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L. F. KEEL ETAL

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METHOD OF PURGING MOLD AND POURING METAL THEREIN

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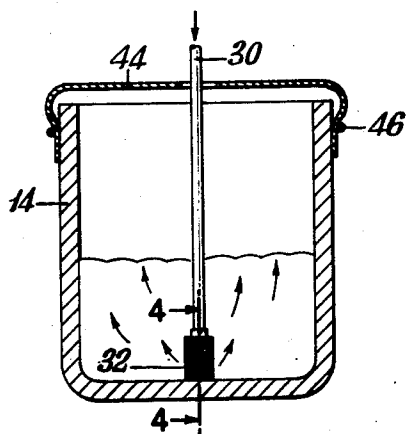


Fig. 1.

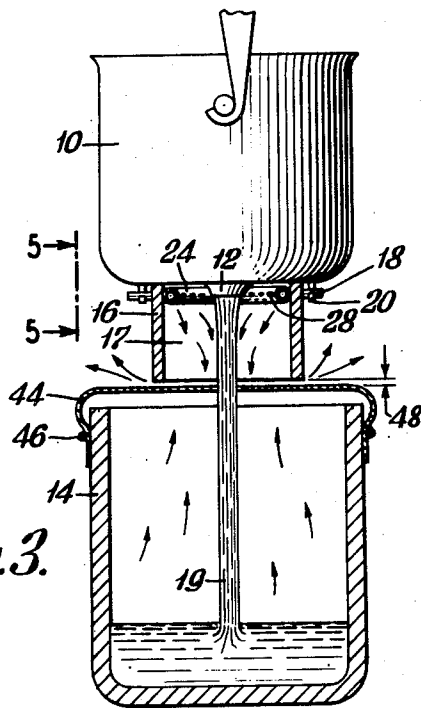


Fig. 3.

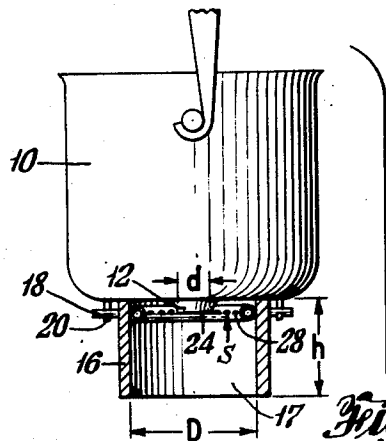


Fig. 2.

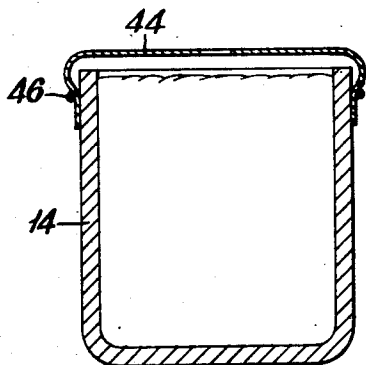
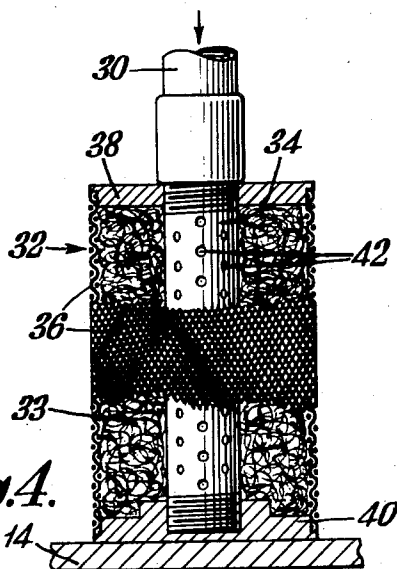


Fig. 4.



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1

3,174,200

METHOD OF PURGING MOLD AND POURING METAL THEREIN

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The present invention relates to a method for teeming or pouring molten metal into a pre-formed mold within an atmosphere of a protective gas. This is a continuation-in-part of an application Serial No. 840,270 filed September 16, 1959 now abandoned.

