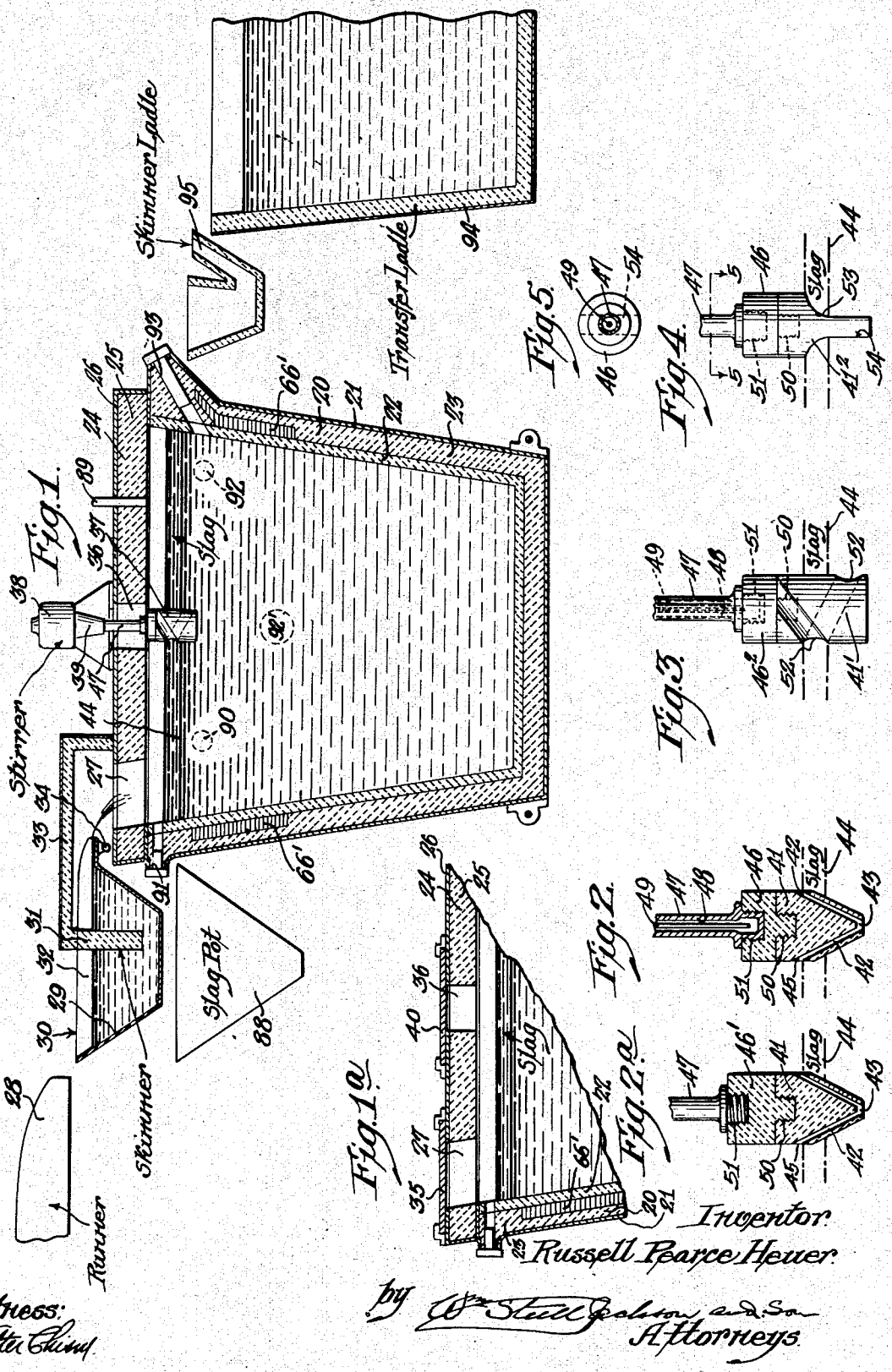
May 18, 1943 R. P. HEUER 2,319,402

DESULPHURIZING APPARATUS

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DESULPHURIZING APPARATUS

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Fig. 7.

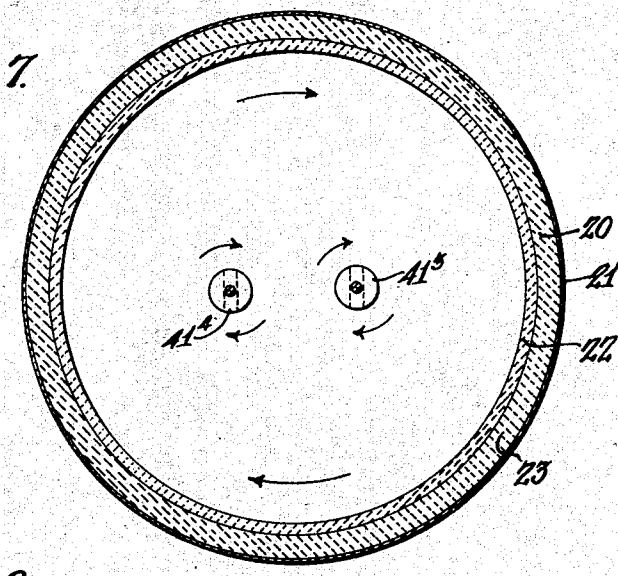


Fig. 6.

