

[54] **APPARATUS FOR FLOAT CONTINUOUS CASTING OF METAL**
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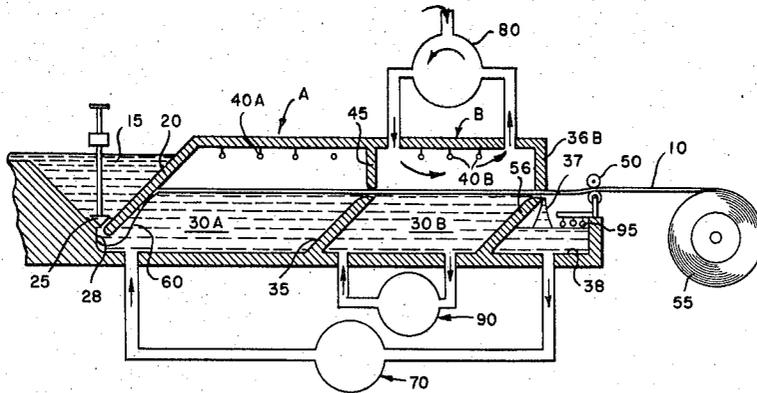
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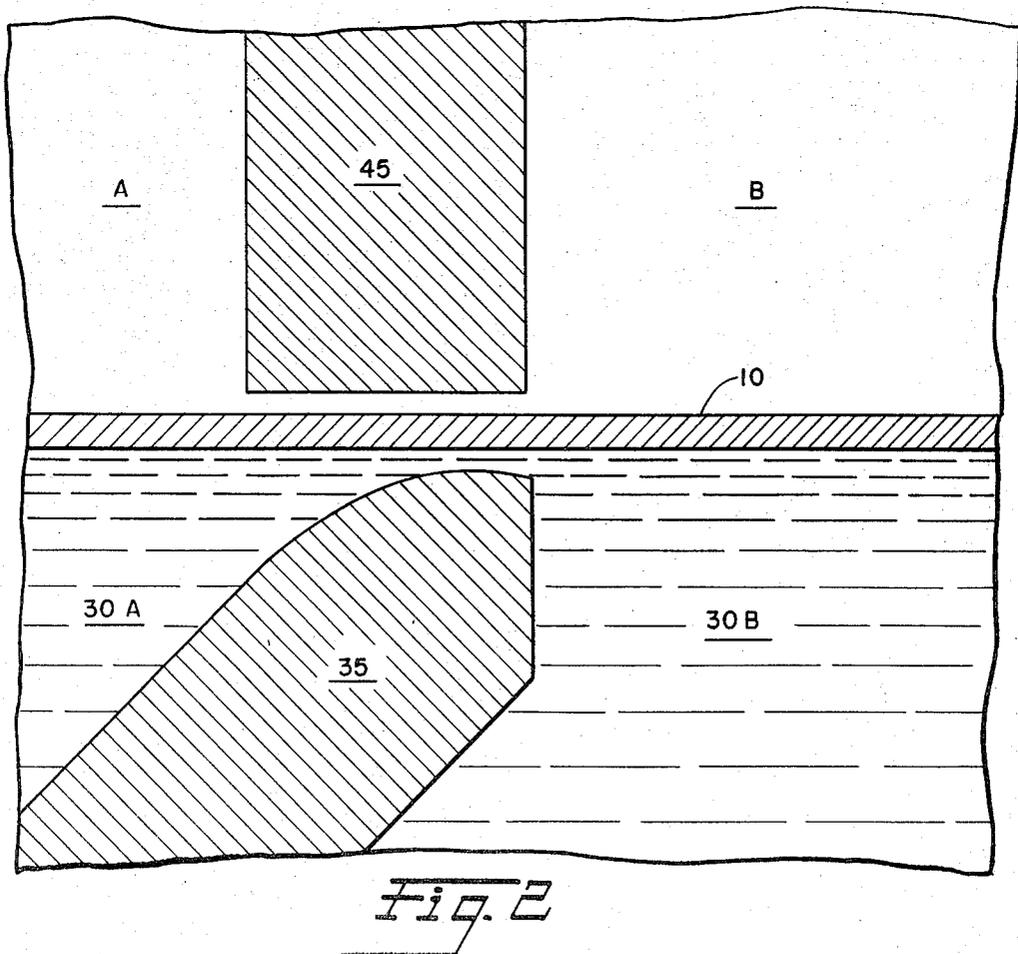
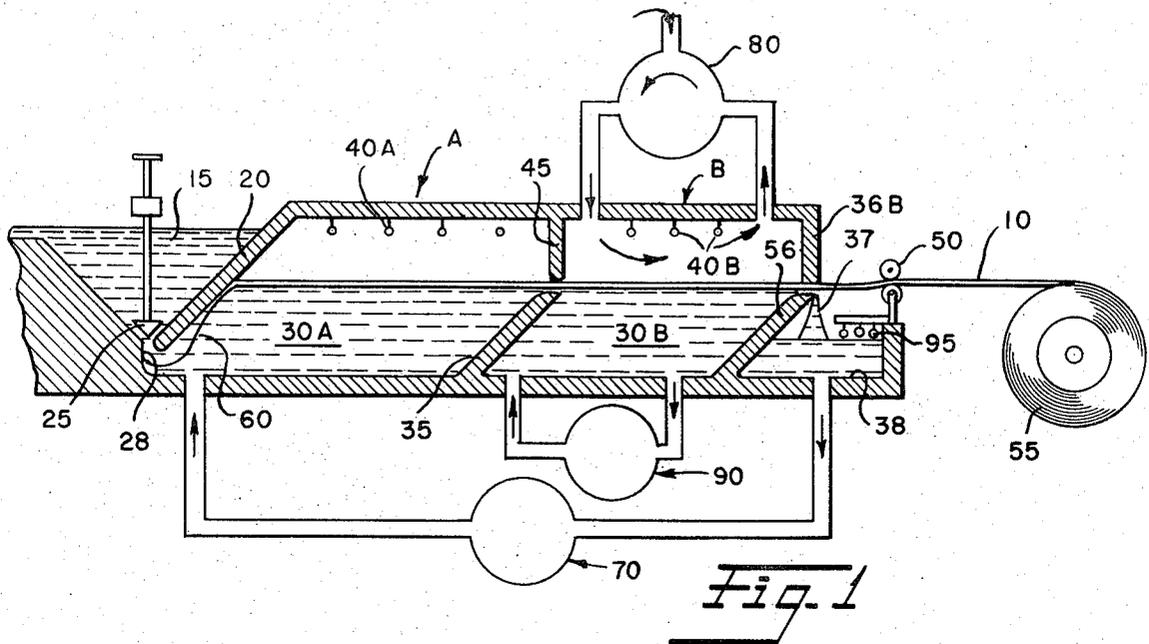
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[57] **ABSTRACT**
 Continuously casting molten metal by dispersing on a heated carrier liquid and rapidly cooling in a second zone containing cooler carrier liquid.

