United States Patent [19]

Nighman

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[45] **Sept. 18, 1973**

[54] **METHOD OF AND APPARATUS FOR COOLING CONTINUOUSLY CAST METAL**

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[52] **U.S. Cl.** **164/4**, 164/89, 164/154, 164/283

[51] **Int. Cl.** **B22d 11/12**

[58] **Field of Search** 164/4, 82, 89, 154, 164/283

[56] **References Cited**

UNITED STATES PATENTS

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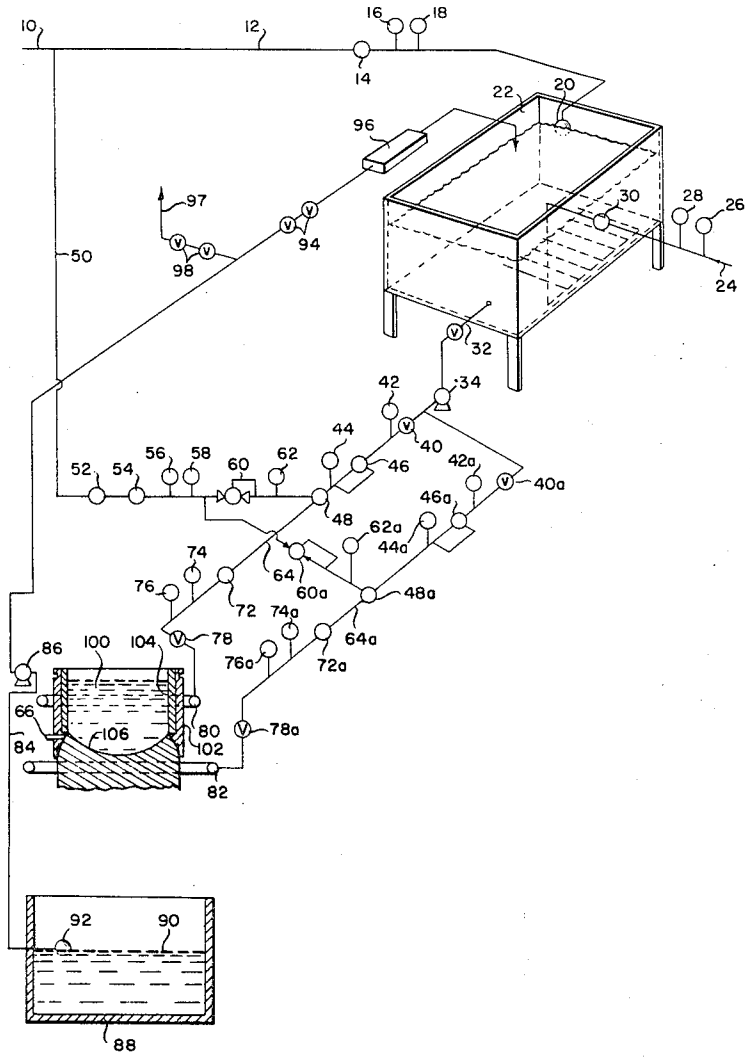
[57] **ABSTRACT**

A method of and apparatus for cooling continuously cast metal wherein the temperature of the coolant may be varied substantially instantaneously. A hot water coolant is applied either to the mold or the metal being continuously cast, or both. Suitably located sensor means at the locus of the mold sense a condition incident to the continuous casting operation. In a preferred form of the invention, separate means are employed to retard the cooling of the metal as it emerges from the bottom of the mold in order to prevent cracking of the metal.

