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METHOD OF AND APPARATUS FOR MAKING STEEL

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Fig-2

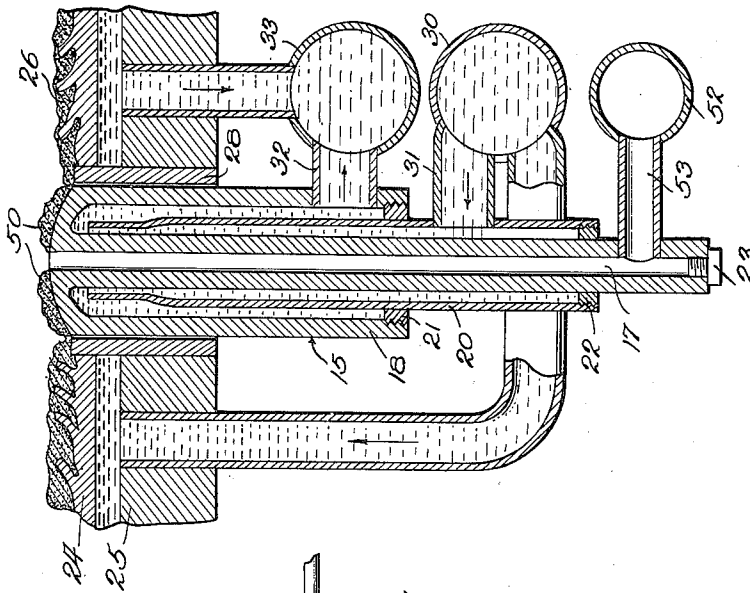
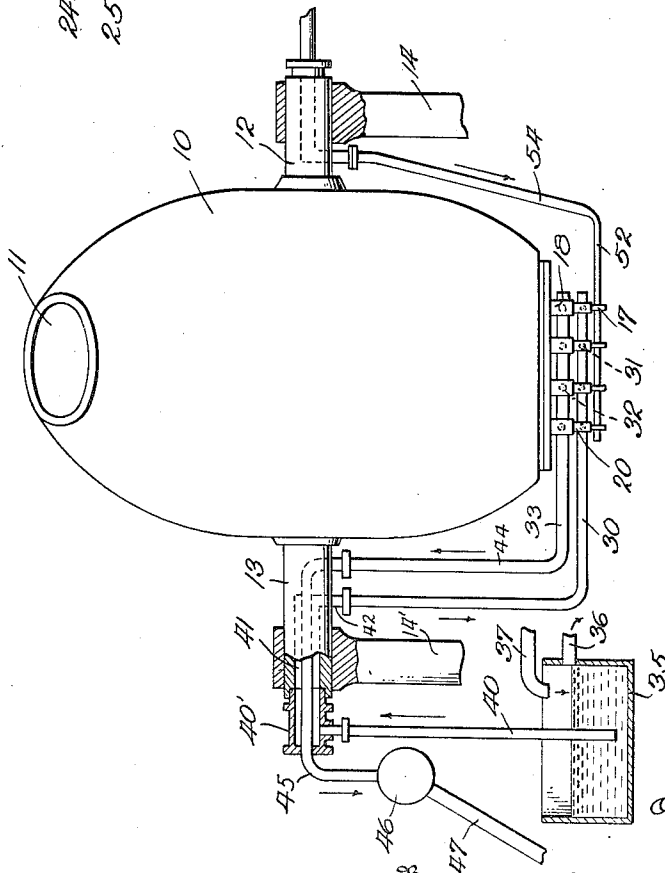


Fig-1



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METHOD OF AND APPARATUS FOR MAKING
STEEL

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This invention relates to methods of and apparatus for treating baths of molten metal with gases and relates more particularly to methods of and apparatus for treating molten iron with concentrated oxygen in a Bessemer converter.