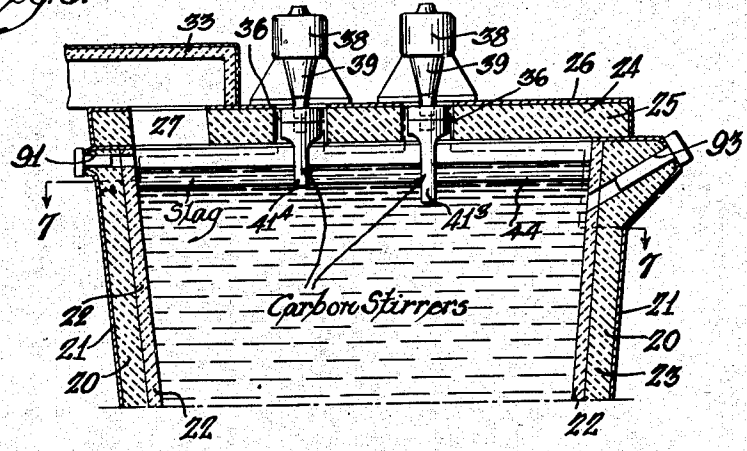


Fig. 8.

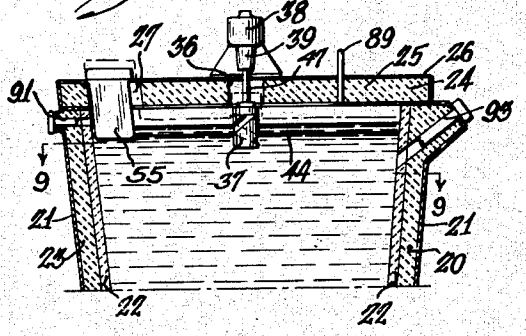
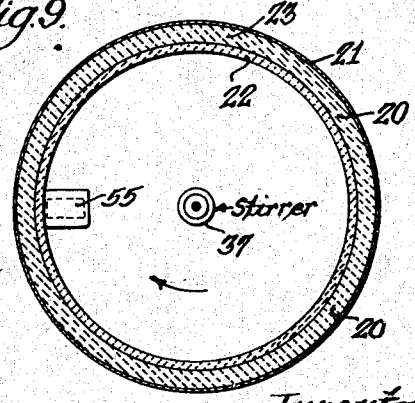


Fig. 9.



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May 18, 1943 R. P. HEUER 2,319,402

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Fig. 11.

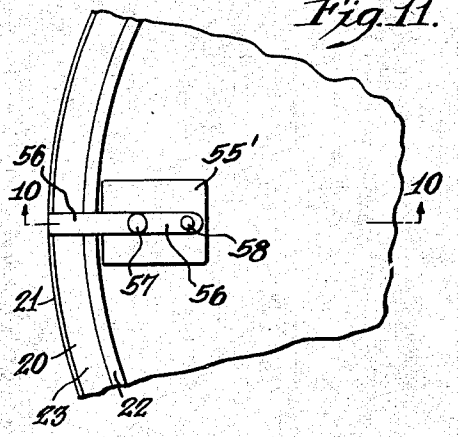


Fig. 14.

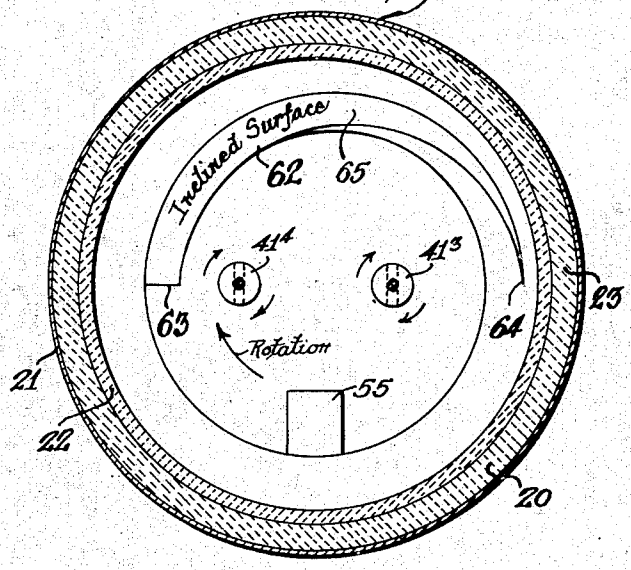


Fig. 10.

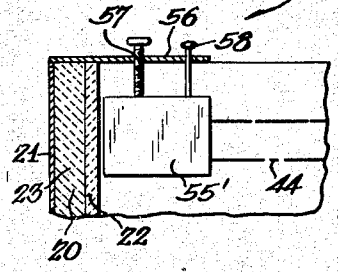


Fig. 13.

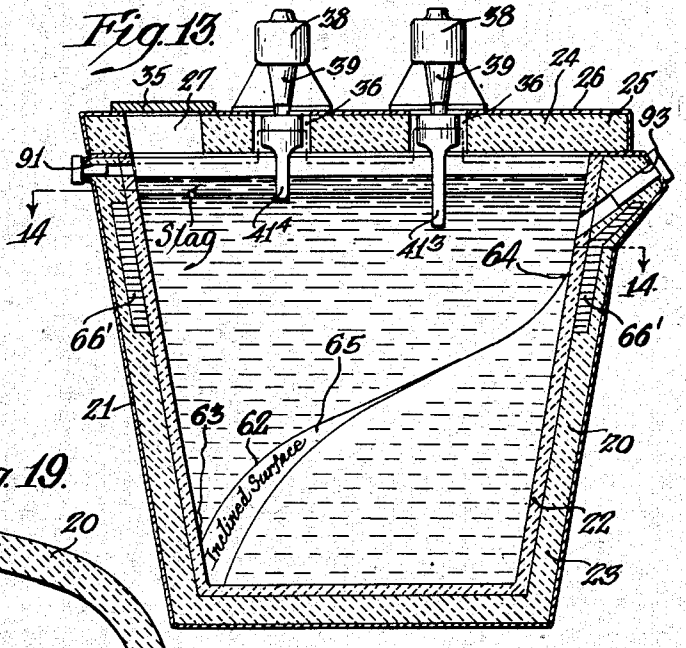


Fig. 12.

