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P. D. HESS ET AL

3,039,864

TREATMENT OF MOLTEN LIGHT METALS

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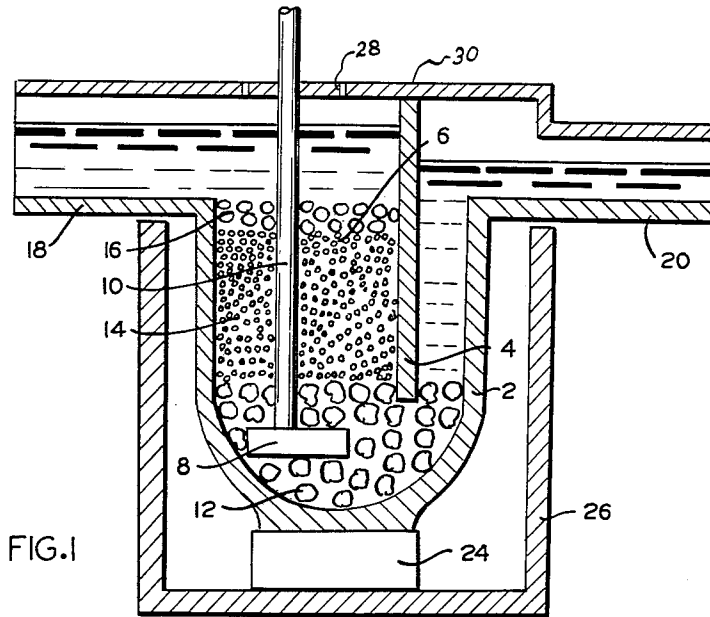


FIG. 1

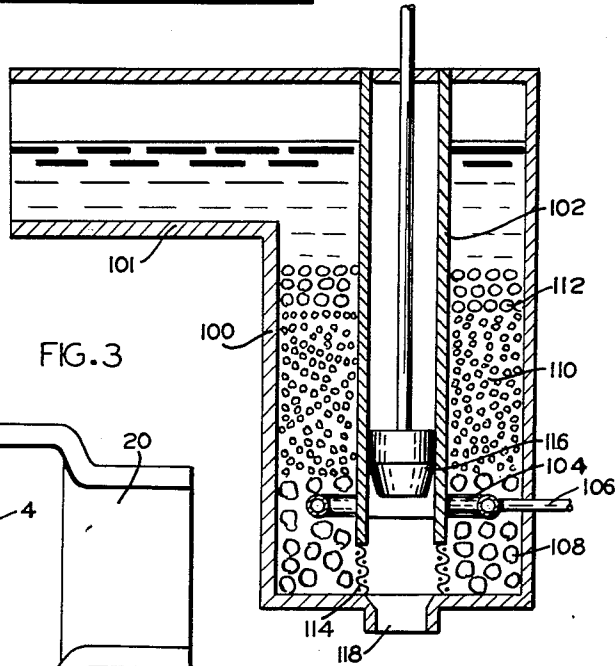


FIG. 3

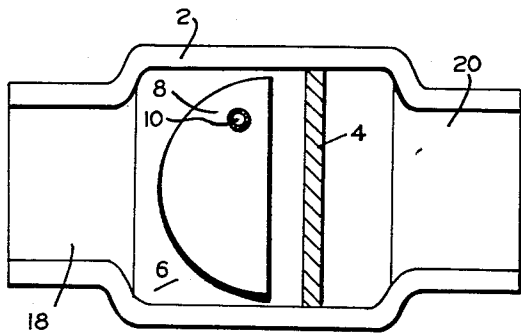


FIG. 2

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3,039,864

**TREATMENT OF MOLTEN LIGHT METALS**  
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This invention relates to the fluxing and filtering of molten light metals to remove gas and finely-divided non-metallic particles therein, and more particularly to a method for such treatment employable during molten metal transfer.

The term "light metal," as used herein, refers to aluminum, magnesium, and to alloys thereof wherein these metals predominate.

In the melting of light metals and their transfer to other receptacles, gas is frequently entrapped or dissolved within the molten metal. This is primarily hydrogen, most of which is probably generated by the reaction with the metal of even small amounts of moisture in the surrounding environment. Also, a film generally forms on the surface of the molten metal which largely consists of the oxides of the light metal and/or its alloying constituents, and this film is broken up and dispersed within the molten metal during subsequent agitation or transfer. Upon casting of the metal article, a considerable amount of gas and oxide particles are entrapped within.