17 Claims, 4 Drawing Figures



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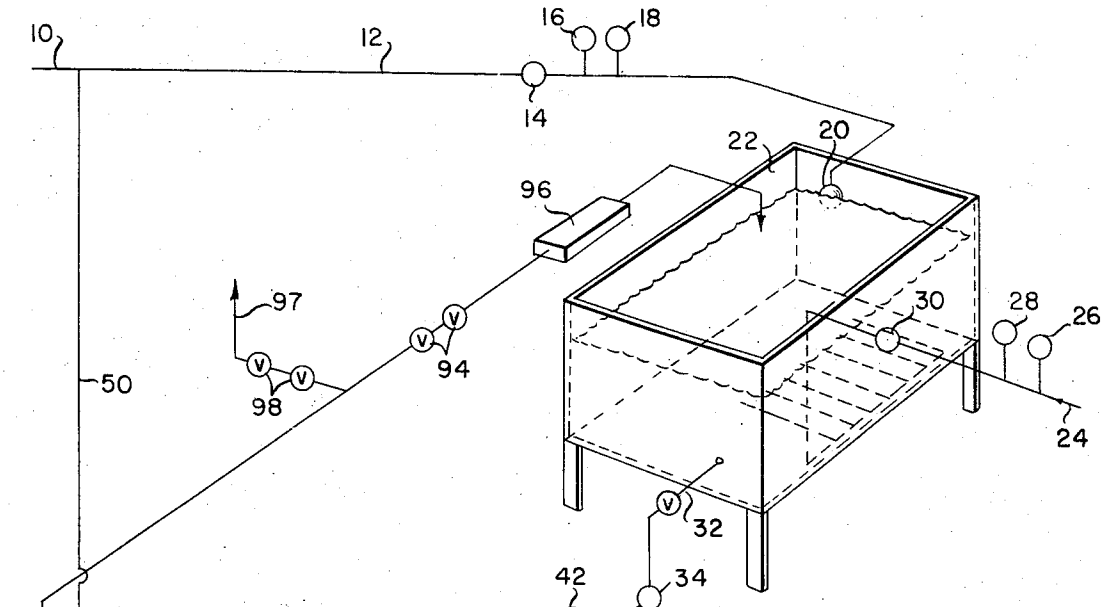

