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APPARATUS FOR PRODUCING ULTRACLEAN ALLOY STEELS

Filed July 18, 1962 2 Sheets-Sheet 1

FIG. 1

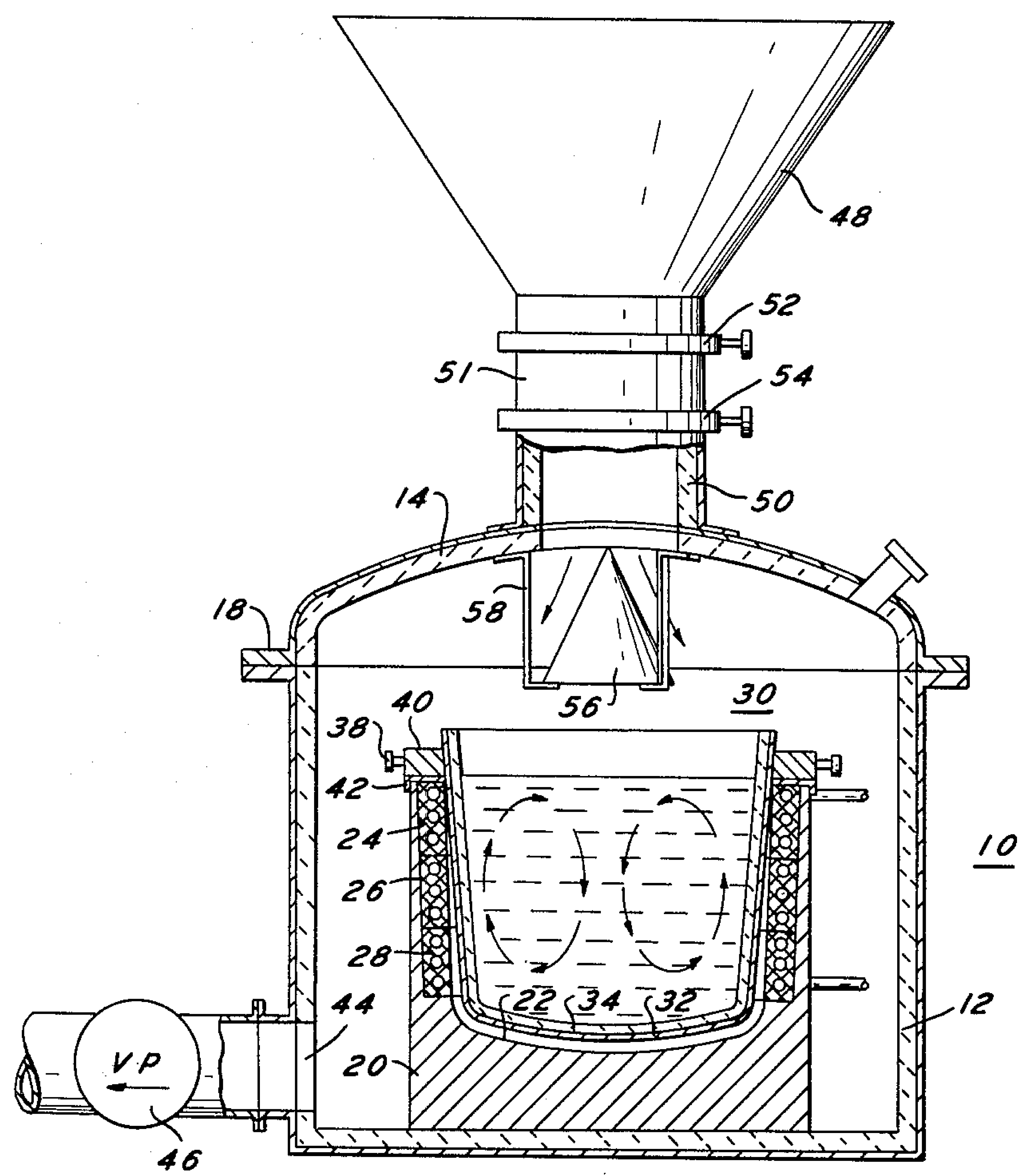

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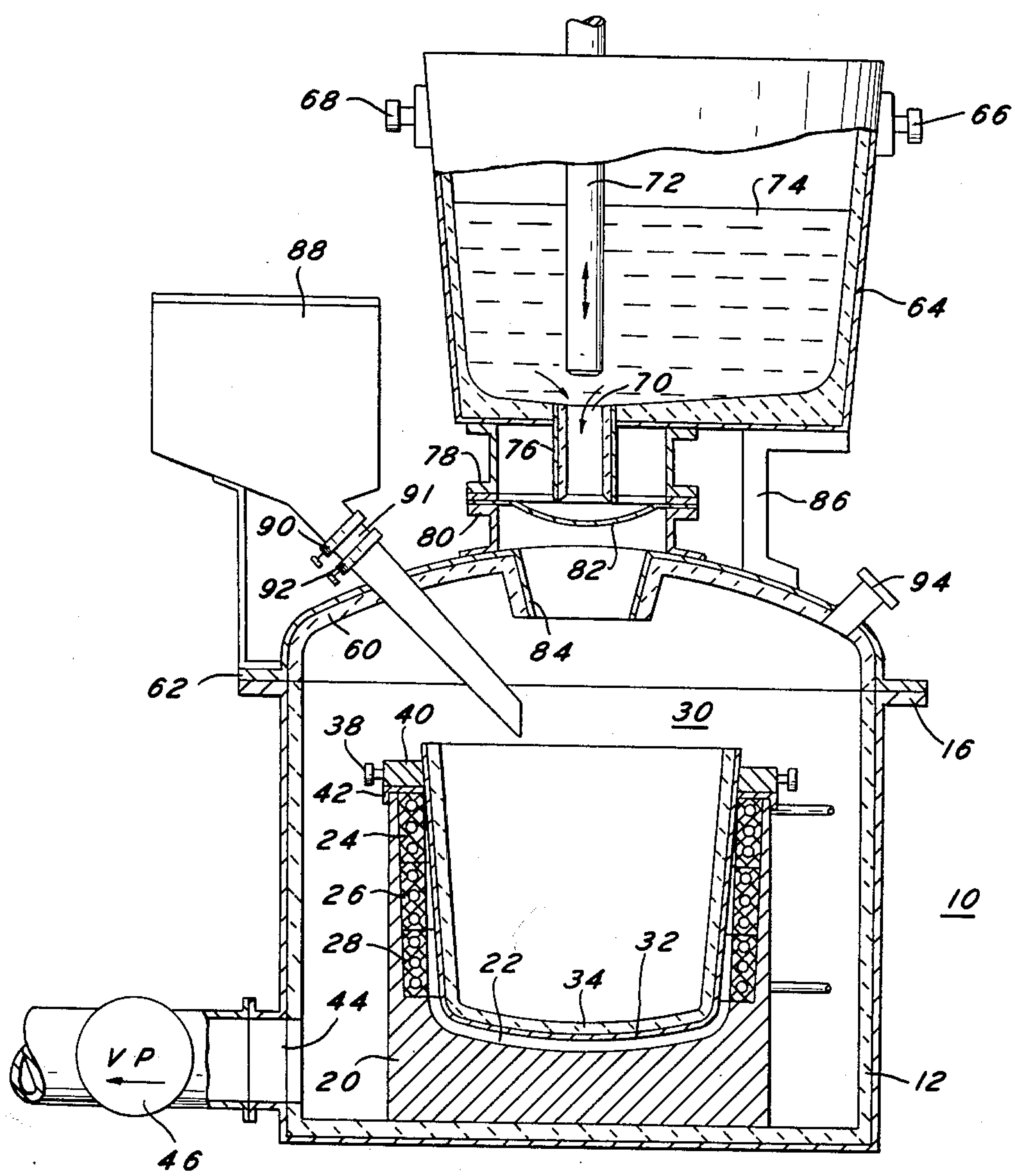
FIG. 2



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APPARATUS FOR PRODUCING ULTRACLEAN ALLOY STEELS

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In general, this invention relates to new and improved methods and apparatus for producing ultraclean alloy steels. More particularly, it relates to the production of ultraclean alloy steels utilizing magnetic mixing in a vacuum chamber for better alloying and degassing.

