H. KOPPERS.

BLAST TREATMENT OF METALS.

APPLICATION FILED SEPT. 3, 1920.

1,357,781.

Patented Nov. 2, 1920.

7 SHEETS—SHEET 1.

Fig. 1.

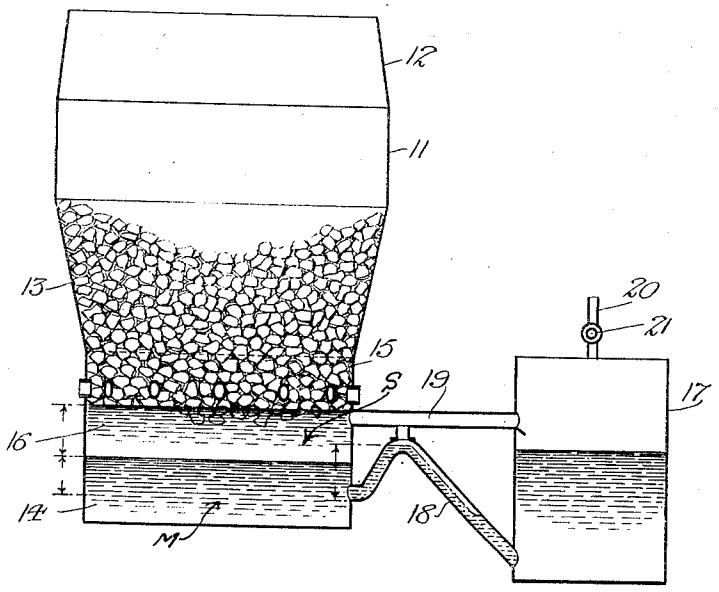
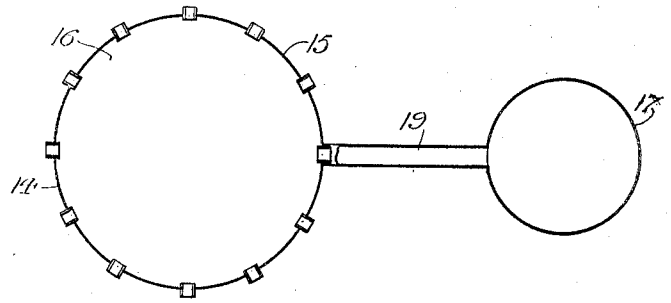


Fig. 2.



Witness:
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Heinrich Koppers
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his Attys:-

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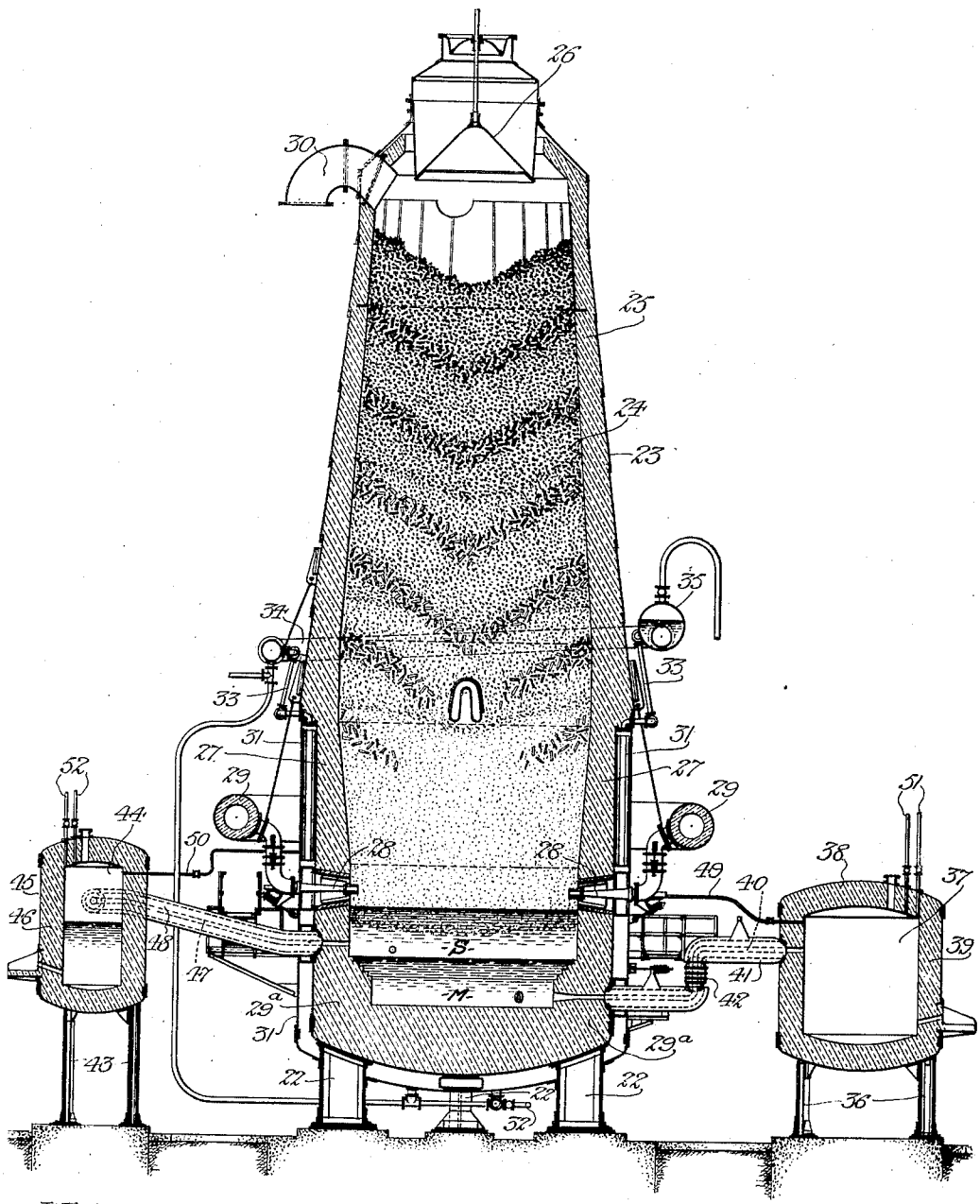
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7 SHEETS—SHEET 2.