In the cast article, a large proportion of the hydrogen is usually considered to be in solution in the solid metal, i.e., it is in the monatomic state, although pockets or voids filled with molecular hydrogen have been observed. In the subsequent fabrication of wrought articles, thermal treatments are generally employed to aid in working the metal or to develop the desired strength, and it is generally considered that such heating produces diffusion of the monatomic hydrogen to any voids or discontinuities within the metal whereat association into molecular hydrogen takes place. It is also believed that the small occluded oxide particles tend to nucleate the formation of hydrogen-filled voids. Recently the problem of so-called "flakes" within the internal metal structure of wrought products has been associated with these hydrogen-filled voids.

Because of the gas pressures developed by the molecular gas, subsequent working of the metal does not effect a heating of the void or discontinuity, and heating of the article at elevated temperatures may increase such pressures to the point where the metal suffers local plastic deformation.

The problem of occluded gas has become increasingly important with the growing requirements for high-strength light metal articles. Any gas-filled void may not only constitute an area of weakness in the final article, but may give rise to flakes, blisters, slivers and other defects which may cause rejection. This recognition has prompted investigations to find a method for the removal of gas from the molten light metal so as to produce a substantially gas-free article.

It has heretofore been proposed to flux molten metals with chlorine, nitrogen and inert gases to reduce the hydrogen content thereof, usually in the ladles or in the melting and holding furnaces. However, large quantities of gas generally remain in the cast article, and the process has been costly and time consuming.

It has also been proposed to filter molten aluminum through a bed of refractory filter medium to remove finely-divided non-metallic solids. This procedure has proven highly beneficial in this respect but has failed to appreciably reduce the gas content of the metal. Originally,

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increases in vacuum density of the castings were considered as reflecting removal of gas but more recent methods of gas determination have indicated that this assumption was not completely correct and that the results were not quantitatively determinative of the gas remaining in the metal.

It is an object of this invention to provide a method for the substantial removal of gas from molten light metals.

It is also an object to provide a rapid method for the simultaneous removal of gas and finely divided solids during the treatment of molten light metals.

A further object is to provide a treatment for simultaneous removal of gas and impurities which is employable in the molten metal transfer line at high metal flow rates.

Other objects and advantages will be evident from the following description and the attached drawing wherein:

FIG. 1 is a longitudinal section of suitable apparatus installed in a molten metal transfer trough for the practice of this invention.

FIG. 2 is a top plan view of the refractory chamber shown in FIG. 1, in the absence of molten metal and refractory material so as to expose the inert gas device.

FIG. 3 is a section of apparatus suitable for use in a casting downsput.

It has now been discovered that gas and non-metallic solids may be substantially removed from molten light metals by a method in which the molten metal is passed downwardly through a bed of refractory filter medium while passing an inert gas upwardly therethrough.

The countercurrent flow of inert fluxing gas and molten metal should be through a distance of at least two inches of filter medium, and preferably six inches or more, and the particles of the refractory filter medium should be substantially of a granular size of 3 to 14 mesh. However, for complete filtering of the molten metal, the total depth of the bed should be at least six inches.

The refractory filter medium is a substance which is inert toward the molten light metal being treated. It must also have a higher melting point, possess high hardness and be of sufficient density to gravitationally remain in place during operation. Among such substances are chromite, corundum, forsterite, magnesite, periclase, silicon carbide and zircon. Of these tabular alumina (synthetic corundum) is preferred. All of these materials, with the exception of forsterite and zircon, are free from silica; but in the case of the last two, the silica is chemically combined with another oxide in such a manner that it is not attacked by the molten light metal. For this reason, all of these materials are regarded as being inert towards the molten light metal.

The fluxing gas must be substantially inert towards the molten light metal. The inert gases of the periodic table, helium, neon, argon, krypton and xenon, and mixtures thereof, are preferred for the practice of this invention. However, nitrogen may also be employed in the treatment of aluminum and those aluminum base alloys where nitride-formation is not of significance. Chlorine, a common fluxing gas, has been found unsuitable for this application because of its tendency to form chlorides as well as to result in clogging of the filter medium after only short periods of operation.

An hourly metal to gas flow rate of about 30 to 500 pounds of metal per cubic foot of inert gas (at 70° F. and 760 mm.) has been found effective. A lesser amount of gas effects insufficient gas removal whereas greater amounts do not increase the removal sufficiently to economically warrant use and may often interfere with the operation of the apparatus.