Ordinarily, when a metal such as molten steel is removed from the melting furnace, it is tapped into a ladle or similar device and thence transferred by a teeming process to ingot molds in which the metal is permitted to solidify prior to being further shaped. In the usual manner, a ladle having a bottom pouring spout and containing the molten steel, is positioned above a suitably shaped ingot mold. A stream of metal is then directed into the mold until a suitable amount has been poured after which the stream is discontinued and the ladle moved to the next mold. On initially striking the mold floor, the liquid metal generally splashes outwardly against the mold walls where particles of the metal adhere and solidify. When air or ordinary atmosphere is present in the mold, this solidifying steel becomes oxidized and adheres to the mold walls and as the liquid level rises, the solidified particles do not remelt and combine with the molten steel but rather adhere to the mold and form imperfectly bonded scabs on the ingot sides.

Another difficulty encountered in the usual casting technique is initiated when the molten stream, on flowing from the ladle or reservoir, adsorbs oxygen from the surrounding atmosphere. The oxides resulting from such adsorption become dispersed throughout the ingot and constitute metallurgical defects which tend to reduce both fatigue strength and transverse strength in the ultimately formed metal. These imperfections are generically classified as oxide inclusions.

While many of the diverse applications and uses to which steel is put are unaffected by inferior material, still, where a higher grade of metal is demanded such as in the instance of precisely designed aircraft components, the above-noted defects and ingot inclusions render the steel highly undesirable. Fabricators and designers of aircraft components are continually asking for cleaner or inclusion free steels in order to utilize the maximum potential properties of the steel which are undesirably affected by imperfections originating during teeming.

It is therefore a principal object of the present invention to provide an improved method for charging a mold.

A further object is to provide a method for charging a mold with a flow of molten metal entirely within an oxygen free atmosphere.

Another object is to provide a method for charging a mold from a pouring ladle containing molten metal, said mold and the space intermediate the mold and ladle having been purged of air and provided with an inert gas atmosphere.

In the drawings:

FIG. 1 is a view of a longitudinal cross section through a metal casting mold prepared for purging according to the invention;

FIG. 2 is a longitudinal view in partial cross section of a casting mold, just prior to the charging operation;

FIG. 3 is a view in partial cross section of the appa-

2

ratus shown in FIG. 2 illustrating the charging operation in accordance with the invention; and

FIG. 4 is a view on an enlarged scale taken along line 4-4 of FIG. 1 of the gas diffuser;

In brief, the invention contemplates a method for teeming molten metal into formed molds whereby the mold interior is substantially purged of oxygen and provided with an inert gas or argon atmosphere. Prior to transferring the molten metal to said mold the pouring ladle or reservoir is positioned directly above the mold and the space intermediate the ladle and mold is maintained free of air by supplying an argon atmosphere during the actual metal transfer period.

As shown in the drawings, the apparatus adapted to carry out the present process consists of a typical ladle 10 for teeming molten metal which, according to practice, is provided with an interior lining of a refractory material. A pouring spout 12 is appended to the ladle lower portion and communicates with the interior thereof for directing a vertical stream of metal into a mold 14. A metal casing member 16 is removably fixed to the lower outer surface of the ladle to surround the pouring spout 12 and define a protective enclosure 17, but leaving the bottom unobstructed.

The casing 16, as shown detailed in FIGS. 2 and 3, may be removable and is provided with outjutting lugs 18 which register in suitable grooves within corresponding tabs 20 protruding from the ladle lower surface. When properly located, the casing 16 is positioned in abutting contact with the ladle lower surface to minimize any possible space therebetween, but as a matter of practicality, a space intermediate the casing and ladle would not be detrimental to the process but would merely increase the amount of inert gas required to shield the down flowing steel stream 19.

The upper end of casing 16 is provided on the interior surface with a formed ring or manifold 24 which comprises a circular gas conduit shaped preferably to conform to the casing surface and fastened thereto by welding or similar means. A gas inlet extending through the casing wall affords means for communicating the manifold with a suitable source of argon or other protective gas. A plurality of jets or openings 28 in the manifold are directed laterally toward the outlet of the pouring spout 12 in order that the protective argon will effectively displace air and fill the entire enclosure 17 defined by the casing.

