Dec. 3, 1968 W. E. SNOW 3,414,250

LADLE FOR USE IN TREATMENT OF MOLTEN METAL

Filed July 31, 1967 2 Sheets-Sheet 1

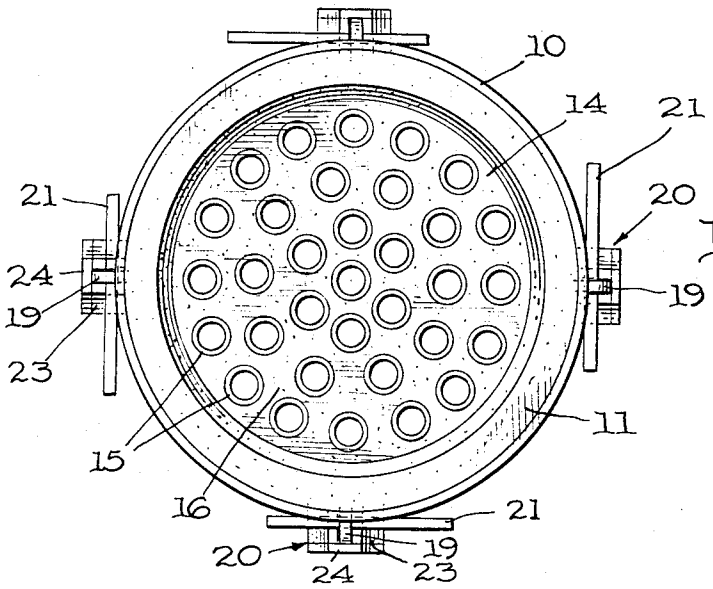


FIG. 2.

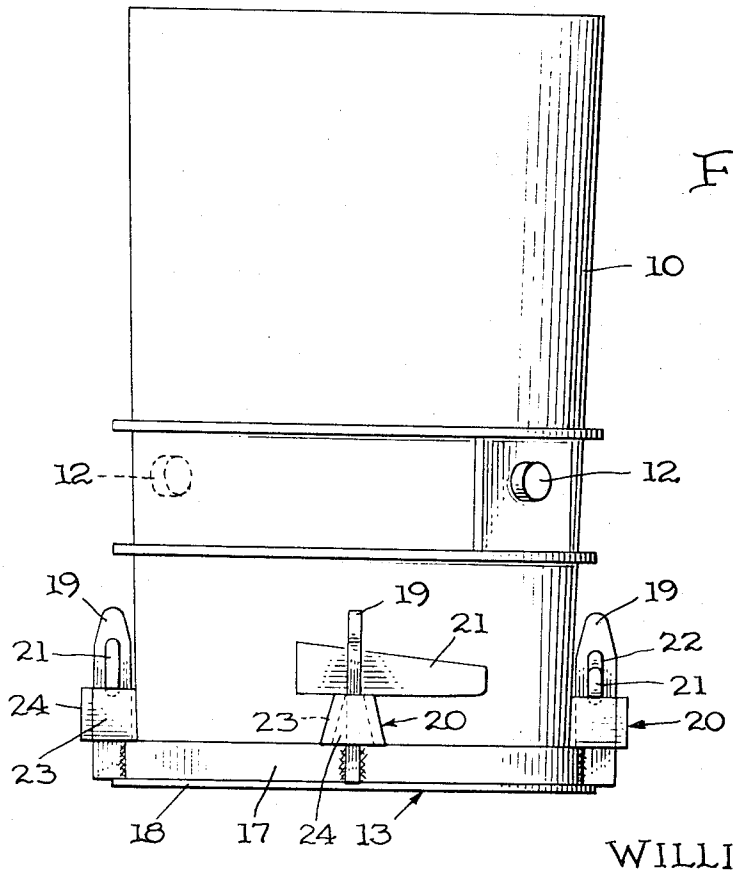


FIG. 1.

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FIG. 3.

