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Mizikar et al.

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[54] **PROCESS FOR COOLING VACUUM-CAST INGOTS**

[75] Inventors: **Eugene A. Mizikar,** Clairton: **Frederick H. Rehmus,** Baldwin Borough, both of Pa.

[73] Assignee: **Jones & Laughlin Steel Corporation,** Pittsburgh, Pa.

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Related U.S. Application Data

[63] Continuation of Ser. No. 869,816, Oct. 27, 1969, abandoned.

[52] **U.S. Cl.** **164/64,** 164/89, 164/283

[51] **Int. Cl.** **B22d 11/10,** B22d 11/12

[58] **Field of Search** 164/64, 89, 256, 164/257, 258, 281, 283

[56] **References Cited**

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Primary Examiner—J. Spencer Overholser
Assistant Examiner—John E. Roethel
Attorney—G. R. Harris et al.

[57] **ABSTRACT**

An ingot of metal continuously cast under vacuum is withdrawn into a cooling chamber maintained at a pressure intermediate casting pressure and atmospheric pressure and cooled therein by sprays of cooling liquid. The seal between the chamber is that effected between the molten metal in the ingot mold and the mold.

5 Claims, 3 Drawing Figures

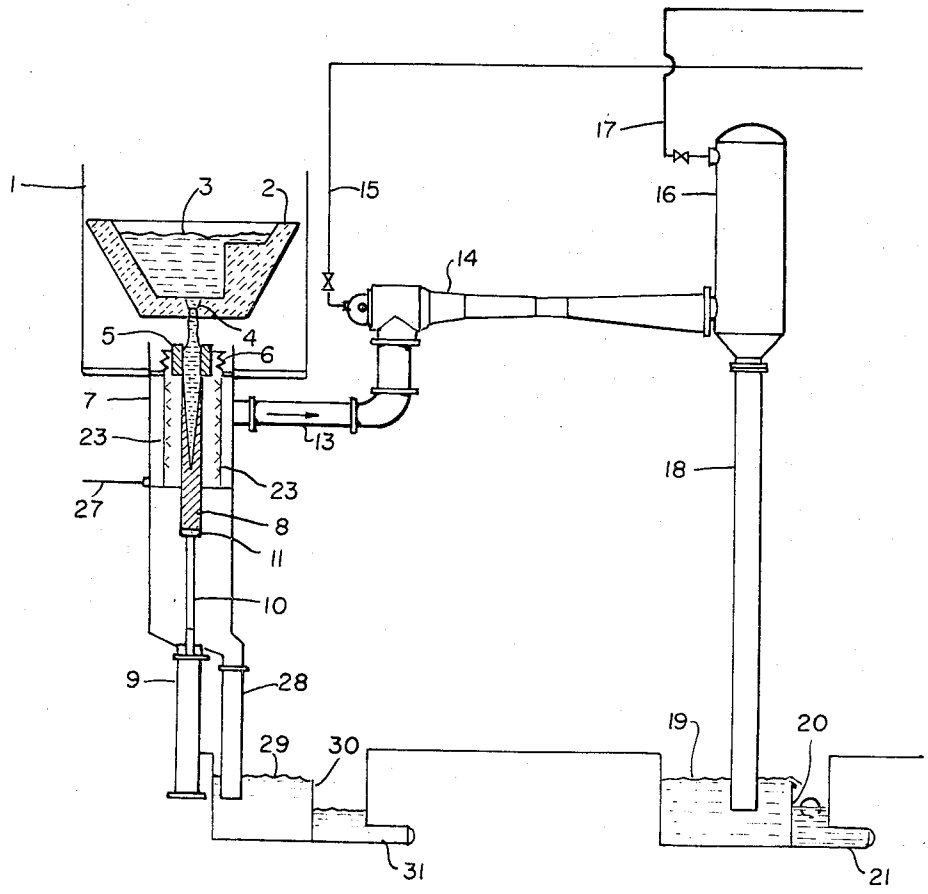


Fig.2

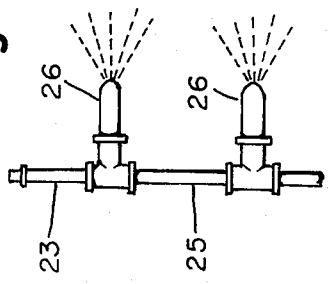


Fig.3

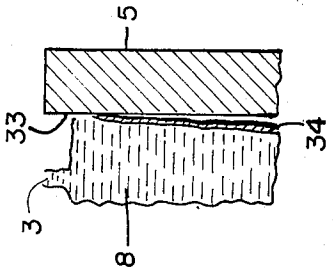
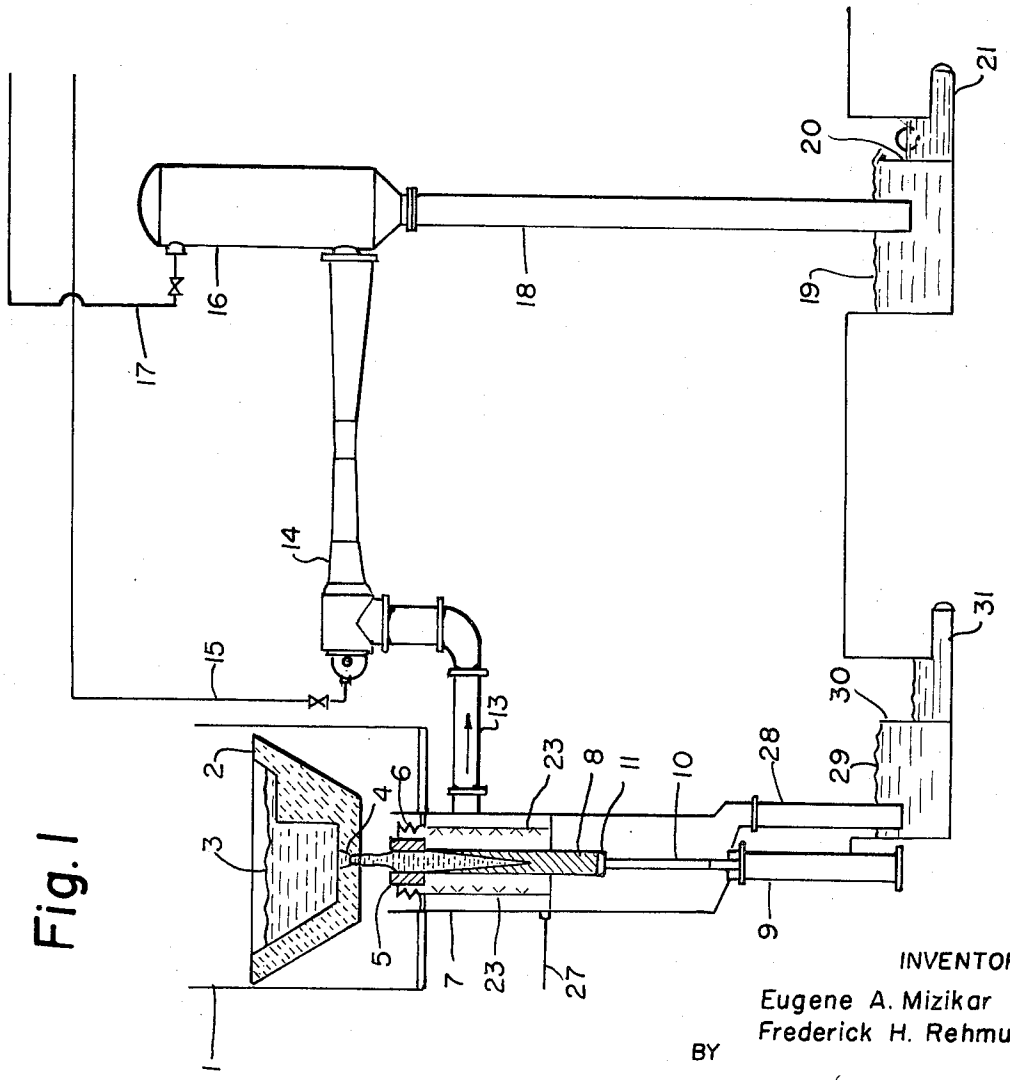


Fig.1



INVENTORS
Eugene A. Mizikar
Frederick H. Rehmus
BY
their ATTORNEY

PROCESS FOR COOLING VACUUM-CAST INGOTS

This invention relates to the cooling of vacuum-cast ingots and the like. It is more particularly concerned with cooling of such bodies by spraying them with cooling liquid under subatmospheric pressure conditions. This application is a continuation of our application Ser. No. 869,816, filed Oct. 27, 1969, now abandoned.

Certain grades of metals and alloys, both ferrous and nonferrous are most advantageously cast or refined and cast under "vacuum," so-called. That term generally means subatmospheric pressures on the order of 10^{-3} mm of Hg. The ingots so produced are frequently cast into open end molds and are withdrawn from the bottom of the mold at a controlled rate. A factor limiting the casting rate of such ingots is their rate of cooling. The cast ingots must be cooled in the reduced pressure zone in which they are cast until no molten metal is exposed to the surrounding atmosphere.

