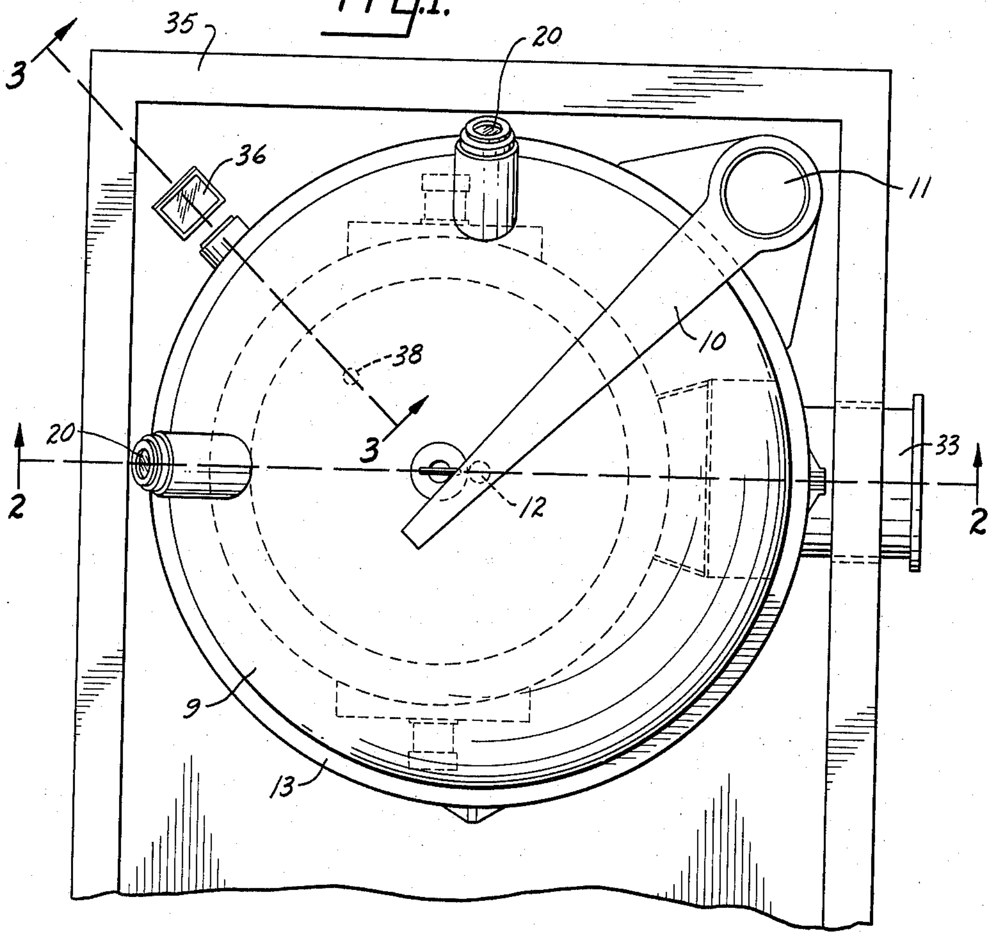
Feb. 22, 1966 C. W. FINKL 3,236,635

METHOD FOR DEGASSING MOLTEN METAL

Filed Dec. 2, 1958

3 Sheets-Sheet 1

Fig. 1.



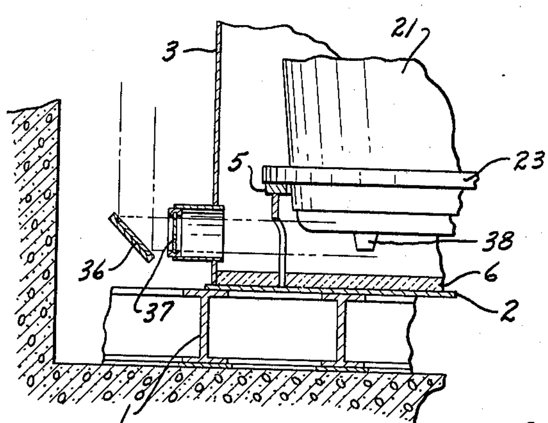


Fig. 3.

INVENTOR.
Charles W. Finkl,
BY Parker & Carter
Attorneys.