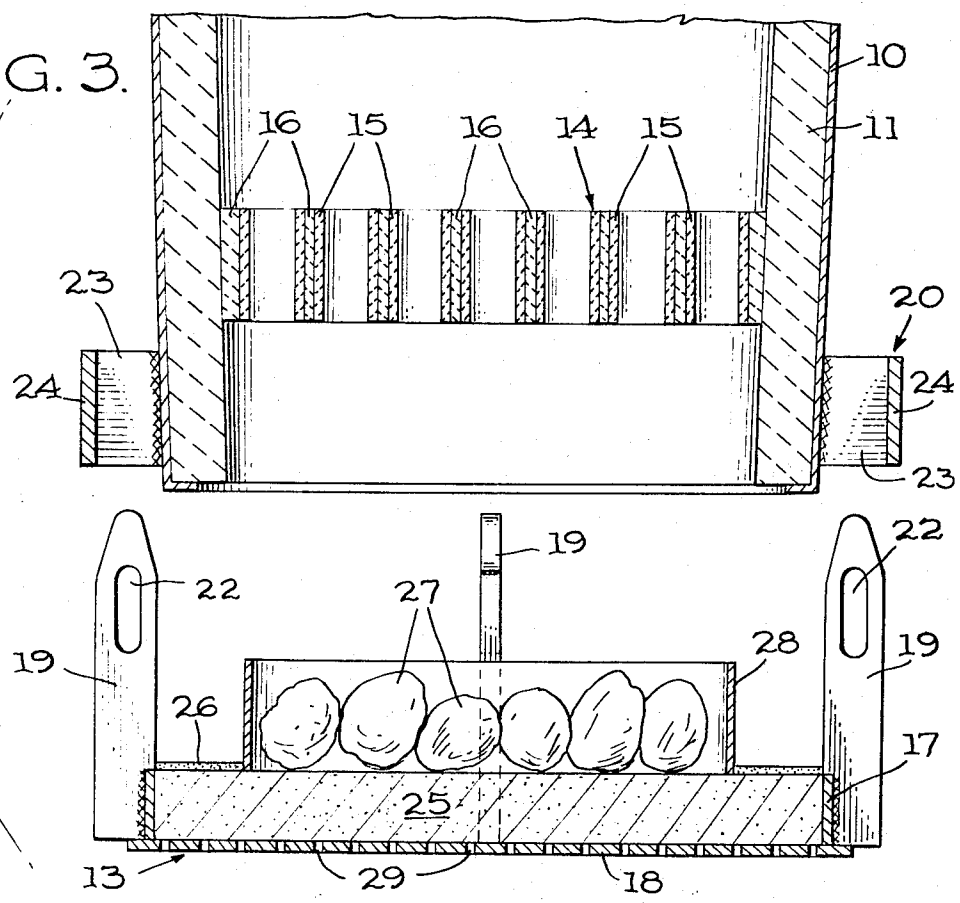
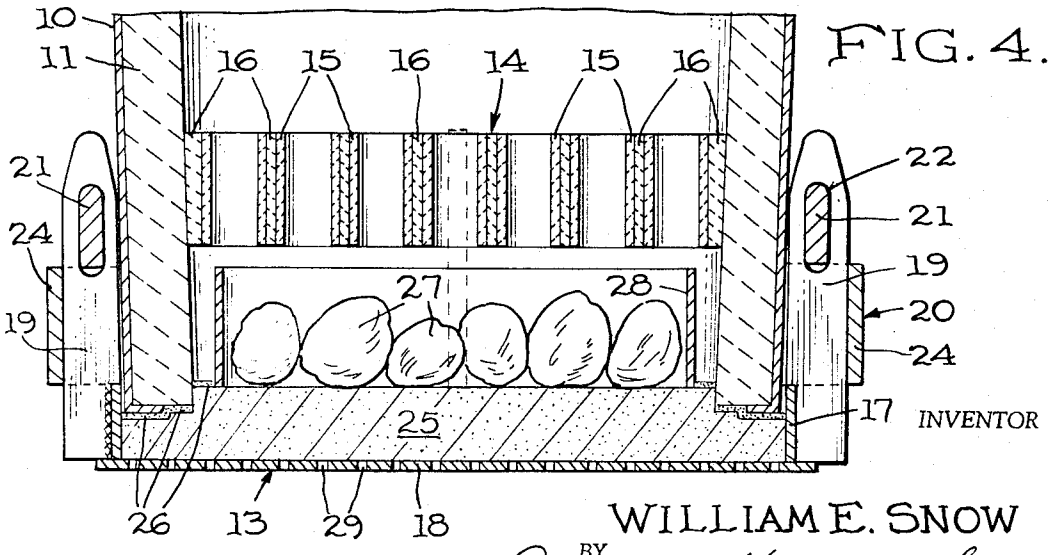


FIG. 4.