It has previously been suggested from time to time by workers engaged in the refining of metals that impurities might more advantageously be removed from metals such as molten iron by passing a blast of pure or substantially pure oxygen through the metal as a substitute for the well-known and long practiced process employing ordinary atmospheric air through the molten bath, as in Bessemerizing. It is known, for instance, that if a blast of pure oxygen is employed in such a process instead of atmospheric air, the resulting metal is substantially free of nitrogen and is of superior quality for this reason, nitrogen in the resulting metal lowering the quality of the metal. It has likewise furthermore been suggested that the use of a blast of substantially pure oxygen instead of atmospheric air would cause the temperature of the entire body of molten metal through which the blast is passed to be raised to a degree substantially higher than it would be raised where the air blast is employed, containing such a large proportion of inert nitrogen, thus permitting considerably larger charges of ore and scrap to be added to the bath during the process of purification and reducing the cost of the entire operation.

Ways and means for producing substantially pure oxygen at relatively low cost have been developed so that the expense involved in the use of a blast of substantially pure oxygen in a Bessemerizing process can no longer be considered to be prohibitive, keeping in mind the advantages which will flow from the use of such a blast, for instance, by the fractional distillation of liquid air, oxygen can be produced at a cost sufficiently low to make its use as a blast medium in a Bessemerizing process entirely economical.

Notwithstanding the fact, however, that metallurgists have realized the desirability of using pure oxygen as a blowing medium, or substantially pure oxygen, from the standpoint of the improved product to be expected, and because of the possibility of using increased amounts of ore and scrap, and substantially pure oxygen is available at relatively low cost, attempts to commercially Bessemerize molten iron with the aid of an oxygen blast which have been actually made from time to time have not proven to be successful. This lack of success can be attributed

to the failure of prior workers in the art provided suitable apparatus in which the process may be carried out, and apparatus which will withstand the high temperatures generated without failure, and enable the operator to pursue the blowing operation as long as may be necessary to effect the desired purification of the metal. It has previously been stated that, where pure oxygen is used as a blast medium a very intense heat is generated in the bath or body of molten material, a heat very much more intense than that realized when the blast medium comprises ordinary atmospheric air. The heat developed when an oxygen blast is employed is most intense at a point relatively close to the orifice of the duct which conveys the oxygen to a point of discharge into the metal. Superheated metal oxides are developed and the temperature becomes such in a relatively short time after the blast is commenced that neither iron nor steel tuyères, whether water cooled or not, nor tuyères of refractory material, can long remain intact. It has been found, for instance, by actual experiment that, when a blast of substantially pure oxygen is substituted for the ordinary air blast, in carrying out a purifying blow in an ordinary Bessemer converter, the bottom of the converter through which the oxygen is introduced, even though water cooled, will fail by burning out within a few minutes after the commencement of the operation. No type of tuyère heretofore known has been able to successfully resist the intense heat thus developed.

After long experimentation, I have discovered a method of and apparatus for utilizing a blast of substantially pure oxygen in a Bessemerizing operation. In accordance with my invention, a special type of tuyère is employed, at least that portion of which encircles the gas discharge port, and is exposed to the heated metal of a bath, being fabricated of a relatively thin layer of a metal of high heat conductivity, means being provided to effect the removal of heat units from this portion of the tuyère at such a very high rate that not only is the temperature of the tuyère kept relatively low, but some of the superposed molten metal of the bath is chilled or cooled to cause the deposition upon the portion of the tuyère referred to of a chilled or frozen layer. During the operation of the process the temperature control must be maintained and such layer of protective metal kept in position, failure to exercise this precaution invariably resulting in immediate failure of the tuyère and hence of the converter.