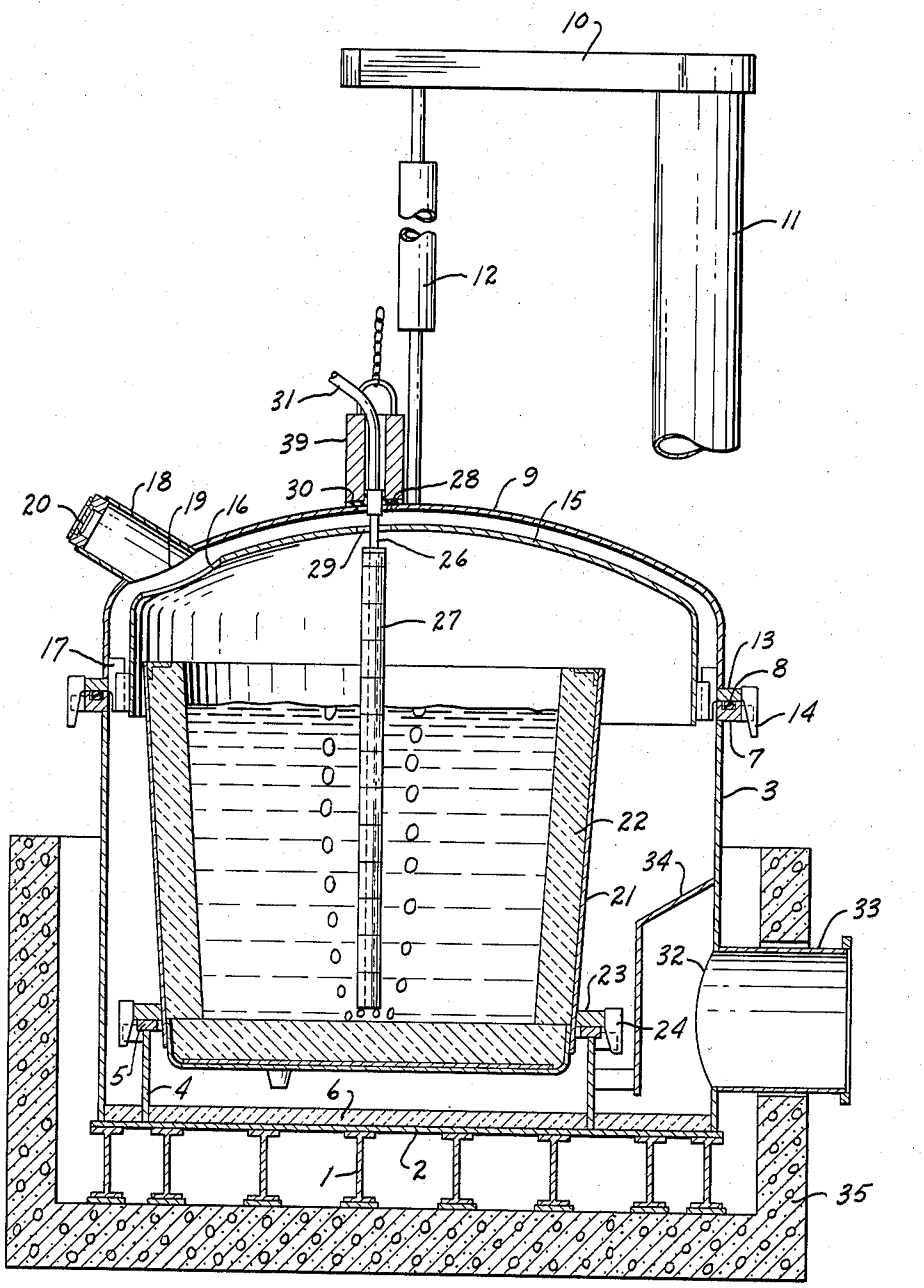


Fig. 2.

INVENTOR.
Charles W. Finkl,
BY Parker & Carter
Attorneys.

