CONVENTION APPLICATION FOR A PATENT

XXX (1) SWISS ALUMINIUM LTD.

We CH-3965 Chippis, Switzerland

hereby apply for the grant of a Patent for an invention entitled: (2)

"METHOD AND APPARATUS FOR THE REMOVAL OF IMPURITIES FROM METAL"

which is described in the accompanying complete specification. This application is a Convention application and is based on the applications numbered (3) 914,511 and 13,029 for a patent or similar protection made in (4) UNITED STATES OF AMERICA on 12th June, 1978 and 21st February, 1979.


Our address for service is Messrs. Edwd. Waters & Sons, Patent Attorneys, 50 Queen Street, Melbourne, Victoria, Australia.

DATED this 8th day of JUNE, 1979.

(5)

SWISS ALUMINIUM LTD.

by: J. A. Barnes

Reg'd. Patent Attorney

To: THE COMMISSIONER OF PATENTS.
COMMONWEALTH OF AUSTRALIA

Patents Act 1952-1969

DECLARATION IN SUPPORT OF A CONVENTION APPLICATION FOR A PATENT OR PATENT OF ADDITION

In support of the Convention Application made by

Swiss Aluminium Ltd.

(hereinafter referred to as the applicant) for a Patent

for an invention entitled:

Method and Apparatus for the Removal of Impurities from Molten Metal

I, Paul Douady and Bruno Squaitamatti

of Swiss Aluminium Ltd., CH-3965 Chippis, Switzerland

do solemnly and sincerely declare as follows:

1. I am authorised by the applicant for the patent to make this declaration on its behalf.

2. The basic applications as defined by Section 141 of the Act were made in the United States of America on the 12th day of June 1978, by Swiss Aluminium Ltd.

3. Joseph A. Clumpner, a citizen of the U.S.A., residing at 296 Prince Towne Drive, Creve Coeur, Missouri 63141, USA

is the actual inventor of the invention and the facts upon which the applicant is entitled to make the application are as follow:

The applicant is the assignee of the said Joseph A. Clumpner.

4. The basic applications referred to in paragraph 2 of this Declaration were the first applications made in a Convention country in respect of the invention the subject of the application.

DECLARED at Chippis, Switzerland

on the 15th day of May 1979.

Swiss Aluminium Ltd.

To: The Commissioner of Patents.
Claim

1. An improved apparatus for use in the degassing of molten metal which comprises:

   chamber means having an elongated side wall portion and a central axis;

   inlet means at a first height for introducing said molten metal into said chamber;

   outlet means at a second height below said first height for removing said molten metal from said chamber;

   fluxing gas inlet means at a third height below said first height for introducing said fluxing gas into said chamber wherein at least said molten metal inlet means is located with respect to said side wall portion for tangentially introducing said molten metal into said chamber in either a clockwise or counterclockwise flow direction such that said.../2
molten metal swirlingly flows in said clockwise or counterclockwise manner from said metal inlet towards said metal outlet as said fluxing gas percolates up through said molten metal.
The following statement is a full description of this invention, including the best method of performing it known to: us:

"METHOD AND APPARATUS FOR THE REMOVAL OF IMPURITIES FROM METAL"
BACKGROUND OF THE INVENTION

The present invention relates to the treatment of liquids with gases and more particularly to the degassing of molten metal. Molten metal, particularly molten aluminum in practice, generally contains entrained and dissolved impurities both gaseous and solid which are deleterious to the final cast product. These impurities may affect the final cast product after the molten metal is solidified whereby processing may be hampered or the final product may be less ductile or have poor finishing and anodizing characteristics. The impurities may originate from several sources. For example, the impurities may include metallic impurities such as alkaline and alkaline earth metals and dissolved hydrogen gas and occluded surface oxide films which have become broken up and are entrained in the molten metal. In addition, inclusions may originate as insoluble impurities such as carbides, borides and others or eroded furnace and trough refractories.

One process for removing gaseous impurities from molten metals is by degassing. The physical process involves injecting a fluxing gas into the melt. The hydrogen enters the purged gas bubbles by diffusing through the melt to the bubble where it adheres to the bubble surface and is adsorbed into the bubble itself. The hydrogen is then carried out of the melt by the bubble.

It is naturally highly desirable to improve the degassing of molten metals in order to remove or minimize such impurities in the final cast product, particularly with respect to molten aluminum and especially, for example, when the resultant metal is to be used in a decorative product such as a decorative trim or products bearing critical specifications such as aircraft forgings and extrusions and light gauge foil stock.
Impurities as aforesaid cause loss of properties such as tensile strength and corrosion resistance in the final cast product.

Rigorous metal treatment processes such as gas fluxing or melt filtration have minimized the occurrence of such defects. However, while such treatments have generally been successful in reducing the occurrence of such defects to satisfactory levels, they have been found to be inefficient and/or uneconomical. Conventionally conducted gas fluxing processes such as general hearth fluxing have involved the introduction of the fluxing gas to a holding furnace containing a quantity of molten metal. This procedure requires that the molten metal be held in the furnace for significant time while the fluxing gas is circulated so that the metal being treated would remain constant and treatment could take place. This procedure has many drawbacks, among them, the reduced efficiency and increased cost resulting from the prolonged idleness of the furnace during the fluxing operation and more importantly, the lack of efficiency of the fluxing operation due to poor coverage of the molten metal by the fluxing gas which is attributable to the large bubble size and poor bubble dispersion within the melt. Further factors comprise the restriction of location to the furnace which permits the re-entry of impurities to the melt before casting, and the high emissions resulting from both the sheer quantity of flux required and the location of its circulation.