In the production of various grades of steel manufactured from processes such as the open-hearth or electric-arc furnaces, there is a need to produce ultraclean steel whose gas content approaches the very low levels obtained by consumable arc or induction melting. Additionally, there is a strong need for a dynamic mixing process which will insure greater shipped tonnage from the same melting output. Steel billets with these advantages must be capable of being produced in existing melting departments of steel mills from the equipment on hand such as large open-hearth or electric-arc furnaces.

At present, ultraclean steels whose gas content is at very low levels can be obtained only by consumable arc or induction melting. For instance, the hydrogen level should be less than one part per million, and the oxygen level less than fifteen parts per million.

The present invention contemplates the addition to the present melting facilities in large steel mills of an inexpensive vacuum chamber capable of reducing the hydrogen content in the steel approximately 50 to 70 percent, the nitrogen content 7 to 15 percent, and the oxygen content by reduction 45 to 65 percent. This simple addition will enable the steel manufacturers to produce steel of greater ductility and cleanliness. These properties will produce a number of economies during subsequent hot working of the resultant alloy. Fewer edge checks, tears, and cracks, a larger reduction per pass and less scrap due to scarfing and grinding the bloom before rolling are all advantages obtained by this process. This process will allow the production of 200 to 300 tons of ultraclean steel alloy in one operation from an open-hearth furnace as opposed to the normal maximum of 50 tons per operation in consumable arc and induction furnaces. Moreover, the dynamic mixing system of this invention enables more economical use of costly alloying additives such as titanium, chromium and cobalt.

This invention contemplates stream degassing as well as area degassing. Area degassing is defined as degassing the surface area of molten metal in a ladle. By mixing the molten metal continuously, the surface area of the molten metal in the ladle changes and degassing is better effected. Moreover, with dynamic mixing in a vacuum chamber and area degassing of the molten metal, it is possible to eliminate a costly and inefficient transfer from one ladle to another of molten metal from the furnace. Thus, super-heating problems created by the necessity of raising the temperature of the molten metal in the last ladle in order to compensate for temperature loss in transfer operations are avoided.

Additionally, the area degassing requires minimum material handling and minimum equipment cycling.

Therefore, it is the general object of this invention to provide a better method of producing ultraclean alloy steels.

Another object of this invention is to provide new and simpler apparatus for producing ultraclean alloy steels from existing melting departments in large quantities.

Another object of this invention is to provide a new and improved vacuum degassing process for molten metals utilizing magnetic stirring.

Another object of this invention is to provide a new and improved system for degassing metals wherein the metal is both stream degassed and area degassed.

Another object of this invention is to provide a better method of adding alloying agents to molten metal wherein more complete alloying is accomplished.

Another object of this invention is to provide simple and more economical apparatus for converting existing melting facilities to the production of ultraclean alloy steels.

Other objects will appear hereinafter.

For the purpose of illustrating the invention there is shown in the drawings forms which are presently preferred; it being understood, however, that this invention is not limited to the precise arrangements and instrumentalities shown.

FIGURE 1 is a partial cross sectional view of a preferred embodiment of the present invention.

FIGURE 2 is a partial cross sectional of a second embodiment of the present invention.

In FIGURE 1, there is shown a vacuum chamber utilized in the present invention and generally designated by the numeral **10**.

The vacuum chamber **10** consists of a bottom receiving pot **12** having a metal shell surrounding an interior refractory surface. The pot **12** has a cover **14** associated therewith. An annular flange **16** forms a lip on the pot to cooperate with an annular flange **18** on the top **14** to seal the vacuum chamber **10** when the top **14** is in place.

