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(54) Title: VERTICAL CONTINUOUS CASTING TECHNIQUES

(57) Abstract: A method and apparatus for vertically upward continuous casting for production of continuous strips of metal is disclosed wherein a molten metal is made to rise vertically upwards through a die surrounded by a cooling means. The metal strip is made to pass through a further cooling means and is withdrawn by means of draw rollers. The metal strip formed is oxygen free and has high conductivity.

## **VERTICAL CONTINUOUS CASTING TECHNIQUES**

### **FIELD OF THE INVENTION**

This invention relates to vertical continuous casting techniques. In particular, this invention relates to a method of vertically upward continuous casting of a strip.

### **BACKGROUND OF THE INVENTION**

The term casting generally refers to individual articles or components made by the solidification of hot liquid metal in a die or a mould. The process for making such components is generally referred to as casting process. The casting process is carried out by allowing hot liquid material to enter into a mould or die in order to obtain solidified individual components by cooling. Casting is used for making complex shapes that would be otherwise difficult or uneconomical to manufacture by other methods or for manufacturing single components.

There are various methods by which individual components can be made by the casting process. The various methods of casting include sand casting, investment casting, high pressure die casting, low pressure die casting and the like.

Sand casting is carried out by applying sand mixed with binders and water around wood or metal pattern having two parts to produce a sand mould.

The mould is removed from the wood or metal pattern and metal is poured into the mould through cavities. After cooling, moulds are broken to remove the castings.

Investment casting is carried out by injecting wax into a metal mould to make patterns, which are connected to a common sprue. The patterns are repeatedly dipped in ceramic slurry and dried which is followed by heating to remove the wax to form ceramic shells. The ceramic shells are heated and filled with molten metal. The ceramic shell containing the molten metal is cooled to solidify the molten metal to form casting.

Low pressure die casting is a method of casting wherein a die or mould is mounted above a sealed furnace containing a molten metal. A riser tube connects the bottom of the die to the molten metal furnace. The furnace containing the molten metal is pressurized (typically 20-100kPa), and the metal is forced up into the mould. When the molten metal solidifies in the die, the pressure is released and the molten metal falls back into the furnace. The casting is then taken out of the die for further processing.

High pressure die casting is a method wherein molten metal is poured into the mould or die through a shroud on the top of the mould or die. When the molten metal solidifies in the die the casting is then taken out of the die for further processing.

However, the methods of casting discussed above are not suitable for casting of continuous lengths of metals and hence different methods have to be used for manufacturing continuous lengths of metal having different cross-

sections. Thus, when continuous lengths of metal are required to be cast, a process of continuous casting is implemented.

Continuous Casting is a process whereby molten metal passing through a die is solidified to form various cast sections of substantial lengths. The process of continuous casting is initiated by causing the molten metal to enter into a die containing a starter device. The molten metal is allowed to attach to the starter device to initiate the casting of continuous lengths of metal. The continuous casting process is carried out either vertically or horizontally.

In the horizontal continuous casting process, the liquid metal is made to continuously enter into a cooled mould or die which is placed such that the molten metal enters the die or mould in the horizontal direction from an inlet pipe. The liquid metal is made to solidify in the mould and is continuously withdrawn in a horizontal direction from the mould or die in order to form a continuous length of metal casting.

In the vertical continuous casting process, the liquid metal is made to continuously enter into a cooled mould or die which is placed such that the molten metal enters the die or mould, either in the vertically upward direction or the vertically downward direction, from an inlet pipe. The liquid metal is made to solidify in the mould and is continuously withdrawn from the mould or die in order to form a continuous length of metal casting.

The process of continuous casting allows lower-cost production of metal sections having better quality, allows manufacturing of continuous lengths of metals and provides increased control over the process through

automation. The continuous casting processes described above is suitable for manufacturing wires, rods, blooms, billet and slabs.

However, the methods of continuous casting mentioned above are not suitable for manufacturing continuous strips of metal. The continuous strips of metal are used for making car bodies, airplane wings, medical tables, roofs for building, transformers etc. The continuous strips of metal are at present produced typically by hot drawing which is an expensive process and cannot be used to produce oxygen free strips. Therefore, there is a need for a process for making a continuously cast strips of metal and metal alloy.

Several attempts have been made for providing process and apparatus for continuous castings of metal strips and bands.

For instance, US Patent 3872913 discloses the continuous method for upward casting of metal wherein the melt is continuously drawn upwards from a supply of the melt by suction through a vertical graphite nozzle the upper portion of which is cooled to solidify the melt enough in the nozzle to endure pulling the solidified product upwards through a cooler having a cross-section which is somewhat greater than that of the product. Attached to a support above the melt supply there is a support for a vertical cooler having three pipes defining a tortuous flow passage there between the ends of which are provided with an inlet and an outlet for passing e.g. cooling water through the passage. The innermost tube of the cooler through which the product is pulled is of somewhat greater diameter than the product and has an opening at the upper part thereof to create suction inside the apparatus. Coaxially attached to and partially surrounded by the lower part

of the cooler there is a graphite nozzle the lower end of which is immersed in the melt supply. One disadvantage of the US Patent 3872913 arises due to the use of vacuum chamber used to cause the necessary suction to raise the molten metal through the die. The installation of such vacuum chamber increases the cost of production. Another disadvantage of US Patent 3872913 is that for proper casting, it is necessary to continuously maintain and supervise the vacuum pressure in the vacuum chamber. Still another disadvantage of the US Patent 3872913 is that it is not suitable for casting of strips.