As an alternative to the batch-type fluxing operations employed as aforesaid, certain fluxing operations were employed in an inline manner; that is, the operation and associated apparatus were located outside the melting or
holding furnace and often between the melting furnace and either the holding furnace or the holding furnace and the casting station. This helped to alleviate the inefficiency and high cost resulting from furnace idleness when batch fluxing but was not successful in improving the efficiency of the degassing operation itself, in that the large size of the units and the undesirably large quantities of fluxing gas required per unit of molten metal were both costly and detrimental to air purity.

A typical inline gas fluxing technique is disclosed in U.S. Patent 3,737,304. In the aforenoted patent, a bed of "stones" is positioned in a housing through which the molten metal will pass. A fluxing gas is introduced beneath the bed and flows up through the spaces between the stones in counterflow relationship with the molten metal. The use of a bed of porous "stones" has an inherent disadvantage. The fact that the stones have their pores so close together results in the bubbles passing through the stones coalescing on their surfaces and thus creating a relatively small number of large bubbles rather than a large number of small bubbles. The net effect of the bubbles coalescing is to reduce the surface area of bubble onto which the hydrogen can be adsorbed thus resulting in low degassing efficiency.

One improved method and apparatus for the inline degassing and filtration of molten metal is disclosed in U.S. Patent 4,052,198 to Yarwood et al. and assigned to the assignee of the present invention. The disclosure teaches an improvement in the degassing and filtration of molten metal using an apparatus which employs a pair of sequentially placed, removable filter-type elements and at least one fluxing gas inlet positioned therebetween. The fluxing gas is introduced into
the melt through the inlet and flows through the first of said plates in countercurrent contact with the melt. The filter plate serves to break up the fluxing gas into a fine dispersion to insure extensive contact with the melt. The filter plates employed are made of porous ceramic foam materials which are useful for the filtration of molten metal for a variety of reasons included among which are their excellent filtration efficiencies resulting from their uniform controllable pore size, low cost as well as ease of use and replaceability. The ceramic foam filters are convenient and inexpensive to prepare and easily employed in an inline degassing and filtration unit.

While the aforenoted U.S. Patent 4,052,198 offers significant improvements over those inline gas fluxing techniques previously known in the art, a number of problems have been encountered. It is desirable for economic advantages and increased productivity to have degassing and filtration systems which can treat molten metal continuously at a rate commensurate with the casting practices. The employment of known inline degassing units such as aforenoted U.S. Patent 3,737,304 for continuous degassing and filtration have been found to be extremely inefficient, thus requiring large multiple chamber arrangements necessary to sufficiently treat the quantities of molten metal which are required for continuous casting operations. As a result of the large size of the treatment units, supplemental heating is required to prevent freeze up of the molten metal as it is being treated. While some improvement in the quantity of molten metal which can be treated has been achieved by using a smaller system such as that disclosed in U.S. Patent 4,052,198 which utilizes ceramic filters and countercurrent gas flow, such a system has been found to have a
limited effectiveness in the quantity of molten metal which can be treated due to the large pressure drops encountered in the simultaneous countercurrent flow of gas and metal through the filter body. As a result of the large pressure drop, a large head of molten metal is developed upstream of the filter element thus requiring either an increase in size of the transfer passageway upstream of the filter element or a decrease in the rate of feeding the molten metal to the treatment unit. In addition to the limited effectiveness of the quantity of molten metal which can be treated in the aforementioned U.S. patent, it has been found that the efficiency of the degassing process leaves much to be desired since it has been found that the fluxing gas bubbles tend to coalesce thereby limiting the efficiency of the kinetics of the adsorption reaction.

Accordingly, it is a primary object of the present invention to provide an improved method and apparatus for treating liquids with gases.

It is the principal object of the present invention to provide an improved method and apparatus for the degassing and filtration of molten metal which utilizes a chamber having an elongated side wall portion characterized by a tangential inlet for at least the molten metal.

It is a particular object of the present invention to provide an improved fluxing gas inlet which minimizes fluxing gas bubble coalescence.
It is still a further object of the present invention to provide an improved filtering and degassing apparatus which allows for an increase in the quantity of molten metal which can be effectively treated.

It is still a further object of the present invention to provide improvements as aforesaid which are convenient and inexpensive to utilize and which result in highly efficient degassing and filtration.

Further objects and advantages of the present invention will appear hereinbelow.

SUMMARY OF THE INVENTION

In accordance with the present invention, the foregoing objects and advantages are readily obtained.