Fig. 3.



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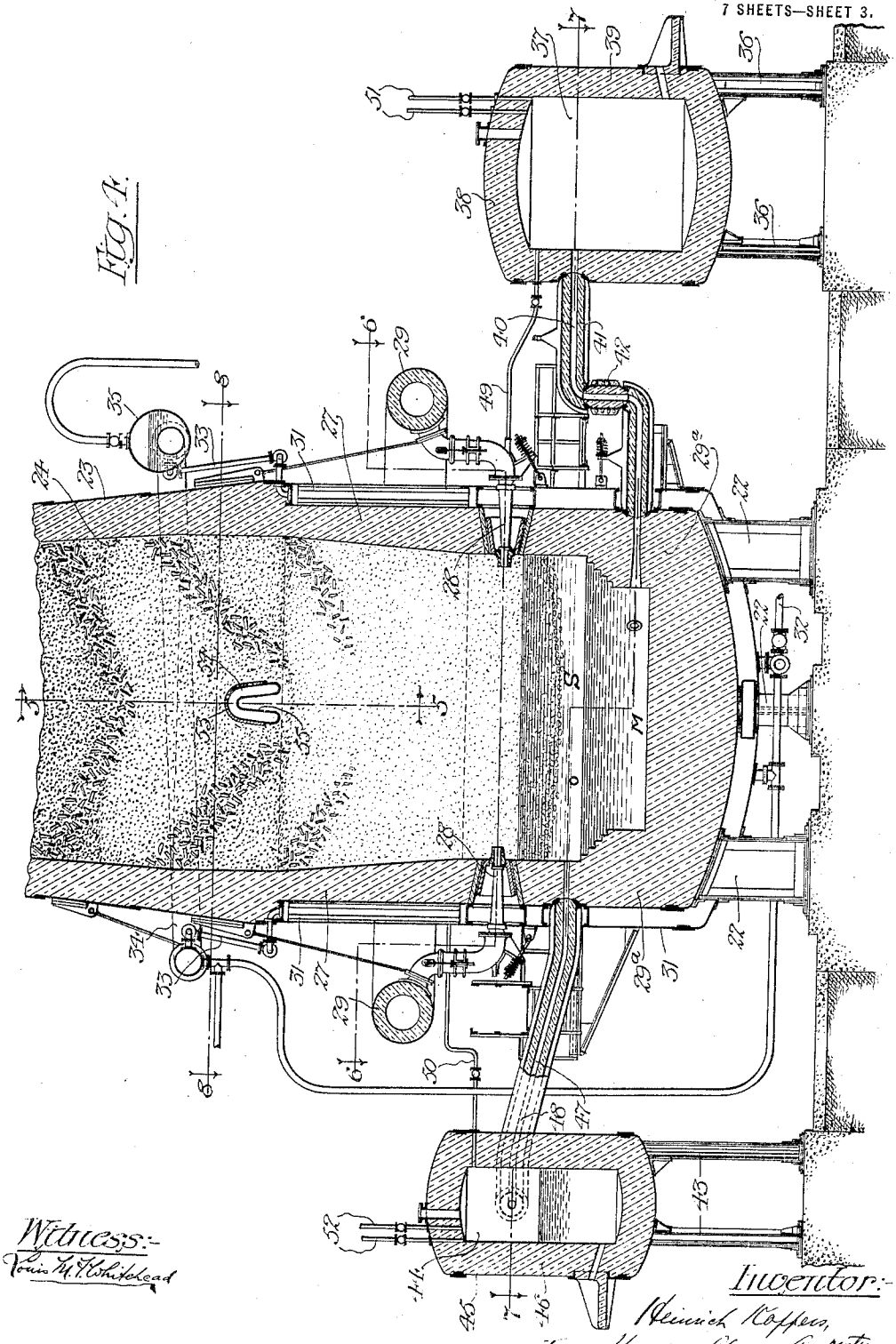
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7 SHEETS—SHEET 3.