A non-magnetic stainless steel ladle receiving stand **20** is mounted on the floor of the pot **12**. The stand **20** has a ladle-shaped cavity **22** on the walls of which cavity are placed water-cooled induction coils **24**, **26** and **28**.

The induction coils **24**, **26** and **28** are separate annular rings each connected through its own individual terminals (not shown) to a source of alternating current outside of the vacuum chamber **10**. The annular coils **24**, **26** and **28** are held in place on the stand **20** by a removable retaining ring **42** of a non-magnetic material.

A ladle **30** containing molten metal to be degassed and alloyed is placed in the ladle cavity **22** with its trunnions **38** and journals **40** resting on the annular lip **42** of the stand **20**. The ladle **30** has a non-magnetic outer surface such as stainless steel of the AISI 300 series or reinforced fiberglass such as Spiralloy, etc. A refractory liner **34** forms the interior surface of the ladle **30**. The molten metal **36** is placed in the ladle **30** from the steel mill furnace.

When the top **14** of the vacuum furnace **10** is removed, the ladle **30** with its molten metal charge **36** is placed on the stand **20** by a suitable crane. It should be noted that for purposes of this invention, the molten metal charge **36** has a minimum layer of slag on the top thereof.

A conduit **44** extends to the interior of the pot **12** and is connected to a vacuum pump **46** for evacuating the chamber **10**.

The cover **14** has a hopper **48** mounted over an opening **50** in the center thereof. The hopper **48** is adapted to have an alloying material therein. Control of the feeding of the alloy material in the hopper **48** is effected by a trap chamber **51** located between two adjacent valves **52** and **54**. The trap chamber **51** is operated by first opening valve **52** to allow a predetermined amount of alloying material into the chamber **51**. The valve **52** is then closed and the valve **54** opened to feed the alloy material to the molten metal in the ladle **30**.

A conical baffle **56** is supported by frames **58** is located immediately below the trap chamber **51**. The baffle **56** is effective to insure the flow of alloy material to the side walls of the ladle 30 for reasons which will be discussed below.

The operation of the vacuum chamber 10 is as follows: At the inception of the operation, the cover 14 is raised a few inches by an overhead crane (not shown) and moved to the side exposing the top of the pot 12. There is at this time no ladle in the support 20. The ladle 30 is filled from the furnace and transported by means of an overhead crane to the pot 12 and placed in the support 20 with its trunnions 38 resting on the lip 42. The lid 12 is then returned to place on the flanges 16.

The vacuum pump 46 then evacuates the chamber 10. The coils 24, 26 and 28 are then energized with alternating current whose frequency is between approximately .2 to 4 cycles per second. This low frequency is necessary in order not to induce any heating in the molten metal charge 36. The magnetic field developed by the coils 24, 26 and 28 passes almost exclusively through the molten metal charge 36 as it is the only ferromagnetic material adjacent to the coil. The varying magnetic fluxes in the coils 24, 26 and 28 set up magnetic forces causing lifting or depression of the molten steel adjacent to the ladle wall, depending upon the phase cycling of the coil.

The low frequency of the induced field and the considerable power supplied to it cause movement of the molten metal in the ladle in the direction of the induced currents. The molten steel can be made to move as much as 40 inches radially inwardly from the outer wall of the ladle. In a practical embodiment, it was found that optimum magnetic stirring occurred between .55 and .7 cycle per second for 100 ton capacity ladles.

As the molten metal is moved from the outer walls toward the center or vice versa, the surface area of the metal is continuously moving. As the surface area of the molten metal changes, it is degassed by the vacuum in the chamber 10. The vacuum pump is able to more effectively degas the metal because of the magnetic stirring. In fact, it has been found that this type of area degassing is as effective as stream degassing. Approximately 50 to 70 percent of the hydrogen in the molten metal, 45 to 65 percent of the oxygen, and 7 to 15 percent of the nitrogen can be removed by this type of degassing.