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3 Sheets-Sheet 3

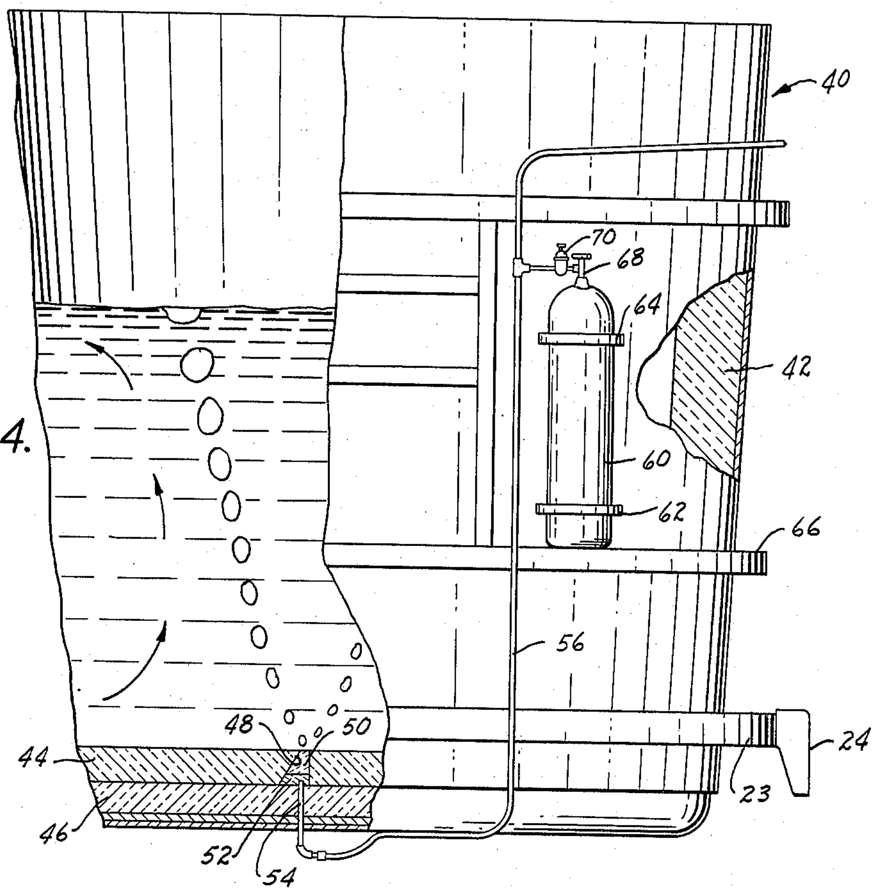

Fig. 4.

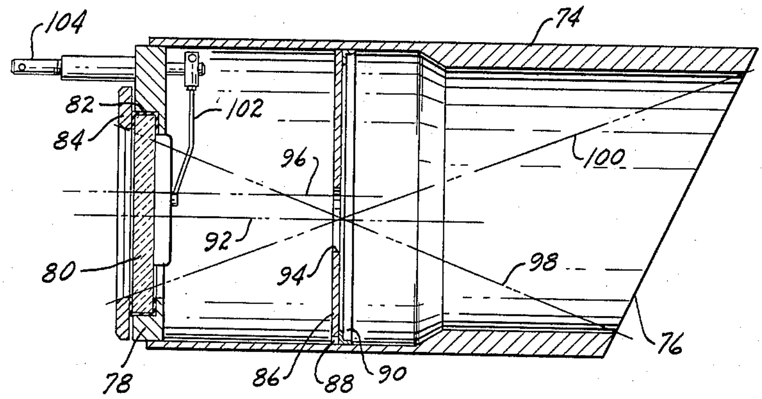

Fig. 5.

INVENTOR.
Charles W. Finkl,
BY
Parker & Carter
Attorneys.

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METHOD FOR DEGASSING MOLTEN METAL

Charles W. Finkl, Chicago, Ill., assignor to A. Finkl & Sons Company, Chicago, Ill., a corporation of Illinois

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23 Claims. (Cl. 75—49)

My invention relates to improvements in method and apparatus for degassing molten metal. It is especially aimed at lowering the hydrogen, nitrogen, and oxygen content, whether in solution or in physical mixture therein, of the metal. These gases, though small in weight in proportion to the mass of metal, are very deleterious.

One example of this invention is to reduce the hydrogen content of molten steel by purging with an inert gas for example, helium or argon, under vacuum conditions. Excess hydrogen promotes flaking and hydrogen embrittlement. These hazards are presently compensated for by heat treatment, but by reducing the hydrogen content, the heat treating time is materially reduced, which in turn reduces cost, and a better overall product results. In addition, since the limiting production factor in quantity runs is often the isothermal annealing, the annealing capacity of the plant is effectively increased.