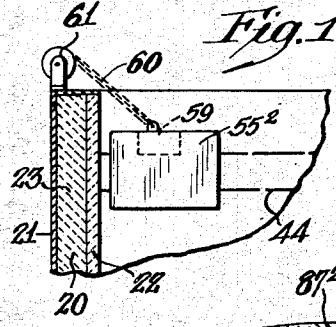
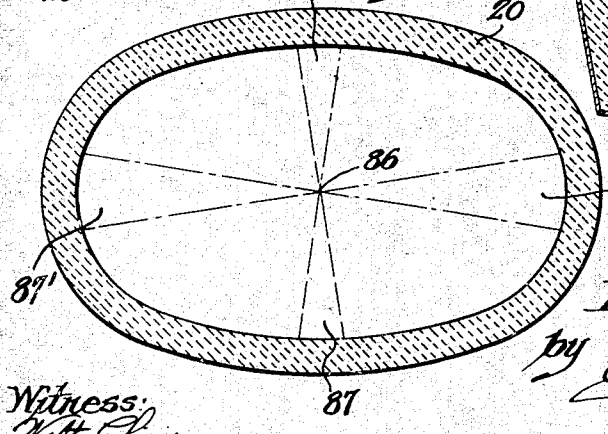


Fig. 19.



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DESULPHURIZING APPARATUS

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Fig. 16.

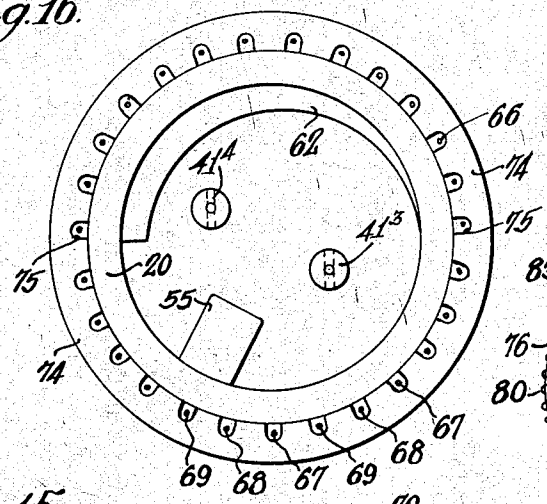


Fig. 17.

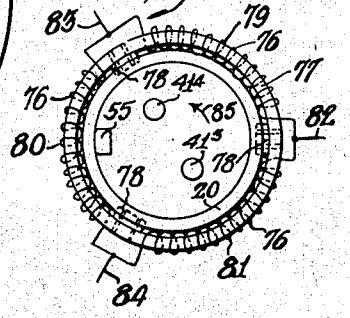


Fig. 15.

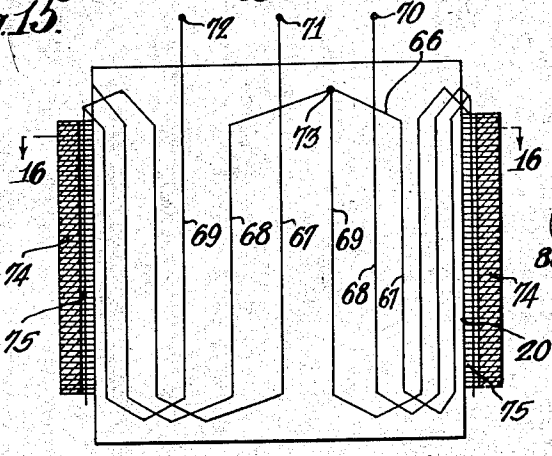


Fig. 18.

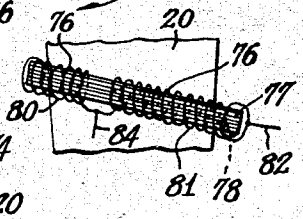
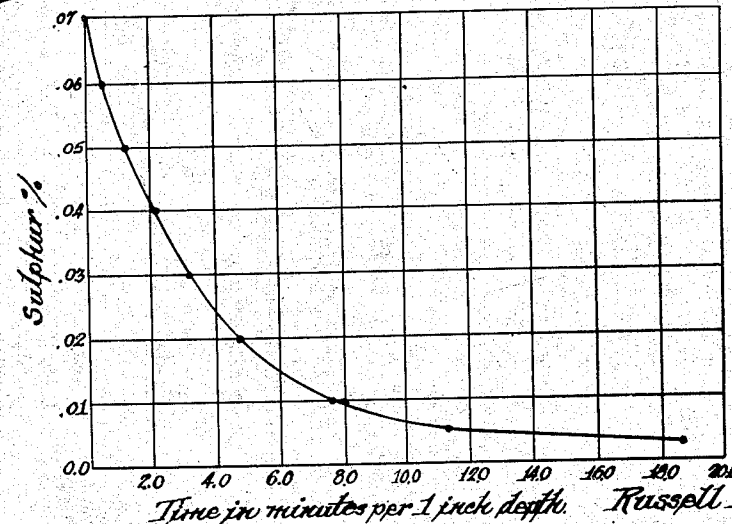


Fig. 20.