I have discovered as a result of study and investigation that, if the discharge end or tip of a tuyère which is used to introduced substantially pure oxygen into a molten bath of iron or steel is to endure during a Bessemerizing process, particularly during the decarbonization period, cooling means must be provided to remove from this exposed uninsulated tuyère tip an amount of heat in excess of 1,500,000 B. t. u.'s per hour for each square foot of exposed surface of the metallic tuyère. After the carbon has been burned out and the blowing with oxygen proceeds, (the oxygen being absorbed by the metal without the development of gases) the cooling of the tuyère tip must be at the rate of approximately 5,000,000 B. t. u.'s per square foot per hour. Advantageously the tip or discharge end of the tuyère may be fabricated of copper, a metal of high heat conductivity, the copper member being only moderately thick. If the tuyère tip is fabricated of copper, as suggested, and, during the oxidizing blow, if heat is removed at the rate of approximately 1,500,000 B. t. u.'s to 5,000,000 B. t. u.'s per square foot per hour, not only will the temperature of the copper tuyère tip be maintained comparatively low, but the metal of the bath immediately in contact with it will, to a certain extent, be chilled and solidified, and caused to deposit as a protective layer over the otherwise exposed surface of the tuyère tip, the effect of which is to protect the tuyère tip and prevent its destruction by the intense heat in its immediate vicinity. This protective layer is maintained throughout the blowing operation, so long as the necessary rate of withdrawal of heat units is maintained with the result that the converter as a whole will be maintained in effective operation. The rate of heat transmission above suggested is higher than ever before mentioned, so far as the applicant is aware. It exceeds by many hundred times the rate of heat transmission in the walls of an ordinary steam boiler and by many times the rate of heat transmission which exists when a water cooled pipe is heated by a large sized welding torch. The thickness of the protective layer of chilled or frozen metal on the surface may be increased by increasing the rate of cooling of the tuyère and will be decreased if the rate of cooling of the tuyère is lowered. As previously stated, if the rate of cooling falls appreciably below 1,500,000 B. t. u.'s per square foot per hour, the protective layer of frozen or solidified metal will melt away rapidly, thus exposing the tuyère, and the tuyère itself will be melted through and destroyed very quickly thereafter. It is of the essence of the invention, therefore, to provide an apparatus for and method of maintaining upon the end of the tuyère or blast device which is used, a protective layer of frozen metal and, if this be done, by properly designing and regulating the cooling instrumentalities, the tuyère and converter may be operated indefinitely.

In a Bessemer converter, tuyères are customarily placed in the converter bottoms but they may be positioned, under certain circumstances, elsewhere than in the bottoms if desired. It is found expedient likewise in applying the invention to a Bessemer process and apparatus to cool the entire bottom of the converter as well as the tuyères, by circulating cooling fluid such as water not only through the tuyères but likewise through conduits, ducts, or chambers built into or associated with the converter bottom. For the operation of a Bessemer converter with concen-

trated or substantially pure oxygen as a purifying gas, it is best to thoroughly water cool the bottom and then to securely attach to the upper surface of the upper bottom plate a relatively thin layer of refractory material. A refractory lining material covering the bottom can only be maintained in effective operation when strongly water-cooled and it is therefore necessary to maintain the layer relatively thin, as otherwise the uppermost portion, at least in the vicinity of the tuyères would be rapidly destroyed.

In order to guard against the occurrence of disastrous explosions, it is much to be preferred that, should the wall or bottom of the converter ladle or other molten metal receptacle break down, the molten metal shall enter the narrow channels for the circulation of the cooling fluid rather than the reverse. For this reason means is provided for maintaining the pressure of the cooling fluid below that of the molten metal at all points where there is any likelihood that the cooling fluid duct may come to communicate with the molten metal due to failure of the ladle or converter wall. With a view to further diminish the danger of explosions, the ducts or channels for water cooling have to be narrow in order to give the smallest possible contact surface between water and liquid metal in case the bottom breaks through.

While particularly applicable to Bessemer converters, both the improved tuyère and the method of operating the same may be made use of, when necessary precautions are taken, for the introduction of oxygen or other gases into bodies of molten metal disposed in other containers.

In the drawing:

Figure 1 is a side elevation showing, rather diagrammatically, a Bessemer converter, having conventional trunnions and disposed for rotation about the horizontal axis of these trunnions, the means for circulating cooling fluid through the tuyères and converter bottom being shown; and

Figure 2 is a longitudinal section through one of the tuyères showing adjacent portions of the converter bottom and certain of the conduits for leading cooling fluid to and from the tuyère and converter bottom.

The body of the Bessemer converter selected for illustration by way of example is indicated by the numeral 10 and this body of course is merely representative of many with which the invention might be advantageously used. Its details, save for certain bottom and tuyère features, are not illustrated inasmuch as they have little bearing upon the present invention and it need only be said that the body 10 of the converter contains the usual cavity for the reception of a molten body of metal, an opening 11 at the top for the escape of gases and for charging and discharging the molten iron or steel, trunnions 12 and 13, respectively, rotatably mounted in bearings on supports 14 and 14', and a water cooled bottom and special water cooled tuyère construction which may be more clearly perceived in Figure 2. A battery of four tuyères 15 may be employed, or a larger or smaller number, as may be desired.