Referring to FIG. 2, the physical dimensions of the casing 16 are dependent on several factors among which are: (a) the diameter d of the ladle pouring spout (b) the degree of divergence of the teem stream and (c) the fact that the top edge of the casing should closely mate with some flat portion on the ladle outer surface to provide a minimum gap therebetween. The effectiveness of the argon atmosphere in protecting the teem stream will depend in large on having the dispensing ring as close as possible to the stream of molten metal, however, the casing diameter D should be great enough to avoid contacting the stream.

To illustrate, the preferred casing size for pouring spouts having an opening between $1\frac{1}{4}$ and 3 inches in diameter, the casing diameter D should properly be between 6 and 16 inches. The height " h " of the casing to afford the best protection should be such that the casing lower edge extends not less than 4 inches below the pouring spout opening. The maximum height h to diameter D ratio is formed to be preferably not greater than 1.

The preferred disposition of the gas manifold 24 within casing 16 to adequately fill space 17 with the protecting gas is determined by the vertical distance between the pouring spout lower surface and the lower surface of

the ladle. This distance should be maintained such that when the casing 16 is in position abutting the ladle outer surface, the manifold 24 will be approximately $\frac{1}{4}$ inch below the pouring spout lower surface.

The mold 14, as shown in the figures, comprises essentially an open topped container for receiving and holding the molten metal during the cooling and solidifying period. As previously mentioned, this mold may be for the purpose of forming ingots or similar bodies which are subsequently rolled or shaped. While not here illustrated, the disclosed process is equally adaptable to use on shaped molds for making sand castings in the usual foundry practice.

It is also notable that the present teeming method is not limited in its application to molds having a top opening for receiving metal. The method is equally applicable in the instance of bottom poured molds wherein a tunnel or molten metal conducting device receives the molten stream and thence directs it to the mold bottom portion. It is understood that when such an apparatus is utilized, the mold cavity as well as the conducting device are both provided with the inert gas atmosphere.

An embodiment of a mold particularly suitable to the process is one having, in the floor or lower surface, means for introducing a purging gas. A preferred means for introducing the gas into an ingot mold is illustrated in FIG. 1 and FIG. 4, and consists of an elongated gas conduit 30 having at the upper or inlet end a suitable coupling for connection to a gas source, and at the lower end, which extends into the mold interior, a gas diffuser 32.

The diffuser 32 is generally positioned on or immediately adjacent the mold floor and consists, as shown in FIG. 4, of a central perforated tube 34 for directing the purge gas into an enclosure 33 defined peripherally by an outer sheath 36, an upper palte 38 fastened thereto, and a lower plate 40 forming an end closure to both the sheath 36 and the central conduit 34. The enclosure 33 may be substantially filled with a gas permeable material such as steel wool or a similar porous metallic material. The primary purpose of the metallic filler is to more evenly disperse the gas issuing from the perforations 42 provided in the lower portion of conduit 34. In this respect, the sheath 36 is constructed and formed such that gas issuing from the diffuser will do so in a relatively uniform manner and thereby create a minimum amount of gas turbulence in the mold. A preferred form of the sheath 36 is found to be a suitably formed cylinder of wire mesh or screening material.

The gas diffuser 32 and gas conduit 30, as shown in FIG. 1, is inserted preferably from the top of the mold with the diffuser resting on the mold floor. It is rather important that the diffuser be so positioned that argon or other purge gas emitting therefrom will completely sweep the mold floor clear of any air which might later be entrapped in the mold corners.

To retain the purging gas in the mold cavity, and maintain the inert atmosphere, a vented top covering 44 is disposed across the mold opening and there held in place.

The mold cover 44 is provided with an aperture which functions as a vent for exiting air or mold gas during the purging period. The aperture may be made in the cover prior to the latter being fastened into place on the mold. Preferably though the aperture is made by merely puncturing the mold cover with the diffuser 30-32, after it has been positioned across the mold opening.