It is old to subject a ladle of steel to a vacuum, thus drawing off some of the hydrogen from the molten metal. Unfortunately almost invariably stratification occurs and while substantial removal of hydrogen from the upper strata can be accomplished, the entire mass is not adequately subjected to the vacuum.

Another proposed solution has been to bubble an inert gas upwardly through the ladle of molten metal. Though claims to much better results have been made, as a practical matter it is seldom possible to reduce the hydrogen content down to a figure smaller to that attained with a vacuum alone.

What is proposed is to place the usual conventional type of ladle in a vacuum chamber, whereby air can be exhausted from the chamber and gas introduced into the bath, thus simultaneously subjecting the surface of the ladle to a vacuum while bubbling the gas through the ladle from the bottom. Under these circumstances, what occurs is that the bubbles of gas travel upwardly through the molten mass, stirring and agitating it and greatly increasing the surface of the liquid exposed to the gas, the surface in this case being not merely the surface of the level of the liquid at the top of the ladle but the combined areas of all the individual gas bubbles as they travel up from the bottom of the ladle to and are discharged through the level of the liquid metal. The hydrogen in the surfaces exposed to these bubbles diffuses into the bubbles and is discharged from the vacuum chamber by the vacuum pump. The gases in the molten metal are usually evolved as hydrogen, nitrogen, and carbon monoxide, but may be evolved in other combinations.

In many applications, this upward travel of the bubbles sets up a current so that there tends to be a circulation of the molten metal upwardly adjacent the center of the ladle and downwardly from the surface around the outer periphery. This agitation insures that a maximum proportion of the molten metal is exposed to the gas and has the opportunity to give up the deleterious hydrogen or other gases in the metal.

The combination of bubbling a gas into the metal while subjecting the surface of the metal to a vacuum greatly increases unexpectedly the degree of removal of the undesired hydrogen or other gas and makes is possible to carry the removal down far below that with either of the other two previously known methods.

The exact amount of bubbled gas needed and the pressures and degrees of vacuum may vary, but in general, it is essential that the bubbled gas be injected into and discharged close to the bottom of the molten metal at a pressure sufficiently above the static head of the metal to insure escape and upward bubbling of the gas. The type of gas bubbled through the melt is not restricted to inert gases, because even dry air may be used. It is only essential that the gas be one that will not combine too readily with the melt.

My invention is illustrated more or less diagrammatically in the accompanying drawings, wherein

FIGURE 1 is a plan view of the device;

FIGURE 2 is a section along the line 2—2 of FIGURE 1;

FIGURE 3 is a section along the line 3—3 of FIGURE 1;

FIGURE 4 is an elevation with parts in section of a modification; and

FIGURE 5 is a modification of an inspection window assembly.

Like parts are indicated by like characters throughout the specification and drawings.

Foundation beams **1** support a platform **2** from which rises a metal tank **3**. A supporting ring **4** rises from the platform **2** and terminates at the top in a bearing ring **5**. Insulation **6** protects the platform **2**. The upper boundary of the tank **3** terminates in a channeled flange **7** adapted to receive a sealing ring **8**. A dome **9** is carried by the pivoted arm **10** on column **11** and rests on the sealing ring **8**. The hydraulic ram **12** is interposed between the center of the dome which is concentric with the tank and the arm **10** so that the dome may be raised and lowered into and out of register with the tank, the tank and dome being both circular. The dome is bounded at its outer lower periphery by a reinforcing flange **13** in opposition to the ring **8**. Aligning fingers **14** on the flange **13** assist in centering the dome on the tank so that when the dome is seated, the seal ring **8** provides a gas tight closure between the dome and tank.

A heat shield **15** which is apertured at **16** is supported by brackets **17** from the dome. Barrel **18** extends from the dome about the aperture **19** and is in register with the aperture **16** in the shield **15**. The contents of the ladle in the vacuum tank may be inspected through an inspection window **20**.

A pouring ladle **21**, which is lined as at **22**, is open at the top and provided with a flange ring **23** which may rest on the bearing ring **5**. The flange ring **23** is provided at **24** with aligning guide elements associated with the ring **5** to center the ladle. The means for supporting and handling the ladle are conventional, form no part of the present invention and are not illustrated. Suffice it to say that the ladle when in position in the tank is eccentric with respect thereto.