Again, US Patent 4688625 discloses a method of vertical continuous casting. A continuous casting furnace for manufacturing an elongated cast product, for example, of copper or its alloy includes a housing defining a chamber. A crucible is accommodated within the chamber for holding a casting material. A heater is mounted on the crucible for melting the casting material. A generally vertically-disposed elongated casting nozzle hermetically extends into the chamber. One of the casting nozzle and the crucible is movable toward the other for immersing a lower end of the casting nozzle in the molten casting material in the crucible. The housing is connected to an inert gas source for introducing inert gas into the chamber when the casting material in the crucible is melted. When the lower end of the casting nozzle is immersed in the molten casting material, the molten casting material is moved along the casting nozzle by the pressure of the inert gas in the chamber. A cooling device is associated with the casting nozzle for solidifying the molten casting material when it is passed through the casting nozzle, thereby forming the elongated cast product. A major drawback of the process of vertically upward casting process disclosed in US Patent 4688625

is the increase in cost which arises due to the use of a separate robust chamber for creating an oxygen free environment and for housing the furnace. Another drawback of the US Patent 4688625 arises due to the cost incurred in inert gas which is used for creating the oxygen-free environment. Another disadvantage of the US Patent 4688625 is that the pressure of the inert gas is required to be maintained above atmospheric pressure in order to cause the molten metal to rise in the die.

Again another US Patent 4719961 discloses a vertical or bow-type continuous casting machine for steel. Continuous casting apparatus is provided having a highly conductive, cooled flow-through mold, a feeder for the mold having an upstream and a downstream section with the downstream section in abutment with the mold, a heater associated with the upstream section for maintaining metal in contact therewith above liquids temperature, the feeder sections being made of refractory material and dimensioned such that the heat from the upstream section is not bled off so rapidly into the cooling elements of the adjacent mold as to start the strand shell development in the upstream section, but sufficiently to let it start in the downstream section of the feeder. The major disadvantage of the vertical casting process of US Patent 4719961 arises due to the vertically downward casting of molten metal. The process of vertically downward casting causes the problem of melt run-outs which accounts for heavy damages during the production process. Another disadvantage of the process disclosed in US Patent 4719961 is that it results in long intervals production shutdown.

Again US Patent 5273103 discloses continuous casting machines for vertically thin-bodies. In vertical thin-bodies continuous casting machines in

which the liquid metal is cast in a mold formed by a pair of counter-rotating rolls with parallel longitudinal axes lying in the same horizontal plane and by a pair of containment plates facing onto the flat ends of the rolls, an electromagnetic device is introduced which produces a field of electromagnetic forces in a desired and given space formed between the plates and roll ends, the orientation and intensity of the forces being such as to impede leakage of liquid metal between the plates and the rolls. The use of electromagnetic device increases the cost of installation. Another disadvantage of US Patent 5273103 is that the electronic device has to be set to produce the desired intensity and direction of the electromagnetic forces.

However, the above mentioned prior art methods of casting are not suitable for manufacturing continuous strips of metal, particularly oxygen free metal strips.

## **OBJECTS OF THE INVENTION**

An object of the present invention is to provide a method for directly casting continuous strips of metal instead of obtaining strips by forging or rolling of slabs.

Further object of the invention is to provide a method of vertically upward continuous casting of strips, which is efficient, economical and less time consuming. The expression "vertically" used in this specification would mean in a direction between 30 degrees to 150 degrees although preferably the direction should be 85 degrees to 95 degrees and still more preferably 90 degrees.

Still further object of the invention is to provide a method of vertically upward continuous casting of strips, which consumes less electricity.

Yet further object of the invention is to provide a method of vertically upward continuous casting of strips, which is simple and safe to use.

Still further object of the invention is to provide a method of vertically upward continuous casting of strips, wherein furnace mouth repair is not required.

Yet a further object of the invention is to provide a method of vertically upward continuous casting of strips, wherein there is no leakage of molten metal or metal run-outs during casting process.

Further object of the invention is to provide oxygen free strips which have better ductility, malleability, high electrical and thermal conductivity.

Still further object of the invention is to provide a method of vertically upward continuous casting of strips which is carried out in an air free environment.

## **SUMMARY OF THE INVENTION**

In accordance with the present invention there is provided a method of vertically upward continuous casting of a strip of a metal/metal alloy, said method comprising the following steps:

- a) making a graphite die defining a passage conforming to the dimension of the strip;
- b) holding a molten metal in a casting chamber in an air free environment and maintaining the temperature in the casting chamber in the range of about 1000°C to 1400°C;
- c) immersing vertically the lower end of said graphite die partially in the molten metal, said graphite die having a nozzle at its operational lower end and a first internal passage leading from said nozzle to the operative outer face of the die;
- d) providing a cooling arrangement on the outer face of said die, said cooling arrangement defining a second internal passage contiguous with said first internal passage;
- e) lowering a dummy bar having slots at its operative lower end through said second and first internal passages to contact the surface of the molten metal;
- f) allowing the molten metal to rise and attach itself to the lower end of said dummy bar and said slots;
- g) raising and lowering said dummy bar in an incremental, alternative and repetitive cycle to extend said molten metal through said first and second internal passages in a solidified state;
- h) cooling the walls of the first internal passage to cause the molten metal to partially cool and solidify in said first internal passage;

- i) causing the solidified molten metal in strip form attached to said dummy bar to rise from said first internal passage into said second internal passage;
- j) raising and lowering the solidified metal in strip form to cool in said second passage;
- k) allowing a relatively cooled metal strip to emerge from said second internal passage; and
- l) drawing the vertically cast cooled strip formed in the process.

Typically, the step of transferring said molten metal from a melting chamber to said casting chamber through an air-tight passageway.

Typically, the step of the air free environment of the molten metal in the casting chamber is achieved by spreading at least one layer of graphite flakes on the surface of the molten metal in the casting chamber and the melting chamber.

Typically, the molten metal is allowed to rise under positive pressure.

Typically, the step of cooling said first internal passage by means of cooling fluid in the temperature range of 15°C to 35°C to cool the molten metal in said first internal passage to about 500°C to solidify it.

Typically, the step of cooling the said second internal passage is in the range of 8°C to 20°C by means of a cooling fluid to cool the metal strip inside the second internal passage to about 200°C.

Typically, drawing includes providing withdrawal rollers and the step of raising and lowering of the solidified metal strip is achieved by angularly displacing said withdrawal rollers in an anti-clockwise and a clockwise direction.

Typically, the displacement in the anti-clockwise direction is greater than the displacement in the clockwise direction.