5 Claims, 2 Drawing Figures





APPARATUS FOR FLOAT CONTINUOUS CASTING OF METAL

This invention relates to a novel process for continuously casting metal on a liquid carrier material sometimes referred to as a float sheet process, for the purpose of producing a flat, smooth surface casting in an economical manner. More specifically, the present invention provides as its primary objective a process for continuously casting metal into flat shapes, plates, strips, etc., all hereinafter generally referred to as "sheet," on a liquid carrier material of higher specific gravity than the metal to be cast and maintained at a temperature at least as high as the liquidus temperature of the cast metal. The invention is particularly suited for aluminum and its alloys, but is not limited thereto. As used herein the term "metal" is intended to mean a pure metal or any alloy combination. Continuous casting of metal onto a liquid carrier is relatively new. The most pertinent prior art are two U.S. Patents to Kuratomi, Nos. 3,565,154 and 3,587,710, which show processes wherein a molten metal is dispersed on a liquid carrier such as lead maintained within a low temperature range.

Briefly, the present invention provides for the manufacture of continuous castings having very smooth surfaces of uniform thickness in an economical manner. This is accomplished by maintaining the carrier liquid at a temperature no lower than the liquidus temperature of the cast metal, whereby the carrier will not unduly cool the cast metal upon contact. This assures the cast metal the opportunity to spread quickly to uniform thickness. Thereafter, in the preferred embodiment of the invention, especially when aluminum or aluminum alloys form the cast metal, a quick cooling phase is applied to the smooth parallel surfaces formed before solidification. The major distinguishing difference of the present invention from the Kuratomi patents is the utilization of the heated casting zone at or above the liquidus temperature of the melt material to be cast, and the subsequent cooling phase. These features of the invention are important in making sheet articles of uniform thickness and of plane surfaces as compared to the cooler casting methods of Kuratomi.

Other objects and advantages of the invention will be seen by those skilled in this art from the following description of the best mode of carrying out the invention, and examples thereof, made in connection with the accompanying drawing wherein;

FIG. 1 is a vertical section view of the preferred apparatus for carrying out the process of this invention, and

FIG. 2 is a blown up portion of FIG. 1.

