surface level up to a higher point such as represented by a maximum level line **34.**

It will be reocgnized that inductor C may take many forms. In one arrangement, inductor C may comprise a three-phase winding having a plurality of pole spans or polar divisions represented by shadow lines **36.** The lower end of inductor C is connected with transformer E by a line **40.** Another line **42** connects transformer E with a pole span of inductor C short of outer end **44** of inductor C. Therefore, the main portion of inductor C between lines **40** and **42** is energized when main switch **46** to generator D is closed. It will be recognized that the electrical connections illustrated are only schematic for simplicity of illustration and that connections from the source of energy to the three-phase winding would actually be made every **120** electrical degrees of winding spacing.

The remaining portion of inductor C, extending between line **42** and terminal end **44,** is connected with transformer E through line **48** which includes normally open switch **50.** It will be recognized that line **42** is connected with transformer E at a point which energizes inductor C at a lower energy level between lines **40** and **42** as compared to full energization of inductor C when switch **50** is closed.

In operation of the device, the electromagnetic induction field produced by energization of the main portion of inductor C between lines **40** and **42** is sufficient to raise metal from receptacle A only to around point **58** which is above maximum metal level **34** in receptacle A. When it is desired to pour a predetermined quantity of metal into a container or mold, switch **50** is closed. This energizes entire inductor C from its inner end **60** to its outer end **44** through lines **40** and **48** at a higher energy level than that provided to that portion of inductor C connected with lines **40** and **42.** Metal then rapidly moves up bottom wall **24** of discharge passage **22** and covers outlet nozzle **30** with a predetermined head **64** of molten metal. Metal will then be discharged through orifice **30** at a predetermined substantially constant rate proportional to head **64.** Inductor C is energized at an energization level in excess of that required to maintain a predetermined constant flow through orifice **30.** Therefore, a metal in discharge passage **22** during a pouring operation includes a lower level **66** moving upward of bottom wall **24** under the influence of the induction field and an upper level **68** moving downward on the lower level under influence of gravity. With this arrangement, fluctuations in the strength of the induction field will have little effect on the rate at which metal is discharged through orifice **30.**

In one arrangement, for a passageway **22** having a rectangular cross-section and a width of 3 1/4 inches, inductor C has been energized for transferring metal from receptacle A to orifice **30** at a rate of 8 ½ pounds per second. This maintains a head **64** of 5 inches, and metal flows through orifice **30** at a rate of 2.2 pounds per second. With passageway **22** inclined upwardly at **18** degrees, metal flows back into receptacle A in an upper layer at a rate of 6.3 pounds per second. In this example, circular orifice **30** has a diameter of 3/4 inch.

Variations in the rate at which metal is pumped up discharge passage **22** by inductor C will not vary head **64** significantly. For example, energization of inductor C to move metal upward at a slightly greater or lesser rate than in the example given will simply cause metal in upper layer **68** to flow back down under influence of gravity at a greater or lesser rate without significantly changing head **64.** In addition, small changes in head **64** produce very small variations in the flow rate through orifice **30** because the flow rate is porportional only to the square root of depth **64.** After a predetermined period of time, a predetermined volume of metal will have been discharged through orifice **30** because it is flowing therethrough at a substantially constant rate. Switch **50** may then be opened. All metal in discharge passage **22** between points **44** and **58** will then rapidly flow back down into receptacle A under influence of gravity, and upper level **68** will also flow back down into receptacle A. Metal flow will then take place only between points **40** and **42.** It will be recognized that the arrangement described provides for alternate energization and deenergization of the induction field at predetermined intervals of time for successively discharging substantially equal predetermined quantities of metal through orifice **30.**

In accordance with another arrangement, a stopper **70** may be provided for selectively opening and closing discharge orifice **30.** Stopper **70** may be connected with a reciprocating rod **72.** Rod **72** has a pin **76** extending through a slot **78** in rod **80** which is pivoted at **82.** A solenoid **84** has a rod **86** connected with another slot **88** in rod **80** by pin **90.** Solenoid **84** may be connected with a timer **92.** A spring **94** may be provided for normally biasing rod **80** in a counterclockwise direction about pin **82** for normally placing stopper **70** in orifice **30** to stop flow of metal therethrough. Energization of solenoid **84** at predetermined intervals of time by timer **92** may move solenoid rod **86** downward to pivot rod **80** clockwise about pin **82** for raising stoppers **70** out of orifice **30** to permit flow of metal therethrough. With this arrangement, entire inductor C from outer end **44** to inner end **60** may be constantly energized at its high energization level for providing excess metal flow to maintain predetermined head **64** over orifice **30.** Selective opening and closing of stopper **70** by timer **92** at predetermined intervals of time will permit successive accurate pours of predetermined volumes of metal.