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Patented May 18, 1943 2,319,402

UNITED STATES PATENT OFFICE

2,319,402

DESULPHURIZING APPARATUS

Russell Pearce Heuer, Villa Nova, Pa., assignor to Essex Research Corporation, Wilmington, Del., a corporation of Delaware

Application January 18, 1941, Serial No. 374,989

8 Claims. (Cl. 266—34)

My invention relates to an apparatus for the treatment of pig iron and the production of steel and principally to the desulphurization of pig iron. This application is a continuation in part of my copending application Serial No. 304,484, filed November 15, 1939, for Desulphurizing apparatus and process, which resulted in Patent No. 2,290,961, issued July 28, 1942.

The apparatus claimed herein finds its greatest usefulness in connection with the operation of a coke blast furnace to produce pig iron higher in sulphur than that ultimately desired, and preferably at a lower cost than normal, by operating the blast furnace at a lower temperature and/or with less basic slag and/or with low grade raw materials causing higher sulphur in the charge. It facilitates treatment of the molten pig iron thus produced with a basic slag external to the blast furnace hearth, to remove the excess sulphur from the molten pig iron. The pig iron thus produced may be used in the form of cast iron or as raw material for making steel. It is, of course, capable of use in desulphurization of other metals.

One of the purposes of my invention is to provide a refractory lined desulphurizing ladle whose axis of symmetry is vertical to contain molten iron, with a basic desulphurizing slag floating on the molten iron, and to provide apparatus to impart rotary motion to the metal, desirably in a horizontal plane, while desirably also producing relative movement between the slag and the iron.

A further purpose is to provide apparatus to rotate molten iron or basic desulphurizing slag in contact with the iron by an impeller or preferably a plurality of impellers turning on a vertical axis and preferably in a ladle whose axis of symmetry is vertical. The impellers will preferably turn in the same direction.

A further purpose is to provide apparatus to rotate molten iron in the presence of a supernatant slag in a ladle having its axis of symmetry substantially vertical and to produce from the rotary movement of the iron, a vertical motion in the iron to bring the impurities in the iron into contact with the slag.

A further purpose is to provide apparatus to agitate molten pig iron in the presence of a supernatant slag in a ladle by means of electromagnetic action and separately to circulate the slag in a different direction.

A further purpose is to provide apparatus to whirl a pig iron bath by horizontal rotary electromagnetic stirring and to maintain a substantial body of molten desulphurizing slag on the bath, the slag being oppositely rotated.

Further purposes appear in the specification and in the claims.

The present application incorporates by reference my United States patents and patent application, Patent No. 2,110,066, granted March 1, 1938, for Iron and steel desulphurization; Patent No. 2,110,067, granted March 1, 1938, for Iron desulphurization; Patent No. 2,177,716, granted October 31, 1939, for Desulphurizing apparatus; Patent No. 2,193,593, granted March 12, 1940, for Iron desulphurization; and Serial No. 304,484, filed November 15, 1939, resulting in Patent No. 2,290,961, granted July 28, 1942, for Desulphurizing apparatus and process. Reference should be had to these patents and this application for further disclosure of the process.

In the drawings no attempt has been made to illustrate all of the possible embodiments of the invention. The forms shown have been chosen from the standpoints of satisfactory operation and convenient illustration of the principles involved. All of the figures are diagrammatic.

Figure 1 is a diagrammatic central vertical section of a desulphurizing vessel in accordance with the present invention, with cooperating structure.

Figure 1*a* is a fragment of Figure 1 showing covers applied over the openings.

Figure 2 is a central vertical section of one form of stirring impeller in accordance with the invention.

Figure 2*a* shows a different length of impeller extension from that shown in Figure 2.

Figure 3 is a side elevation of a variant form of stirring impeller in accordance with the invention.

Figure 4 is a side elevation of a further variant form of stirring impeller.

Figure 5 is a section of Figure 4 on the line 5—5.

Figure 6 is a diagrammatic central vertical section of a modified form of desulphurizing vessel.

Figure 7 is a section of Figure 6 on the line 7—7.

Figure 8 is a central vertical section of a further modification in the desulphurizing vessel.

Figure 9 is a section of Figure 8 along the line 9—9.

Figure 10 is a fragment showing a modified form of dam applied to the structure of Figure 8.

Figure 11 is a fragmentary top plan view of Figure 10.

Figure 12 is a fragmentary central vertical

section showing a further modification in the dam of Figure 8.

Figure 13 is a central vertical section of a further modification in the desulphurizing vessel.

Figure 14 is a section of Figure 13 on the line 14—14.

Figure 15 is a side elevation of a modified form of desulphurizing vessel with an electrical diagram of a polyphase inductor coil applied thereto, the magnetic core being sectioned away for convenience in illustrating the coil.

Figure 16 is a section of Figure 15 on the line 16—16.

Figure 17 is a diagrammatic top plan view of a variant form of electromagnetic stirring ladle.

Figure 18 is a fragmentary side elevation of Figure 17.

Figure 19 is a diagrammatic horizontal section of a modified desulphurizing vessel.

Figure 20 is a curve showing the rate of sulphur removal from pig iron under special controlled conditions.

In the drawings like numerals refer to like parts, and in the specification like symbols refer to like subjects matter.

In order to obtain the best desulphurizing action with many slags I have found that it is necessary to keep the temperature of the pig iron as high as possible.

To take advantage of this accentuated desulphurizing action at higher temperature, I place the desulphurizing vessel in a position adjoining the blast furnace. In this manner I avoid any temperature loss such as would occur if the molten iron from the blast furnace is first placed in a transfer ladle and then transported to a desulphurizing vessel located, for example, at the mixer in the steel making plant.