Referring now to the DRAWING, the process and apparatus of FIG. 1 illustrates the use of two very distinct temperature zones in which the flat, smooth surfaced sheet metal 10 is formed. The metal 15 to be cast, or melt, is first heated to a molten state, cleaned and degassed in a well-known manner, and delivered into a feed vessel 20 having outlet flow control means 25. The outlet 28 may be positioned at a different level than shown with respect to sheet 10; however, in its preferred form the invention contemplates use of a gravity feed underpour system such as illustrated. The latter is designed to deliver the melt into the casting apparatus with little or no turbulence to produce the smoothest article possible at an early stage in the process.

The two temperature zones are established in chambers indicated generally as A and B. A carrier liquid of higher specific gravity than melt 15 is contained in carrier vessels 30A and 30B.

The liquid should have the following characteristics:

1. Its density in the operating temperature range must be higher than that of the metal to be cast.
2. It has to remain liquid without boiling in a temperature range from about 50° C. above the metal liquidus temperature to below the melt solidus temperature or at least substantially below the liquidus temperature of the metal to be cast.
3. It has to be virtually inert to the metal to be cast.
4. It should have a relatively low vapor pressure within the operating temperature range.

There are several liquids which meet these requirements for aluminum and its alloys. Aluminum melts at 660° C. Most of its alloys solidify in a temperature range from slightly below 660° C. to above 600° C.

For example, with aluminum as the melt to be cast, a good carrier liquid material is a ternary eutectic composed of 81.5 wt percent BaCl₂, 16.0 wt percent KCl, and 2.5 wt percent CaF₂ with a eutectic temperature of about 560° C.

Another suitable group of carrier liquid materials for aluminum and aluminum alloys are low-melting heavy glasses. The system Na₂O-SiO₂ - PbO-SiO₂ has two eutectics below 600° C., while the system 3 PbO-2 SiO₂ - Na₂O-SiO₂ has one eutectic at 590° C. with about 40 mol percent PbO. There are a number of other materials suitable for the purpose of this invention. Generally, glasses containing lead oxide and potash are low-melting and have densities up to 6.2.

Carrier liquid vessels 30A and 30B are separated by a thermal barrier wall 35 which, as shown more clearly in FIG. 2, reaches upward and slightly rearwardly to form a weir over which a thin layer of carrier liquid is permitted to travel and on which liquid sheet 10 rides into chamber B. Wall 36 at the rearward end of chamber B is of essentially the same construction as wall 35, having a spill-over carrier liquid at 37 into vessel 38. In the upper regions of chambers A and B are located a series of heating elements 40A and 40B, radiant burners or of other suitable heater means, depending on the melt material to be processed and temperatures desired. Heating elements 40B are needed for the initial heating of carrier liquid in vessel 30B only. The upper regions are also separated by another thermal barrier wall 45 which is adapted to reach downward almost to the top surface of sheet 10.

A pair of transport rolls 50, or other suitable means, is provided to raise sheet 10 slightly above the carrier liquid and to move the sheet to the coiling equipment 55. The transport rolls are driven at variable speed to move the metal sheet 10 through the apparatus depending on the thickness desired and in coordination with the feed vessel 20 and flow means 25.

In operation the melt 15 is permitted to flow through outlet 28 between wall 20 and carrier liquid in 30A as shown for illustration purposes by line 60. The desired amount of melt to enter chamber A is synchronized, within a given time period, with the removal rate controlled by transport rollers 50. The underpour system delivers melt 15 by gravity. The lighter metal floats upwards due to buoyancy in the heated, inert carrier liq-

uid and forward due to the slant of wall 20 and movement of sheet 10.