Fig. 1

Fig. 2

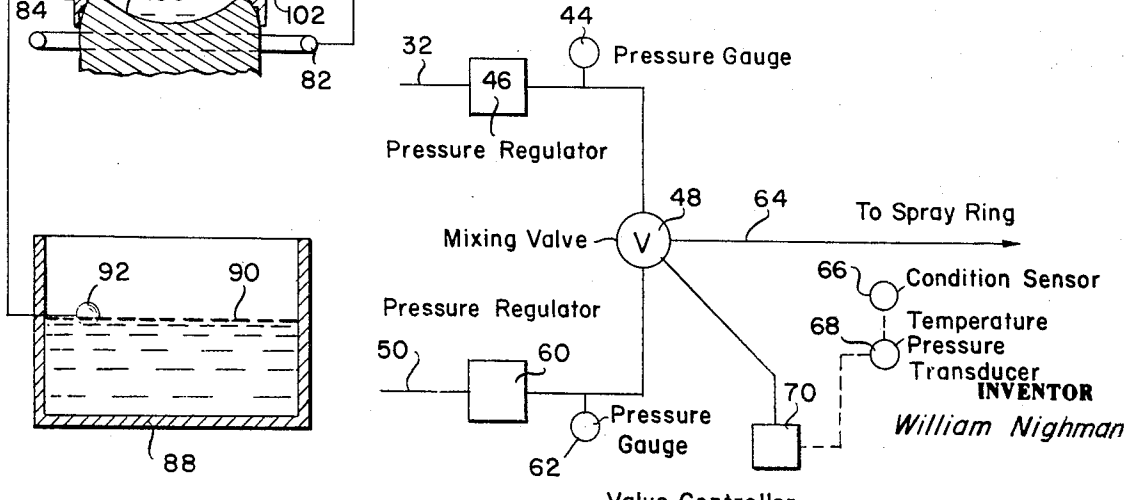

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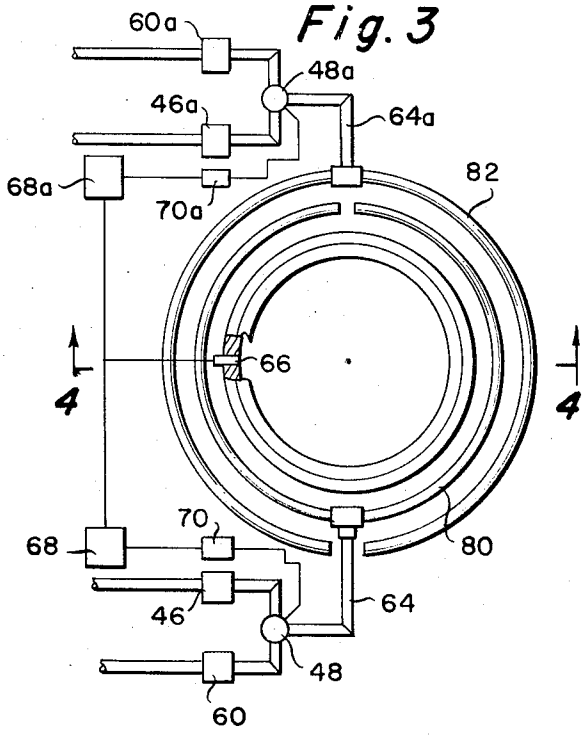
Fig. 3



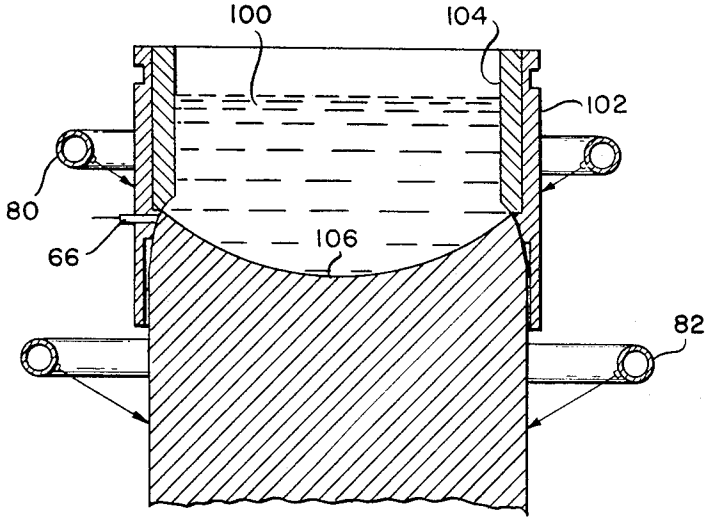


Fig. 4

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METHOD OF AND APPARATUS FOR COOLING CONTINUOUSLY CAST METAL

This invention relates to a method of and apparatus for cooling continuously cast metal and more particularly to such a method and apparatus for using a hot water coolant.

Heretofore it has been known to sense the temperature of either the mold or the metal and to minimize movement of the freeze line by varying the volume of flow of coolant. Such methods have used coolant at substantially ambient temperature or less up to about 80° F. and have relied upon the volume of flow of coolant in order to control temperature conditions of the mold.

In accordance with the present invention, a hot water coolant is employed that is one having a temperature from about 100° F. to about 160° F. and the temperature is controlled in response to the sensing of a selected operating condition. Any one of a large number of conditions indicative of a satisfactory continuous casting operation may be sensed and used to control the coolant. For example, the condition may be the temperature of the mold iteslf, or the depth of the crater at the freeze line, or the input temperature of the molten metal itself. The sensor device may be a heat sensing element such as a thermocouple or a ray detection means such as an X-ray device, a gamma ray detection device or an ultrasonic detection means.

After the condition has been sensed, the temperature of the hot water coolant is varied substantially instantaneously in a manner predicated upon the sensed condition. That is, the temperature of the coolant is varied to counteract the change or variation in the sensed condition.

The advantages which accrue through the use of a hot water coolant in the manner prescribed herein comprise the elimination of coarse grain growth during high temperature homogenization of automotive alloys; the control of cooling capacity of coolant through temperature rather than hard to maintain flow rates, that is, a simpler spray design; the ability to obtain substantially flat butts on ingots through the reduction in cooling at the start of ingot casting; the attainment of increased safety in that hot water apparently is less likely to catalyze unit explosions; and an improved condition in that no valves stick with water in the "off" position.