The present invention comprises an improved method and apparatus for treating liquids with gases and more specifically for use in the degassing and filtration of molten metal, especially aluminum. A preferred embodiment of the present invention comprises a highly efficient degassing and filtration apparatus comprising an elongated substantially cylindrical chamber having a metal inlet at the top thereof and a metal outlet at the bottom. While in the preferred embodiment the chamber is shown as being cylindrical, it should be appreciated that the shape of the chamber could be in an octagon shape or the like as long as the shape allows the metal to flow in a swirling rotating fashion as it passes from the inlet of the
chamber to the outlet thereof. In order to achieve the desired swirling flow of molten metal from the metal inlet to the metal outlet, it is a requirement that the metal inlet is positioned with respect to the cylindrical chamber wall so as to tangentially introduce the liquid. In the preferred embodiment, a plurality of fluxing gas inlet nozzles are located in the chamber wall below the metal inlet and preferably between the metal inlet and the metal outlet.

In accordance with the method of the present invention, degassing of molten metal is conducted by passing the metal through the cylindrical chamber from the metal inlet to the metal outlet wherein the metal is brought into swirling contact with a fluxing gas while the metal flows downwardly as it continues to rotate until it finally leaves the chamber through the outlet. By injecting the fluxing gas into a swirllingly rotating metal stream, the dispersion of the degassing bubbles is maximized and thus by optimizing nozzle size the effective adsorption of gaseous impurities is increased. As the diameter of the swirling tank reactor increases the fluxing gas bubble dispersion at the center of the tank decreases. Thus, in a further embodiment of the present invention, in order to achieve maximum fluxing gas bubble dispersion the location of the fluxing gas nozzles are varied with respect to the central axis of the swirling tank reactor. In addition, the nozzles may be, if desired, located at various heights with respect
to the outlet of the tank. In the preferred embodiment of the present invention, the nozzle tips are conical shaped so as to prevent deposit build up in the area of the orifice of the nozzle which can lead to clogging of the nozzle. A filter-type medium provided with an open cell structure characterized by a plurality of interconnected voids may be positioned in the cylindrical chamber between the metal inlet and the metal outlet and ideally downstream of the fluxing gas inlet nozzles. Alternatively, the filter may be located in a separate system mounted downstream of the metal outlet of the swirling tank reactor. However, if the degassing chamber is used without a filter medium, it is preferred that the metal outlet be tangentially located so as to assist in the swirling movement of the molten metal as it travels from the inlet to the outlet.

The method of the present invention may employ a fluxing gas such as an inert gas, preferably carrying a small quantity of an active gaseous ingredient such as chlorine or a fully halogenated carbon compound. The gas used may be any of the gases or mixtures of gases such as nitrogen, argon, chlorine, carbon monoxide, Freon 12, etc., that are known to give acceptable degassing. In the preferred embodiment for the degassing of molten aluminum melts, mixtures of nitrogen-dichlorodifluoromethane, argon-dichlorodifluoromethane, nitrogen-chlorine or argon-chlorine are used. In addition, an inert gaseous cover such as argon, nitrogen, etc. may be
located over the surface of the molten metal to minimize the
readsorption of gaseous impurities at the surface of the melt.

The present apparatus and method provide a considerable
increase in productivity in the degassing of molten metal as
degassing is continued without interruptions of the melting
furnace. Further, the design of the apparatus enables its
placement near to the casting station whereby the possibility
of further impurities entering the melt are substantially
eliminated. The employment of the method and apparatus of
the present invention provides a considerable improvement in
the degassing of molten metal by optimizing the efficiency of
the adsorption of the gaseous impurities.

The apparatus of the present invention minimizes the bubble
size of the purged gas while maximizing the gas bubble
dispersion thereby increasing the effective surface area for
carrying out the adsorption reaction thus optimizing the
degassing of the molten metal.

In addition, the efficiency of the present invention
permits degassing to be conducted with a sufficiently lower
amount of flux material whereby the level of effluence resulting
from the fluxing operation is greatly reduced.

By virtue of the employment of a filter-type medium within
the cylindrical chamber, the apparatus and method of the
present invention are capable of achieving levels of melt purity
heretofore attainable only with the most rigorous of processing.
BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic top view of the apparatus of the present invention used for the degassing and filtration of molten metal.

Figure 2 is a schematic side view of the apparatus of the present invention.

Figure 3 is a schematic top view of the apparatus of the present invention taken along line 3-3 of Figure 2.

Figure 4 is a schematic sectional view of the apparatus of the present invention.

Figure 5 is a schematic top view of a second embodiment of an apparatus in accordance with the present invention.

Figure 6 is a schematic side view of the embodiment of Figure 5.

Figure 7 is a schematic sectional view of the embodiment of Figure 5.

Figure 8 is a schematic side view of a third embodiment of an apparatus in accordance with the present invention.

Figure 9 is a schematic sectional side view of a fourth embodiment of an apparatus in accordance with the present invention.

Figure 10 is a schematic top view of the embodiment of Figure 9.