After the molten metal charge 36 has been degassed, the alloying material in the trap chamber 51 is fed into the ladle 30. Since the alloying material is forced to flow down the conical baffle 56 toward the outer walls of the ladle 30, it does not flow toward the center of the molten charge 36. The magnetic stirring of the molten metal being from the outer walls toward the center carries that alloying material which falls to the outer walls of the ladle in toward the center with the resultant effect of excellent alloy homogeneity due to the magnetic stirring.

Since only one ladle was necessary in the operation, only one temperature drop occurred, the drop in temperature when the molten metal was poured from the furnace into the ladle. This temperature drop is approximately 50° to 70° F. Such a temperature drop is permissible and there is minimum need for reheating or preheating the molten metal so as to give rise to superheating problems. After the steel alloy has been produced by this process, the lid 14 is raised and moved to the side. Then a crane removes the ladle 30 before the start of another operation.

The second embodiment of the present invention is shown in FIGURE 2. In this operation, the lid 14 of FIGURE 1 has been replaced by a lid 60 having an annular flange 62 to cooperate with the lip 16 on the pot 12. A ladle 64 is mounted on the lid 60 in a manner to be discussed below. The ladle 64 has trunnions 66 and 68, and is adapted to receive molten metal from the open-hearth or other furnace. At the bottom of the ladle 64 there is a nozzle opening 70 controlled by the vertically movable stopper rod 72. When the ladle 64 is filled, the stopper rod 72 is of course in its lowermost position sealing off the nozzle opening 70. Thus, the ladle 64 has a molten metal charge 74, such as steel, aluminum, etc., therein. The nozzle 76 extends from the bottom of the ladle 64 toward the interior of the chamber 10. It should be noted that the ladle 30 is empty and is adapted to receive the molten metal charge 74 from the ladle 64.

The nozzle 76 is connected to an annular flange 78 which cooperates with an annular flange 80 on the lid 60 to hold a rupture disc 82 in place. Ladle 64 has legs (not shown) which are longer than nozzle 76. A refractory spray sleeve 84 directs the molten metal from the ladle 64 into the ladle 30. When the stopper rod 72 is raised, the molten metal flows through nozzle 76, ruptures the disc 82 and is directed through the spray sleeve 84 into the ladle 30. Prior to the raising of the stopper rod 72, the chamber 10 was evacuated by the vacuum pump 46. The rupture disc 82 formed a seal in the top of the chamber 10 so that the evacuation could be effected.

When the molten metal ruptured the disc 82 and flowed through the sleeve 84, it was stream degassed by the vacuum in the chamber 10. Additionally, if it is desired to react a gas with the molten metal, a conduit 94 can be placed on the lid 60. The conduit 94 would have a suitable source of reacting gas attached thereto. The reacting gas would be directed toward the stream of molten metal. One such reacting gas could be chlorine which would act as a reducing agent to combine with impurities and gases in molten metal such as aluminum which would subsequently be removed as a gaseous by-product by the vacuum pump 46.

The ladle 64 is generally supported on a standard 86 mounted on the lid 60. When the stopper rod 72 is returned to its closed position after the molten metal in the ladle 64 has flowed into the ladle 30, the evacuation of the chamber 10 may be continued.

An alloy material hopper 88 is also mounted on the lid 60. The alloy material hopper 88 has a trap chamber 91 formed by two valves 90 and 92. The hopper 88 directs alloying material into the molten metal in the ladle 30 where it is homogeneously combined with the molten metal due to the magnetic stirring therein.

The system shown in FIGURE 2 has the advantage of utilizing stream degassing with further area degassing if desired. However, it does require the use of two ladles and two transfer of molten metal. The first transfer is from the furnace to the ladle 64 and the second from the ladle 64 to the ladle 30. This causes a drop in the temperature of the molten metal of about 120° to 160° F. as opposed to only 50° to 70° F. in the embodiment shown in FIGURE 1. Additionally, it is difficult to utilize the baffle principle of placing the alloy material on the edges of the interior of the ladle 30 as was shown in FIGURE 1.