We have found that a suitable cover 44 is provided by a thin, flangible metal foil such as aluminum foil. Two specific advantages are achieved through the use of a metal foil; first, the cover may be readily formed over the mold edges and then fastened, and secondly the frangible cover will be easily melted and pierced by the molten stream as it flows from the ladle. Since the cover 44 will offer virtually no resistance to the downward flowing teem stream, there is no need to accurately align the ladle with the mold cover aperture.

In practicing the disclosed metal pouring process, the following description of the sequential steps to be followed is made with particular reference to FIGS. 1, 2 and 3. The mold, as shown in FIG. 1, is prepared for the initial purging operation by being first covered with an aluminum sheet 44 which is fastened peripherally to form a closure across the mold opening. In actual practice, there may be a hot top positioned at the top of the ingot mold. Before purging, the joint between the mold and the hot top must be sealed to prevent the back infiltration of air during and after purging. This may be done, for example, by tamping asbestos rope or rolled aluminum foil into the joint. When a hot top is used, the aluminum sheet 44 forms a closure across the hot top opening.

The gas diffuser 32 and conduit 30 are then inserted through a vent hole in the aluminum foil for introducing argon at the mold bottom surface. This hole or aperture as previously mentioned may be provided before the cover 44 is positioned or alternatively it may be made when the diffuser is inserted into the mold. Purging of the mold is done preferably just prior to the pouring or teeming of the metal in order to minimize the infiltration of air back into the air purged mold. For best results, it has been found that the air purging operation should begin at a time that will allow only about two minutes to elapse between the termination of the purge period and the start of the subsequent teeming operation.

The method of purging with argon or another inert gas, as herein referred to, is fully described in a copending application Serial No. 781,414, filed December 17, 1958, now Patent No. 3,012,591, issued December 12, 1961 and comprises essentially a process for the introduction of an inert gas such as argon into a receptacle containing a gas or air which is to be displaced by the purging gas. In accordance with the disclosed method, purging gas is introduced into one end of the receptacle in such a manner that the incoming gas forms a substantially uniform front transversely across the receptacle and with further introduction of gas the front is advanced uniformly and vertically through the receptacle thereby purging the displaced gas out the opposite end. Depending on which of the gases is heavier, the purge gas may be introduced at either the top or bottom of the receptacle.

In the present invention which preferably utilizes argon as the purging gas, it is advantageous to introduce the argon at the bottom of the mold in a uniformly dispersed manner in order that, with further addition thereof, the intergas layer front will rise vertically through the mold and displace all air therefrom. This air displacing method is highly advantageous because of the minimized degree of air and argon mixing which takes place in the mold, a factor which suggests both efficiency and economy. It has been found, for instance, that essentially all the air may be removed from the mold by use of as little as 1.25 mold volumes of argon when introduced as heretofore noted. This is in sharp contrast to the 7 to 10 mold volumes of purging gas which would ordinarily be required to purge an equivalent receptacle or mold if the purge gas were introduced in a stream or jet such as to cause excessive turbulence and gas mixing.

Immediately after purging, the molten metal containing ladle 10 is positioned directly above the argon filled mold 14 as shown in FIG. 2 with the pouring spout 12 aligned above the mold top opening. Since the molten stream will readily pierce the cover 44 upon contact therewith, alignment need not be so critical as to position the pouring spout above the aperture. At this point, argon flow to the manifold 24 may be commenced in order to displace substantially all of the air from the space adjacent the pouring spout 12 and within the casing member enclosure 17. Argon flow is then continued for at least 8 to 10 seconds before the molten stream 19 is released from the ladle by removal of the flow retarding plug.