Fig. 1.



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BLAST TREATMENT OF METALS.

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7 SHEETS—SHEET 4.

Fig. 5.

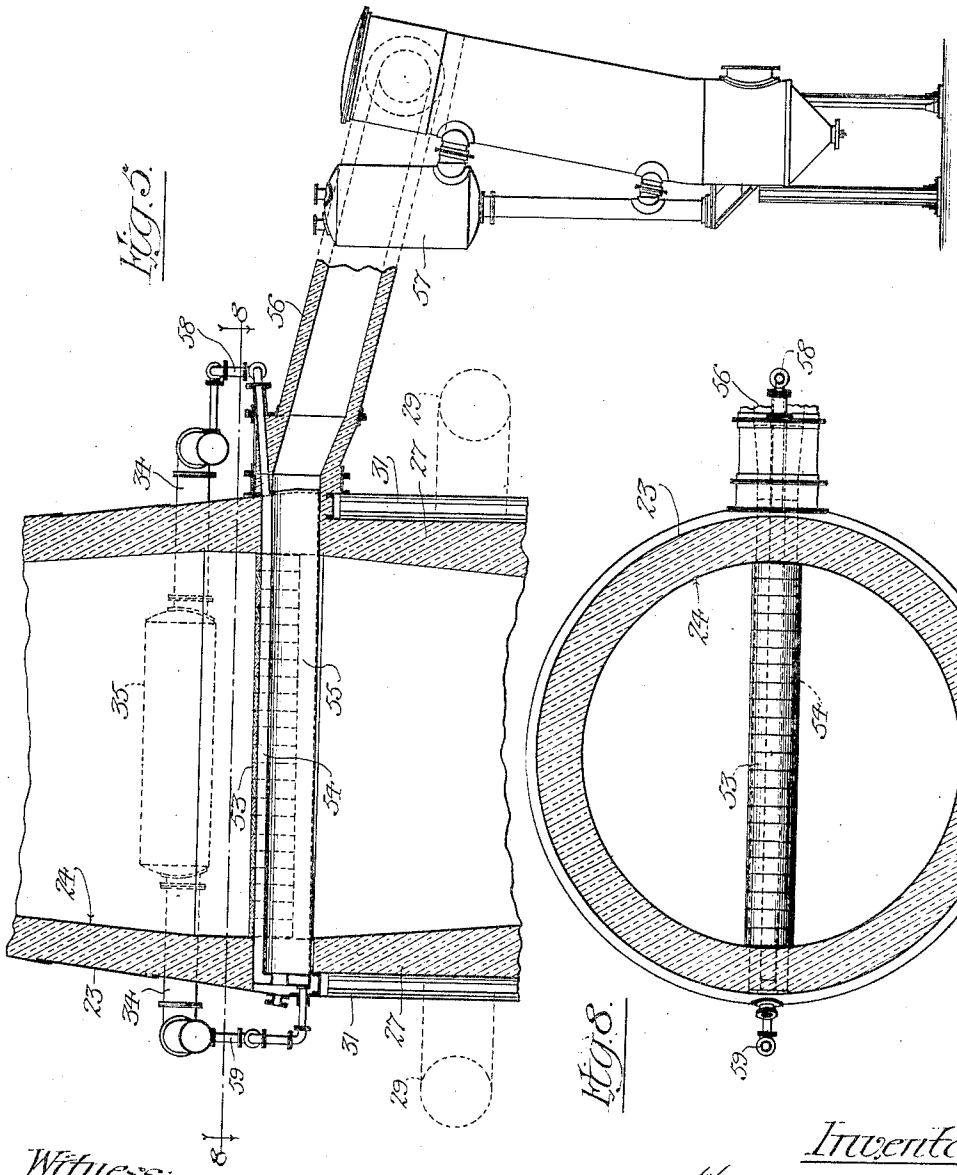


Fig. 8.