Contaminations caused by impurities containing silica are to be avoided and this can be effected by passing the molten iron through a small tea-pot ladle or similar device just before it enters the desulphurizing vessel. In this way the siliceous impurities are separated and the desulphurizing slag is kept uniform with as high a ratio of lime to silica as intended.

Agitation of the desulphurizing slag and molten pig iron is necessary in order to cause the desulphurizing reaction to proceed with convenient speed. The present inventor has performed experiments without agitating the molten slag and molten pig iron. Figure 20 shows the rate of sulphur removal under certain fixed conditions, using a slag consisting of 40% blast furnace slag, 30% fluorspar and 30% burnt lime, without agitation. In this figure the molten pig iron contained 0.07% sulphur at the beginning of the experiment. This iron was treated with desulphurizing slag of the composition just noted under deoxidizing conditions and freedom from air contamination, and samples of iron were withdrawn for chemical analysis at specified times. In Figure 20 the experimental data has been plotted in a curve showing, as the ordinate, the percentage of sulphur present in the iron, and, as the abscissa, the elapsed time for the reaction expressed in minutes per inch of depth of the metal bath.

The rate of sulphur removal is proportional to the depth of molten metal. From the curve it will be seen that, in order to lower the sulphur content from 0.07% to 0.005%, approximately 12 minutes are required for each one inch of depth of metal bath. In a customary pig iron ladle a depth of metal of 60 inches or more is to be expected. Thus for a depth of 60 inches, an elapsed time of 720 minutes or 12 hours would be required to desulphurize to the above extent. This time is too long for most operating conditions.

The rate of reaction can be speeded up appreciably by agitating the molten metal and/or the slag in order to produce relative motion between the slag and the metal at their point of contact, the so-called slag-metal interface. It is believed that the slow speed of desulphurization which is obtained in a quiet bath is due to the resistance which the sulphur encounters in the regions closely adjoining the slag-metal interface whilst passing from the metal to the slag. When contact is first established between the pig iron and the slag, the slag rapidly absorbs sulphur but the reaction soon slows down because, without agitation, the system approaches equilibrium only in the limited region which is not too far removed from the slag-metal interface. By providing a relative motion between the mass of the slag and the iron, thereby bringing fresh slag and iron into the zone adjacent to the slag-metal interface, it is possible to speed the removal of the sulphur. By continuing this process of relative motion the difficulties of slow speed operation as described above in quiet baths can be overcome. The present invention is concerned with agitation to produce relative motion between the slag and the metal in order to speed up the reaction and obtain a higher content of sulphur in the slag and/or a lower content of sulphur in the iron than would otherwise be obtained.

Figure 1 illustrates a desulphurizing vessel **20** equipped with a mechanical agitating device for obtaining increased relative motion between the molten pig iron and the supernatant slag. Such a vessel might contain from 40 to 200 tons or more of molten pig iron. The slag layer might approximate 1% to 10% or more of the depth of the molten iron. The shape of the vessel is approximately circular or oval in cross section and the axis of symmetry, that is, the axis running perpendicular to the plane of circular or oval cross section, is vertical.

The axis of symmetry as referred to herein will be what is commonly called the major axis in the ordinary case. Where the ladle cross section is circular, it will be the axis of generation of the ladle.

The vessel is provided with a suitable steel shell **21** substantially gas tight and capable of protecting the contents from access of the atmosphere or other oxidizing gases. The refractory lining **22** consists preferably of carbon or magnesite bricks which have suitable resistance to the corrosive action of the ladle contents. In order to conserve heat, these refractory bricks may be backed up with refractories **23** having lower thermal conductivity, as for example fireclay brick having an appreciably larger percent of pore space than normal for such products. In some cases fireclay brick may also be used in direct contact with the contents of the ladle, as for example in the lower part where the slag does not come into contact with the fireclay refractories for long periods of time.

A roof or cover **24** is provided for the ladle. Fireclay or other suitable refractories **25** such as carbon or magnesite can be used in lining this roof. The roof can be supported by hangers or other suitable means (not shown) from the external steel shell **26**.

An opening **27** is provided for charging the

molten iron and slag. Usually the slag will be charged before the molten iron although this is not always critical. The iron will be tapped from the blast furnace or other source of supply through a runner 28. In order to prevent silica and other undesirable impurities from entering the desulphurizing ladle, a skimming ladle 29 is provided. The iron leaves the runner 28 and enters the open top of the skimming ladle at 30. This ladle is provided with a dam or skimmer 31. The molten iron passes beneath this skimmer and the floating impurities are held back at 32. The exit end of the skimming ladle is provided with a cover 33 which reduces access of air to the interior of the treatment ladle. After the desulphurizing ladle is properly filled, the source of molten iron is cut off at the runner. The iron still remaining in the skimming ladle is poured into the desulphurizing ladle by tilting the skimmer about the trunnion 34. Thereupon the skimming ladle and cover are removed and a suitable permanent cover 35 is placed on the ladle to cover the opening 27 as shown in Figure 1*a*.

An opening 36 is provided in the cover 24 of the ladle for an impeller 37. This impeller is preferably a self-contained unit having an electric motor 38 and speed reducer 39. The motor will preferably be a variable speed direct current motor producing an impeller speed of 50 to 200 revolutions per minute or more. The speed chosen may vary with different installations. The impeller and its operating mechanism cooperate with the cover 24 to reduce access of air at this point and may be removed as a unit from the desulphurizing vessel and a cover 40 substituted as shown in Figure 1*a*.