Figure 11 illustrates the nozzle tip design for the fluxing gas nozzles used with the preferred apparatuses of the present invention.
DETAILED DESCRIPTION

Referring to Figures 1-4, an apparatus is illustrated in location with a molten metal transfer system which may include pouring pans, pouring troughs, transfer troughs, metal treatment bays or the like. The apparatus and method of the present invention may be employed in a wide variety of locations occurring intermediate the melting and casting stations in the metal processing system. Thus, Figures 1 and 2 illustrate a first embodiment of a refractory swirling tank reactor 10 comprising an elongated cylindrical side wall 12 and a bottom wall 14 which form degassing and filtration cylindrical chamber 16. Molten metal tangentially enters cylindrical chamber 16 through inlet launder 18 at the top of cylindrical chamber 16 and exits therefrom through outlet launder 20. In the embodiment illustrated in Figures 1-4, the outlet 20 is shown to be tangential, however, it should be noted that a tangential outlet is of little consequence when a filter medium is used in the apparatus. An inert gaseous cover such as argon, nitrogen, etc., not shown, is provided over the top of chamber 16 so as to minimize the readsoption of gaseous impurities at the surface of the molten metal. Cylindrical side wall chamber 12 is provided with a peripheral rim 22 positioned upstream of outlet means 20 and in proximate location therewith. The peripheral rim 22 as illustrated in Figure 4 defines a downwardly converging bevelled surface which enables for the installation and replacement of an
appropriately configured filter-type medium 24. The filter-type medium 24 has a corresponding bevelled peripheral surface 26 provided with seal means 28 which is adapted to sealingly mate with peripheral rim 22 within cylindrical chamber 16.

In accordance with the preferred embodiment of the present invention, side wall 12 is provided on its circumference with a plurality of fluxing gas inlet nozzles 30 located above filter-type medium 24 for introducing a fluxing gas into the molten metal as it passes through cylindrical chamber 16 from inlet 18 to outlet 20. As illustrated in Figure 3, the nozzles introduce the fluxing gas tangentially into the molten metal in the same directional flow, i.e., clockwise or counterclockwise as the molten metal so that the metal will continuously swirl in chamber 16 as it travels from inlet 18 to outlet 20. However, as noted previously, it is only necessary that an adequate swirling flow is generated and such may be achieved if the metal is tangentially introduced. Under some circumstances, as will be made clear with reference to the embodiment of Figure 5 discussed hereinbelow, it is desirable to introduce the gas at substantially right angles to a tangent of the chamber wall.

In the embodiment of Figures 1-4, the use of a cylindrical degassing and filtration chamber in combination with a tangential metal inlet and tangential fluxing gas inlets has a distinct advantage over conventional methods and apparatuses for filtering and degassing molten metal. In accordance with the present
invention, in order to optimize the efficiency of the degassing process; that is, maximize the efficiencies of the kinetics of the adsorption reaction, the introduction of the fluxing gas into the melt should be optimized so as to provide minimum bubble size and maximum bubble density while eliminating bubble coalescence. Thus, the orifice size of the nozzles should be controlled in order to minimize bubble size in order to maximize surface area for the adsorption reaction. The orifices are made as small as possible consistent with preventing plugging of the orifices with metal. The nozzles may be in the form of a straight tube, a converging type nozzle, or a supersonic converging-diverging nozzle. In accordance with the present invention as illustrated in Figure 11, it is preferred that the fluxing gas nozzle tip be conical in shape so as to prevent deposit build up in the orifice of the nozzle which can lead to clogging of the same. Referring to Figure 11, nozzle tip 30 is illustrated having a diverging conical tip portion 36 and orifice 34. The orifice size in the nozzle tip is made as small as possible consistent with preventing plugging of the orifice of the nozzle tip with molten metal. In accordance with the present invention, the orifice size may range from .005 inch to .075 inch and the preferred range being from .010 inch to .050 inch. It is preferred that the diverging portion 36 of nozzle tip 32 form with the axes of the orifice 34 an angle of from about 10 to 60° and preferably 20 to 40°. The bubble
distribution throughout the melt as well as preventing bubble coalescence may be further controlled by the pressure at which the fluxing gas is introduced. Gas pressures in the range of 5 psi to 200 psi, preferably greater than 20 psi, have been found optimum in the degassing of molten aluminum and its alloys.

The fluxing gas which may be employed in the present apparatuses and method comprises a wide variety of well known components including chlorine gas and other halogenated gaseous materials, carbon monoxide as well as certain inert gas mixtures derived from and including nitrogen, argon, helium or the like. A preferred gas mixture for use in the present invention for degassing molten aluminum and aluminum alloys comprises a mixture of nitrogen or argon with dichlorodifluoromethane from about 2 to about 20% by volume, preferably 5 to 15% by volume. Another preferred gas mixture consists of preferably 2 to 10% by volume chlorine with nitrogen or argon. In conjunction with these gas mixtures, a gaseous protective cover of argon, nitrogen or the like may be used over the molten metal so as to minimize readsorption of gaseous impurities at the surface of the melt.

An embodiment of the present invention calls for the provision of a filter-type medium positioned within the cylindrical chamber. Accordingly, the filter-type medium comprises a filter medium such as that illustrated in Figure 4. The filter medium possesses an open cell structure, characterized by a plurality of interconnected voids, such that the molten metal may pass
therethrough to remove or minimize entrained solids from the final cast product. Such a filter may comprise, for example, a solid filter medium made from sintered ceramic aggregate, or a porous carbon medium. In the preferred embodiment, a ceramic foam filter is utilized as described in U.S. Patent 3,962,081 and may be prepared in accordance with the general procedure outlined in U.S. Patent 3,893,917, both of which U.S. patents are incorporated herein by reference. In accordance with the teachings of said U.S. patents, the ceramic foam filter has an air permeability in the range of from 400 to 8,000 x 10^-7 cm^2, preferably from 400 to 2,500 x 10^-7 cm^2, a porosity or void fraction of 0.80 to 0.95 and from 5 to 45 pores per linear inch, preferably from 20 to 45 pores per linear inch. The molten metal flow rate through the filter may range from 5 to 50 cubic inches per square inch of filter area per minute.