A gas injection pipe 26, which is open at the lower end and surrounded by insulating sleeve members 27, extends downwardly through an aperture 28 in the dome and aperture 29 in the shield and may be raised and lowered by any suitable hoist mechanism, the details of which are not here shown. A seal 30 is carried by the upper end of the pipe 26, and so disposed that when the pipe is in its lower position, the seal closes the port 28 and makes a gas tight joint between the pipe 26 and the dome 9. A gas conduit 31 provides a carrier agent or gas from any suitable source, the details of which are not here shown.

At the lower part of the tank adjacent one side, is an aperture 32 in register with a gas exhaust pipe 33 which leads to a suitable vacuum connection. A baffle 34 extends inwardly from the wall of the tank 3, to mask the opening 32 to prevent heavy particles from entering the vacuum system. A concrete foundation pit 35 encloses the lower part of the structure.

FIGURE 3 illustrates a safety arrangement. The mirror 36 in the pit can be seen from above the pit and reflects the window 37 through which the operator may check the bottom of the tank. If there should be any leakage, for instance through the stopper nozzle 38 or otherwise, the operator will see that so that the ladle can be immediately withdrawn.

The insulated gas injection pipe is lighter than the solid molten metal so the weight 39 may be added to the pipe to give it weight sufficient to overcome specific gravity of the molten metal and remain in penetrated gas injection position.

Under some circumstances it may be desirable to inject the gas through the bottom of the ladle, the result being substantially the same.

An alternate structure for practicing this method is illustrated in FIGURE 4. Ladle 40 is provided with a vertical lining 42. The bottom is composed of a double layer construction of refractory material 44 and 46. Upper layer 44 may be composed of a plurality of individual sections which when assembled provide an aperture 48 near the center of the bottom. Alternately, the aperture may be formed in a single slab of lining.

A diffusing plug, consisting of an upper portion 50 and a lower portion 52, is located in aperture 48. Gas injection pipe 54 projects upwardly through the bottom of the ladle and terminates in the body of the lower portion of the plug. This portion is composed of a porous refractory material so that the carrier agent discharged from the injection pipe will pass upwardly. The upper portion may similarly be composed of a porous refractory material or it may be a removable metallic nozzle.

The injection pipe is connected to a gas conduit 56 which extends upwardly along the outside of the ladle and is connected to suitable valving on the exterior of the tank enclosing the ladle. The particular valving structure is not essential and accordingly has not been illustrated. The conduit may be connected by a flexible hose to a tank or other source of gas under pressure.

A gas bottle 60 secured to the ladle by clamps 62 and 64 containing bubbling gas under pressure is supported on a ledge 66 extending about the exterior of the ladle. Pressure regulator 68 maintains a substantially uniform pressure into an orifice 70. Suitable regulatory controls may be provided to control the flow rate of gas. If tank 60 contains less than the amount of gas needed to completely bubble a heat, the additional supply required may be furnished by the exterior source.

Bubbling a gas through a ladle under vacuum may cause a boil so violent that drops of the metal may splash into the sight glass structure and completely obscure the glass. In FIGURE 5, an inspection window assembly is shown which may be utilized in place of the unobstructed tube 18 of FIGURE 2. The assembly includes an outer housing 74 open at one end 76 and closed by a glass retainer wall 78 at the opposite end. End 76 has been formed at a substantial angle in order to provide a convenient angle of sight into the ladle. A window glass 80 and seal 82 are received in the glass retainer wall 78. Abutment plate 84 maintains a tight engagement between the glass and wall.

An apertured plate 86 is positioned near the midportion of the casing and held in place by a key and slot arrangement 88 and rolled angle 90. The center line 92 of aperture 94 is located slightly below the center line 96 of the sight glass so that lines of sight 98 and 100 reproduce the open area at end 76 at the glass 80. A wiper 102 having a projecting handle 104 may be utilized to sweep the inside of the sight glass. The aperture plate prevents spattering of the sight glass by materially reducing the area exposed to the boiling metal.

The use and operation of my invention are as follows:

The molten metal, which may for example be a ferrous alloy, is poured into the ladle in the usual way. Meanwhile the dome has been swung aside to leave the vacuum tank open. The crane lowers the ladle into the vacuum tank. At the same time vacuum commences to be drawn from the tank, the crane hooks are disconnected, the ladle being seated in the position shown in FIGURE 2. Then the dome is swung into register with the tank and is lowered to seal the tank about the mating peripheries of the tank and dome. Then the pipe 26 is lowered through the dome and shields until it reaches a point a little above, perhaps three inches or so, the bottom of the ladle and the aperture through which the pipe was lowered, is sealed. Vacuum continues to be drawn from the tank. As soon as a seal is accomplished, a carrier agent or gas, for example—helium though argon or other gases may be used—is forced into the pipe at a pressure above the ferrostatic pressure of the molten iron in the ladle and commences to bubble up through the liquid, being drawn out as a result of the vacuum drawn on the tank.

