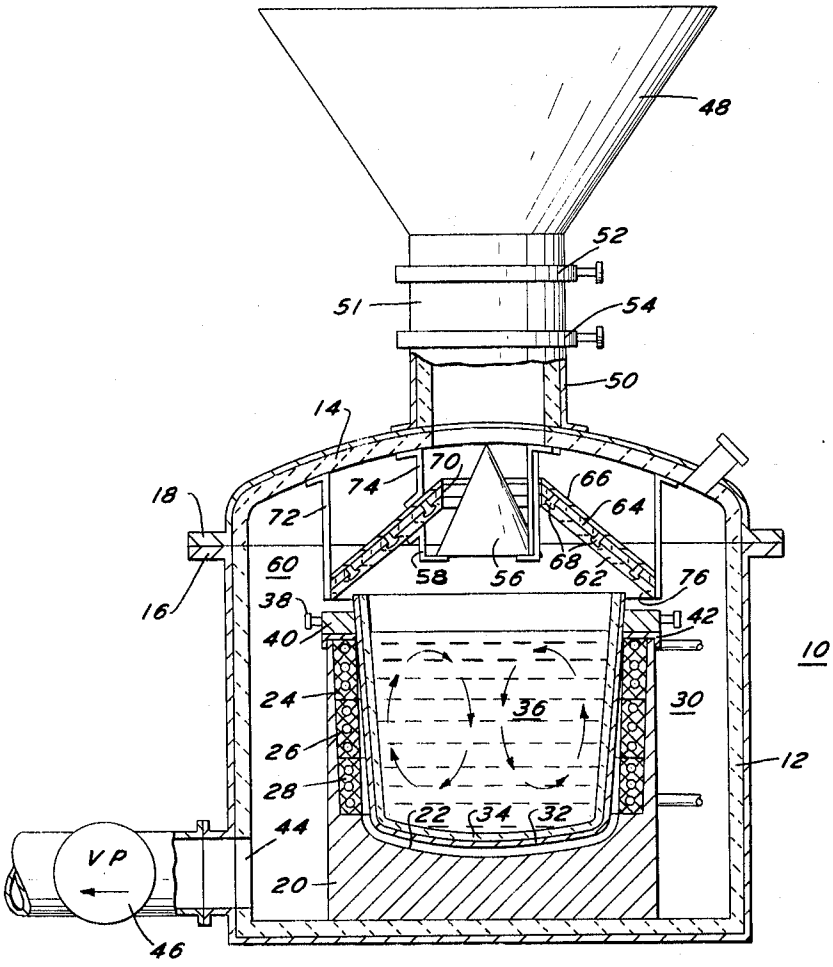
March 8, 1966 A. E. HOKANSON 3,239,204

VACUUM DEGASSING APPARATUS

Filed Feb. 5, 1963



INVENTOR.
ALAN E. HOKANSON
BY Arthur H. Seidel
ATTORNEY

United States Patent Office

3,239,204

Patented Mar. 8, 1966

3,239,204

VACUUM DEGASSING APPARATUS

Allan E. Hokanson, Meadowbrook, Pa., assignor, by mesne assignments, to Pennsalt Chemicals Corporation, Philadelphia, Pa., a corporation of Pennsylvania

Filed Feb. 5, 1963, Ser. No. 256,374
2 Claims. (Cl. 266—34)

In general, this invention relates to improved methods and apparatus for producing ultraclean alloy steels without unnecessary temperature losses. More particularly, it relates to the production of ultraclean alloy steels in which heat loss due to radiation is substantially reduced.

The invention described in the above-mentioned copending application is directed to magnetic mixing of alloying materials with stream and 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 was possible to eliminate a costly and inefficient transfer from one ladle to another of molten metal from the furnace. Thus, one cause of temperature loss in the alloying process was eliminated and superheating problems created by the necessity to raise the temperature of the molten metal to compensate for this loss were avoided.

However, a problem still existed in the temperature loss which occurred during the area degassing process. That is, the molten metal was normally magnetically stirred for approximately twenty minutes. During this time, a loss of 110° F. was observed in the molten metal. This temperature loss was due to convection, conduction and radiation. However, the main source of this loss was due to radiation.

It is, therefore, the general object of this invention to avoid and overcome the foregoing and other difficulties of prior art practices by the provision of a new and better method and apparatus for producing alloy steels.

More particularly, it relates to a new and better method of eliminating radiation losses of molten metal being stirred within a ladle in a vacuum chamber.

A further object is to provide new and simpler apparatus for producing ultraclean alloy steels in large quantities utilizing existing melting departments in steel mills.