In the instance where the filter medium of the present invention is designed to be a throwaway item, it is essential to provide an effective means of sealing the filter medium. It is greatly preferred to seal the filter medium in place using a resilient sealing means as illustrated and discussed earlier, which peripherally circumscribes the filter medium at the bevelled portion thereof. The resilient sealing means should be non-wetting to the particular molten metal, resist chemical attack therefrom and be refractory enough to withstand the high operating temperatures. Typical seal materials utilized in
aluminum processing include fibrous refractory type seals of a variety of compositions, as the following illustrative seals: (1) a seal containing about 45% alumina, 52% silica, 1.3% ferric oxide and 1.7% titania; (2) a seal containing about 55% silica, 40.5% alumina, 4% chromia and 0.5% ferric oxide; and (3) a seal containing about 53% silica, 46% alumina and 1% ferric oxide.

Referring to Figure 4, molten metal is delivered to a refractory swirling tank reactor 10 through tangential inlet launder 18 at the top of cylindrical chamber 16. Fluxing gas is introduced into the molten metal through nozzles 30 in the bottom of chamber 16, the fluxing gas being injected in the same direction as the molten metal is introduced into the chamber. The molten metal contents in chamber 16 flows downward to outlet launder 20 as it continues to swirl in the direction that the fluxing gas is introduced. As the molten metal passes through the chamber 16, the fluxing gas, depicted as a plurality of bubbles, flows upwardly through the melt in substantially countercurrent flow with the melt, the gaseous impurities diffuse through the melt, adhere to the fluxing gas bubble, is adsorbed into the bubble itself and is subsequently carried up to the surface as the bubbles percolate up through the melt thereby removing any impurities.

The swirling tank reactor illustrated in Figures 1-4 is particularly suitable for the degassing of molten aluminum
where the internal diameter of the reactor is up to 12" in diameter. The number of nozzles and the amount of fluxing gas employed depends greatly on the flow rate of the metal to be treated. The angles of the jet nozzles may vary from 10° to 90° as measured between the axes of the nozzles and the tangents of the points along the circumference of the wall portion of the cylinder through which the axes pass as measured is represented by the letter A in Figure 3. It should be appreciated that when a plurality of nozzles are employed they need not be at the same angles.

The following examples are illustrative of the first embodiment of the present invention.

**EXAMPLE 1**

A swirling tank reactor as illustrated in Figure 1 having an internal chamber diameter of 8" was located in an existing molten metal transfer system. The distance between the metal inlet and metal outlet was 25" with the effective distance from the metal inlet to the nozzles being 18". A ceramic foam filter medium was disposed below the nozzle inlets and above the molten metal outlet. Two nozzles were employed having an orifice size of .025". The nozzles were positioned at an angle of 20° as taken from the tangent of the chamber wall. A melt of molten metal was passed through the fluxing box at a flow rate of 85 pounds per minute. A fluxing gas mixture of 10% by volume dichlorodifluoromethane in argon was introduced through
the nozzles at a flow rate of .5 cubic feet per minute. Both
the molten metal and fluxing gas were introduced in a counter-
clockwise direction when looking at the chamber from the top.
The hydrogen content of the molten metal was measured both
before and after treatment in a TMA tester under STP conditions.
The hydrogen content was found to vary from .36 to .40 cc of
hydrogen per 100 grams aluminum before treatment to .08 to .14
cc of hydrogen per 100 grams of aluminum after the degassing
treatment thus representing an extremely efficient degassing
operation.

EXAMPLE II

The same apparatus as previously described for Example I
was employed. The metal flow rate through
the swirling tank reactor was at a flow rate of 96 pounds per
minute. A fluxing gas of a mixture of 10% by volume dichloro-
difluoromethane in argon was introduced into the chamber at
a flow rate of .5 cubic feet per minute. It was found that
the hydrogen content as measured in a TMA tester under STP
conditions varied from .35 to .38 cc of hydrogen per 100 grams
aluminum to .10 to .12 cc of hydrogen per 100 grams aluminum.
This again represents an extremely efficient degassing operation.

A wide variety of instances exist where the apparatus and
method of the present invention in all of the above disclosed
variations may be employed. Specifically in the instance of
a continuous casting operation, a pair of flux filtration
chambers may be employed in parallel arrangement. In such an
operation, the great length and associated total flow of metal
involved may require the changing of a filter medium in mid-run. Such changes may be facilitated by the employment of parallel flow channels each containing a chamber, together with a means for diverting flow from one channel to the other, by valves, dams or the like. Flow would thus be restricted to one chamber at a time and would be diverted to an alternate channel once the head drop across the first chamber became excessive. It can be seen that such a switching procedure could supply an endless stream of filtered metal to a continuous casting station.