There are several advantages in employing a ladle whose axis of symmetry is vertical for desulphurizing pig iron. This makes it possible to locate the desulphurizing slag at the level of maximum ladle cross section with utilization of full ladle capacity. Thus the slag-metal interface is of maximum area for a convenient refractory structure. Refractory repairs and replacements are much easier in a ladle whose axis of symmetry is vertical than in one whose axis of symmetry is horizontal. In a normal ladle whose axis of symmetry is vertical, a larger proportion of the pig iron will be at relatively great depth in the ladle than in a ladle whose axis of symmetry is horizontal. Therefore in a ladle whose axis of symmetry is vertical, there is greater importance in securing efficient stirring and stirring which is effective from the standpoint of desulphurization.

Different types of impellers may be used to impart stirring primarily in a horizontal plane, but with an upward stirring component. Figure 2 shows a pumping type of impeller of circular cross section made suitably of carbon refractories. The body of the impeller 41 has pumping passages 42 extending diagonally upward and outward as shown. The number of pumping passages 42 is not critical. The effect of the pumping impeller is to lift molten metal from the bath into contact with the desulphurizing slag. The inlet 43 of the pumping impeller will preferably be located below the slag-metal interface 44 and the outlet 45 above the slag-metal interface, as shown, to cause distribution of molten metal directly into the slag. The level of the impeller 41 is made adjustable as required by using any one of several different lengths of extensions 46. Extension 46 may be also made of carbon refractory or may be made of so-called sillimanite refractory or other high aluminous material. Figure 2*a* shows a different length of extension 46'. The impeller assembly is carried on the rotating shaft 47 which may be made of a suitable heat resistant metal with a hollow interior 48 into which cooling air or other fluid is blown by a suitable pipe 49. The impeller, extension and shaft are desirably threaded to one another at 50 and 51.

Another form of impeller capable of lifting pig iron is shown in Figure 3. In this case the impeller head $41'$ is desirably made of carbon refractory. It is attached to the rotating mechanism by means of a sillimanite, cyanite or other extension 46^2. The carbon refractory is machined to provide a spiral fluting 52. The impeller is mounted so that the spiral fluting preferably extends into the pig iron and below the slag-metal interface 44. The rotation of the stirrer produces a corresponding rotary movement in the slag and metal with which it is in contact. By virtue of the fluting, a vertical motion is also produced which preferably lifts the iron and the slag above the level which it would normally take if the fluting were absent. The effect of the pumping impeller is to lift the molten metal from the bath and bring it into better contact with the desulphurizing slag thereby exposing fresh slag-metal interfaces to speed up the sulphur removal.

An alternative apparatus for producing the required agitation is shown in Figures 4 and 5. This consists of a rotating stirrer of carbon or other suitable refractory which is supported by a sillimanite extension 46 as shown in Figures 2 and 3. The stirrer 41^2 can be made from a round carbon electrode of suitable diameter, for example 10 inches to 15 inches or more if necessary. The round electrode can be machined to form a rectangular or other section 53 having one or more plane surface 54. For example, a rectangle 5 inches wide and 10 inches to 15 inches or more in length might be used. The stirrer is immersed in the slag and metal. By its rotation a corresponding rotary motion of the contents of the ladle is produced.

For better results two or more stirrers 41^3 and 41^4 may be used as shown in Figures 6 and 7. If two stirrers are used, they should be spaced so that the clearance between the rotating carbons should not be too great, as for example, a clearance of approximately 6 inches to 18 inches. These stirrers may rotate in the same direction or in opposite directions. If they are rotated in the same direction, the entire mass of liquid contents of the ladle will be given a corresponding rotating motion as shown by the arrows in Figure 7.

Where a plurality of stirrers are to be used as in Figures 6 and 7, improved results are obtained by having the stirrers effective at different levels in the bath. Thus in Figure 6 the stirrer 41^3 extends deeper into the bath than the stirrer 41^4, the latter stirrer operating chiefly in the slag and not extending any great depth below the slag-metal interface. These two stirrers produce a relative movement between the slag and the metal and also between respective portions of the metal.

In order to speed up the rate of reaction it is desirable to have a relative movement between the slag layer and the metal. The natural tendency would be for the slag layer and the metal layer to rotate together and the relative motion

between the two would not be as great as desirable. Increased relative motion can be obtained by using the apparatus shown in Figures 8 and 9. A dam 55 is immersed in the slag layer and if desired, below the slag-metal interface 44. Any desired number of dams may be used. The effect of the dam is to impede the rotation of the slag whilst permitting a relatively unhampered rotation of the pig iron, thereby causing relative motion between the pig iron and the slag. The dam may if desired occupy the opening 27 when metal is not being charged, with suitable packings to exclude air.

Where there is considerable variation in the level of the pig iron, it is desirable to make the height of the dam adjustable so that the dam will always extend down to the slag-metal interface and also preferably slightly below the interface as shown. In Figures 10 and 11 I show a refractory dam 55' suitably of carbon refractory supported on a bracket 56 and adjustable as to height by an adjusting screw 57 threaded through the bracket and making thrust bearing connection with the dam 55'. To prevent the dam from rotating, a guide 58 extends from the dam through an opening in the bracket 56.

In some instances it is preferable to use a floating dam 55^2 as shown in Figure 12. This dam, preferably of carbon refractory, automatically adjusts itself with respect to the level of the slag-metal interface and its volume-weight may be adjusted by adding weights 59 to make it float with any desired degree of submergence. While the dam 55^2 may float freely, it is preferable to flexibly restrain it, as by a refractory chain 60 anchored to the vessel 20 at 61. The structures of Figures 10 to 12 will be provided with a suitable gas-tight cover as shown in Figure 1.