Typically, the step of raising and lowering of the metal strip includes providing stop and rest between the anti-clockwise and clockwise displacement.

Typically, the method includes a step of cooling the metal strip emerging from said second passage and entering the withdrawal roller.

Typically, the cooling is achieved by providing cooled idle rollers, cooled to a temperature of 8°C to 20°C, between the outlet of the second internal passage and the inlet to the withdrawal rollers to cool the metal strip to about 100°C.

In accordance with a preferred embodiment of the present invention there is provided an apparatus of vertically upward continuous casting of a metal strip, said apparatus comprising:

- a) a furnace partitioned into a melting chamber and a casting chamber;

- b) a graphite die defining a first internal passage;
- c) an insulating protection tube surrounding the graphite die and the first cooling means.
- d) a first cooling means for cooling the die;
- e) a second internal passage contiguous with the first internal passage in said die;
- f) a second cooling means for cooling the second passage; and
- g) a drawing means for drawing cast strips through said first and second internal passages.

Typically, a nozzle is provided at the entrance of the first internal passage.

Typically, a venturi is provided at the entrance of said nozzle.

Typically, the protection tube is refractory lined.

Typically, the graphite die is spaced apart from the protection tube and the defining space is packed with insulating material typically of glass wool, ceramic wool and the like.

Typically, fitting means are provided to rigidly fit the second cooling means to said graphite die.

Typically, a support means in the form of an M. S. plate is provided to support the first cooling means in the protection tube.

Typically, the venturi is formed in said protection tube.

Typically, idle rollers are provided between the secondary cooling means and the drawing means.

Typically, a third cooling means is provided to cool said idle rollers.

Typically, the first cooling means, the second cooling means and the third cooling means are continuous.

Typically, a servomotor is provided to the drawing means for raising and lowering the metal strip incrementally, alternatively and repetitively during casting.

Typically, a dummy bar is provided for leading the strip during casting through the first passage, the second passage and the drawing rolls.

Typically, at least one layer of graphite flakes is provided in said casting chamber to isolate said molten metal to come in contact with air.

## **BRIEF DESCRIPTION OF THE ACCOMPANYING DRAWINGS**

Other aspects of the invention will become apparent by consideration of the accompanying drawings and their description stated below, which is merely illustrative of a preferred embodiment of the invention and does not limit in any way the nature and scope of the invention.

**Figure 1** shows a front cross-sectional view of an apparatus according to the invention for continuous vertical casting of strips;

**Figure 2** shows the cross-sectional view of a die along with a first cooling means in a protection tube;

**Figure 3** shows a side cross-sectional view of an apparatus according to the invention for continuous vertical casting of strips without the strip;

**Figure 4** shows a side cross-sectional view of **figure 3** showing the strip being produced;

**Figure 5** shows a front view of a dummy bar provided with slots for acting as starter; and

**Figure 6** shows a side view of withdrawal rollers along with the dummy bar.

## **DETAILED DESCRIPTION**

Referring to the accompanying drawings, an apparatus for a method of vertical continuous casting of strip, in accordance with this invention is generally indicated by reference numeral (10) and is particularly shown in **figure 1**.

**Figure 1** show a furnace (12) used in the vertically upward continuous casting of a strip (52). The melting chamber (14) and the casting chamber

(18) are interconnected by means of an air-tight passageway (16). A metal/metal alloy is melted in the melting chamber (14) and the molten metal/metal alloy (20) is maintained at a temperature of about 1000°C to 1400°C. The molten metal/metal alloy (20) enters the casting chamber (18) through the passageway (16) from the melting chamber (14). The surface of the molten metal/metal alloy (20) in the furnace (12) is covered by graphite flakes (24) to prevent the molten metal/metal alloy (20) from reaction with the atmospheric oxygen and thus maintaining an air free environment.

**Figure 2** shows a protection tube (36) housing a die (46), a first cooling means (44), an M.S. back up plate (42) and an insulating material (38). The protection tube (36) is provided with a lining typically of a refractory material (40). The protection tube (36) is provided with a venturi (21).

The die (46) used for casting the strip (52) defines a first internal passage (22), shown in **figure 2**, open at both ends. One end of the first internal passage (22) of the die (46) is provided with a nozzle (23) while the other end leads into a second internal passage (33) of a second cooling means (32) as shown in **figure 3**. The dimension of the first internal passage (22) of the die (46) is slightly greater than the required dimension of the strip (52). The die (46) is typically made of graphite and provides a non-wetting surface for the molten metal (20). The die (46) typically has a length of 300mm.

The venturi (21) of the protection tube (36) cooperates with the nozzle (23) of the die (46). The die (46) is surrounded by the first cooling means (44) which is further supported by the M.S. back up plate (42). The die (46) and the first cooling means (44) are spaced apart from the protection tube (36) to

define a space which is packed with insulating material (38). The insulating material (38) is typically glass wool.

The first cooling means (44) is provided with an inlet (28) and an outlet (30) for circulating water, in the temperature range of 15°C to 35°C, which acts as a coolant. The first cooling means (44) is typically of copper. The coolant in the first cooling means (44) helps in cooling the die (46) and maintains the temperature of the molten material in the range of 1000°C to 500°C. In a preferred embodiment of the invention the molten metal (20) in the die (46) solidifies as a result of cooling after a traverse of 150 mm, that is, half the lengths of the passage in the die (46).

The second cooling means (32) is provided with a second internal passage (33), open at both ends. The dimension of the second internal passage (33) is made to conform to the dimension of the first internal passage (22) of the die (46). The second cooling means (32) causes the cooling of the second internal passage (33) with the help of water or a fluid in the range of 8°C to 20°C and maintains the second internal passage (33) such that the strip emanating from the second internal passage (33) has a temperature of about 200°C. The second cooling means (32) has a length of 500 mm.

A rail and rail guide assembly (51), shown schematically in **figure 3**, is provided to lower and raise the die (46) enclosed in the protection tube (36) and the second cooling means (32) in the molten metal (20). The operation of the rail and rail guide assembly (51) in order to precisely control the movement of the die (46) and the second cooling means (32) is controlled by a motor (not shown in figure).