Controlling the temperature of the quenchant, in continuous casting, at an elevated level reduces the cooling rate of the solidifying ingot. Reducing the cooling rate markedly affects the internal metallurgical structure through increased precipitation of phases, increased size of dendrites, and increased grain size. It is known that it is relatively easy to produce non-earing sheet from slowly cooled ingots compared with D.C. cast ingots. Reduced cooling rates also minimize the thermal stresses that are responsible for ingot butt curling and ingot cracking.

Other inherent advantages and improvements of the present invention will become more readily apparent upon considering the following detailed description of the invention and by reference to the drawings in which:

FIG. 1 is a schematic diagram of one form of the present invention;

FIG. 2 is a fragmentary schematic diagram of a portion of FIG. 1;

FIG. 3 is a diagrammatic plan view of a continuous casting mold to which the present invention is applied, and,

FIG. 4 is a vertical cross sectional view taken along Line 4—4 of FIG. 3.

Referring now to FIG. 1, make up water for use as a coolant in the present invention is supplied through conduit **10** and thence through conduit **12** into a mixing tank **22.** In a typical installation, the make up water for the coolant system will have a temperature of about 90° F. and a pressure of 50 pounds per square inch. A flowmeter is shown at **14** in conduit **12,** a temperature gauge at **16** and a pressure gauge **18.** A mechanical float valve is placed in tank **22** at **20.** A typical tank capacity is 3,500 gallons.

Saturated steam is applied through line **24** into the tank **22.** This saturated steam line **24** is monitored by temperature and pressure gauges **26** and **28,** respectively, and the steam is admitted through an automatic control valve **30.** In this manner, heated water is removed from tank **22** through conduit **32** with the aid of a booster pump **34.** In a typical installation conduit **32** is a 6 inch diameter pipe and pump **34** can deliver 430 gallons per minute at a 115 foot head.

From pump **34** the hot water coolant is delivered in parallel paths toward identical mixer valves **48** and **48***a* respectively. Each parallel path has identical control components including valves **40, 40***a;* temperature gauges **42, 42***a;* pressure gauges **44,44***a;* and pressure regulators **46, 46***a,* respectively. The temperature of the hot water coolant derived from both the make-up water source and the saturated steam source is controlled substantially instantaneously by the mixer valves **48** and **48***a.* Thereafter, the hot water coolants are delivered to spray rings **80** and **82** through parallel paths having suitable controls such as flowmeters **72, 72***a;* temperature gauges **74, 74***a;* pressure gauges **76, 76***a;* and valves **78, 78***a,* respectively.

The hot water coolant delivered to spray ring **82,** FIGS. **3** and **4,** through one of the parallel paths from pump **34** effects a reduced cooling at a fixed distance, such as 1 to 14 inches, below the mold **102.** Normally wipers in the form of either air knives or rubber-like material which operate like squeegees are used to prevent ingot cracking especially on large ingots (16–27 inches in diameter) for forging or rolling applications. Such wipers operate to remove the cooling water from the ingot surface beneath the mold in order to eliminate ingot cracking. It has been found that the mechanical wipers become worn and torn in service and continually add to the maintenance burden. The air knives are undesirable because they are difficult to manifold properly and they create undesirable noise and require complicated piping. By employing a hot water coolant, from about 100° F. to about 160° F., typically at a distance of from about 1 inch to about 14 inches below the mold, ingots are produced without cracks and the mechanical wipers and air may be eliminated. The use of hot water in this manner effective-retards the cooling of the metal as it emerges from the bottom of the mold and prevents the metal from cracking.

Returning again to FIG. 1, some of the cool make up water in conduit **10** is diverted through conduit **50** toward a three-way mixer valve **48** where it is mixed in a controlled manner with the hot water through put from line **32.** Conduit **50** is provided with a gate valve **52,** check valve **54,** pressure gauge **56,** temperature

gauge 58, identical pressure regulators 60 and 60*a* and pressure gauges 62 and 62*a*. The output from three-way mixing valves 48, 48*a* are taken through flow lines 64, 64*a* to spray rings 80 and 82.