Witness:
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7 SHEETS—SHEET 5.

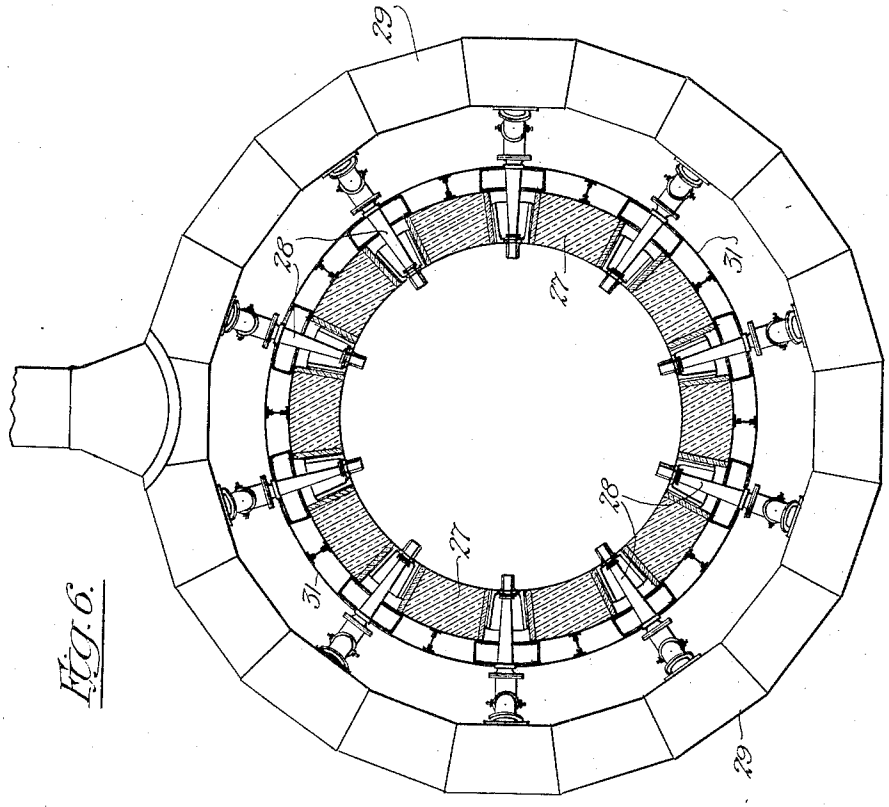


Fig. 6.

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7 SHEETS—SHEET 6.

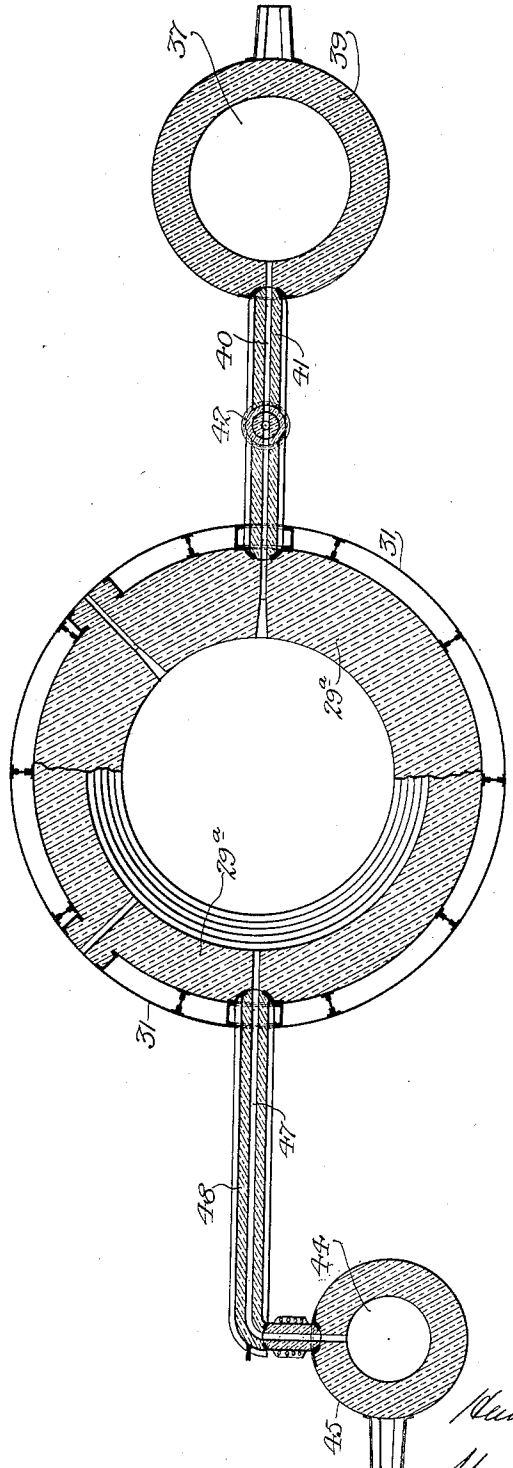


Fig. 7.