The flow rate of metal through the bed of refractory filter medium will be determined by the head of molten

metal or metal hydrostatic pressure, depth of the bed, fluxing gas flow rate and mode of preparation of the filter bed. In the present method, improvement in filtering efficiency and metal flow rate has been noted when the filter bed is prepared by adding the refractory material to an initial body of molten metal in the filtering container and allowing the refractory to settle therein. This improvement is particularly notable in the case of apparatus wherein the metal flow is U-shaped, such as illustrated in FIG. 1. More particularly, the refractory material is washed, dried and preheated to a temperature of 1200 to 1600° F., and preferably above 1400° F., after which it is added to the filtering container which has been initially provided with molten metal sufficient to cover the refractory material which is added thereto. The refractory is allowed to settle and may be tamped lightly. Thereafter, molten metal is passed therethrough. In this method of preparation, the fluxing gas should be introduced prior to commencement of metal flow to degas the initial body of metal. Additional information concerning this method of refractory bed preparation can be found in the copending application of K. J. Brondyke and P. T. Stroup, Serial No. 655,746, filed April 29, 1957, now Patent No. 2,863,558. Utilizing an 8 inch deep filter bed prepared in this manner in an apparatus similar to that in FIG. 3 with an hourly metal to gas flow rate of about 470 pounds of metal per cubic foot of gas, it is possible to treat 168 pounds of metal per hour per square inch of filter bed.

The filter medium may also be prepared by heating the refractory and adding it to the dry filter container or the dry container with the refractory bed in place may be heated to the desired temperature; in either instance, the temperature of the unit should be high enough to prevent chilling and freezing of the molten metal which is subsequently introduced.

The device for introducing the fluxing gas into the filter bed may be any of the well-known media, such as porous or perforated pipes and plates, or the bottom of the filter chamber may be constructed of a porous or perforated material so that gas introduced into a manifold below it will diffuse into the filter chamber.

A base for the refractory filter medium is preferably prepared by the use of larger ceramic bodies, such as alumina balls, having a diameter of 1/4-3/4 inch or more. This permits rapid flow of the metal under the baffle of FIG. 1, or rapid discharge from the apparatus of FIG. 3, wherein it also serves as a physical retainer for the finer ceramic bodies of the filter medium. A layer of these coarser bodies may also be placed at the top of the fine filter medium to prevent its displacement. These larger refractory particles are considered to have little, if any, effect upon the gas removal or upon the removal of solid impurities.

During the filtration operation, it is essential that the apparatus be maintained at a temperature between about 120 and 1600° F. to prevent freezing of the molten metal, and also to maintain the molten metal level above the top of the refractory material so as to prevent cohesion of the refractory mass which is now quite wet with molten metal and impurities.

It has been found that the countercurrent flow of inert gas in the refractory filter medium not only does not impair the filtering action of the filter medium in removing finely divided solids but, in actuality, tends to improve it. The present invention removes the dissolved hydrogen much more thoroughly than conventional fluxing techniques. Much less fluxing gas is required, and a combined fluxing-filtering action is performed during metal transfer, thus saving the time required for furnace fluxing as conventionally employed. Furthermore, the method is easily employed in the treatment of large volumes of metal, thus permitting its use in general casting practice.

Furthermore, the present invention has enabled substantial lowering of the gas content of metal that had been previously fluxed with chlorine for considerable periods

of time in the holding furnace in accordance with conventional practice.

Results have proven this method far more effective than either the refractory filter or fluxing gas alone. If the filter alone is used finely divided solids are removed but gas content is substantially unchanged. If gas fluxing alone is used, there is produced an undesired turbulence in the metal which often results in the entrapment and/or generation of finely divided solids.

That the filter medium of the present invention exerts a very great influence on the efficiency of gas removal has been determined by comparison to the results obtained by use of conventional packing materials. Apparently, in the diffusion of gas from the molten metal into the fluxing gas, a surface phenomenon is involved which limits the diffusion of the hydrogen from the metal into the inert gas bubble, such as a film at the interface between the metal and the fluxing gas bubble.

This surface phenomenon theory has been postulated because of the variance in efficiency of the various gases in conventional fluxing techniques. Although all gases (free from hydrogen) should theoretically permit diffusion of hydrogen from the melt at an equal rate, chlorine has proved much more effective in furnace and crucible fluxing. Since there is no reaction between the chlorine and hydrogen, it has been suggested that the chlorine overcomes some film or surface phenomenon.

In the method of the present invention, the inert gases have proven to be far more effective than an equivalent amount of the normally superior chlorine. This would indicate that fluxing the molten metal in accordance with the present invention has the effect of reducing or eliminating this retarding film and permits rapid diffusion of hydrogen into the inert gas bubbles, possibly because the solid impurities have been the interfering agency.