The ladle 10 is properly positioned for the teeming operation when the lower edge of casing 16 is spaced

within a few inches of the mold cover 44, as indicated at 48. It is desirable to maintain some spacing or gap 48 so that gas being displaced from the mold, by the entering molten metal, may escape to the atmosphere. This escaping gas constitutes a substantial volume and is not only argon forced from the mold, but also gases which evolve from the metal. Indicative of the preferential width of gap 48 which may exist between the mold cover 44 and the casing 16, it has been found that to prevent infiltration of undesirable gases back into the argon filled mold, during teeming, the exit velocity of gas passing through the gap 48 should reach a minimum of 0.25 feet per second. Where of course, the conditions prevailing in the vicinity of the teeming operation, such as strong drafts or air currents, would upset an orderly flow of gas from the mold, it is necessary to increase the gas flow from manifold 24 to maintain a purely argon atmosphere.

Under normal operating conditions existing in a mill, it has been found that 1000 to 1200 cubic feet per hour of argon flow will give satisfactory protection to a molten stream and mold when the total exposed area in the gap 48 is between $\frac{1}{2}$ and 2 square feet. This was determined in tests wherein the argon flow of 1000 to 1200 cubic feet per hour was maintained utilizing a casing 16 having a diameter of 10" to 13" and a gap 48 of from 2" to 8". It should be noted that in the event the ladle is lowered a sufficient distance as to break through the aluminum foil cover 44, in effect, eliminating the gap 48, the down flowing argon will still provide a protective layer to the incoming metal stream. Regardless of the gap 48, a continuous flow of argon from the manifold 24, along with the inflowing steel stream, is an essential element of the invention to avoid aspiration of air into the enclosure 17 as the teeming proceeds.

On the basis of the amount of argon used per ton of steel teemed in accordance with the process, it has been determined that, in general, argon consumption may vary from 10 to 20 cubic feet. This wide range of values stems from several variables including the teeming time, condition of the pouring ladle spout, type of steel, etc.

The disclosed argon purging method possesses many advantages not heretofore available in the metal casting art. For instance, the simplicity of equipment and the operation thereof constitutes a highly desirable feature as contrasted with similar methods such as vacuum casting, and completely enclosing both mold and melting furnace in a controlled atmosphere. Also, while it has been previously suggested and demonstrated that a protective atmosphere might be provided for teeming alloy steel utilizing nitrogen as the shielding gas, this system, as practiced, does not afford to the steel the degree of cleanliness measured by the amount of non-metallic inclusions, as does the present process. Our novel combination of mold purging method using argon gas, together with the argon shielded teeming operation, affords essentially complete elimination of oxygen from the entire space through which the molten steel must pass.

The use of argon as the protective atmosphere is preferable to the use of nitrogen for several reasons. Notably, in steels in which titanium is added as a carbon stabilizer, reaction with nitrogen is objectionable because the stabilizing effects of the titanium are reduced by combinations with nitrogen. Further, as regards steel used in rails and ship plate, the nitrogen content of such metals must be minimized due to its effect on lower impact strength.

Indicative of the beneficial effect derived through the use of the present method, the following example illustrates the sharp reduction in non-metallic inclusions realized in a comparison best conducted as follows. The procedure followed in the test program was to examine two specimens taken from each of six steel ingots; the specimens were grouped in pairs at the beginning, middle and end of the teeming of the heat. One ingot of each of these pairs was air cast according to the existing

standard operation and the other was argon cast according to the method of the invention. One of the two specimens from each ingot was taken from the top of the ingot, the other from approximately the middle section.

EXAMPLE I

Heat No. F 6721, Grade SAE 4140 steel of aircraft quality

Air-Cast			Argon-Cast		
Ingot No.	Position	Inclusion Rating	Ingot No.	Position	Inclusion Rating
1	Top	7	2	Top	0
1	Middle	32	2	Middle	4
3	Top	33	4	Top	5
3	Middle	16	4	Middle	22
5	Top	12	6	Top	1
5	Middle	17	6	Middle	1
Air-Cast			Argon-Cast		
Average-inclusion rating=19.5			Average-inclusion rating=5.5		

A comparison of the average inclusion rating for the air-cast and argon-cast ingots as noted above, illustrates the benefits derived from the argon casting method of the invention. Ingot No. 4 in the above Example I was argon cast without benefit of teem stream protection; that is, the mold was purged with argon before pouring but the teem stream argon protection was not used. Though its average inclusion rating, 13.5, is better than that of the No. 3 air-cast ingot, 24.5 (average of top and middle tests, poured from the same location in the heat, it nevertheless shows the effects of the absence of the teem stream protection, having a much higher average inclusion rating than either of the other two argon-cast ingots.