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LADLE FOR USE IN TREATMENT OF MOLTEN METAL

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10 Claims. (Cl. 266—34)

ABSTRACT OF THE DISCLOSURE

A ladle for use in the treatment of molten metal having a refractory-lined metal shell open at both top and bottom, a separately formed bottom closure detachably connected to the shell, and a wall of refractory material fixed to and extending transversely across the interior of the shell at a position adjacent, but spaced above, the bottom end thereof, the space between the wall and the bottom closure being adapted to contain a quantity of treating material in lump-like form, and the wall having a plurality of vertically extending openings therein for permitting contact between molten metal in the ladle and the treating material. The openings in the wall may be formed by ceramic tubes having inside diameters less than the minimum lump size of the treating material so as to prevent the treating material from floating upwardly to the surface of the molten metal.

Background of the invention

This invention relates to ladles for use in connection with the introduction of low boiling point reactive metals into molten baths of other metals for such purposes as degassing, slag reduction, alloying and nodularization, and more particularly to a ladle of improved construction for use in treating molten metal with treating agents in the form of briquettes, filled metallic skeletons and impregnated porous refractories.

It is well known that metals selected from Groups I, I–*a*, II and II–*a* of the periodic table of elements can be used in the treatment of other molten metals for the purpose of degassing, desulfurizing, deslagging or causing the formation of nodular graphite to produce ductile iron. These selected reactive metals have been used primarily to treat base metals such as copper, steel or cast iron under conditions where the temperature of the metal to be treated is greater than the boiling point of the reactive treating metal used.

For example, magnesium, having a boiling point of 2030° F., is commonly used to treat molten cast iron at temperatures of from 2500° to 2900° F., while calcium, having a boiling point of 2625° F., may be used to treat molten steel at temperatures of from 2800° to 3200° F. Under such conditions, the addition to the molten bath of the reactive metal in pure form can result in explosive violence when the reactive metal is converted to a vapor or gas by the heat of the treated metal.

Prior to the present invention, several methods have been proposed looking toward the minimization or elimination of the problem of violence when treating molten metals with reactive metals of the character above described, such as alloying, powder or mechanical injection, briquetting and the use of filled or impregnated metallic skeleton and porous refractory materials. All of these methods, however, have certain disadvantages when carried out in accordance with the teachings of the prior art.

In the alloying method, the reaction is controlled by dilution of the low boiling point metal with higher boiling point metals which do not produce a violent reaction. For example, alloys containing magnesium, such as magnesium-ferrosilicon, copper-magnesium and nickel-magnesium-silicon have been used, the ferrosilicon, copper or nickel having an extremely high boiling point and acting as a moderator to reduce the violence of the reaction. Calcium alloys, such as calcium-manganese-silicon and calcium-silicon, are other examples of dilution of the reactive metal by alloying with high boiling point metals or metalloids. The alloying method, however, requires the payment of a premium price for the low boiling point metal content in the alloy because of the special furnaces and procedures required in its manufacture.

In the injection method, the reactive metal is forced or blown into the molten metal bath by the use of injection devices of various forms, the violence being controlled by allowing only a small amount of the reactive metal to come into contact with the molten metal at any one time. Examples of this method are the injection of magnesium powder using pressurized nitrogen gas as a carrier, and the injection of magnesium in wire form through a refractory tube. In these procedures, the preparation of magnesium in powder form, or the production of rolled or extruded rods or wires thereof, and the expense involved in the use of a carrier gas and the mechanical equipment required, increase substantially the cost of production of the treated metal.

In the briquetting method, mechanical mixtures of powdered reactive metals, such as magnesium, and powdered carrier materials, such as carbon or magnesia, are pressure molded into briquettes, either with or without incorporation of a binder, and the briquettes are introduced into a bath of molten metal in one of the conventional ways hereinafter described. Here, again, the cost of the contained percentage of low boiling point metal is excessive, and difficulty has been experienced in obtaining a slow controlled release of the reactive metal into the molten metal without excessive violence.