A plurality of withdrawal rollers (50) acts as a means for drawing the strip out of the process. At least one idle roller (48) is provided between the secondary cooling means (32) and the withdrawal rollers (50). A third cooling means (not shown in figure) is provided to cool the idle rollers (48) to a temperature typically in the range of 8°C to 20°C. The idle rollers (48) helps in cooling as well as guiding the formed strip (52) coming out of the second cooling means (32) towards the set of withdrawal rollers (50). The withdrawal rollers (50) are operated with the help of a servomotor (not shown in figure).

A dummy bar (34), shown in **figure 5** and **figure 6**, is used as a start-up device for attaching the molten metal. The dummy bar (34) consists of a metal attaching portion (56) having the same dimension as the desired dimension of the formed metal strip (52) and a withdrawal portion (58) provided to allow the dummy bar (34) to extend the dummy bar (34) upto the withdrawal rollers (50). The metal attaching portion (56) is provided with slots (54) for allowing the solidified molten metal fix to the dummy bar (34).

**Figure 4** shows the casting of the molten metal (20) to form the strip (52). The second cooling means (32) is fitted using bolts on the side opposite to the nozzle (23) of the die (46). The first internal passage (22) of the die (46) is aligned with the second internal passage (33) of the second cooling means (32), so as to form a single contiguous passage. The gap between the bolted ends of the die (46) and the second cooling means (32) is sealed with a sealing material to further enhance the continuity of the aligned first internal passage (22) and the second internal passage (33).

The casting metal (20) is made to melt in the melting chamber (14) by heating the casting metal to a temperature of about 1000°C to 1400°C. The molten metal /metal alloy (20) is transferred to the casting chamber (18) through the passageway (16). At least one layer of graphite flakes (24) is provided on the top surface of the molten metal. The graphite flakes (24) being lighter in weight than the molten metal (20), floats on the surface of the molten metal (20) thus preventing the molten metal to come in contact with air.

The dummy bar (34), shown in **figure 5** and **figure 6**, is inserted into the first internal passage (22) of the die (46) through the second internal passage (33) of the second cooling means (32). The dummy bar (34) is inserted in the first internal passage (22) of the die (46) such that the dummy bar (34) lies just above the nozzle (21) of the die (46).

The assembly of the die (46) and the second cooling means (32) is immersed in the molten metal (20) in the casting chamber (18) such that the die (46) is partially immersed in the molten metal (20).

The assembly of the die (46), the first cooling means (44), the insulating material (38) housed in the protection tube (36) is partially immersed in the molten metal (20) in the casting chamber (18). The nozzle (23) of the die (46) in co-operation with the venturi (21) of the protection tube (36) enables in causing a positive displacement of the molten metal (20) into the first internal passage (22) of the die (46). The molten metal (20) in the first internal passage (22) of the die (46) is attached to the metal attaching portion (56) of the dummy bar (34). When the molten metal (20) is attached to the

metal attaching portion (56) of the dummy bar (34), the withdrawal rollers (50) are operated with the help of servomotor (not shown in figure). The withdrawal rollers (50) are provided with an angular displacement in the anti-clockwise and clockwise direction so as to continuously raise and lower the attached molten metal (20). The angular displacement of the withdrawal rollers (50) is provided in an incremental, alternative and repetitive cycle.

The incremental, alternative and repetitive cycle of the withdrawal rollers (50) causes the dummy bar (34) to rise along with the attached molten metal (20) away from the casting chamber (18) typically by 7 mm. The raised dummy bar (34) along with the attached molten metal (20) is held in position typically for 1 second. The raised dummy bar (34) along with the attached molten metal (20) is then lowered towards the casting chamber (18) along with the attached and partially solidified molten metal strip through a distance typically of 1.3 mm. The lowered dummy bar (34) along with the attached partially solidified molten metal (20) is held in the lowered position typically for 1 second so that a thin layer of the molten metal (20) attaches itself to the molten metal strip attached to the dummy bar (34). The incremental, alternative and repetitive cycle is continued till the desired length of the strip (52) is obtained.

The metal strip (52) typically forms/ solidifies after passing through 150 mm. The metal strip (52) coming out of the first internal passage (22) to the second internal passage (33), is at a temperature of about 500°C as it enters the second internal passage (33) and is about 200°C on coming out of the second cooling means. The formed metal strip (52) is further cooled to a temperature of 100°C after passing through the internally cooled idle rollers

(48). However, the relative temperature are a matter of design optimization and the final temperatures of the strip (52) in the first internal passage (22) and the second internal passage (33) is dependent upon the length of the passage and the resident times of the strip in the respective passages. Idle rollers (48) may be provided between the exit of the second internal passage (33) and the withdrawal rollers (50) which may be cooled to further reduce the temperature of the metal strip (52) to a manageable temperature of 100°C.

The solidified and formed strip (52) coming out of the draw roller assembly (47) is made to form coiled rolls of metal strip (52). The metal strip obtained by the present invention has a thickness typically in the range of 8 mm to 25 mm and has a width typically in the range of 125 mm to 400 mm.

The strips formed can be further rolled to obtain strips of thickness as low as about 2 mm to 3.5 mm in the casting line itself and by further processing the strip (52) can be rolled to a thickness of 0.04 mm.

## **TRIALS**

The strips formed in accordance with this invention by the above method were tested for ductility (40%), conductivity (97%), malleability, X-ray diffraction for cracks and holes and the product passed all test standards. It was also found to be oxygen free and could be used as such or after annealing for various applications. The cost of making the strip in accordance with this invention was also calculated to be almost 200% less

than the cost of making the strip according to vacuum process. The apparatus is also comparatively less expensive.