The vacuum during some stages of the process may be one millimeter of mercury or less. Several minutes will usually be required to take the vacuum down to that point depending on such factors as the capacity of the vacuum system, the size of the vacuum container and piping, the type of steel under treatment, and the size of the ladle. The purging gas is then forced into the metal, the time depending upon the size of the heat, type of metal under treatment, depth of ladle, and other factors. After the gas is turned off, the vacuum system is valved off and a neutral gas such as nitrogen is introduced into the chamber in order to guard against the formation of an explosive atmosphere. Air is then admitted to bring the pressure within the chamber up to atmospheric. In the embodiment of FIGURE 2, the gas pipe is drawn out of the ladle, if used, and the dome is raised and swung aside and the ladle withdrawn.

Just as soon as the ladle is placed, vacuum can be started and just as soon as the pipe is inserted into the ladle or the gas control valves of FIGURE 4 are opened, the gas will start to flow. As above indicated, the gas pressure must be sufficient to overcome the static head of the metal. The static head of the metal is one atmosphere for approximately each five feet of depth but as the pressure in the tank falls less and less gas pressure is needed to insure operation. One convenient way of controlling the flow of gas is to regulate gas pressure to twenty pounds per square inch, thereafter gas will pass through a variable orifice flowmeter. Pressure downstream will vary in consonance with the pressure required to insure a continuous flow of the gas at the desired rate to remove the particular amount of hydrogen in the liquid metal.

A typical example of the results obtained with this process as compared to the present processes utilizing only a vacuum or a gas individually is described in the accompanying table. These results are relative, and even lower results might be obtained under different conditions in which only a vacuum or a purging gas are utilized. In these heats, a sixty-ton ladle containing a medium carbon steel having a Chrome-Nickel-Moly analysis of approximately .90, 1.0, and .30 respectively was utilized. The ladle was placed in a vacuum system defining approximately 1200 cubic feet having a four stage steam ejector pump system.

	No. 1, Bubbled Only	No. 2, Vacuum Only	No. 3, Bubbled and Vacuum
Heat Description:			
Size of Heat, Tons	36	35	35
Gas Bubbled	Helium	None	Helium
Flow Rate, c.f.h	300		300
Amount Gas Bubbled, Cu. Ft.	100		87½
	No. 1, H_2	No. 2, H_2	No. 3, H_2
Gas Analysis Results:			
Electric Furnace Before Tap	4.9	6.5	5.4
Ladle Surface Before Process	5.1	7.3	5.3
Ladle Surface After Process	4.9	5.3	4.2
Metal From Ladle Stream After 14 Tons Have Been Poured	4.8	5.5	3.1
Metal From Ladle Stream After 31 Tons Have Been Poured	4.9	5.5	2.7
	Absolute Pressure, Millimeters Hg		
Time in Tank, Min.:			
0	760	760	760
2	760	330	330
4	760	160	170
6	760	46	40
8	760	4.2	1.4
10	760	.44	.66
12	760	.38	.56
14	760	.28	.51
16	760	.24	.44
17	760	.23	.39

Under some conditions, a unique phenomenon characterized by a violent boil occurs. Just a few minutes after a vacuum of one millimeter is reached, the absolute pressure in the tank will rise sharply and the metal will boil so violently so as to almost overflow the ladle. The boil can then be controlled by dropping the initial stages of the vacuum until the boil subsides to a flat bath. The best results are generally obtained when this condition occurs. Although the exact physical and chemical changes have not been ascertained it is thought that the boil may result from a disassociation of oxides and nitrides.

The foregoing tabular results show that the combined use of the vacuum and purging yields a hydrogen content of only slightly over 50% of the best results obtainable by prior methods.

Although lower absolute values might be obtained by the use of either purging or vacuum alone under different conditions with a particular steel, the simultaneous use of vacuum and a purging gas invariably produces better results.