As shown in Figure 2, each tuyère, which is generally indicated at 15, comprises several parts, the elongated central tube or duct 17 for the passage of gas, the considerably shorter outer cylindrical casing 18 which at its upper end is integrally connected to the upper end of the duct 17, and a thin walled tubular member 20 concentric with and encircling the tubular duct 17 and disposed within the casing 18. An annular clo-

sure ring 21 closes the annular gap between the inner surface of casing 18 and the outer surface of tube 20, at the lower end of the casing, and an annular closure ring 22 closes the gap between the inner surface of tube 20 and the outer surface of duct 17, at the lower end of the tube. The lower end of the gas duct 17 is closed by a plug 23. The tube 20 at its upper end is slightly reduced in wall thickness, and slightly reduced in inside diameter, so that fluid passing upwardly through the annular space between the duct 17 and the tube 20 will be in most rapid movement as it discharges from the upper end of the tube due to decrease in area of the fluid conduit as this point is approached. The end of the tube 20 is quite close to the inner surface of the annular web which connects the upper ends of tube 17 and casing 18 of the tuyère so that, if a cooling fluid be passed upwardly between the tube 20 and duct 17, it will flow directly against the undersurface of the top of the tuyère and thence will pass downwardly between the outer surface of tube 20 and the inner surface of the outer casing 18 of the tuyère.

The bottom of the particular converter which is shown comprises two metallic plates indicated at 24 and 25, the upper plate 24 being relatively thin and provided with upturned integral tongues, pins or other projecting elements, which serve to retain in position a relatively thin layer of refractory material 26 previously applied to the surface of the plate while in plastic condition. The plates are spaced apart, as shown, are preferably disposed in exact parallelism, and are provided with registering cylindrical apertures, there being two registering apertures for each tuyère. A short cylinder 28 projects through and closely fits within each pair of registering cylindrical apertures in the plates, this cylinder being retained in position by welds, if desired, and serving to seal off the space between the plates so that a cooling fluid in this space may not escape into the tuyère openings. As a matter of fact, each cylinder 28 defines a cylindrical tuyère opening within which one of the tuyères is positioned, the tuyère fitting the cylinder loosely so as to be removable as an entirety, the upper surface of the tuyère being initially exposed to the bath and not covered with refractory or other protective material. A manifold for conducting a cooling liquid such as water to the several tuyères is indicated at 30 and it will be observed in Figure 2 that this manifold communicates, through a tubular member 31, with the annular space between the outer surface of the gas duct 17 and the inner surface of tube 20 so that liquid flowing through tube 20 will pass upwardly, be discharged against the undersurface of the annular top of the tuyère, and thence pass into the annular space between the outer surface of tube 20 and the inner surface of the tuyère casing 18. From this space the liquid will pass into short tube 32, thence into the cooling fluid offtake manifold 33.

A receptacle for the reception and storage of cooling liquid is indicated at 35, this receptacle being in the nature of an open tank having an overflow 36 and a source of supply 37. Liquid from supply pipe 37 flows into the tank at a rate, at all times sufficient to maintain the level of the liquid body constant at the height of the overflow 36. Leading upwardly from the tank is the conduit 40 and the upper end of this conduit is secured to a cylindrical stationary casing 40' which is in constant communication with a cylindrical chamber 41 formed in trunnion 13, the in-

ner end of chamber 41 being connected by tubular conduit 42 with the supply manifold 30 previously referred to. The offtake manifold 33 is in constant communication, through the upwardly extending tube or duct 44, with a horizontally extending tubular member 45 which passes through the cylindrical chamber 41 formed in the trunnion 13 and thence downwardly to a point where it is connected to the intake of a pump diagrammatically indicated at 46. The discharge port of the pump is in communication with a discharge pipe 47 by means of which the liquid delivered by the pump may be directed in a reservoir to be cooled before being recirculated.