Heretofore, the mold and the apparatus for withdrawing the ingot therefrom has been enclosed in the evacuated chamber in which the ingot is cast. The ingot can cool only by radiation, and it is usually withdrawn from the mold in proximity to water cooled elements which act as heat sinks. The cooling rate so obtained is low.

It is commonplace to cool ingots continuously cast at normal atmospheric pressure by sprays of cooling liquid, usually water. The cooling rates so obtained are high. Heretofore, it has not been considered possible to cool hot ingots by sprays of water or other cooling liquid under the reduced pressures required for vacuum casting. When water is sprayed through a nozzle, it expands and loses temperature. It is known that when water is sprayed into a chamber maintained at vacuum casting pressure, it either vaproizes or appears as snow or ice. Its cooling properties in either of these states are much inferior to those properties in its liquid state.

It is an object of our invention to provide apparatus and process for accelerated liquid cooling of vacuum cast ingots or the like. It is another object to provide such apparatus and process for cooling vacuum cast ingots under a pressure intermediate vacuum casting pressure and atmospheric pressure. It is still another object to provide such apparatus and process for continuously withdrawing a vacuum cast ingot into a cooling chamber of intermediate pressure and continuously cooling it therein. Additional objects of our invention will appear in the course of the following description thereof.

Vacuum cast ingots are conventionally cooled in a vacuum because it is not feasible to withdraw them continuously from the vacuum chamber. The difficulty is in providing a seal between ingot surface and chamber that will support a pressure differential between atmospheric pressure and presures of about 10^{-3} mm of Hg. We have discovered that the seal formed between the molten metal teemed into the ingot mold and the mold will support a significant pressure differential, though not of the order above mentioned, and that the ingot can be liquid spray cooled in a cooling chamber at a subatmospheric pressure higher than the casting chamber pressure. Our invention will be more readily comprehended by reference to the attached drawings of an embodiment thereof presently preferred by us.

FIG. 1 is an elevation, partially schematic and partially in cross-section, of apparatus of our invention.

FIG. 2 is an enlarged detail of the spray nozzle arrangement of the apparatus of FIG. 1.

FIG. 3 is an enlarged detail in cross-section of the seal between the molten metal and the ingot mold in FIG. 1.

In the figures, chamber 1 adapted for vacuum casting of metals encloses a tundish 2 which holds molten metal 3 and is replenished from time to time by means not shown. Tundish 2 is provided with a bottom nozzle 4 through which the molten metal 3 flows into an open end upright mold 5. Chamber 1 is sealed to the outside of mold 5 by sealing means 6.

Also sealed to the mold 5 by sealing means 6 is a closed cooling chamber 7 into which the solidified ingot 8 descends from the lower end of mold 5. Below cooling chamber 7 and sealed to the lower end thereof is hydraulic cylinder 9. The piston rod 10 of cylinder 9 is capable of extension upwardly to the bottom of mold 5 and carries a plug 11 which at the beginning of the casting operation is positoned inside the lower end of mold 5. The molten metal 3 teemed into mold 5 falls onto plug 11 and freezes there. As the ingot 8 builds up the piston rod 10 of hydraulic cylinder 9 is retracted, lowering plug 11 and ingot 8, into cooling chamber 7. The cooling chamber 7 is provided with a door, not shown, through which ingot 8 is removed after it has been cooled.

Out of cooling chamber 7 opens an exhaust duct 13 which is connected to steam evacuator 14. Steam is supplied to evacuator 14 through steam line 15 from a source not shown. Evacuator 14 discharges into a barometric condenser 16 which is supplied with water through pipe line 17 from a source not shown. The condensate from condenser 16 is discharged through barometric leg 18 into a sump 19 provided with a weir 20 arranged to maintain a liquid level in sump 19 above the lower end of barometric leg 18. The overflow of weir 20 is carried off by drain pipe 21.

Within cooling chamber 7 banks of vertically spaced nozzles 23—23 are disposed on all sides of the pathe of travel of ingot 8, so as to spray cooling liquid on the hot ingot. The construction of these banks 23 is shown in detail in FIG. 2. Each bank 23 comprises a vertical pipe 25 to which are attached vertically spaced spray nozzles 26—26. Cooling liquid is supplied from a source not shown through pipe 27 which connects with each vertical pipe 25. The lower end of cooling chamber 7 is formed so that liquid drains therefrom through a barometric leg 28 into a sump 29. Sump 29, like sump 19 previously described, is provided with a weir 30 which maintains the level of the liquid therein above the lower end of barometric leg 28. The overflow of weir 30 is carried off by drain 31.