For a more detailed explanation, reference is made to the attached drawing wherein FIGS. 1 and 2 illustrate one form of apparatus suitable for the practice of the present invention. The refractory chamber or crucible 2 is partitioned by the transverse baffle 4 to provide a fluxing section 6, in which there is situated a fluxing gas device 8, which may be a porous or perforated manifold, and which is connected to the fluxing gas supply by the entry tube 10. Alternatively, several perforated or porous tubes may be employed. In the device illustrated, a layer of large refractory particles 12 has been placed at the base of the refractory chamber, and the finer ceramic bodies 14 constituting the refractory filter medium have been deposited thereon. Upon the filter medium a layer of large refractory particles 16 has been superposed.

Molten metal from the furnace flows into the apparatus from the inlet trough 18, passes downwardly through the filter medium 14 wherein it is fluxed by the countercurrent flow of inert gas from the fluxing gas device 8. It then passes under the baffle 4, upward and is discharged through the outlet trough 20.

The refractory chamber 2 is shown seated on the block support 24 within the heated enclosure 26 which maintains the apparatus at the proper temperature. This may be accomplished by internal heating or by passage of hot gases through the enclosure 26.

The fluxing gas device 8 is desirably situated to minimize any flow of gas to the opposite side of the baffle 4 and thus prevent turbulence of the molten metal in the outlet trough. Placing the fluxing device above the level of the base of the baffle or so that the angle between its near end and the bottom of the baffle is 15 degrees or less has been found satisfactory. Several vents 28 are provided in the fluxing side of the trough cover 30 to permit escape of the inert gas and prevent a pressure buildup above the metal.

Referring now to FIG. 3, apparatus in accordance with the present invention has been provided in the downspout of casting apparatus. The downspout 100 attached to the inlet trough 101 is provided with a centrally-

disposed plunger guide tube 102 and a fluxing gas device or ring 104 connected to the fluxing gas supply by the entry tube 106. Preferably, a layer of large ceramic bodies 108 is first deposited within the apparatus and then the filter medium of fine refractory bodies 110 is introduced, after which a layer of large ceramic bodies 112 may be superposed.

A screen or grate 114 may also be provided between the bottom of the guide tube 102 and the base of the downspout 100, or a baffle arrangement may be employed, to act as a mechanical retainer for the refractory bodies. The bevelled plunger 116 may be lowered into contact with the sides of the downspout discharge 118 to prevent further discharge of molten metal during preparation of the filter bed according to the "wet" method or, during operation of the device, it can maintain the filter medium submerged in molten aluminum during transfer of the downspout from one mold to another. However, it may sometimes be desirable to use disposable filter media, i.e., to change the filter medium after each casting operation. The downspout is preferably maintained at temperature by several gas burners located about its periphery.

Exemplary of the efficacy of the present invention is the data in Table 1 which indicates the results obtained by treating an alloy nominally composed of aluminum, 4.4 percent copper, 0.8 percent silicon, 0.8 percent manganese and 0.4 percent magnesium. The device employed was a trough filter of the type illustrated in FIG. 1 which was provided with a 12 inch bed of refractory filter medium comprised of 3 to 6 mesh tabular alumina deposited upon an 8 inch base of 3/4 inch alumina balls, and prepared in accordance with the preferred practice. A porous carbon diffuser was placed in the tabular alumina balls for introducing argon into the filter bed. The temperature of the apparatus was maintained at about 1350° F.

TABLE 1

*Hydrogen-Solids Removal by Crucible-Type Inert Gas-Filter*

| Metal Flow,<br>Lbs./Hr. | Gas<br>Flow,<br>Cu. Ft./<br>Hr. | Lbs./Hr.<br>C.F.H. | Vacuum Density, <sup>1</sup><br>g./cc. |       | Hydrogen, <sup>2</sup><br>Ml/100 g. |       | Percent<br>Hydro-<br>gen Re-<br>moved |
|-------------------------|---------------------------------|--------------------|----------------------------------------|-------|-------------------------------------|-------|---------------------------------------|
|                         |                                 |                    | Before                                 | After | Before                              | After |                                       |
| 3,140-----              | 16.9                            | 186                | 2.3                                    | 2.79  | 0.27                                | 0.08  | 70                                    |
| 2,090-----              | 17.4                            | 120                | 2.2                                    | 2.76  | 0.43                                | 0.13  | 70                                    |
| 1,080-----              | 18.2                            | 59                 | 2.4                                    | 2.78  | 0.34                                | 0.06  | 82                                    |

<sup>1</sup> Vacuum density tests may be made in apparatus of the type described in *Light Metals* (London), vol. 15, pages 396, 397 (September 1952). The molten metal is frozen under a vacuum of 5 mm. and the density determination is made on the casting.