To further promote better transfer of the impurities from the molten iron to the slag, the apparatus shown in Figures 13 and 14 can be applied either alone or in conjunction with the dam 55 and/or the two stirrers 41^3 and 41^4 as shown. In this type of apparatus the refractory lining is constructed to form an inclined vane 62 extending around the ladle circumference from point 63 near the bottom to point 64 near the top and providing a vane shelf 65 which is a maximum at 63 and a minimum at 64. The vane 62 is capable of converting some of the rotary motion of the liquid iron in the ladle into vertical motion, thereby bringing the metal from the bottom of the ladle upward to establish contact with the supernatant slag. The rotatory action of the metal may be imparted by the stirrers 41^3 and 41^4 or in other suitable ways.

Instead of using the mechanical agitators for producing a rotary motion in the molten pig iron in the ladle, it is also possible to produce a rotary motion by means of electromagnetic action. By using polyphase alternating current to produce rotating magnetic fields in an iron core suitably placed around the periphery of the ladle, preferably at or below the slag-metal interface, the current induced by the alternating electromagnetic field in the molten metal contained in the ladle causes a rotary motion of the metal in the way that rotary motion is produced in a polyphase induction motor.

Figures 15 and 16 show such a polyphase stirring ladle having a winding 66 intended for three-phase alternating current, with phase field coils 67, 68 and 69 connected to a source at 70, 71 and 72 and connected together at 73 (Figure 15). Star connection is shown, but it will be evident that any suitable system of connections may be used. The winding is surrounded by an annular magnetic core 74 suitably slotted to receive the winding as at 75 and desirably laminated. Low frequency alternating current at, for example, 25 to 100 cycles will preferably be used.

The device of Figures 15 and 16 will cause simultaneous rotation of both the slag and the metal. To secure differential movement between the slag and the metal, a slag dam 55 of any desired type will desirably be used as shown in Figure 16; or an inclined vane 62 as also shown in this figure; or mechanical stirrers will be employed as shown at 41^3 and 41^4 in Figure 16, preferably causing the slag to rotate oppositely from the metal.

Figures 17 and 18 illustrate a variant electromagnetic stirring device. The desulphurizing vessel 20 is surrounded by a polyphase field winding 76 of Gramme ring type, wound on an annular magnetic core 77, suitably laminated, and provided with magnetic poles 78. In the specific construction, a three-phase winding consists of phase coils 79, 80, and 81 connected in delta formation to three-phase lines 82, 83, and 84 from an alternating current source at commercial frequency. The magnetic core 77 and the poles 78 will desirably be assembled from separate units, fastened together in any suitable manner.

The winding 76 and core 77 are very desirably inclined or canted with respect to the horizontal as shown in Figure 18, so that in addition to a horizontal rotary or whirling motion in the iron, there will be a helical upward stirring component due to the inclination of the winding and core.

There will preferably be one coil and one pole for each phase, and, of course, the number of phases in the polyphase system may be varied. In general, the smaller the number of poles, the faster the stirring, other conditions being unchanged. It is very desirable to have the structural arrangement of the poles such that the flux from pole to adjoining pole will pass through a substantial portion of the iron bath and not merely through the wall of the ladle. It is preferable, therefore, to use a small number of poles, for example from two to six poles.

The ladle of Figures 17 and 18 is desirably provided with a slag dam 55 and with impellers 41^3 and 41^4. While the iron whirls in upward helical paths, the whirling of the slag is retarded by the dam 55. The impellers 41^3 and 41^4, which operate in the slag, will desirably rotate the slag oppositely from the rotation of the iron. For example, if the iron rotates in the direction of the arrow 85, the slag will preferably be rotated by the impellers in the opposite direction.

It will, of course, be understood that in Figures 15 to 18 the ladles will be provided with air tight closures.

Instead of a moving wave form of electromagnetic stirrer as shown in Figures 15 to 18, a pool-surrounding coreless induction form of any well known type may be used. In Figure 1 an inductor coil 66' surrounds the upper portion of the metal bath adjacent the slag-metal interface. The neighboring structural parts of the ladle will desirably be made of non-magnetic metals or alloys or non-metallic materials. A suitable alternating current of low frequency, for example 25 to 100 cycles, will be connected to the coil 66'. The coil will desirably carry a high wattless current due to resonance obtained through suitably connected condensers as well known in the art.

In some respects the inductor coil stirring is undesirable as it is accompanied by considerable heat obtained at relatively high cost.

The ladles for containing the molten metal and slag to be rotated as described above should have a vertical axis of symmetry about which the rotation takes place. For example, the interior could be shaped in the form of a cylinder or inverted truncated cone. The major axis of the cylinder or cone stands approximately vertical and rotation occurs about this axis. It is not necessary that the cross section of the ladle on a plane at right angle to this axis of symmetry be circular. Indeed, it may be advantageous to use some other shape as for example an elliptical or oval section, thereby facilitating the formation of new areas of slag-metal interface as the metal rotates about its natural axis. For example, the oval cross section shown in Figure 19 when rotated by any of the means described turns about an axis located at the point **86**. An element **87** of slag-metal interface is rotated by this motion to the position **87'**. By so doing the area of the interface is increased. Further rotation causes the element to move to 87^2 with attendant decrease in area of the slag-metal interface. At position 87^3 the area is again increased. Thus a repeated formation of new areas of interface occurs by rotating the slag and metal in an oval shaped vessel.