A still further object of this invention is to provide an improved method of reducing heat losses due to radiation in a ladle within a vacuum chamber.

Other objects will appear hereinafter.

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 manufactured approximately 50–70%, the nitrogen content 7–15%, and the oxygen content by reduction 45–65%. This simple addition enables the steel manufacturers to produce steel of greater ductility and cleanliness. These properties produce a number of economies during subsequent hot working of the resultant alloy steel. Fewer edge checks, tears, and cracks, a large 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. The dynamic mixing system of this invention enables more economical use of costly alloying additives such as titanium, chromium and cobalt. Moreover, the heat loss due to radiation during the vacuum degassing is reduced 75 percent. In a practical embodiment of the present invention, the heat loss during a twenty minute area degassing of a ladle was reduced from a normal 110° F. drop to 50° F. It should be understood that this was a 75 percent drop in heat loss due to radiation. The other losses due to convection and conduction are not capable of being controlled in this maner. However, these latter losses are small in comparison to the radiation loss.

Radiation is the term applied to heat transfer resulting from wave motion through space. An understanding of the theory behind the present invention can best be gained by examining the theoretical equation for the quantity of heat q passing from one plane surface to another plane parallel surface.

$$q(\text{B.t.u. per hr.}) = 0.172 \times 10^{-8} A(T_1^4 - T_2^4) \cdot F_E$$

In the equation, A is the area, T_1 is the absolute temperature of the emitting surface, T_2 is the absolute temperature of the receiving surface, and F_E is an emissivity factor. For parallel planes, F_E is evaluated by use of the equation:

$$F_E = \frac{1}{\frac{1}{P_1} + \frac{1}{P_2} - 1}$$

where P_1 and P_2 are the emissivities of the emitting and receiving surfaces. Thus, it can be seen that as T_2 approaches T_1, the quantity of heat passing from one plane surface to another is reduced. Additionally, since P_1 in the case of a molten metal bath is constant at the emissivity of the molten metal bath (usually about .29), the only variation in F_E is due to P_2.

The present invention contemplates the use of a heat shield placed immediately above the molten metal bath and having a surface which is preheated to a temperature approaching the heat of the molten bath, and which surface has a low emissivity. As can be seen from the last-mentioned equation, as P_2 is reduced, F_E is similarly reduced.

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

In the drawing, 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 metallic 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 **12** 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. 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 **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 the 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 alloying 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 the valve 52 to allow a predetermined amount of alloying material into the chamber 51. The valve 52 is then closed and valve 54 opened to feed the alloying material to the molten metal in the ladle 30. A conical baffle 56 is mounted 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.

On the interior of the cover 14 and spaced immediately above the ladle 30 is a heated refractory heat shield built in accordance with the principles of the present invention utilized to minimize the radiation losses. The heat shield 60 has the surface closest to the molten metal bath 36 formed of aluminum oxide, Al_2O_3, which is a material having a low emissivity and capable of withstanding the high temperatures which occur during the processing of the molten metal. It should be understood that any other material might be utilized which combines these properties.

The shield 60 has a layer 64 of Fiberfrax or asbestos behind the aluminum oxide layer. These two layers are supported by a metallic shell 66 having integral T-shaped ribs 68 extending into the aluminum oxide layer 62. The aluminum oxide layer 62 is normally formed around the ribs 68 and allowed to harden and set so that it will be held in place. Other means of holding the layers 62 and 64 to the shell 66 could be utilized within the principles of the present invention.

The conical heat shield 60 has an opening 70 at its apex through which the baffle 56 is placed. The baffle 56 is supported by frames 58 mounted on heat shield 60. The heat shield 60 is itself supported by suitable supports 72 and 74 at the inner and outer peripheries of the shield. These supports 72 and 74 space the heat shield 60 from the ladle 30 so that a gap 76 is provided around the edges of the shield 60 from the support 20 so that the surface of the molten bath 36 can be suitably degassed.

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 steel mill 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.

While the lid 14 is moved to the side, a suitable heating means such as a gas burner is placed adjacent the aluminum oxide layer 62. The aluminum oxide layer 62 is then heated to approximately the temperature of molten steel. The temperature of molten steel is normally about 2800° F. It is within the contemplation of this invention that the temperature of the aluminum oxide layer 62 need not be exactly 2800° F., but could be as low as 2400° F. However, it is important that this layer be preheated in order to limit the amount of heat transfer between the shield and the surface of the molten metal.

After the low emissivity refractory layer 62 is heated to the temperatures indicated, the lid 14 is then returned to place on the flange 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 to the molten metal charge 36 as it is the only ferro-magnetic material adjacent to the coils. 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 coils.