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BLAST TREATMENT OF METALS.

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1,357,781.

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7 SHEETS—SHEET 7.

Fig. 9.

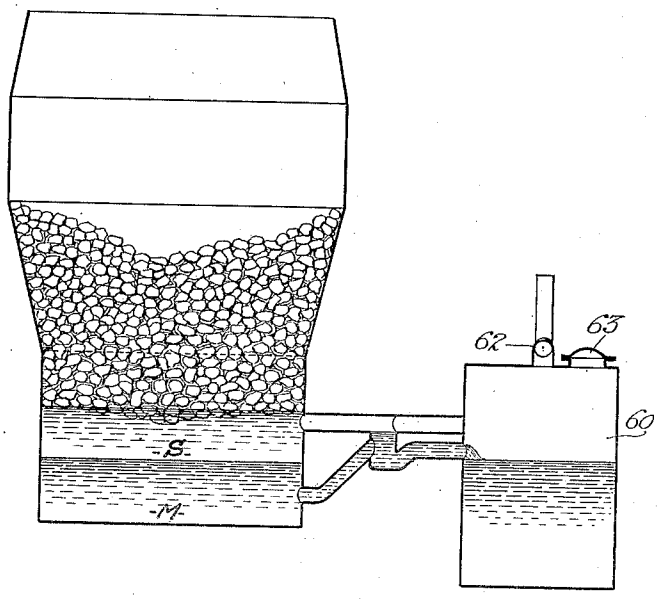
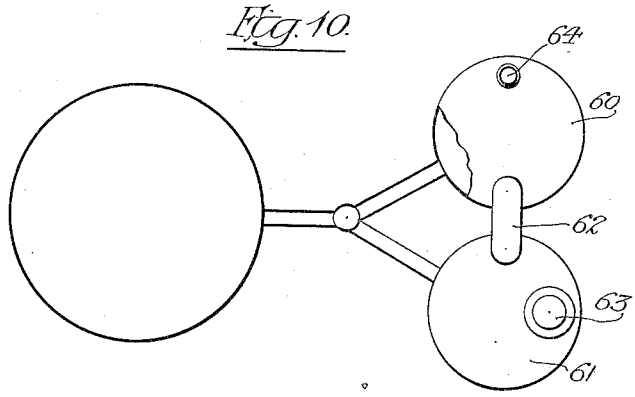


Fig. 10.



Witness:-

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Inventor:-

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UNITED STATES PATENT OFFICE.

HEINRICH KOPPERS, OF ESSEN-ON-THE-RUHR, GERMANY, ASSIGNOR TO THE KOPPERS DEVELOPMENT CORPORATION, A CORPORATION OF PENNSYLVANIA.

BLAST TREATMENT OF METALS.

1,357,781. Specification of Letters Patent. Patented Nov. 2, 1920.

Application filed September 3, 1920. Serial No. 408,081.

To all whom it may concern:

Be it known that I, HEINRICH KOPPERS, (assignor to The Koppers Development Corporation, of Pennsylvania,) a citizen of Germany, residing in Essen-on-the-Ruhr, Germany, have invented a new and useful Improvement in Blast Treatment of Metals, of which the following is a specification.

This invention relates generally to the treatment of metals, such as iron and its alloys, and has for one of its objects to effect efficient desulfurization of the metal, thereby obtaining a high grade product containing a minimum proportion of sulfur.

The presence of sulfur, especially in iron and its alloys, greatly impairs the quality of the metal, when occurring in other than extremely small proportions. When present in iron, sulfur makes the iron much more liable to rust; in fact, the tendency of iron to deteriorate when exposed to atmospheric conditions is augmented by the presence of sulfur, which constitutes an important factor in promoting such deterioration. In the case of steel, the presence of sulfur not only makes the steel liable to rust, but imparts a brittle quality to the steel making it difficult to shape and impairing its strength. Consequently, it is of great importance in the metallurgical industries to restrict the quantity of sulfur in such metals as iron and steel to mere traces. This invention provides a novel and improved treatment of the metal in a metallurgical furnace, such for example as a blast furnace employed for reducing iron ore, or a cupola for remelting or refining raw metal, or such other furnaces as may be utilized for carrying out the processes of the invention, by which processes the sulfur content in the product of the furnace is limited to mere traces, which do not appreciably impair the quality of the metal.