The coolant applied to the continuously cast metal is received in a sump container 88 wherein the level of the liquid 90 is controlled with the aid of a float control 92 in conventional manner. The expended coolant is recirculated by means of return line 84 with the aid of pump 86 to the tank 22. A suitable strainer is employed at 96 with valve controls thereto at 94. A cooling tower return line 97, valved at 98, interconnects with return line 84.

The mold 102 as shown in FIG. 4 contains molten metal 100 and is lined with a wall 104 of insulating material (such as is disclosed in U.S. Pat. No. 2,983,972, for example) just above the freeze line 106.

A typical control circuit is indicated in FIG. 2 whereby the temperature of the coolant in line 64 is controlled on a substantially instantaneous basis with the aid of a sensor means 66 and elements 68 and 70 for regulating the mixing valve 48. The nature of elements 68 and 70 will vary in relation to the nature of the condition sensor means 66. For example, when the condition sensor means is a thermocouple 66 (as shown in FIGS. 3 and 4) disposed in the wall 102 of the casting mold, a temperature pressure transducer 68 and a valve controller 70 are provided.

By way of a specific example, a thermocouple inserted in the mold wall at 66 produces an electrical signal in the millivolt range and is conducted to a Moore Products MV to P millivolt-to-pressure transducer, similar to Model 7711. This produces penumatic signals in about the 3 to 15 psi range from the millivolt input signals. A supply of compressed air, not shown, is needed. The transducer 68 supplies a Moore Products Indicating Control Station 70, for example, similar to Moore Product's Model 52 N4 T2. The controller operates a mixing valve such as Honeywell Model 1601 which has a Moore Positioner to prevent hunting. The Honeywell mixing valve can either use steam or hot water and may be flow rate variable in accordance with the model used. The Moore controller can either control directly (higher temperature-hotter water) or the opposite (higher temperature-cooler water) by an internal wiring change.

A control circuit such as that shown in FIG. 2 may also be used to control the water temperature to spray ring 82. In this instance, make-up water is supplied through conduits 10 and 50 and then through a parallel conduit having a pressure regulator 60*a* and a pressure gauge 62*a* therein to mixing valve 48*a*. A hot water input to mixing valve 48*a* is obtained by tapping into line 32 with a conduit having pressure gauge 44*a* and pressure regulator 46*a* therein. As is illustrated in FIGS. 1 and 3, the output of mixing valve 48*a* is delivered through conduit 64*a* to spray ring 82.

It is possible to use the same condition sensor 66 for both spray rings 80 and 82. Such an arrangement is illustrated in FIG. 3 where an impulse from condition sensor 66 is applied to a temperature-pressure transducer 68*a* which is connected to a valve controller 70*a* to control a three-way valve 48*a*. This parallel circuitry is provided with pressure regulators 46*a* and 60*a* which are identical, respectively, with pressure regulators 46 and 60 in FIGS. 2 and 3.

If desired, the control circuits for the respective spray rings 80 and 82 may operate at a fixed temperature differential from the same sensor 66. Alternatively, plural sensors 66 may be employed. For example, large ingots may be cast advantageously by using cooler water at the location of the first spray ring 80 and hotter water at the second spray ring 82. This alters the coolant efficiency in such a way that cooling is retarded at the second spray ring location 82 to produce an effect similar to that of mechanical wipers.

As has already been noted, when a temperature sensing means such as a thermocouple is employed, it may be positioned to sense the temperature of the mold or of the metal including the input temperature of the molten metal. Radiant temperature sensing means such as the use of two color pyrometers may be employed. The hot water coolant temperature range is from about 100° F. to about 160° F. with a preferred optimum temperature for the water coolant being from about 140° F. to about 145° F. While the invention has been described with respect to a single valve means 48 or 48*a* it is to be understood that plural valves may be used to supply the desired hot water coolant.