With reference to Figures 5-7, a second embodiment of the present invention is illustrated wherein the nozzle arrangement and location is particularly suitable for larger diameter sized swirling tank reactors. As previously stated, as the diameter of the reactor increases the dispersion of gas bubble to the center of the metal in the reactor decreases. This problem is overcome by employing a swirling tank reactor 110 having a first substantially cylindrical side wall portion 112 and a second downwardly converging side wall portion 114 which together form degassing chamber 116. While the first side wall portion 112 is illustrated as being substantially cylindrical in shape, it should be appreciated that the same could be octagonal in shape or any other shape which would allow for the metal to flow in a swirling rotating fashion as it passes through the degassing chamber 116. Molten metal enters the degassing
chamber 116 through an inlet launder 118 located at the top of the chamber 116 and positioned tangentially with respect to first side wall portion 112 and exits therefrom through outlet launder 120 located at the bottom of chamber 116. Thus, the molten metal tangentially enters the degassing chamber 116 and flows in a swirling rotating fashion through chamber 116 and out the outlet launder 120 in the same manner as described with reference to the embodiment of Figure 1. As illustrated in Figures 5-7, if desired, a substantially cylindrical side wall section 122 may be provided beneath the downwardly sloping converging side wall section 114 and be adapted to receive an appropriate filter-type medium. As can best be seen in Figure 7, cylindrical side wall portion 122 is provided with a peripheral rim 124 positioned upstream of the outlet means 120 and in proximate location therewith. The peripheral rim 124 as illustrated defines a downwardly converging bevelled surface which enables for the installation and replacement of an appropriately configured filter-type medium 126. The filter-type medium 126 has a corresponding bevelled peripheral surface 128 provided with resilient seal means 130 which is attached by means of press fit to sealingly mate with peripheral rim 124 and side wall portion 122 in the same manner as the filter of Figure 4. It should be appreciated that the filter element need not be incorporated in the side wall portion 122 but may be mounted as a separate assembly downstream from the
swirling tank reactor 110. In addition, an inert gaseous cover such as argon, nitrogen, etc., not shown, may be provided over the top of chamber 116 so as to minimize the readsorption of gaseous impurities at the surface of the molten metal.

In accordance with the present invention, as illustrated in the second preferred embodiment shown in Figures 5-7, the swirling tank reactor 110 is provided with a first substantially cylindrical side wall portion 112 and a second downwardly converging side wall portion 114 beneath side wall portion 114 so as to form degassing chamber 116. In accordance with the present invention, the downwardly converging side wall portion 114 is provided on its circumferential surface with a plurality of fluxing gas inlet nozzles 132 of the type illustrated in Figure 11 for introducing a fluxing gas into the molten metal as it passes through chamber 116 from the tangential inlet 118 to the outlet 120. In order to obtain optimized bubble dispersion through the entire melt as it passes from the inlet to the outlet the nozzles 132 are positioned at different heights on the circumferential surface of side wall portion 114. In this manner, maximum fluxing gas bubble dispersion is achieved by locating the fluxing gas nozzles at various distances with respect to the central axis of the swirling tank reactor. For example, if the side wall portion 112 is 20 inches in diameter the optimum fluxing gas bubble dispersion may be obtained by locating a first set of fluxing gas nozzle
tips at a radial distance of about 9 inches from the central axis of the swirling tank reactor and a second set of nozzle tips at a radial distance of about 6 inches from the central axis of the swirling tank reactor. In accordance with the present invention the efficiency of the degassing process is thereby optimized; that is, the kinetics of the adsorption reaction is maximized by optimizing the fluxing gas bubble dispersion. It should be appreciated that while both sets of fluxing gas nozzle tips are illustrated as being located in converging side wall portion 114, like results could be obtained by locating the first set of nozzle tips in side wall portion 112 and the second set of tips in side wall portion 114.

Figure 8 illustrates a third embodiment of a swirling tank reactor in accordance with the present invention wherein the swirling tank reactor 210 comprises a first cylindrical side wall portion 212 and a second cylindrical side wall portion 214 which together form degassing chamber 216. In the same manner as previously discussed with regard to Figures 5-7, the degassing chamber 216 is provided with a tangential inlet 218 at the top thereof and an outlet 220 at the bottom thereof. Molten metal is introduced into degassing chamber 216 through tangential inlet 218 and flows in a swirling rotating fashion through chamber 216 from the inlet 218 to the outlet 220. If desired, filter means may be located in the bottom of side wall portion 214 above and proximate to the outlet 220 in the same
manner and by the same means as discussed above with regard to the first and second embodiments of the present invention.

In accordance with the present invention, in order to achieve optimum fluxing gas bubble dispersion, a first set of conical nozzle tips 232 as illustrated in Figure 8 are provided in side wall portion 212 in the swirling tank reactor 210 and a second set of fluxing gas nozzle tips 232 are provided in the second side wall portion 214 of the swirling tank reactor 210. It has been found that maximum fluxing gas bubble dispersion can be obtained by locating the tips in such a manner. For example, if the diameter of side wall portion 212 is in the order of 18 inches to 20 inches the diameter of second side wall portion 212 should be in the order of 10 inches to 12 inches. The nozzles are located at a radial distance from the center of the reactor similar to those of Figure 5.