Another important object of the invention is to control temperature conditions in the furnace, such as a blast furnace, to restrict the highest temperatures to the melting zone of the furnace, *i. e.*, the region of the twyers and also to recover from the furnace part of the gases having a higher calorific value. As a result of this improvement, extremely high temperatures are limited to the melting zone, thereby preventing fusion and agglomeration in the upper part of the furnace, where relatively cooler temperatures are required for the preparation of the charge. By maintaining such relatively cool temperatures in the upper or preparatory zone of the furnace, hanging of the charge is prevented, and the charge may sink uninterruptedly from the top of the furnace to the hearth.

The invention has for further objects such other improvements or advantages in operation and such other advantageous results as may be found to obtain in the improved processes and apparatus hereinafter described as illustrative examples.

In the accompanying drawings, forming a part of this specification, and showing, for purposes of exemplification, a preferred manner in which the invention may be embodied and practised, but without limiting the claimed invention specifically to such illustrative instance or instances:

Figure 1 is a vertical section through a diagrammatic representation of an apparatus for practising the improvements of the present invention;

Fig. 2 is a horizontal plan view of the same;

Fig. 3 is a vertical sectional elevation of an actual blast furnace for carrying out the invention;

Fig. 4 is an enlarged vertical section of the lower portion of the furnace illustrated in Fig. 3;

Fig. 5 is a vertical sectional elevation on the line 5—5 of Fig. 4;

Fig. 6 is a horizontal sectional elevation on the line 6—6 of Fig. 4;

Fig. 7 is a horizontal sectional elevation on the line 7—7 of Fig. 4;

Fig. 8 is a horizontal sectional elevation on the line 8—8 of Fig. 4;

Fig. 9 is a vertical section through a diagrammatic representation of a modified form of apparatus for carrying out the invention; and

Fig. 10 is a horizontal plan view of the apparatus illustrated in Fig. 9.

The same characters of reference indicate the same parts throughout the several views.

One example of carrying out the invention is illustrated by the apparatus shown diagrammatically in Figs. 1 and 2. This apparatus is intended for practising the im-

proved desulfurizing process in conjunction with a process for reducing iron ore to obtain raw iron, commonly known as pig iron. Referring to said Figs. 1 and 2, the reference numeral 11 represents a blast furnace constituted of the stack 12 in the upper part, the bosh 13 in the intermediate part and the hearth 14 at the bottom. Between the bosh 13 and the hearth 14 are the twyers 15 arranged in series around the furnace and constituting a means for supplying to the interior of the furnace a blast of preheated air to effect combustion of the fuel. The charge to be treated in the furnace is introduced into the top of the stack 12 in the usual way and, when in the furnace, consists of the usual mixture of iron ore, carbon in the form of coke, and a basic material such as limestone, for neutralizing the acidity of the ash and forming the slag, which floats or stratifies on the top of the molten metal in the bottom of the hearth.

In addition to its neutralizing action on the acidity of the ash, the limestone slag stratum indicated by the reference character "S" has an affinity for sulfur and such property of the slag to absorb sulfur is augmented by contact of incandescent carbon which dips into the slag stratum. The molten metal flows in small drops or in the form of a spray downwardly through the solid portions of the charge in the melting zone, and dropping through the slag stratum on top of the mass of molten metal indicated at "M" in the bottom of the hearth, the small drops of molten metal are subjected to the action of the slag which action is augmented by the submerged pieces of incandescent carbon. Thus a large and prolonged surface contact of the molten iron with the slag and incandescent carbon is obtained, and during such passage of the iron through the slag stratum, a reaction is effected between the basic compounds present in the slag and the sulfur contained in the metallic iron, causing sulfur to be absorbed from the iron and retained by the slag, with which the sulfur combines to form principally the compound, calcium sulfid. The absorption of sulfur by the slag may be represented, for example, by the following two equations:

$$CaO+C=CO+Ca$$
$$Ca+FeS=CaS+Fe$$

From these two equations, it will be observed that the incandescent carbon induces the reaction resulting in the formation of calcium sulfid and pure iron. The calcium sulfid is soluble in and will be retained by the slag. The importance of the presence of incandescent carbon is illustrated by the first formula given above, inasmuch as the action of the carbon is to first reduce the calcium oxid to metallic calcium, thereby augmenting the affinity of the slag stratum for absorption of sulfur from the metal which passes through the slag.