Porous sintered iron and other porous metallic bodies have had their pores filled with a reactive metal in molten form, and then, after solidification of the latter, have been used as treating agents by submersion in a bath of the molten metal to be treated. In this method, the metallic skeleton is intended to slow evolution of the reactive metal vapor into the molten bath and thereby reduce the degree of violence. Bodies of porous metallurgical coke, porous carbon and porous graphite having their pores impregnated with a reactive metal are also known to be effective treating agents for molten metals. For example, when magnesium-impregnated coke is submerged in molten iron, the magnesium in the pores of the coke is converted into vapor and enters the molten iron in a relatively slow, controlled manner due to the moderating effects of the coke.

In the treatment of molten metals with any of the above-described treating agents, it is a matter of economic importance to insure maximum utilization (or "recovery" as it is normally described in the foundry industry) of the treating agent. The three most commonly used procedures for introducing alloys, briquettes, metallic skeletons or porous refractory materials containing a reactive metal into molten metal are (1) the open ladle method, (2) the sandwich method, and (3) the plunging method.

In the open ladle method, the treating agent is placed on the bottom of a conventional ladle and the metal to be treated is simply poured into the ladle on top of the treating agent. This procedure generally results in the lowest recovery of the three procedures.

In the sandwich method, a specially designed ladle is provided with a pocket or depression in the bottom into which the treating agent is placed, after which a layer of steel scrap, in the form of punchings or clippings, is placed over the treating agent before the molten metal to be treated is poured into the ladle. The steel scrap tends to hold the treating agent on the bottom of the ladle and to

form a protective cover to slow down the initial reaction. This method results in better recovery of the reactive agent than the open ladle procedure.

In the plunging method, the treating material is placed in an inverted ceramic cup or bell which is then plunged into a bath of the molten metal to be treated and maintained submerged below the surface thereof until the reactive metal has dissipated. This method normally results in a higher degree of recovery than either the open ladle or the sandwich method, but the greater recovery or utilization of the reactive metal is offset to some extent by the high cost of the ceramic plunger and the increased labor costs of operating and maintaining the latter.

When subjected to contact with molten metal, alloys in lump form containing reactive metal in effect dissolve or disintegrate from the surface of the lumps, the latter becoming smaller and smaller until they disappear. Properly manufactured briquettes, filled metallic skeletons and impregnated porous refractories react by expulsion of the reactive metal in vapor form with little or no change in the outside shape or size of the carrier during evolution of the metallic vapor, although briquettes normally disintegrate and metallic skeletons dissolve after the reaction is complete. However, porous refractory carriers, such as porous coke, carbon or graphite, normally maintain their original shape and size even after all of the impregnated reactive metal has vaporized. Because of these different characteristics of the respective types of treating agents, alloys are generally used in the open ladle and sandwich treating methods, while briquettes and impregnated porous refractory materials are normally used in the plunging method, particularly because, due to their low density and inherent tendency to float, briquettes and impregnated porous refractory materials result in extermely low recoveries when used in the open ladle and sandwich methods.

Although these prior methods have been used in the past with varying degrees of satisfaction, a need still exists for an improved method or device for more effectively utilizing treating agents in the form of briquettes, filled metallic skeletons nad impregnated porous refractories, which method or device (a) should hold the treating agent as close to the bottom of the treating ladle as practicable so as to insure a maximum height of molten metal over the treating agent, (b) should disperse the treating agent uniformly over the bottom of the ladle so as to minimize violence of the reaction and to increase recover, (c) should eliminate the use of expensive equipment such as ceramic plungers, and (d) should be relatively inexpensive from the standpoint of both the initial cost of equipment and materials, and the labor involved in operation and maintenance.

Summary of the invention

The present invention resides in a metal treatment ladle of improved construction which meets the objectives set forth above by providing an otherwise conventional ladle with certain novel features resulting in increased recovery or utilization of the reactive treating metal, decreased violence of the reaction, decreased equipment and labor costs, and increased production per hour of operation. The greater recovery also results in decreased consumption and cost of the reactive metal.