Figures 9 and 10 illustrate a fourth embodiment in accordance with the present invention wherein a swirling tank reactor 310 comprises a substantially cylindrical side wall portion 312 forming fluxing gas chamber 316 having a tangential inlet 318 and an outlet 320. As discussed above with regard to the embodiments of Figures 5 and 8 molten metal tangentially enters fluxing chamber 316 from tangential inlet 318 and flows in a swirling rotating fashion through chamber 316 and out the outlet 320. Filter means may be provided in the bottom of chamber 316 proximate to the outlet 320 in the same manner as
discussed with the embodiment of Figures 5-7. In accordance with the present invention, the preferred fluxing gas nozzle tips illustrated in Figure 11 are provided in two sets in the side wall 312 of swirling tank reactor 310. In order to achieve the desired fluxing gas bubble dispersion, a first set of tips 332 are located at a first radial distance from the central axis of the swirling tank and a second set of nozzles are located at a second radial distance from said central axis similar to those of Figure 5. In this manner, the fluxing gas bubble dispersion may be maximized thereby optimizing the overall efficiency of the degassing operation.

The dimensions of the swirling tank reactor, the number of nozzles and the amount of fluxing gas employed in the embodiments of Figures 5, 8 and 9 depends greatly upon the flow rate of the metal to be treated. It has been found that for flow rates of 500 pounds per minute the diameter of the fluxing chambers 116, 216 and 316 respectively as defined by side wall portions 112, 212 and 312, respectively, should be about 18 to 20 inches in diameter with the length of the chambers from the metal inlet to the metal outlet being in the order of 2 to 6 feet. For a swirling tank reactor of the dimensions noted above it has been found that in order to achieve maximum fluxing gas bubble dispersion and thereby optimize the efficiency of the degassing apparatus a first set of three nozzle tips should be located at a radius of about 8
inches to 9 1/2 inches in the central axis of the reactor and a second set of three nozzle tips be located at a radius of about 5 inches to 6 1/2 inches from the central axis. It has been found that in order to achieve optimized fluxing gas bubble dispersion the nozzles should be located substantially perpendicular to the tangent of the points along the circumference of the wall portion of the cylinder. It should be appreciated the nozzles may be mounted in pivotable ball-joints in the wall of the tank reactor so as to allow for angular adjustments. Furthermore, the nozzles may be mounted so as to enable the same to be radially adjusted with respect to the central axis of the swirling tank reactor.

The following example is illustrative of the present invention.

**EXAMPLE III**

The swirling tank reactor as illustrated in Figure 9 having an internal chamber diameter of 18 inches was located in an existing molten metal transfer system. Six fluxing gas nozzle tips were employed in the side wall portion of the swirling tank reactor. A first set of three nozzles extended 2 1/2 inches into the reactor and an alternate second set of nozzle tips extended approximately 1/2 inch into the tank reactor. A melt of molten metal was passed through the fluxing chamber at a flow rate of 500 pounds per minute. A fluxing gas mixture of 6% by volume dichlorodifluoromethane in argon was introduced into the melt through the nozzles at a total flow
rate of 70 liters per minute (measured at standard temperature and pressure conditions). The axis of the orifice nozzles formed an angle of 90° with the tangent of the side wall portion of the cylindrical chamber. The inlet hydrogen levels of the molten metal was measured at 0.23 cc hydrogen per 100 grams of aluminum. After treatment in a swirling tank reactor the hydrogen level was reduced to 0.17 cc of 100 grams of aluminum as measured by the Alcoa Telegas instrument. This represents a substantial decrease in hydrogen content thus illustrating the efficiency of the degassing operation.

It is to be understood that the invention is not limited to the illustrations described and shown herein, which are deemed to be merely illustrative of the best modes of carrying out the invention, and which are susceptible of modification of form, size, arrangement of parts and details of operation. The invention rather is intended to encompass all such modifications which are within its spirit and scope as defined by the claims.
THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. An improved apparatus for use in the degassing of molten metal which comprises:
   
   chamber means having an elongated side wall portion and a central axis;

   inlet means at a first height for introducing said molten metal into said chamber;

   outlet means at a second height below said first height for removing said molten metal from said chamber;

   fluxing gas inlet means at a third height below said first height for introducing said fluxing gas into said chamber wherein at least said molten metal inlet means is located with respect to said side wall portion for tangentially introducing said molten metal into said chamber in either a clockwise or counterclockwise flow direction such that said molten metal swirlingly flows in said clockwise or counterclockwise manner from said metal inlet towards said metal outlet as said fluxing gas percolates up through said molten metal.

2. An apparatus according to claim 1 wherein both said inlet means are located with respect to said side wall portion for tangentially introducing said molten metal and said fluxing gas in the same direction.
3. An apparatus according to claim 2 wherein said fluxing gas inlet means is in the form of a plurality of nozzles each having an orifice, the axes of said orifices intersect said side wall portion at a plurality of points along the circumference thereof and form with the tangents of said points a plurality of angles.

4. An apparatus according to claim 1 wherein said plurality of orifices are of controlled size so as to minimize fluxing gas bubble size thereby optimizing the degassing of said molten metal.

5. An apparatus according to claim 4 wherein said orifices size range from .005" to .075".

6. An apparatus according to claim 4 wherein said orifices size range from .010" to .050".

7. An apparatus according to claim 1 wherein said outlet means is located with respect to said side wall portion for tangentially removing said molten metal from said chamber.