In accordance with the invention, the above described factors which augment desulfurization of the iron are maintained continuously in their condition of maximum effect as regards desulfurization, during continuous operation of the furnace. In order to effect this result and to secure a maximum desulfurizing effect promoted by the action of the slag and immersed carbon, the invention provides for the maintenance of a continuous mass of slag in the hearth of the furnace, as contra-distinguished from ordinary practice in which substantially the whole mass of slag is discharged from the furnace each time a cast is made. By the invention, such bulk discharge at any time of the sulfur-absorbing slag is avoided, thereby maintaining at all times conditions within the furnace which result in maximum desulfurization and promote the obtaining of a product of uniformly low sulfur content. The conditions which promote maximum desulfurization result from the continuous maintenance of the slag stratum in contact with carbon, to render continuously effective the liberation of substances involving an affinity for the sulfur of the iron. In fact the pig iron obtained, as a result of the practice of the invention, contains appreciably less sulfur than is present in pig iron obtained by ordinary processes, without excessive slag volume, there being only small traces of sulfur present in the pig iron obtained by this invention. The invention therefore involves a process for the efficient desulfurization of iron in the large bulks commensurate with blast furnace operation. Furthermore, the invention may, if desired, be exploited for the purpose of producing pig iron having a specified maximum sulfur content, in which case it will be possible to utilize, in the furnace, coke having a greater proportion of sulfur than could be used in present practice, to obtain pig iron of the required specifications. Consequently, coke produced from many coals, which has been heretofore rejected for metallurgical purposes, is made available for such purposes. The continuous maintenance of the slag stratum, moreover, has the additional advantage of preventing sudden sinking of the charge, the charge being allowed to sink gradually into the hearth during continuous operation of the furnace. The slag stratum in contact with carbon also constitutes a reducing medium that completes the reduction of iron oxid of unreduced ore or reoxidized iron.

One way of practising the invention is illustrated in Figs. 1 and 2 and this consists in maintaining continuously during the operation of the furnace constant levels respectively of the molten metal and super-

posed slag stratum in the hearth of the furnace. This is accomplished by effecting continuous withdrawal of the metal and slag separately from their respective strata into a separate closed chamber or receiving vessel 17, in which there are maintained pressure conditions substantially equal to those that obtain in the interior of the furnace. Connecting the hearth 14 of the blast furnace with the closed chamber 17 is a metal overflow-duct 18. This duct extends upwardly from the hearth of the furnace at a point below the level of the molten metal and thence downwardly to the closed chamber 17. The hearth of the furnace, at a point below the level of the twyers 15 but above the level of the molten metal, is also connected with the closed chamber 17 by means of an overflow duct 19 through which slag and gas pressure may pass to the closed chamber 17. The gas pressure passing into the chamber 17 serves to equalize the pressures within such chamber with respect to those within the furnace, thereby preventing variation in the respective levels of the metal and slag masses in the hearth of the furnace as the gas pressures in the furnace vary. The fixed slag overflow pipe 19 will determine the height of the slag level, whereas the fixed location of the crest of the metal overflow pipe 18 will determine the height of the level of the molten metal. In practice, the relation of these respective heights may be expressed as follows: The height of the crest of the metal overflow pipe above its junction point with the hearth of the furnace equals the height of the molten metal in the furnace above said junction point plus two-sevenths of the height of the slag stratum in the hearth of the furnace, assuming that the specific gravity of the slag be two and that of the iron be seven.

In this manner, constant levels both of slag and of molten metal are maintained in the hearth of the furnace and this condition is combined with continuous discharge both of slag and of the raw metal from the furnace into the receiver 17. Intermittent casting operations, such as are in common use, are eliminated from the furnace and the casting is effected, as desired, from the receiving vessel 17 instead. Thus conditions which insure a maximum absorption of sulfur from the metal are maintained uninterruptedly in the furnace and a product having a minimum content of sulfur is attained. Inasmuch as the casting is effected from a vessel exterior of the furnace, the blast through the twyers may be maintained continuously, with the result that there would be no interruption in the production of the furnace during casting. The gas which enters the receiving vessel 17 through the overflow pipe 19 may be discharged through a gaspipe 20 controlled by a water cooled valve 21, and conducted for use in other operations.