## **TECHNICAL ADVANTAGES**

The product as described herein above offers several advancements over similar products disclosed in the prior art. The vertically upward continuous casting process in accordance with the present invention helps in directly producing continuous lengths of metal strips. The vertically upward continuous casting process in accordance with the present invention is simple in construction. The vertically upward continuous casting process in accordance with the present invention helps in reducing the losses. The vertically upward continuous casting process in accordance with the present invention also helps in reducing electricity consumption. The vertically upward continuous casting process in accordance with the present invention is safe to handle and require minimum manual work.

While considerable emphasis has been placed herein on the components and component parts of the preferred embodiments, it will be appreciated that many embodiments can be made and that many changes can be made in the preferred embodiments without departing from the principles of the invention. These and other changes in the preferred embodiment as well as other embodiments of the invention will be apparent to those skilled in the art from the disclosure herein, whereby it is to be distinctly understood that the foregoing descriptive matter is to be interpreted merely as illustrative of the invention and not as a limitation.

## Claims:

1. A method of vertically upward continuous casting of a strip of a metal/metal alloy, said method comprising the following steps:
  - a) making a graphite die defining a passage conforming to the dimension of the strip;
  - b) holding a molten metal in a casting chamber in an air free environment and maintaining the temperature in the casting chamber in the range of about 1000°C to 1400°C;
  - c) immersing vertically the lower end of said graphite die partially in the molten metal, said graphite die having a nozzle at its operational lower end and a first internal passage leading from said nozzle to the operative outer face of the die;
  - d) providing a cooling arrangement on the outer face of said die, said cooling arrangement defining a second internal passage contiguous with said first internal passage;
  - e) lowering a dummy bar having slots at its operative lower end through said second and first internal passages to contact the surface of the molten metal;
  - f) allowing the molten metal to rise and attach itself to the lower end of said dummy bar and said slots;
  - g) raising and lowering said dummy bar in an incremental, alternative and repetitive cycle to extend said molten metal through said first and second internal passages in a solidified state;

- h) cooling the walls of the first internal passage to cause the molten metal to partially cool and solidify in said first internal passage;
  - i) causing the solidified molten metal in strip form attached to said dummy bar to rise from said first internal passage into said second internal passage;
  - j) raising and lowering the solidified metal in strip form to cool in said second passage;
  - k) allowing a relatively cooled metal strip to emerge from said second internal passage; and
  - l) drawing the vertically cast cooled strip formed in the process.
2. The method as claimed in claim 1, which includes the step of transferring said molten metal from a melting chamber to said casting chamber through an air-tight passageway.
  3. The method as claimed in claim 1, wherein the step of said air free environment of the molten metal in the casting chamber is achieved by spreading at least one layer of graphite flakes on the surface of the molten metal in the casting chamber.
  4. The method as claimed in claim 1, wherein said molten metal is allowed to rise under positive pressure.
  5. The method as claimed in claim 1, which include the step of cooling said first internal passage by means of cooling fluid in the temperature

range of 15°C to 35°C to cool the molten metal in said first internal passage to about 500°C to solidify it.

6. The method as claimed in claim 1, which include the step of cooling the said second internal passage is in the range of 8°C to 20°C by means of a cooling fluid to cool the metal strip inside the second internal passage to about 200°C.
7. The method as claimed in claim 1, wherein drawing includes providing withdrawal rollers and the step of raising and lowering of the solidified metal strip is achieved by angularly displacing said withdrawal rollers in an anti-clockwise and a clockwise direction.
8. The method as claimed in claim 7, wherein the displacement in the anti-clockwise direction is greater than the displacement in the clockwise direction.
9. The method as claimed in claim 1, wherein the step of raising and lowering of the metal strip includes providing stop and rest between the anti-clockwise and clockwise displacement.
10. The method as claimed in claim 1, wherein the method includes a step of cooling the metal strip emerging from said second passage and entering the withdrawal roller.
11. The method as claimed in claim 1, wherein said cooling is achieved by providing cooled idle rollers, cooled to a temperature of 8°C to 20°C,

between the outlet of the second internal passage and the inlet to the withdrawal rollers to cool the metal strip to about 100°C.

12. An apparatus for vertically upward continuous casting of a metal strip, said apparatus comprising:
  - a) a furnace partitioned into a melting chamber and a casting chamber;
  - b) a graphite die defining a first internal passage;
  - c) an insulating protection tube surrounding the graphite die;
  - d) a first cooling means for cooling the die;
  - e) a second internal passage contiguous with the first internal passage in said die;
  - f) a second cooling means for cooling the second passage; and
  - g) a drawing means for drawing cast strips through said first and second internal passages.
13. The apparatus as claimed in claim 12, wherein a nozzle is provided at the entrance of the first internal passage.
14. The apparatus as claimed in claim 12, wherein a venturi is provided at the entrance of said nozzle.
15. The apparatus as claimed in claim 12, wherein said protection tube is refractory lined.

16. The apparatus as claimed in claim 12, wherein said graphite die is spaced apart from the protection tube and the defining space is packed with insulating material typically glass wool.
17. The apparatus as claimed in claim 12, wherein fitting means are provided to rigidly fit the second cooling means to said graphite die.
18. The apparatus as claimed in claim 12, wherein a support means in the form of an M. S. plate is provided to support said first cooling means in said protection tube.
19. The apparatus as claimed in claim 12, wherein said venturi is formed in said protection tube.
20. The apparatus as claimed in claim 12, wherein idle rollers are provided between the secondary cooling means and the drawing means.
21. The apparatus as claimed in claim 12, wherein a third cooling means is provided to cool said idle rollers.
22. The apparatus as claimed in claim 12, wherein the first cooling means, the second cooling means and the third cooling means are continuous.
23. The apparatus as claimed in claim 12, wherein a servomotor is provided to the drawing means for raising and lowering the metal strip incrementally, alternatively and repetitively during casting.