The gas injection tube at the center of the ladle insures that as the gas bubbles up, it travels along a path generally axial with respect to the ladle entraining with it molten metal. This molten metal will flow vertically, then radially, along the surface and will tend to migrate downwardly along the outer periphery of the ladle, such migration being also promoted by the fact that cooling of the metal is from the ladle walls inwardly. The bubbling accomplishes two things. First, the individual bubbles act as carrier agents to remove some included gas and secondly the agitation induced moves virgin metal from the bottom to the top of the ladle where it may be subjected to the vacuum. The vacuum is effective to a depth of a few inches to a few feet depending on boil.

As mentioned, a variety of factors must be taken into account, but perhaps the most important ones are the analysis of the steel, the depth of the ladle, and the method of analyzation. It has been found that included gas diffusion into the purging gas, and perhaps into CO, varies in a geometrical ratio to the ladle depth. With the equipment utilized in the exemplary heats, the rate of diffusion varied approximately proportionally to the square of the depth. The method of analyzation includes such factors as where the sample is taken, i.e. whether in a molten condition or from the finished product, how taken, i.e. by a pin tube, an evacuated copper cylinder, or a core drill from the finished product, and the equipment used in running the hydrogen content analysis. In the exemplary heats, evacuated pin tubes were used to take the sample from a bare ladle spoon, and a Fisher Serfass Fusion Gas Analyzer was used to run the sample.

The amount of slag present and the addition of aluminum will also affect the results. When the slag forms a continuous blanket over the surface, the bubbling action is reduced, and the vacuum is less effective. The addition of aluminum ties up the oxygen which prevents formation of CO. The CO also acts as a purging gas into which the hydrogen can diffuse.

Although only a single gas source near the bottom center of the ladle has been described, any convenient number of pipes or plugs located in suitable positions may be utilized. The number and position will depend on such factors as the size of ladle.

I claim:

1. A method of removing deleterious gases from a confined volume of molten metal in a receptacle, said method including the steps of subjecting the surface of the confined volume of molten metal to a vacuum sufficient to degas the molten metal, and simultaneously passing a sufficient quantity of a carrier agent upwardly through the molten metal to induce a circulation entirely within the receptacle which brings substantially undegassed molten metal from remote areas in the receptacle to the surface.

2. The method of claim 1 further characterized in that the carrier agent is a gas having little affinity for the molten metal.

3. The method of claim 2 further characterized in that the carrier agent is an inert gas.

4. The method of claim 1 further characterized in that the carrier agent is a gas selected from the group consisting of argon, helium, and dry air.

5. The method of claim 1 further characterized in that the carrier agent is passed upwardly through the molten metal from a point close to the bottom of the receptacle.

6. A method of degassing a batch of molten metal in a ladle, said method including the steps of subjecting the surface of the molten metal to a vacuum sufficient to degas the molten metal, and simultaneously bubbling a sufficient volume of purging gas having little affinity for the molten metal upwardly through the molten metal to induce a circulation within the ladle which brings substantially undegassed molten metal from remote areas in the ladle to the surface.

7. The method of claim 6 further characterized in that the purging gas is an inert gas.

8. The method of claim 6 further characterized in that the purging gas is bubbled upwardly through the bottom of the ladle.

9. The method of claim 6 further characterized in that the purging gas is bubbled upwardly through the molten metal from a point slightly above the bottom of the ladle.

10. A method of removing undesired gases from a batch of molten metal in a ladle, said method including the steps of subjecting the surface of the molten metal to a vacuum sufficient to degas the molten metal, and simultaneously bubbling a sufficient volume of purging gas having little affinity for the molten metal upwardly through the molten metal at approximately the center of the ladle to thereby induce an upward circulation adjacent the center and a downward circulation adjacent the periphery of the ladle which brings substantially undegassed molten metal from remote areas in the ladle to the surface.

11. A batch method of removing undesired gases in a batch of molten metal in a ladle, said method including the steps of subjecting the surface of the molten metal to a vacuum on the order of about 1 millimeter of mercury or less, and simultaneously bubbling a sufficient volume of purging gas having little affinity for the molten metal upwardly through the molten metal to thereby induce a circulation within the ladle which brings substantially undegassed molten metal from remote areas in the ladle to the surface.