As the melt 15 reaches the surface of carrier liquid in 30A it forms a liquid layer or sheet having a thickness dependent principally upon the densities of carrier liquid and melt, their surface tensions and on the feed rate of the melt as regulated by the take-up speed of the transport rollers 50. It is important that the melt be introduced in a heated environment in which the carrier liquid and the gaseous, inert medium above sheet 10 in chamber A are maintained at or above the liquidus temperature of the melt. The melt may, in such an environment, seek its equilibrium thickness which it maintains during its travel period through the apparatus. The gaseous medium is preferably inert such as nitrogen or other suitable gases, however, radiant heaters maintaining the temperature in these atmospheres may be utilized, so long as undue reaction or contamination of the melt material does not occur. The width of the apparatus itself is not critical except that it should be sufficiently wide to permit the melt to reach its equilibrium thickness, and consequent width if so desired. One of the chief advantages of the invention is in casting initially in a hot zone so that the melt to be cast can flow over the carrier liquid to the equilibrium thickness and width or it can be restricted as desired. The process, therefore, has a large degree of width freedom flexible for making a wide range of products. However, it is also contemplated within the scope of the invention to provide apparatus of less than equilibrium width when thicker sheet material is desired, or to provide vertical heat resistant knives in the path of the melt to produce multiple sheets in a single run. In one modification of the invention the side walls of the carrier liquid vessels may be provided with an electromagnetic field of sufficient strength to repel the melt in order to prevent melt-wall contact and binding. A smooth even flow through the apparatus is thereby assured. The length of chamber A is, therefore, determined by the nature of the melt material and the desired width it is to reach as it travels there-through on the hot carrier liquid. The latter is maintained at the appropriate temperature by means of heating elements therein and/or by heating in the recirculating apparatus indicated generally as 70, but in any case the heat exchange means for the chamber A carrier liquid is adapted to maintain it at a temperature approximately within the range of from the melt liquidus temperature to 50°C above it. The gas in chamber A, nitrogen for example, is maintained under slight pressure by conventional means. In chamber B occurs the cooling of the process. Solidification of metallic materials such as aluminum or its alloys should be quick to avoid undesirable coarse grains and segregation of intermetallic crystals, and in the present invention, solidification should be carried out only where a smooth interface between metal and carrier liquid exists. Lastly, the solidification should be carried out rapidly enough to ensure commercially attractive production rates. The thermal barrier walls 35 and 45 define the transition from chamber A to chamber B in which an inert gas above sheet 10 and carrier liquid 30B is maintained at temperatures substantially below the liquidus temperature of melt 15. As mentioned above, and as shown in FIG. 2, a small space between walls 35 and 45 and sheet 10 is provided to pre-

vent any deforming direct contact with sheet 10. The clearance should be as small as possible while being sure to prevent this contact.

Wall 35 is slanted rearwardly, and the upper edge thereof is rounded and slanted to assure a smooth, non-turbulent flow from chamber 30A and 30B.

As sheet 10 floats into chamber B, it is immediately contacted by cooler carrier liquid and overhead gas, whereby solidification is rapidly achieved as desired. The size of chamber B is determined by the volumes needed to maintain the temperature for cooling gas and carrier liquid and by the metal surface which requires cooling. The carrier liquid material must be capable of being heated in excess of the melt liquidus temperature in or before entering chamber A and yet must remain a substantially free flowing liquid when cooled to substantially below the melt liquidus temperature in chamber B. The gas temperature in chamber B is maintained by a cooling system indicated generally as 80, and the gas flow is in the direction of the flow of sheet 10 for optimum quick cooling efficiency with the cold nitrogen for example. The cooling chamber B is long enough to solidify the metal material being cast and designed for early removal from contact with the carrier liquid. The cold nitrogen and the cooled carrier liquid reduce the sheet temperature quickly to solidify the metal and to allow sheet separation from the carrier liquid and handling by the transport and coiler rolls. After such separation and before winding on the coil roll the sheet can be exposed to further cold air or other quenching media, for example, to below 400°C. in the case of aluminum. Similarly, a temperature control, temperature adjusting and recycling system 90 is provided for the carrier liquid. The heaters in chamber B are needed only during start-up for bringing the carrier liquid to the desired temperature below the melt liquidus temperature.

Vessel 38 catches the carrier liquid overflow 37 and is equipped with heating means 95 to prevent solidification. Heat barrier walls 36 and 36B prevent excessive escape of cooling gas and carrier liquid, yet are spaced from sheet 10 in substantially the same manner as described above for walls 35 and 45.

The heating to above liquidus temperature of the metal to be cast, followed by smooth, even flow onto the carrier liquid where the melt is permitted to reach equilibrium thickness under the conditions of the process with smooth upper and lower surfaces, followed by rapid cooling in an environment substantially below the liquidus temperature of the melt material characterizes the novel features of the preferred embodiment of this invention. The advantages of smooth surfaces, good crystalline structure, controllable thickness, are primarily achieved from above characteristics.

Example I

To produce an aluminum sheet, use a carrier liquid having the following ingredients:

- 81.5 weight percent BaCl₂ (≈61 mole percent)
- 16.0 weight percent KCl (≈34 mole percent)
- 2.5 weight percent CaF₂ (≈5 mole percent)

Such a mix forms a ternary eutectic at about 560° C and has a density higher than liquid or solid aluminum. Its vapor pressure is low and it does not react with aluminum.