24. The apparatus as claimed in claim 12, wherein a dummy bar is provided for leading the strip during casting through the first passage, the second passage and the drawing rollers
25. The apparatus as claimed in claim 12, wherein at least one layer of graphite flakes is provided in said casting chamber to isolate said molten metal to come in contact with air.
26. A metal strip made in accordance with the method of any one of the claims 1 to 11.
27. A metal strip made in an apparatus in any one of the claims 12 to 25

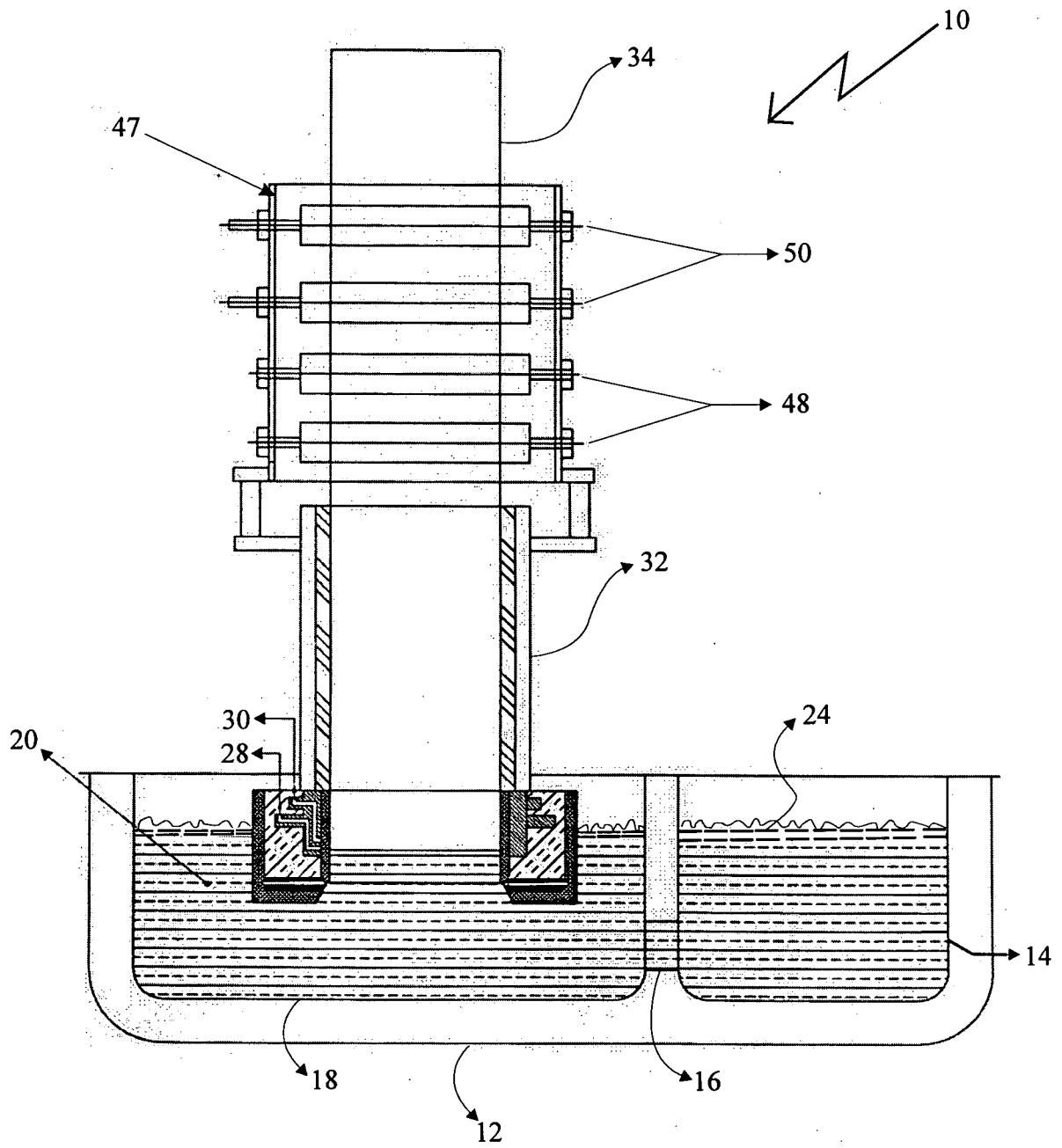