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 is effective on the surface of the molten metal charge 36 as there is a suitable spacing 76 between the heat shield 60 and the ladle 30 and support 20.

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 60 percent of the oxygen, and 7 to 15 percent of the nitrogen can be removed by this type of degassing.

It should be noted that the emissivity of the molten metal was constant. As stated previously, the heat transfer q between the molten metal surface and another plane surface increases with an increase in the temperature differential between the metal surface and the other surface and also increases with the emissivity of the other surface. Although the equation discussed previously was for two plane surfaces, the basic principles are also applicable to a plane surface and a conical surface such as is herein present. The formula for these two surfaces would be far more complicated to determine. It is enough to say that the heat transfer between the surface 62 and the surface of the molten metal charge 36 increases with the temperature differential between the two surfaces and with increased emissivity of the surface 62. By making the surface 62 of a material of low emissivity (approximately .22 to .4) which is preheated to a temperature close to or equal to the temperature of the molten metal, the heat transfer between the two surfaces is minimized. With this system, the metal in the ladle being stirred "sees" a hot refractory so that radiation losses are cut drastically.

If stream degassing is desired, the hopper 48 can be removed along with its supporting structure and a suitable ladle can be mounted on the lid 14. The molten metal would pass through the opening 70 and be stream degassed as it flowed into the ladle 30. Thus, the metal would be both stream and area degassed.

While being stream degassed, the metal would pass near the preheated layer 62 of refractory low emissivity material. In the same manner as was discussed previously, there would be little heat transfer between these two surfaces.

It can easily be understood that the heat shield 60 can be mounted on the floor of the pot 12, on the ladle 30 or support 20, or on the cover 14 as shown. Any suitable mounting is within the contemplation of this invention if the spacing 76 is maintained while the shield 60 is correctly positioned over the ladle 30. It should be noted, however, that by mounting the shield 60 on the cover 14, it is

then possible to remove both the shield **60** and the cover **14** in one simple operation while maintaining its correct alignment with respect to the support **20** at all times.

After the molten metal charge **36** has been degassed in the manner discussed, 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 is necessary in the operation shown in the drawing, only one temperature drop occurs, the drop in temperature when the molten metal is poured from the furnace into the ladle. This temperature drop is approximately 50–70° 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. Additionally, the low heat loss during the area degassing due to the heat shield **60** limits the temperature drop during such area degassing to another 50° F. 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. While this is occurring, the layer **62** is being reheated up to the desired temperature.

The process shown 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, the 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 described means more economical use of costly alloy materials such as titanium, chromium and cobalt.

The present invention 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. Apparatus for degassing alloy steel comprising a vacuum chamber having a removable cover, a nonmagnetic ladle support within said chamber for receiving and supporting a ladle, said support having a central cavity of sufficient depth so as to receive therein substantially the entire body of a ladle, said support having coils mounted thereon for surrounding a ladle when such ladle is disposed within said cavity, said coils being adapted to be connected to a source of low frequency alternating current for stirring molten metal in a ladle, a heat shield, means supporting said heat shield between said cover and said support, said heat shield having a refractory surface juxtaposed to the support so that heat will not be absorbed from molten metal within a ladle on said support.

2. Apparatus for degassing alloy steel comprising a vacuum chamber having a removable cover, a support within said chamber for receiving a ladle, vacuum means for evacuating the chamber, a heat shield mounted above the support adapted to be juxtaposed to but spaced from the open top of a ladle removably mounted on the ladle support, said heat shield mounted within said vacuum chamber in dependent relation from said cover, said heat shield being supported a predetermined distance from a ladle on said ladle support, said heat shield having an opening at the center thereof, said vacuum chamber having a valve opening immediately above said heat shield opening, feed means mounted on said vacuum chamber for feeding metal through said valve opening and said heat shield opening into a ladle mounted on said ladle support, a non-magnetic ladle mounted on said ladle support, said ladle support being formed of a non-magnetic material, and coils mounted on said ladle support and surrounding said ladle, said coils being adapted to be connected to source of low frequency alternating current.

References Cited by the Examiner

UNITED STATES PATENTS

1,131,488	3/1915	Dolensky	75—49
2,253,421	8/1941	De Mare	75—49
3,071,458	1/1963	Finkl	75—49
3,084,038	4/1963	Finkl	75—49
3,145,096	8/1964	Finkl	75—49

OTHER REFERENCES

Byrne, J. W.: "World's Largest Vacuum Induction Furnace," Metal Progress, April 1960, pp. 83–86.

BENJAMIN HENKIN, *Primary Examiner.*

DAVID L. RECK, *Examiner.*