12. A batch method of removing deleterious gases from a batch of molten metal in a receptacle, said method including the steps of subjecting the surface of the batch of molten metal to a vacuum sufficient to degas the molten metal in the absence of a slag blanket of a thickness which prevents the metal from being effectively exposed to the vacuum, and simultaneously agitating the molten metal to thereby set up a circulation entirely within the receptacle which exposes remote substantially undegassed portions of molten metal directly to the vacuum at the surface of the batch, and adding an inert agent to thereby reduce the danger of explosion.

13. A method of degassing a batch of molten metal in a receptacle, said method including the steps of placing molten metal in the receptacle, subjecting the surface of the molten metal to a vacuum sufficient to degas the molten metal, simultaneously exposing substantially undegassed molten metal from remote areas in the receptacle directly to the vacuum by passing a sufficient volume of a carrier agent upwardly through the molten metal to induce a circulation within the receptacle which brings substantially undegassed molten metal from remote areas in the receptacle to the surface, flooding the area above the surface of the molten metal in the receptacle with an inert agent to thereby reduce the danger of explosion, and thereafter exposing the receptacle to atmospheric conditions.

14. A batch method of degassing molten metal in a ladle, said method including the steps of tapping molten metal into a ladle, subjecting the molten metal to a vacuum sufficient to degas the molten metal, simultaneously bubbling a sufficient volume of purging gas at a pressure above the head of the metal upwardly through the molten metal to induce a circulation entirely within the ladle which brings substantially undegassed molten metal from remote areas in the ladle to the surface, flooding the area above the surface of the molten metal in the ladle with an inert gas to thereby reduce the danger of explosion, and then exposing the ladle to atmospheric conditions.

15. In a process of removing deleterious gases by a vacuum purging treatment from a batch of molten steel having a depth greater than the depth to which the vacuum alone is effective, the steps comprising subjecting the surface of the batch to a vacuum sufficiently low to effectively degas it, and, simultaneously with subjection of the steel to the vacuum, passing a gaseous purging agent which does not combine with or migrate into the steel upwardly through the batch to thereby cause substantially undegassed molten steel in areas of the batch remote from the surface to be exposed to the vacuum at the surface, the subjection of the surface of the batch to the vacuum occurring in the absence of a slag blanket thereon which prevents the boiling metal from being effectively exposed to the vacuum.

16. The process of claim **15** further characterized in that the gaseous purging agent is dry air.

17. The process of claim **15** further characterized in that the gaseous purging agent is an inert gas.

18. The process of claim **15** further characterized in that the vacuum approaches 1 mm. of Hg absolute during subjection of the steel to the vacuum.

19. In a process of removing deleterious gases by vacuum treatment from a batch of molten steel, the steps comprising subjecting the surface of the batch to a vacuum sufficiently low to effectively degas it, and, simultaneously with subjection of the steel to the vacuum, passing dry air upwardly through the batch to thereby cause substantially undegassed molten steel in areas of the batch remote from the surface to be moved to the surface.

20. The process of claim **19** further characterized in that the vacuum approaches 1 mm. of Hg absolute during subjection of the steel to the vacuum.

uum treatment from a batch of molten steel, the steps

21. In a process of removing deleterious gases by vacuum treatment from a batch of molten steel, the steps comprising subjecting the surface of the batch to a vacuum sufficiently low to effectively degas it in the absence of added heat, and, simultaneously with subjection of the steel to the vacuum, passing a gaseous purging agent which does not combine with or migrate into the steel upwardly through the batch to thereby cause substantially undegassed molten steel in areas of the batch remote from the surface to be moved to the surface.

22. The process of claim **21** further characterized in that simultaneous vacuum and purging treatment occurs in the absence of a slag blanket which prevents the boiling metal from being effectively exposed to the vacuum.

23. The process of claim **22** in which the gaseous purging agent is dry air.

References Cited by the Examiner

UNITED STATES PATENTS

1,921,060	8/1933	Williams	75—49 X
2,054,922	9/1936	Betterton et al.	266—34
2,054,923	9/1936	Betterton et al.	75—49 X
2,726,952	12/1955	Morgan	75—49
2,776,204	1/1957	Moore	75—49
2,826,489	3/1958	Wagner	75—49 X
2,852,246	9/1958	Janco	266—34
2,871,008	1/1959	Spire	75—60
2,893,860	7/1959	Lorenz	75—49

FOREIGN PATENTS

568,803	7/1958	Belgium.

BENJAMIN HENKIN, *Primary Examiner.*

RAY K. WINDHAM, DAVID L. RECK, *Examiners.*