The processes shown in FIGURES 1 and 2 may be applied to a wide variety of steel grades. These include tool steels, bearing steels, deep drawing steels, hot rolled strip for cutlery and similar purposes, and specialized electrical grades. These are all ultraclean alloy steels. As shown, this vacuum steel making process can be applied to existing open-hearth and other furnace units so as to achieve the low levels of gas content obtained by consumable arc or induction melting furnaces.

The coils 24, 26 and 28 are usually water cooled or intermittently water cooled and separately excited. This allows for easy replacement by the steel manufacturer. The coils 24, 26 and 28 can be simply removed by taking off the bolted flange 42. Each one of the coils 24, 26 and 28 being nested in the support 20 will then be accessible to an overhead crane which could lift them out of place.

Because of the extremely homogeneous melt achieved by the magnetic stirring, the process shown in FIGURES

1 and 2 means more economical use of costly alloy materials such as titanium, chromium and cobalt.

The present inventon may be embodied in other specific forms without departing from the spirit or essential attributes thereof and, accordingly, reference should be made to the appended claims, rather than to the foregoing specification as indicating the scope of the invention.

I claim:

1. Molten steel handling apparatus comprising a chamber, vacuum means for evacuating said chamber, a nonmagnetic ladle in said chamber for receiving molten metal, said ladle including a cup-shaped fiberglass shell, and inductive means in said chamber for inducing low frequency electro-magnetic force currents in molten metal in said ladle to continuously move molten metal up to the surface level thereof while said ladle is in said chamber.

2. Molten steel handling apparatus comprising a chamber, vacuum means for evacuating said chamber, a nonmagnetic ladle in said chamber for receiving molten metal, inductive means in said chamber for inducing low frequency electro-magnetic force currents in molten metal in said ladle to continuously move metal up to the surface level thereof while said ladle is in said chamber, a hollow stand in said chamber for receiving and removably supporting said ladle, said stand supporting said inductive means, and said inductive means including a coil concentric with said ladle.

3. Apparatus in accordance with claim 2 wherein said stand includes a removable flange for supporting said ladle, said flange being additionally adapted to hold said coil in place whereby said coil may be easily lifted out of said stand when said ladle and flange are removed.

4. Molten steel handling apparatus comprising a chamber, vacuum means for evacuating said chamber, a nonmagnetic ladle in said chamber for receiving molten metal, said ladle including a stainless steel cup-shaped shell, a supporting stand in said chamber removably supporting said ladle, and inductive means supported by said stand for inducing low frequency electro-magnetic force currents at a frequency of between .2 and .8 cycles per second in molten metal in said ladle to continuously move metal up to the surface level thereof while said ladle is in said chamber.

5. Molten steel handling apparatus comprising a chamber, vacuum means for evacuating said chamber, a nonmagnetic ladle in said chamber for receiving molten metal, inductive means in said chamber for inducing low frequency electro-magnetic force currents in molten metal in said ladle to continuously move metal up to the surface level thereof while the ladle is in said chamber, a hollow stand in said chamber removably supporting said ladle by a surface adjacent the upper end of said stand cooperating with a portion of the ladle axially spaced from the bottom of the ladle, said stand supporting said inductive means, and said inductive means including a coil concentric with said ladle.

6. Molten steel handling apparatus comprising a chamber, vacuum means for evacuating said chamber, a nonmagnetic ladle in said chamber for receiving molten metal, inductive means in said chamber for inducing low frequency electro-magnetic force currents in molten metal in said ladle to continuously move metal up to the surface level thereof while said ladle is in said chamber, said chamber including a removable cover supporting an alloy material hopper thereon, an alloy material directing means associated with said hopper, said alloy material directing means including a conical refractory member supported by said lid and positioned to direct the alloy material toward the side walls of said ladle.

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