An illustrative cycle of operations with reference particularly to Figure 1 is as follows: The desulphurizing ladle is charged through the opening **27** with the required amount of desulphurizing slag from the pot **88**. This desulphurizing slag may, for example, comprise 70 per cent of molten blast furnace slag previously withdrawn from the blast furnace, 20 per cent of burned lime and 10 per cent fluorspar. The blast furnace is tapped and about 150 tons of iron is transferred into the ladle **29**. As described above, all siliceous contaminations should be removed from the flowing stream of iron by dams or skimming devices. The desulphurizing ladle and its charge is then closed against free access of air or oxygen to the interior. Desulphurizing is continued using agitation until the proper sulphur content of the iron has been obtained. For best results vacuum may be applied to the ladle, as through a vacuum connection **89**.

After the desulphurizing reaction is completed, the slag is removed by tilting the ladle **20** about the axis **90** and allowing the slag to run out the opening **91** (suitably closed against air contamination when not in use) into the slag pot **88**. Thereupon the ladle is tilted in the reverse direction about the axis **92** and the iron is poured through the tea-pot spout **93** (suitably sealed when not in use) into the transfer ladles **94**. An axis is also provided at **92'** for pouring the entire ladle content, slag and iron, in emergency. Two or more transfer ladles **94** may be used if necessary and the stream of metal from the desulphurizing ladle can be interrupted by tilting the ladle **20** whilst a new transfer ladle is brought into position. It is important that any desulphurizing slag remaining in the desulphurizing ladle be kept from entering the transfer ladles **94**. The inclined tea-pot spout **93** is effective to prevent this. If further precautions are necessary the small tea-pot skimmer ladle **95** can be placed just ahead of the transfer ladles **94**.

With good agitation and efficient slags, a pig iron containing 0.015% sulphur or 0.010% sulphur or less may be obtained from a blast furnace product containing initially as much as 0.10% to 0.30% sulphur or more. The sulphur content of the slags may rise to 5% or 10% sulphur or more and a ratio of sulphur in slag to sulphur in the iron of 500:1 or 1000:1 and even 5000:1 or more, all depending upon the chosen conditions.

Of course, the processes and apparatus described herein may be used for the removal of sulphur from molten pig iron supplied by furnaces other than a blast furnace, as for example a cupola. The use for such purposes is expressly included herein.

In view of the invention and disclosure variations and modifications to meet individual whim or particular need will doubtless become evident to others skilled in the art, to obtain all or part of the benefits of my invention without copying the structure shown, and I, therefore, claim all such in so far as they fall within the reasonable spirit and scope of my invention.

Having thus described my invention what I claim as new and desire to secure by Letters Patent is:

1. A desulphurizing vessel closed to the atmosphere and provided with a refractory lining adapted to hold a charge of molten pig iron and a body of molten desulphurizing slag on the iron, electromagnetic means to induce electric current within the metal as a secondary for imparting a generally horizontal rotary stirring to the iron and means for rotating the slag in a direction opposite from that of the iron.

2. A vessel for desulphurizing molten metal whose major vessel axis is vertical having a refractory lining and adapted to contain molten metal and desulphurizing slag on the molten metal, walls forming a charging opening, a metal tap opening and a slag tap opening at a different level from the iron tap opening on a side opposite to the metal tap opening, means for closing the openings against air contamination, means for tilting the vessel about an axis adjoining one tap opening for discharging from that tap opening and means for tilting the vessel about an axis adjoining the other tap opening for pouring from that tap opening.

3. A vessel for desulphurizing metal, whose major axis is vertical, having a refractory lining to receive molten metal and slag, means for lifting the metal from a level just below the slag and delivering it upon the surface of the slag, and separate means for stirring the body of the metal.

4. A vessel for desulphurizing metal whose major vessel axis is vertical, having a refractory lining to receive molten metal and slag, means for circulating this slag at upper level without circulating a substantial part of the molten metal and separate independent means for circulating the molten metal at the same metal upper level at which the slag is circulated, one of the means being electromagnetic and operated by inducing electric current within the molten metal as a secondary.

5. A vessel for desulphurizing molten iron having a vertical axis and adapted to hold molten iron and slag floating upon the molten iron, a mechanical stirrer for the slag when the slag reaches an upper level of the stirrer, stirring the slag independently of electromagnetic circulation of the iron and electromagnetic means for stirring the iron differently from the stirring of the slag when the slag reaches said level.

6. A vessel for desulphurizing molten iron

whose major axis is vertical, adapted to contain molten iron and slag floating on the iron, a mechanical circulating means for circulating the slag without circulating a substantial part of the body of the iron and electromagnetic means acting by inducing current within the iron as a secondary, located below the mechanical means, circulating the body of the iron as distinguished from the slag when the slag level is that within which the mechanical circulating means is adapted to operate.

7. A vessel for desulphurizing molten iron having a refractory lining adapted to contain the molten metal and desulphurizing slag on the molten iron, walls forming a charging opening, an iron tap opening and on the side opposite to the iron tap opening, a slag tap opening, means for tilting the vessel about axes adjoining the respective tap openings for discharge from these tap openings, mechanical stirring means adapted to stir the slag without stirring a substantial part of the body of the iron when slag is present between the levels of the two tap openings and electromagnetic means for stirring the iron separately from the stirring of the slag, acting by induction of current within the iron as a secondary.

8. A vessel for desulphurizing molten metal whose major axis is vertical, having a refractory lining, a mechanical circulating device adapted to operate in the slag when the slag reaches an upper level and a pool-surrounding coil located in the upper part of the vessel and below the mechanical circulating device, said pool surrounding coil being adapted to induce electric current within the upper part of the molten metal rather than in the slag when the molten metal and slag reach the level at which the mechanical circulating device is effective.

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