In general, the invention comprises a metal treatment ladle wherein the refractory-lined metal shell of the ladle is open at both top and bottom, and is provided with a separately formed, detachable bottom closure and a wall of refractory material extending transversely across the interior of the shell at a position above the bottom end thereof, the space between the wall and the bottom closure being adapted to contain a quantity of treating material, and the wall being provided with a plurality of vertically extending openings therein for permitting contact between molten metal in the ladle and the treating material.

Brief description of the drawings

FIG.1 is a side elevation of one form of metal treatment ladle embodying the invention showing the bottom closure member detachably connected to the ladle shell;

FIG. 2 is a top plan view of the assembled ladle of FIG. 1;

FIG. 3 is an exploded vertical sectional view of the lower portion of the ladle shell and the bottom closure member, showing the elements as they exist prior to assembly of the ladle, and also showing a quantity of lump-like treating material carried by the closure member; and

FIG. 4 is a vertical section of the lower portion of the assembled ladle ready to receive a charge of molten metal to be treated.

Description of the preferred embodiment

There is illustrated in the accompanying drawings a presently preferred form of ladle embodying the invention which is especially well adapted for treating molten cast iron with a treating agent of the character disclosed in Patent No. 3,321,304, particularly porous coke in lump form having the pores thereof filled with magnesium. Although the following description will therefore be directed primarily to this specific use of the ladle, it will be understood that the structure of the present invention is also usable with various other treating materials in the form of briquettes, or bodies of porous metallic or refractory materials filled or impregnated with reactive metal.

As shown in the drawings, the ladle comprises a normally vertical steel shell **10** having a refractory lining **11** and trunnions **12**, similar to conventional metal treatment ladles except that the shell is open at the bottom as well as at the top, and a separately formed bottom closure member **13** which is adapted to be detachably connected to the bottom end of the shell by means hereinafter described. The shell **10** may be truly cylindrical or, as shown, may taper slightly from top to bottom, while the lining **11** may be formed from either fire bricks, a poured refractory or a rammed refractory, using conventional materials and techniques.

The shell **10** is also provided with an apertured wall **14** of refractory material which is fixed to and extends transversely across the interior of the shell at a position adjacent, but spaced above, the bottom end of the shell, leaving a space therebeneath sufficient to accommodate a suitable quantity of treating material, such as magnesium-impregnated coke in lump form. In the embodiment illustrated, wall **14** is composed of a plurality of vertically disposed ceramic tubes **15** disposed symmetrically, in spaced apart relationship, about the vertical axis of the shell (see FIG. 2), the spaces between tubes **15**, and between the latter and the refractory shell lining **11**, being filled with a refractory mortar **16** which both holds the tubes in place and binds the wall assembly **14** to the shell lining **11**.

The ceramic tubes **15** may conveniently be of the relatively inexpensive type commonly known as tile down gates, conventionally used as gates and runners for molten metals in the production of castings in sand molds. The inside diameters of the tubes should be less than the minimum lump size of the treating agent to be used, while their length should be sufficient to insure resistance against breakage when molten iron is poured into the ladle. For example, in a ladle having an iron capacity of approximately 4000 pounds, the wall **14** may comprise a total of 20 tubes each having an inside diameter of 2" and a length of 9", the refractory mortar **16** consisting of a mixture of fireclay, crushed fire bricks and water, and the lower ends of the tubes being located 7½" from the bottom of the shell **10**. In a ladle having an iron capacity of 7000 pounds, a total of 35 ceramic tubes 2½" in inside diameter and 6" long have been used to form a wall

wherein the lower ends of the tubes are located 9½" from the bottom of the shell.

The bottom closure member **13** consists of an open topped steel pan having a vertical cylindrical wall **17** welded to a horizontal bottom plate **18**, the wall **17** having an inside diameter only slightly greater than the outside diameter of the bottom end of ladle shell **10** so as to telescope therewith, and a height of approximately 2" to 4". The bottom plate **18** of the closure member has a diameter greater than the outside diameter of wall **17** so as to provide a ledge on which rest the lower ends of a plurality of vertically extending steel ears **19** which are adapted to cooperate with a like number of steel lugs **20** fixed to the outside of shell **10** adjacent the bottom thereof and steel wedges **21** for detachably connecting the closure member to the bottom of the ladle.