The advantages accruing through the use of the present invention occur without varying the volumetric flow of the coolant. However, it will be apparent that the expedient of varying the flow rate of the hot water coolant may also be practiced in combination with the present invention.

While presently preferred embodiments of the invention have been illustrated and described, it will be recognized that the invention may be otherwise variously embodied and practiced within the scope of the claims which follow.

What is claimed is:

1. A method of continuous casting wherein molten metal is solidified to form an ingot and the molten metal adjacent the ingot is restrained from flowing laterally during solidification as the ingot is withdrawn relative to the restraining means, comprising the steps of:
   a. applying a coolant to at least one of said restraining means and said metal to promote solidification of the metal,
   b. sensing a selected operating condition related to maintaining a cooling rate effective for satisfactory operation as solidification occurs,
   c. controlling the temperature of said coolant so as to counteract the effect of changes in the sensed condition.

2. The method of claim 1 wherein said step of controlling the temperature of said coolant includes maintaining the temperature of said coolant from about 100° F. to about 160° F.

3. The method of claim 1 including the additional step of maintaining the rate of flow of coolant substantially constant.

4. The method of claim 3 wherein said step of controlling the temperature of said coolant includes maintaining the temperature of said coolant from about 140° F. to about 145° F.

5. The method of claim 1 wherein said controlling operation includes mixing cooler and hotter water and varying the proportions thereof to provide substantially instantaneous regulation of the coolant temperature.

6. The method of claim 5, including the additional steps of applying a cold water coolant to said means for restraining lateral flow of said molten metal and a hot

water coolant to the ingot as it emerges from said restraining means.

7. The method of claim 6 wherein said coolant has a temperature from about 100° F. to about 160° F.

8. The method of claim 1 wherein the selected operating condition sensed which is related to maintaining a cooling rate effective for satisfactory operation as solidification occurs is the temperature of a portion of the mold.

9. The method of claim 1 wherein the selected operating condition sensed which is related to maintaining a cooling rate effective for satisfactory operation as solidification occurs is the input temperature of the molten metal.

10. The method of claim 1 wherein the selected operating condition sensed which is related to maintaining a cooling rate effective for satisfactory operation as solidification occurs is the depth of the crater between the molten metal and the solidified metal.

11. A method of continuous casting wherein molten metal is solidified to form an ingot and the molten metal adjacent the ingot is restrained from flowing laterally during the solidification as the ingot is withdrawn relative to the restraining means, comprising the steps of:

a. mixing cooler and hotter fluids to provide a hot water coolant,
b. applying said coolant to at least one of said restraining means and said metal to promote solidification of the metal,
c. regulating the temperature of said coolant on a substantially instantaneous basis to control solidification of the ingot.

12. The method of claim 11 including the additional steps of applying a cold water coolant to said means for restraining lateral flow of said molten metal and a hot water coolant to the ingot as it emerges from said restraining means.

13. In a continuous casting apparatus for solidifying molten metal to form an ingot, including means for restraining the flow of molten metal laterally during solidification as the ingot being formed is withdrawn relative to the molten metal, the improvement which comprises:

a. means for applying a hot water coolant to at least one of said means for restraining the flow of molten metal and said metal to promote solidification of the metal,
b. means for mixing cooler and hotter fluids to provide said hot water coolant, and
c. means for varying the proportions of said cooler and hotter fluids to provide substantially instantaneous regulation of the coolant temperature to control solidification of the ingot.

14. The apparatus of claim 13 wherein said means for varying the proportions of said cooler and hotter fluids includes a mixing valve means.

15. Apparatus for continuous casting of metals as defined in claim 13 including additional means for applying hot water coolant to said ingot as it emerges from said restraining means.

16. The apparatus of claim 15 wherein said means for varying the temperature of said coolant on a substantially instantaneous basis includes:

a. temperature sensing means,
b. temperature-pressure transducer means connected to said temperature sensing means,
c. valve controller means activated by said temperature-pressure transducer means, and
d. a mixing valve controlled by said valve controller means.

17. The apparatus of claim 16 including additional means for applying hot water coolant to said metal as it emerges from said restraining means.

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