It is understood that modifications of the above described method and apparatus may be made without departing from the spirit and scope of the invention.

What is claimed is:

1. A method for forming a metal casting substantially free of oxide inclusions which comprises: providing a pouring ladle containing a molten charge of the metal to be cast, providing a mold having a cavity therein with opposed ends defining the contour of the casting to be formed, one of said ends having an opening to receive a stream of the molten metal, providing said open end with a frangible sheet having a venting aperture therethrough to afford a substantial closure to the mold cavity, introducing to the other end of said mold cavity a flow of a non-oxidizing purging gas, diffusing said purging gas flow across said other end to establish a substantially horizontal front extending transversely of the mold cavity, continuing the flow of purging gas at a sufficient rate to advance said front along the mold cavity in a direction toward the venting aperture, thereby displacing any other gas contained in the mold with said purging gas, thereafter positioning the metal containing pouring ladle in alignment with the mold cavity opening, and in close proximity thereto to define a slight space therebetween, providing to the space defined by said vented frangible metal sheet and the pouring ladle a flow of a non-oxidizing gas to establish a non-oxidizing atmosphere in said space, and introducing a stream of the molten metal from the pouring ladle to pass through the frangible mold closure, and enter said mold cavity while simultaneously continuing the flow of non-oxidizing gas during said pouring period at a sufficient rate to maintain the non-oxidizing atmosphere about the molten metal stream.

2. Method for forming a metal casting substantially free of oxide inclusions which comprises: providing a pouring ladle containing a molten charge of the metal

to be cast, providing a mold having a cavity therein with opposed upper and lower ends, the upper of said ends having an opening to receive a stream of the molten metal from said pouring ladle, said cavity being normally occupied by a residual gas, fastening across the opening at said one mold end a metallic foil sheet having a venting aperture therethrough, said aperture being of a substantially lesser cross-sectional area than the mold opening thereby providing a substantial closure of the mold cavity, introducing to the other end of said mold cavity a flow of a non-oxidizing purging gas, diffusing said gas flow across the cavity other end to establish a substantially horizontal diffusion front between the purging gas and said residual gas, said front extending transversely of the mold cavity, thereafter continuing the purging gas flow to advance the horizontal front vertically along the mold cavity and toward the closure aperture at a sufficient rate to prevent diffusion of the purge gas and said residual gas, until the residual gas is substantially displaced from the mold cavity, positioning the pouring ladle in substantial vertical alignment with the mold opening and upwardly adjacent thereto to afford a slight space therebetween, providing the space between said metallic foil closure, and the pouring ladle with a flow of the purging gas to establish a non-oxidizing atmosphere, and introducing a stream of the molten metal from the pouring ladle to pass through the metallic foil closure and enter the mold cavity while containing the flow of purging gas about the molten stream to maintain the non-oxidizing atmosphere.

3. A method substantially as described in claim 2 in

which the volume of gas used in purging the mold cavity is between 1.25 and 7 times the volume of the mold cavity.

4. In a method of casting metal wherein the mold into which the metal is to be poured is purged of its residual gas by the introduction of a non-oxidizing purging gas, prior to the pouring of the metal therein, the improvement which comprises fastening a metallic foil sheet having an aperture therethrough across the opening of said mold to provide a substantial closure thereof, introducing the non-oxidizing purge gas to the mold to purge it of its residual gas, and thereafter pouring the molten metal through the metallic foil closure and into the mold whereby said closure will be melted away by said molten metal.

5. A method as claimed in claim 4 in which the metallic foil has an aperture having a cross-sectional area substantially smaller than the cross-sectional area of the mold opening and wherein argon comprises said non-oxidizing purging gas.

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