In the absence of an ingot in mold 5, cooling chamber 7 is connected to closed chamber 1 by that ingot mold. When molten metal 3 is teemed into mold 5, the molten metal 3 forms with ingot mold 5 a seal as is illustrated in detail in FIG. 3, thereby sealing off chamber 1 from chamber 7. The molten metal 3 makes contact with the inside wall of mold 5 near its upper end over an area 33. The molten metal 3 begins to freeze in a thin skin 34 from the bottom upwards. On freezing, this skin 34 tends to shrink away from mold 5, degrading the seal, but the seal is constantly renewed by fresh molten metal 3 teemed into mold 5 from tundish 2. The seal, therefore, is that effected by the dynamic head 33 of unfrozen metal in ingot 5.

We have found that the seal formed between the molten metal being teemed into the mold and the mold will support a pressure differential on the order of 5 mm of Hg. By this we mean that the leakage through this seal will be small enough that it can be accommodated by conventional vacuum pumping apparatus. Those skilled in the art of commercial vacuum casting of metals know that the term "seal" used with respect to such vacuum systems is always relative and, in fact, indicates a tolerable rate of leakage. Such evacuated chambers are always continuously pumped and a seal may comprise or include an actual opening, such as a narrow slit, as long as the leak through it is not large enough to overload the pumping apparatus. For example, in furnaces in which the charge is melted by electron beams, the electron emitting apparatus is commonly positioned in a separate chamber maintained at a lower pressure that the melting chamber and the elctron beam passes into the melting chamber through a slit.

We prefer to cool hot ingots with water sprayed onto the ingot in our cooling chamber which is maintained by continuous pumping at a pressure on the order of 5 mm Hg. It is most desirable in such circumstances to maintain the cooling chamber differential pressure so that the absolute cooling chamber pressure is somewhat greater than about 4.6 mm of Hg. Below a pressure of 4.58 mm of Hg. water sprayed into the cooling chamber either vaporizes or freezes, depending on its temperature, but cannot exist in the liquid state and so is ineffective in cooling the ingot. Above a pressure of 4.58 mm Hg., the water exists in the liquid state over a range of temperatures above 0° C. This range is much narrower at 5 mm Hg. pressure than it is at atmospheric pressure. However, if the cooling water should freeze as it is sprayed into the chamber, the heat of the ingot will melt it, rather than convert it directly to vapor. Since, as we have mentioned, the pressure in casting chamber **1** is very low, on the order of 10^{-3}mm of Hg., the pressure differential between cooling chamber **7** and chamber **1** and the absolute pressure in cooling chamber **7** are substantially the same.

It is known that in the liquid cooling at atmospheric pressure of cast or hot rolled metal a layer of cooling liquid vapor forms on the surface of the metal and tends to insulate the metal from the cooling liquid. This condition is aggravated in our apparatus because the boiling point of the cooling liquid is lower at the subatmospheric pressure in our cooling chamber. In order to penetrate this film of vapor the cooling liquid must be sprayed at high pressure from nozzles located close to the surface of the hot metal. We prefer to use spray pressures of the order of 100 psi and when casting ingots 6 inches square, for example, to position the nozzles not more than 4 or 5 inches from the ingot surface. We prefer to supply through the cooling liquid sprays some excess of cooling liquid over that vaporized so that cooling liquid must be drained from the cooling chamber through barometric leg **28.** The vapor arising from the evaporation of cooling liquid in our cooling chamber tends to increase the pressure therein. Therefore we control the operation of ejector **14** to maintain a constant differential pressure between casting chamber **1** and cooling chamber **7.**

We claim:

1. The process of cooling an ingot of metal continuously cast into an open end mold in a casting zone maintained at a pressure below atmospheric pressure comprising continuously transferring the ingot from the casting zone into a cooling zone maintained at a pressure intermediate that of the casting zone and atmospheric pressure by withdrawing it from the discharge end of the mold so that the zone of contact between molten metal and mold seals off the casting zone from the cooling zone, and spraying cooling liquid onto the ingot in the cooling zone.

2. The process of claim **1** in which the pressure in the casting zone is not greater than about 10^{-3} mm of Hg.

3. The process of claim **1** in which the pressure in the cooling zone is somewhat greater then the pressure at which the cooling liquid exists in the liquid state in said cooling zone.

4. The process of claim **3** in which the cooling liquid is water and the pressure in the cooling zone is at least about 4.6 mm of Hg.

5. The process of claim **4** in which the cooling water is sprayed onto the ingot at high pressure.

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