8. An apparatus according to claim 1 wherein said chamber is cylindrical and has inside wall surfaces adapted to support a removable filter-type medium at a fourth height in said chamber above said second height and below said first height.
9. An apparatus according to claim 8 wherein said filter medium is a ceramic foam filter having an open cell structure characterized by a plurality of interconnected voids surrounded by a web of ceramic.

10. An apparatus according to claim 9 wherein said ceramic foam filter medium has an air permeability in the range of 400 to 8,000 \times 10^{-7} \text{ cm}^2, a porosity of 0.80 to 0.95 and a pore size of from 5 to 45 ppi.

11. An apparatus according to claim 1 including a first and a second fluxing gas inlet means located below said first height for introducing said fluxing gas into said chamber, said first fluxing gas inlet means being located at a first radial distance from said central axis of said chamber means and said second fluxing gas inlet means being located at a second radial distance from said central axis of said chamber means.

12. An apparatus according to claim 11 wherein said elongated side wall portion comprises a first part having a first diameter and a second part located beneath said first part.

13. An apparatus according to claim 12 wherein said second part is in the form of a downwardly converging side wall portion.
14. An apparatus according to claim 12 wherein said second part is substantially cylindrical in form and has a diameter smaller than said first diameter.

15. An apparatus according to claim 13 wherein said first fluxing gas inlet means is located in said first part of said elongated side wall portion and said second fluxing gas inlet means is located in said second part of said elongated side wall portion.

16. An apparatus according to claim 13 wherein both said first and said second fluxing gas inlet means are located in said second part of said elongated side wall portion at different heights below said first height.

17. An apparatus according to claim 14 wherein said first fluxing gas inlet means is located in said first part of said elongated side wall portion and said second fluxing gas inlet means is located in said second part of said elongated side wall portion.

18. An apparatus according to any one of claims 5-7 wherein each of said first and said second fluxing gas inlet means comprises at least one conical shaped nozzle tip.

19. An apparatus according to any one of claims 5-7 wherein each of said first and said second fluxing gas inlet means comprises three conical shaped nozzle tips.

20. An apparatus according to claim 18 wherein said at least one nozzle tip has an orifice, said orifice size range from .005 inch to .075 inch.

21. An apparatus according to claim 18 wherein said at least one nozzle tip has an orifice, said orifice size range from .010 inch to .050 inch.

22. An apparatus according to any one of claims 11, 15
and 16 wherein said chamber means has inside wall surfaces adapted to support a removable filter-type medium at a fourth height in said chamber above said second height and below said first height.

23. An apparatus according to claim 22 wherein said filter medium is a ceramic foam filter having an open cell structure characterized by a plurality of interconnected voids surrounded by a web of ceramic.

24. An apparatus according to claim 23 wherein said ceramic foam filter medium has an air permeability in the range of 400 to $8,000 \times 10^{-7}$ cm$^2$, a porosity of 0.80 to 0.95 and a pore size of from 5 to 45 ppi.
25. A method for the degassing of molten metal by passing said molten metal through a chamber and purging said molten metal with a fluxing gas by passing said fluxing gas through said metal, the improvement comprising providing a chamber having an elongated side wall portion and a central axis, providing said chamber with molten metal inlet means at a first height, molten metal outlet means at a second height below said first height and fluxing gas inlet means at a third height below said first height, tangentially positioning said molten metal inlet means with respect to said side wall portion such that said molten metal swirlingly flows in a clockwise or counterclockwise manner from said molten metal inlet to said molten metal outlet as said fluxing gas percolates through said molten metal.

26. The method of claim 25 comprising tangentially positioning both said inlets.

27. The method of claim 26 comprising positioning said fluxing gas inlet means such that the axes thereof intersect said side wall portion at a plurality of points along the circumference thereof and form with the tangents of said points a plurality of angles.
28. The method of claim 25 further including a first and a second fluxing gas inlet means below said first height, positioning said first fluxing gas inlet means at a first radial distance from said central axis and positioning said second fluxing gas inlet means at a second radial distance from said central axis.

29. The method of claim 28 comprising positioning said fluxing gas inlet means such that the axes thereof intersect said side wall portion at a plurality of points along the circumference thereof and form with the tangents of said points an angle of about 90°.

30. A swirling tank reactor for use in the treatment of liquids with gases comprising chamber means having an elongated side wall portion, a bottom wall portion and a central axis, inlet means at a first height for delivering said liquid to said chamber, outlet means at a second height below said first height for removing said liquid from said chamber, gas inlet means at a third height below said first height for delivering said gas to said chamber wherein said liquid inlet means is located with respect to said side wall portion so as to substantially tangentially deliver said liquid to said chamber in either a clockwise or counterclockwise flow direction such that said liquid swirlingly flows in said clockwise or counterclockwise manner from said liquid inlet to said liquid outlet as said gas percolates through said liquid.
31. A swirling tank reactor according to claim 30 further including a first and a second fluxing gas inlet means below said first height, positioning said first fluxing gas inlet means at a first radial distance from said central axis and positioning said second fluxing gas inlet means at a second radial distance from said central axis.

DATED THIS 5th DAY OF JUNE, 1979

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