Ears **19** project radially outwardly from wall **17** to which the lower portions of their inner edges are welded, and are provided adjacent their upper ends with vertically elongated slots **22** which receive the wedges **21** when the ladle is assembled. Each of lugs **20** consists of two upwardly converging side plates **23** which are welded to and extend radially outwardly from ladle shell **10**, and a vertical end plate **24** which is welded to the outer edges of side plates **23** so as to form an upwardly converging guideway for an ear **19**. Wedges **21** are formed with flat bottom edges adapted to bear on the flat upper edges of side plates **23** of lugs **20**, and with inclined, rounded upper edges adapted to bear against the correspondingly rounded upper edges of slots **23**, the maximum height of the wedges being greater than the vertical dimension of the slots **23**.

Before connecting the bottom closure member **13** and shell **10** to form the assembled ladle shown in FIGS. 1 and 2, a quantity of loose, finely divided refractory material, such as molding sand, is placed in the pan portion of member **13**, and is rammed and leveled so as to provide a compacted layer **25** (FIG. 3) of suitable depth and density to seal the bottom end of the shell against the escape or leakage of molten metal when the ladle is filled. The sealing material used preferably should be a molding sand of the same type as that normally used in iron and steel foundries, and should have sufficient clay and water content to provide a good "green bond." If desired, a thin layer **26** of powdered coke or graphite dust may be placed on the surface of the sand layer **25** adjacent the periphery thereof so as to lie between the bottom end of the ladle shell and the sand when the ladle is assembled and to act as a parting agent facilitating detachment of the closure member **13** from the ladle shell **10** after the treatment has been completed.

A predetermined quantity of treating material **27**, such as magnesium-impregnated coke in lump form, is then placed on top of the rammed sand layer **25** in the central portion thereof before the ladle shell and the closure member are connected together. In order to maintain the lumps of treating material in the center of sand layer **25** so that they will lie within the space bounded by wall **14** and the lower end of shell lining **11** when the ladle is assembled, a retaining ring or collar **28**, of a diameter less than the inside diameter of the lower end of lining **11**, may be placed on top of the sand layer before the treating material is placed. Retaining ring **28** may be made of thin sheet metal or any other suitable material which will not adversely affect the treatment when it is dissolved by the heat of the molten metal being treated.

After the bottom closure member has been thus prepared, as indicated in FIG. 3, the ladle shell is lowered onto the closure member, as by means of a conventional ladle lifting and transporting bail (not shown) connected to the trunnions **12**, while aligning the lugs **20** with the ears **19**. Wedges **21** are then driven into the slots **22** in ears **19** so as to force the bottom ends of shell **10** and lining **11** into the peripheral portion of sand layer **25**, thereby further compressing that portion of the sand, as indicated in FIG. 4, and creating a seal which effectively prevents leakage from the bottom of the assembled ladle when the molten metal to be treated is poured into the ladle.

When the ladle shell and bottom closure member have been assembled and temporarily locked to one another in the manner described, the lumps of treating material are effectively trapped in the space between the sand layer **25** and the bottom of wall **14**. A predetermined weight of the molten metal to be treated is then poured rapidly into the ladle, some of it passing downwardly through tubes **15** into the space beneath wall **14** and into direct contact with the treating material. The treating material starts to react immediately, but is prevented from floating to the surface of the molten metal by the wall **14**, due to the fact that the lump size of the material is so selected as to be greater than the inside diameter of tubes **15**. As the reactive metal within the treating material is converted into gas or vapor, it passes upwardly through the tubes and through the molten metal in the ladle with considerably less violence than is normally experienced with the open ladle, sandwich and plunging methods of the prior art. During the ladle treatment, a small amount of gas and steam is produced in the sand layer **25**. Consequently, the bottom plate **18** of closure member **13** is provided with a plurality of vent holes **29** which enable escape of the gas and steam, thus preventing upward passage thereof through the molten metal which would adversely affect recovery of the magnesium or other reactive metal in the treating material.