It will be observed that the level of the liquid in the tank 35 is below the bottom of the converter and hence the pressure of the liquid in the system of conduits above the level of the liquid in tank 35 must be less than atmospheric. It follows that the pressure of the liquid in the cooling liquid space intermediate bottom plates 24 and 25 will be less than atmospheric and likewise the cooling liquid which is passing through the cooling liquid ducts of the tuyères. As it is obvious that the pressure of the molten metal above the bottom of the converter will be greater than atmospheric, it must necessarily follow that, in the event of a failure of the upper plate 24 of the bottom, or a burning away of the top of the tuyère, so that metal and cooling liquid can come into contact, the superior pressure of the metal will cause it to enter the cooling liquid duct and the danger of a serious explosion be thus avoided, which danger would be present were the cooling liquid under such pressure that it would be forced in substantial volume into the molten metal.

The velocity of the water which emerges from the upper end of the tube 20 (Figure 2) in the form of an annular jet and impinges against the undersurface of the annular top of the tuyère may advantageously be approximately 20 feet per second and, in the case of a tuyère constructed in the manner shown and positioned approximately as indicated in Figure 2 with respect to the converter bottom, and which tuyère is fabricated of copper, the top of the tuyère may be maintained sufficiently cool to cause the deposition thereon of solid or "frozen" metal, indicated by the shaded portions 50, despite the fact that the upper end of the tuyère is in contact with exceedingly highly superheated liquid metal and corrosive metal oxides. The flow of cooling water may be increased or decreased to bring about the maintenance of a metallic protective layer of the desired thickness and, when this is done, the tuyère body is adequately protected from the molten metal. Should the rate of cooling of the tuyère be materially decreased, however, the deposited layer 50 will promptly liquefy and thus expose the tuyère to the direct action of the superheated metal. When this occurs, the tuyère will be rapidly burned through.

The oxygen gas is supplied through a manifold 42 (Figure 2) connected to the lower end of the gas duct 17 by a tubular member 53, the manifold 52 being in turn connected to a substantially vertically extending conduit 54 (Figure 1) which is in communication with one which passes outwardly axially through the trunnion 12 to a suitable source of supply.

In the practice of the invention I prefer to form the gas channels of the tuyères of reduced size as compared with those of the usual tuyère employed where an air blast is used, without increasing the number of tuyères, and to use higher

pressures. Thus the tuyère shown in the drawing has an outside diameter of approximately one and one-quarter inches and the oxygen duct a diameter of one-eighth of an inch, the oxygen duct area being less than one-fifth that of the air duct area of the conventional tuyère. By using higher pressures I project the oxygen streams into the molten bath at higher velocities than those employed in Bessemerizing with air, pressures used varying between forty and one hundred fifty pounds per square inch. By using higher velocities and pressures, and oxygen streams of reduced diameters, the formation of red smoke (iron oxides, etc.) is largely avoided, thus minimizing loss of metal during blowing. The oxygen blast which I employ may comprise substantially pure oxygen or contain oxygen in amount between 75% and 100%. In the appended claims the term "concentrated" is used to describe both pure oxygen and that which contains nitrogen up to about 25%.

The converter bottom construction shown in Figure 2 has been employed with success substantially as illustrated, plate 24 being about $\frac{1}{4}$ " in thickness, the refractory layer about $\frac{1}{4}$ " or slightly less, and the space between plates 24 and 25 being about $\frac{1}{8}$ " wide. With plate 24 relatively thin the refractory layer 26 may be kept sufficiently cool and will not be melted away by the intense heat of the bath whereas a heavier coat of refractory would be largely destroyed. Furthermore, the narrow space between plates 24 and 25 is a safety feature of value, adequate cooling being effected without the aid of a large quantity of water, in fact, a very small body of water being in this cooling chamber at any one time. Should for any reason the upper plate 24 fail, and molten metal come in contact with the cooling water, only a very minor explosion would result, instead of one of major violence. The tuyère itself contains but a small body of water at any one time, a factor of importance for the same reason.

This application is a continuation-in-part of my copending application, Serial No. 201,622, filed April 12, 1938.