FIGURE 1

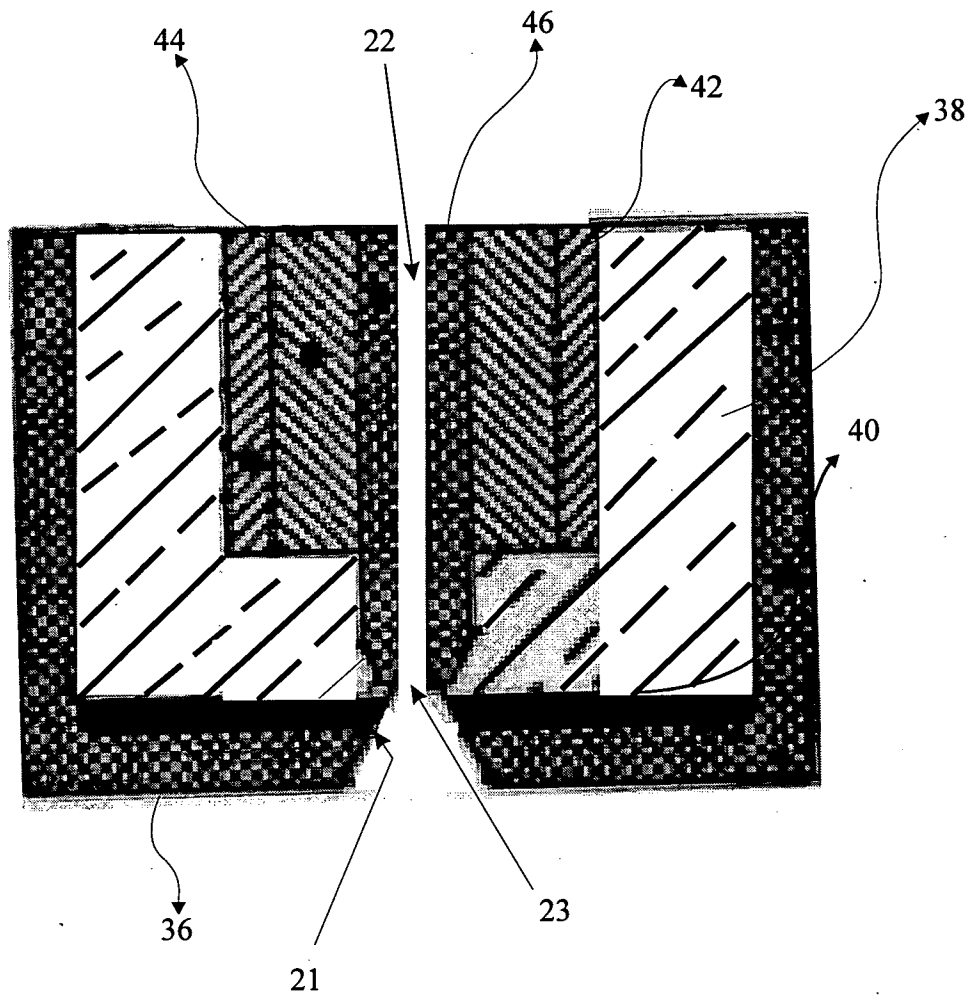


Figure 2

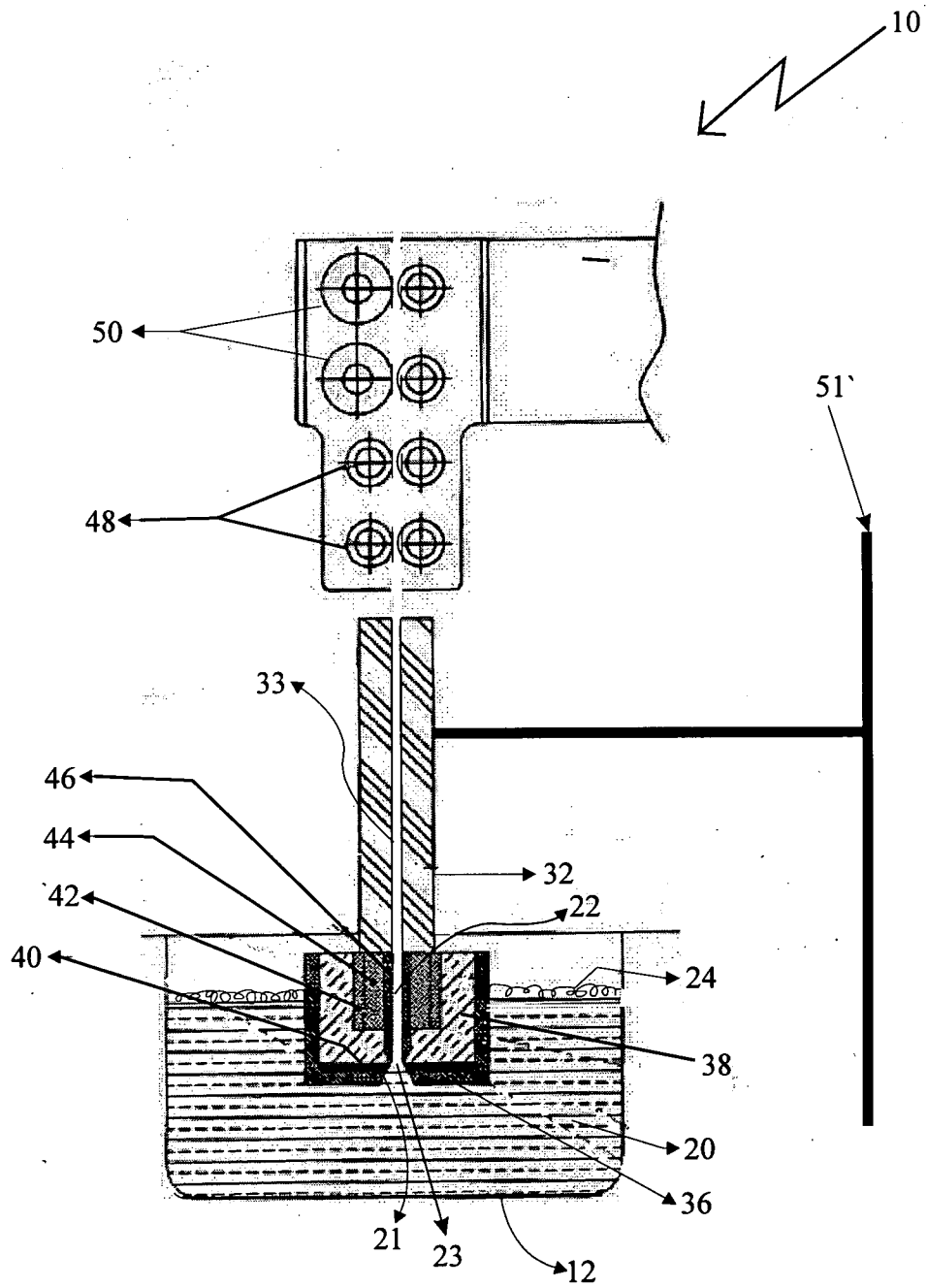


Figure 3

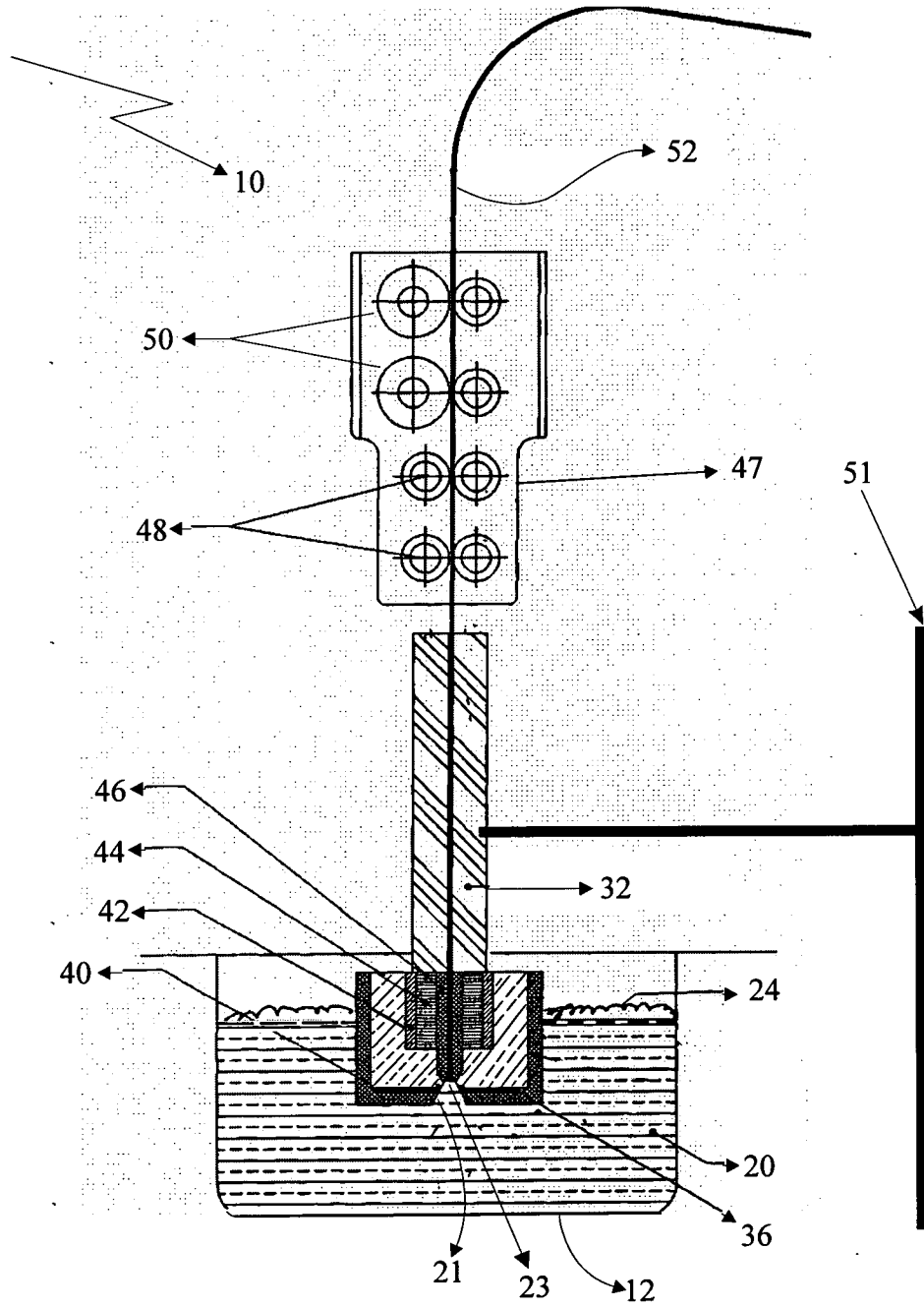


Figure 4

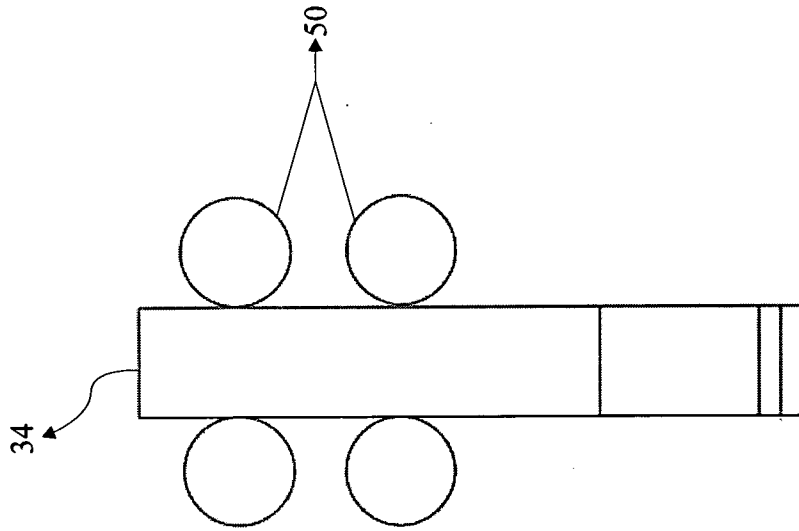


Figure 6

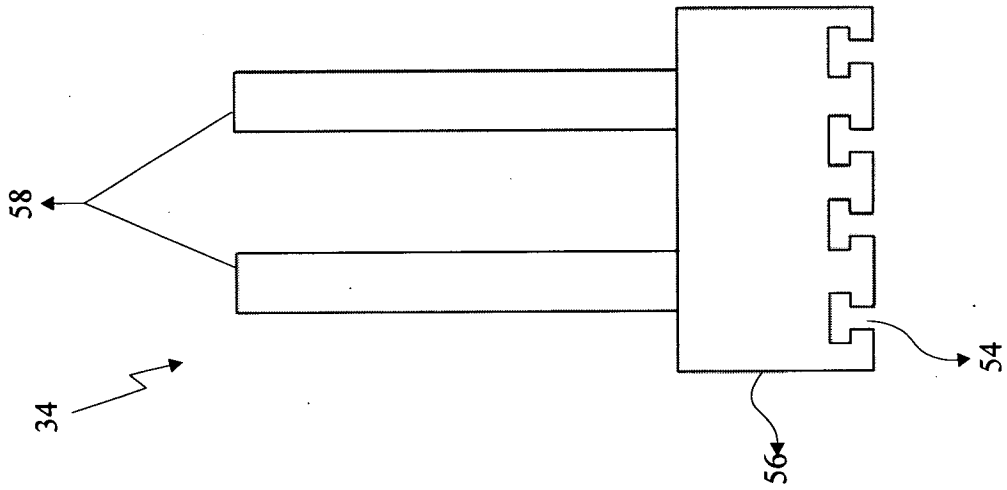


Figure 5