The metal cast can be aluminum of commercial purity, i.e., alloy 1100, with a composition (in weight percent) of 99.10 percent Al, 0.10 percent Si, 0.60 percent Fe, 0.14 percent Cu, remainder trace elements.

Prepare the aluminum to be cast by melting, cleaning and degassing by conventional means and charge the feed vessel. Begin introducing the aluminum through the underpour flow control until a sheet of desirable width and thickness is formed and adjust the speed of take-up roller to maintain the sheet. The metal introduced underneath the salt solution surface in vessel 30 A should have a temperature of 690° C. while maintaining the temperature of the salt solution in vessel 30 A throughout the casting process at 670 ± 5 C.

As the metal floats on top of the carrier liquid and spreads evenly over the carrier liquid surface to a thickness of about one-tenth inch, no oxidation of the metal surface will take place since the space above is preferably filled with nitrogen gas kept at a temperature of 670 C ± 5.

The liquid metal, after spreading, travels uniformly while supported by the carrier liquid from vessel 30 A over the heat barrier 35 into vessel 30 B. Upon entering vessel 30 B the metal will quickly solidify since the carrier liquid in vessel B is maintained at 600° C ± 5 C while the nitrogen in vessel B is maintained at 20° C ± 5° C. Solidification of alloy 1100 is completed at 655° C.

The solidified metal exits from vessel 30 B while still being carried on liquid salt solution. The latter separates by gravity from the metal sheet upon exit from vessel 30 B to be recycled to vessel 30 A. The solid metal sheet is gripped by transport rollers 50 and withdrawn at a rate synchronized with the liquid metal input to vessel 30 A.

Example II

This example follows the same procedure of Example I with the following exceptions:

The carrier liquid is lead alloyed with 0.2 percent (wt) aluminum (saturation at 658° C). A protective agent adhering to the lead surface is added to prevent diffusion of lead into the aluminum and to facilitate separation of the solidified aluminum sheet from the liquid lead. As a variation the aluminum can be introduced not by underpour but by overflow onto the lead bath in vessel 30 A. The lead in vessel 30 A should be kept at a temperature of 660° C ± 2 C and in vessel 30 B at 300° C ± 5 C.

In another modification of the invention, thickness of the metal sheet is regulated by providing a movable barrier across the top of wall 35. It stays in this position until the melt in chamber A has reached the desired thickness. At that moment the barrier is moved at a controlled rate across the surface of carrier liquid in 30 B. The rate of barrier movement is adjusted so that the same amount of sheet 10 moves across wall 35 for solidification as liquid melt is added to chamber A. Thus, the thickness of the solidified sheet 10 can be properly maintained.

It is also within the scope of this invention to protect

the upper surface before, during, and after solidification from oxidation. This can be done by either a third liquid layer having similar characteristics as the carrier liquid but a density lighter than that of the metal being cast, or by an inert gas as utilized above.

Aluminum and its alloys are most suitable for this casting process, however, other metals and their alloys, including magnesium, beryllium, and even iron and steel may also be processed by this technique, provided the well-known protective measures are taken to prevent oxidation and health hazards, and provided the proper heavy carrier liquids are selected.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

What is claimed and desired to be secured by United States Letters Patents is:

1. Apparatus for continuously casting a metal material comprising, a feed vessel for containing the metal material in molten state with outlet means for metering said material into the apparatus for processing,

a first chamber comprising a first vessel for containing a heated liquid carrier material, inlet and outlet means on opposite ends of said first vessel for delivering and casting said metal material on said carrier liquid, and permitting passage thereof out of said first vessel while still residing on said carrier liquid,

a second chamber adjacent said first chamber comprising a second vessel adapted to contain a cooler carrier liquid, said second vessel positioned with respect to said first vessel to receive said cast metal material but limiting the flow of carrier material from the first to second vessels, and means for causing said metal material to sequentially travel through said apparatus over said heated carrier material and cooler carrier material.

2. Apparatus as defined in claim 1, wherein said first vessel inlet is comprised of an opening below the surface level of said heated carrier liquid when contained therein, and said outlet is comprised of a weir wall over which said heated carrier material is permitted to flow.

3. Apparatus as defined in claim 2, wherein said first chamber is further comprised of a virtually closed compartment over said first vessel for virtually containing heated inert gas.

4. Apparatus as defined in claim 3, wherein said second vessel is comprised of a rear wall over which a thin layer of said cooler carrier liquid is adapted to flow in normal operation of said apparatus.

5. Apparatus is defined in claim 4, wherein said second chamber is further comprised of a compartment over said second vessel for containing cooled inert gas.

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