Having thus described the invention, what is claimed as new and desired to be secured by Letters Patent is:

1. In a Bessemer converter or the like, the combination with the converter body of a tuyère for the projection of a stream of oxygen into a body of molten metal within the converter, that portion of the tuyère which is exposed to the molten metal, and in which the oxygen discharge port is formed, being fabricated of a material of high heat conductivity, and means for projecting a stream of cooling water moving at high velocity against the underside of said tuyère portion to cool this portion of the tuyère at such a high rate that a layer of chilled metal is maintained on the surface thereof, to protect the same against the action of the highly heated molten metal adjacent the oxygen discharge port.

2. The method of purifying a body of molten iron retained in a vessel or container which comprises projecting into said body, from an aperture formed in a tuyère member of high heat conductivity, a stream of concentrated oxygen, and removing heat from said member at such a high rate that a layer of "frozen" or solidified metal is deposited on the member to protect the same.

3. The method of operating a Bessemer converter having a tuyère fabricated of metal of high

heat conductivity which comprises projecting a stream of concentrated oxygen through said tuyère into molten metal within the converter, and projecting a stream of cooling fluid against said tuyère to maintain the same at a sufficiently low temperature to cause the deposition thereon of a protective layer of "frozen" or solidified metal.

4. The method of purifying molten metal which comprises depositing a body of such metal in a vessel a portion of the wall of which is a relatively thin metallic member of high heat conductivity, projecting an oxygen stream into the molten metal body through an aperture formed in said member, and cooling said wall portion at such a rapid rate that a protective layer of "frozen" metal is formed on the inner surface thereof.

5. The method of purifying metals, which comprises placing a body of metal in molten condition within a vessel having a wall portion of relatively small area and high heat conductivity, projecting a stream of substantially pure oxygen into said molten metal body through an aperture in said wall portion and thereby elevating the temperature thereof to a degree destructive to said vessel, and maintaining the integrity of the vessel by cooling the said wall portion of reduced area at such a rate that a protecting and insulating layer of "frozen" metal is formed on its inner surface.

6. In an apparatus for manufacturing steel, in combination, a Bessemer converter or the like having a cavity for holding a molten charge to be blown, the wall of the converter having a conduit associated therewith and in heat exchanging relation thereto through which conduit a cooling fluid may be passed to withdraw heat from the container wall, and means for circulating a cooling fluid through said conduit while maintaining the pressure of such fluid less than the pressure of the molten metal at the elevation of said conduit, whereby, in the event that the duct is brought into communication with the charge holding cavity through failure of the ladle wall the molten metal will enter the duct and cooling liquid will not enter the charge holding cavity.

7. The combination set forth in claim 6 in which the liquid circulating means includes a pump which draws the cooling liquid upwardly to and through said duct from a body of fluid located below said duct.

8. The combination set forth in claim 6 in which said conduit is formed in the container bottom and a second conduit is disposed in parallelism therewith and connected thereto at spaced points, said second conduit being disposed in heat exchanging relation to a tuyère extending through the converter wall.

9. In a Bessemer converter, a metallic tuyère extending through the converter wall, the inner end thereof being accessible to the molten content of the converter, and means for directing a high velocity jet of cooling liquid against said end to cause the deposition on said tuyère end of a protective layer of solidified metal.

10. The combination set forth in claim 9 in which the tuyère comprises a central conduit for gas, an encircling chamber for cooling liquid and a tube coaxial with the gas conduit and defining, with the outer surface of said conduit, a passage of annular cross-section with a discharge port closely adjacent the inner end of the tuyère.

11. In a Bessemer converter of the type pro-

vided with means for causing the development of very high temperatures in close proximity to the bottom, a bottom construction comprising a relatively thin plate, a layer of refractory superposed thereon, said layer being approximately as thick as the plate, means for water cooling the plate, and tuyères positioned in suitable registering apertures provided in said plate and layer for their reception.

12. In a Bessemer converter of the type provided with means for causing the development of very high temperatures in close proximity to the bottom, a bottom construction comprising closely spaced upper and lower plates, means for

circulating water at high velocity between said plates, a refractory covering for the upper plate, the upper plate being relatively thin and the refractory covering therefor of substantially the same thickness, and tuyères located in registering apertures of the upper and lower plates and refractory covering, for discharging upwardly directed jets of gas through said bottom.

13. The combination set forth in claim 12 in which the water space, the upper plate, and the refractory covering are of the same approximate thickness.

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