After the reaction has been completed, the ladle may be skimmed and then poured into the desired casting or transferred into another ladle. After the ladle is emptied, the wedges **21** are driven out of the ears **19** so as to detach the closure member **13** from the ladle shell **10**, whereupon the spent treating material and sand may be dumped from the member **13** and the latter prepared for the next treatment. Since the tubes **15** and mortar **16** forming well **14** are refractory materials, the ladle shell may be used for a number of treatments before replacement of the wall is necessary.

One of the advantages of the ladle of the present invention not mentioned above is that the treatment can be carried out while the ladle is being transported from one location to another within the foundry with a consequent saving in time and labor. A further saving in production time results from the fact that the same ladle shell can be recycled with a bottom closure member other than the one used for the last preceding treatment, and which can be charged with sand and treating material while the ladle shell is in use with the other closure member.

Although only one specific embodiment of the invention has been described and illustrated in the accompanying drawings, it will be obvious to those skilled in the art that various modifications can be made in the form, details of construction and arrangement of the parts of the ladle without departing from the inventive concept. For example, it will be evident that means other than the ear, lug and wedge arrangement disclosed may be used for detachably connecting the bottom closure member to the ladle shell, and that the force required for sealingly assembling the shell and closure member can be provided by mechanical means such as hydraulic rams, instead of by manually wedging the elements together. Reference is therefore to be had to the appended claims for a definition of the limits of the invention.

I claim:

1. A ladle for use in the treatment of molten metal comprising a refractory-lined metal shell open at both top and bottom, a separately formed bottom closure member for said shell, means for detachably connecting said closure member to said shell, a wall of refractory material fixed to and extending transversely across the interior of said shell at a position above the bottom end thereof, the space between said wall and said closure member being adapted to contain a quantity of treating material, and a

plurality of vertically extending openings in said wall for permitting contact between molten metal in said shell and said treating material.

2. A ladle as claimed in claim 1 including a quantity of compacted, finely divided refractory material in said bottom closure member for sealing the bottom end of said shell against the escape of molten metal.

3. A ladle as claimed in claim 1 wherein said bottom closure member is in the form of an open topped pan having a bottom plate and an upstanding cylindrical wall, the inside diameter of said wall being slightly greater than the outside diameter of the bottom end of said shell so as to have a telescopic fit therewith.

4. A ladle as claimed in claim 3 including a quantity of compacted sand in said bottom closure member for sealing the bottom end of said shell against the escape of molten metal.

5. A ladle as claimed in claim 1 wherein the means for detachably connecting said bottom closure member to said shell comprises a plurality of elongated ears fixed to and extending upwardly from said closure member, a like plurality of ear-receiving lugs fixed to said shell adjacent the bottom end thereof, the upper ends of said ears having vertically elongated slots therein located above the upper surfaces of said lugs, and a like plurality of wedges passing through said slots and resting on the upper surfaces of said lugs.

6. A ladle as claimed on claim 1 including a layer of compacted sand in said bottom closure member for sealing the bottom end of said shell against the escape of molten metal, and means for maintaining a quantity of said treating material in position on top of said sand layer within the space bounded by said wall of refractory material and the lower end of said shell.

7. A ladle for use in the treatment of molten metal comprising a refractory-lined metal shell open at both top and bottom, a separately formed bottom closure member for said shell, means for detachably connecting said

closure member to said shell, and an apertured wall of refractory material fixed to and extending transversely across the interior of said shell at a position adjacent to, but spaced above, the bottom end thereof, the space between said wall and said closure member being adapted to contain a quantity of treating material in lump form, said wall including a plurality of vertically extending ceramic tubes for permitting contact between molten metal in said shell and said treating material.

8. A ladle as claimed in claim 7 wherein the inside diameters of said tubes are smaller than the minimum dimension of the lumps of treating material to be used.

9. A ladle as claimed in claim 7 wherein said bottom closure member is in the form of an open topped pan having a bottom plate and an upstanding cylindrical wall, the inside diameter of said wall being slightly greater than the outside diameter of the bottom end of said shell so as to have a telescopic fit therewith, and including a layer of compacted sand in said closure member for sealing the bottom end of said shell against the escape of molten metal.

10. A ladle as claimed in claim 9 including means for maintaining a quantity of said treating material in position on top of said sand layer within the space bounded by said wall of refractory material and the lower end of said shell.

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