In a preferred arrangement, discharge passage **22** is somewhat channel-shaped and bottom wall **24** has a substantial width. Slight variations in the rate at which metal is moved up passage **22** by inductor C will then produce very insignificant changes in head **64** because the substantial width of upper level **68** will allow slightly greater or lesser flow with minor fluctuations in head **64.**

Instead of having excess metal returned in an upper level in the discharge passageway, it will be recognized that it is possible to have a separate return passage or return means to the receptacle for the excess metal. Excess metal would then overflow into the separate return passage when the predetermined head is reached. One arrangement for doing this is shown in FIG. **3.** An outlet conduit **102** has an inlet **104** communicating with receptacle A and an outlet **106** discharging through end wall **26** against baffle **107** above orifice **30** and above normal head **64** which is being maintained. A carbide pump P in conduit **102** is driven by an electric motor for transferring metal from receptacle A to discharge orifice **30** at a rate in excess of that required to maintain the predetermined discharge rate. The desired head **64** will then be developed and maintained while excess metal simply flows down passageway **22.** It will be recognized that it is possible to use this arrangement with the previously described stopper so that pump P is constantly delivering metal. However, it will be recognized that this arrangement may be used without a stopper and that the motor driving pump P may be successively energized and de-energized while making successive pours of substantially equal volume. It will be recognized that the apparatus of the arrangement in FIG. **3** is the same as that described with reference to FIG. **1** except for replacement of inductor C by pump P.

In accordance with another arrangement, as shown in FIG. **4,** the terminal end portion of discharge passage **22** may be provided with a downwardly extending box-like portion **112** having a discharge orifice **114.** A return passageway or conduit **116** may then be connected with box-like member **112** at any desirable level **118** above orifice **114.** Return passageway or conduit **116** may then be connected through a sidewall of passageway **22** or directly with receptacle A. Metal transferred to box member **112** either by induction, mechanical pumping or gas pressure then simply returns to receptacle A through return passageway **116** while desirable head **118** is maintained substantially constant. The connection between box member **112** and return passageway **118** may also include an adjustable gate for regulating return flow to adjust predetermined head **118.** This arrangement may also be used with the stopper previously described.

Instead of a mechanical pump P for conduit **102** of FIG. **3** it will be recognized that it is also possible to surround conduit **102** with an induction coil so that electromagnetic force is still used for supplying metal to discharge orifice **30.** It will be recognized that it is also possible to use gas pressure for forcing metal from receptacle A to discharge orifice **30** if excess metal is returned to a separate non-pressurized vessel. Arrangements including more than one receptacle, with one being provided for pouring and the other for return metal are also possible. Arrangements wherein discharge orifice **30** is completely separate from receptacle A are also possible.

Although the invention has been described with reference to a preferred embodiment, it is obvious that equivalent alterations and modifications will occur to others skilled in the art upon the reading and understanding of this specification. The present invention includes all such equivalent alterations and modifications and is limited only by the scope of the claims.

Having thus described my invention, I claim:

1. A method of pouring liquid metal from a receptacle through a discharge orifice, comprising the steps of; transferring metal from said receptacle to said orifice to completely cover said orifice with a substantially predetermined head of liquid metal so that liquid metal flows through said orifice at a substantially constant predetermined rate proportional to said head, continuing to transfer metal from said receptacle to said orifice at a rate in excess of that required to maintain metal flowing through said orifice at said predetermined rate, and returning excess metal to said receptacle at a rate substantially equal to the transfer rate less the predetermined discharge rate, said predetermined head being maintained by returning to the receptacle metal transferred to the orifice in excess of the predetermined discharge rate.

2. The method of claim **1** wherein said orifice includes selectively openable and closable stopper means for selectively opening and closing said orifice to flow of metal therethrough, and further including the step of opening and closing said stopper means at predetermined intervals of time for successively discharging substantially equal predetermined quantities of metal through said orifice.

3. A method of pouring liquid metal from a receptacle having an upwardly inclined discharge passage terminating at a discharge orifice, comprising the steps of:

moving metal from said receptacle upwardly through said discharge passage with an electromagnetic induction field at a sufficient rate to completely cover said discharge orifice with a substantially predetermined head of liquid metal, and maintaining said substantially predetermined head so that metal flows through said orifice at a substantially constant predetermined rate, said step of moving metal from said receptacle upwardly through said discharge passage being carried out at a rate in excess of that required to maintain metal flowing through said orifice at said predetermined rate so that metal in said discharge passage includes a lower level moving upwardly under influence of said induction field and an upper level moving downwardly under influence of gravity, said substantially predetermined head being maintained by having excess metal moved up said passage flow back down in said upper level under influence of gravity.

4. The method of claim **3**, and further including the step of alternately energizing and de-energizing said induction field at predetermined intervals of time for successively discharging substantially equal predetermined quantities of metal through said discharge orifice.

5. The method of claim **3**, wherein said discharge orifice includes selectively openable and closable stopper means for selectively opening and closing said orifice to flow of metal therethrough, and further including the step of opening and closing said stopper means at predetermined intervals of time for successively discharging substantially equal predetermined quantities of metal through said discharge orifice.

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