<sup>2</sup> Hydrogen determinations made by the "Telegas" instrument described in the *Journal of the Institute of Metals* (London), vol. 86, pp. 212-219 (1958).

Exemplary results obtained by treating the same aluminum alloy in a downspout device of the type illustrated in FIG. 3 are set forth in Table 2. The filter bed was prepared according to the preferred method by depositing in an initial body of molten metal an 8 inch bed of 3 to 6 mesh tabular alumina on about 3 inches of 3/4 inch alumina balls. A perforated metal diffuser ring was placed in the alumina balls for introducing argon gas into the filter bed. The temperature of the unit was maintained at about 1350° F. during the casting operation.

TABLE 2

*Hydrogen-Solids Removal by Downspout Inert Gas-Filter*

| Metal Flow,<br>Lbs./Hr. | Gas<br>Flow,<br>Cu. Ft./<br>Hr. | Lbs./Hr.<br>C.F.H. | Vacuum Density, <sup>1</sup><br>g./cc. |       | Hydrogen, <sup>2</sup><br>Ml/100 g. |       | Percent<br>Hydro-<br>gen Re-<br>moved |
|-------------------------|---------------------------------|--------------------|----------------------------------------|-------|-------------------------------------|-------|---------------------------------------|
|                         |                                 |                    | Before                                 | After | Before                              | After |                                       |
| 2,040-----              | 10.6                            | 192                | 2.2                                    | 2.77  | 0.21                                | 0.08  | 62                                    |
| 2,040-----              | 10.6                            | 192                | 2.3                                    | 2.78  | 0.37                                | 0.12  | 68                                    |

<sup>1</sup> See footnote, Table 1.

<sup>2</sup> See footnote, Table 1.

As is evident from the data in the preceding tables, the method of the present invention is highly effective in removing gas from the molten metal while simultaneously eliminating undesirable finely divided, non-metallic solids.

The method is very rapid, adaptable to use in conventional metal transfer systems, and relatively inexpensive in comparison to the general commercial practice of fluxing in the melting furnaces. By the method of this invention, a greatly superior product can be obtained, both as cast and after subsequent working operations and attendant thermal treatments.

Having thus described the invention, we claim:

1. In the treatment of molten light metals for the substantial removal therefrom of gas and finely divided solids, the method comprising providing a container through which the molten light metal is passed, said container having a filter bed therein composed of refractory granules 3 to 14 mesh in size and inert toward the molten light metal, completely covering said bed with molten metal, introducing metal to be treated above the bed and passing it downwardly therethrough, at the same time passing an inert fluxing gas upwardly through at least a portion of the bed and in countercurrent relationship to the descending molten metal for a distance of at least two inches in the bed, said fluxing gas as spent gas and the gas derived from the molten metal being released from the surface of molten metal that has not passed through said bed.

2. The method according to claim 1 wherein the proportion of inert fluxing gas introduced to the metal being treated is one cubic foot of fluxing gas to 30 to 500 pounds of molten metal.

3. The method according to claim 1 wherein the inert fluxing gas is introduced adjacent the bottom of the filter bed.

4. The method according to claim 1 wherein the filter

bed of 3 to 14 mesh refractory granules is supported upon coarser refractory bodies.

5. The method according to claim 1 wherein the filter bed of 3 to 14 mesh refractory granules is supported upon coarser refractory bodies and the inert fluxing gas is introduced in the mass of said supporting refractory bodies.

6. The method according to claim 1 wherein the refractory bodies are preheated to a temperature between 1200 and 1800° F. and added to a body of molten metal in the container before filtering is commenced.

7. In the treatment of molten light metals for the sub-

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stantial removal therefrom of gas and finely divided solids, the method comprising providing a container in a metal transfer system through which the molten light metal is passed, said container having a filter bed therein composed of refractory granules 3 to 14 mesh in size and inert toward the molten light metal, completely covering said bed with molten metal, introducing metal to be treated above the bed and passing it downwardly there-through, at the same time passing an inert fluxing gas upwardly through at least a portion of the bed and in countercurrent relationship to the descending molten metal for a distance of at least two inches in the bed, said fluxing gas as spent gas and the gas derived from the

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molten metal being released from the surface of the molten metal above the filter bed.

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**UNITED STATES PATENT OFFICE  
CERTIFICATE OF CORRECTION**

Patent No. 3,039,864

June 19, 1962

Paul D. Hess et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 5, TABLE 1, footnote 1, line 2 thereof, for  
"396, 397" read -- 306, 307 --.

Signed and sealed this 16th day of October 1962.

(SEAL)

Attest:

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