In Figs. 3 to 8 inclusive, there is illustrated an application of the invention to a complete blast furnace apparatus. The furnace illustrated in these figures is supported by pedestals 22 of any approved construction and consists essentially of an outer metallic shell 23 surrounding an inner refractory lining 24. The upper part of stack 25 of the furnace converges toward the bell top 26 through which the charge is introduced into the furnace by the usual charging apparatus. The middle or downwardly converging bosh 27 terminates at the twyers 28 and below the twyers 28 there is formed a hearth 29^a. The twyers 28 are disposed in series around the furnace, as shown more particularly in Fig. 6, and are connected at their outer ends with a bustle pipe 29 which encircles the furnace and supplies the hot blast to the twyers. Gas is taken off from the top of the furnace by means of a gas offtake pipe 30. The bosh 27 and the hearth 29^a of the furnace are surrounded by a water jacket 31 supplied with cooling water from an inlet 32 at the bottom of the water jacket. The cooling water rises in the jacket 31 and discharges through outflow pipes 33 at the outer end of the water jacket into a water main 34 which communicates with a waste heat boiler 35.

Supported on suitable pedestals 36 of any approved construction is a closed vessel or chamber 37 constituted essentially of an outer metallic shell 38 and an inner refractory lining 39. The chamber or vessel 37 functions as a receiver for the molten metal from the hearth of the furnace and is connected with the hearth of the furnace by means of a metal overflow duct 40 formed in the refractory lined pipe sections 41. The pipe section 41 that empties into the receiving vessel 37 is, as shown in Figs. 3 and 4, located above the pipe section that connects directly with the hearth of the furnace, and said two pipe sections are connected by a vertical joint 42. Also mounted on suitable pedestals 43 is a closed vessel 44 formed of an outer metallic shell 45 and an inner refractory lining 46. The vessel or chamber 44 constitutes a receptacle for the slag and communicates with the hearth of the furnace above the level of the metal by means of a slag overflow duct 47 formed in a refractory lined pipe section 48. For equalizing the pressures within the chambers or vessels 37 and 44 with respect to the pressure within the furnace, said chambers 37 and 44 are respectively connected with the interior of the furnace by means of gas pipes 49 and 50. Suitable gas outlets 51 and 52 may also be provided for the vessels 37 and 44.

The furnace illustrated in Figs. 3 to 8 inclusive operates on the principle described in connection with the diagrammatic representations of Figs. 1 and 2. Instead however of withdrawing the slag and molten metal into a single vessel, the slag and molten metal are respectively permitted to overflow into the separate vessels 44 and 37, permitting casting of the metal as desired from the vessel 37 without the necessity for further removing slag. If desired, the vessels 37 and 44, instead of receiving the metal and slag discharges from a single furnace, may serve as receiving vessels for several furnaces.

A further improvement provided by the invention consists in withdrawing continuously from the furnace a portion of the furnace gas while the gas is passing upwardly through the furnace. This portion of gas is withdrawn from the furnace at a zone located just above the bosh, thereby permitting a portion of the heat to pass immediately to the exterior of the furnace instead of flowing upwardly through the stack of the furnace. This results in promoting relatively cool or moderate temperature conditions in the stack part of the furnace, thereby confining the melting zone to the bosh or lower part of the furnace and preventing melting or fusion in the stack part of the furnace, where it is essential to keep the charge in as loose a condition as possible in order to facilitate gradual and uninterrupted sinking of the charge into the melting zone. The gas withdrawn from above the bosh is of relatively higher temperature than gas ordinarily taken off from the top of the stack and has a low content of carbon dioxid, as well as being substantially free from sulfur. Another effect of taking off a portion of the gas just above the melting zone is to delay the reduction, which ordinarily is completed at a level considerably above the melting zone, so that the reduction may extend to lower levels than has heretofore been possible, thereby permitting shortening of the furnace and also conserving a large volume of gas of high calorific value, which is substantially sulfur-free and hence is highly useful for metallurgical purposes. In addition, this maintaining of relatively cool temperature conditions in the stack permits the use of higher blast temperatures, which are restricted to the melting zone. In this manner, the temperature in the stack may be controlled independently of an increase in fuel consumption in the region of the twyers. If it be desired to increase the production of rich gas in the furnace by increasing the coke charge, the greater amount of heat thereby attained is available in the bosh or melting zone to promote desulfurization and fusion of the iron, without increasing temperature conditions in the stack or upper part of the furnace. This permits the blast furnace to be run as a gas producer, in conjunction with its operation as a reduction furnace, without augmenting temperature conditions in the upper portion of the furnace, while at the same time utilizing in the melting zone and the hearth of the furnace the greater amount of heat which results from increased coke consumption, to promote desulfurization of the iron and reduction of other metals present in the charge. The reduction of other elements present in the charge, such as manganese and silicon, is further promoted by the incandescent carbon dipping into the slag stratum which floats on top of the mass of molten metal in the bottom of the hearth.

For carrying out the withdrawal of a portion of the gas, there is provided an inverted U-shaped pipe 53 which extends across the furnace at a level just above the top of the bosh, as clearly shown in Figs. 3 and 4. This pipe 53 may be covered with a jacket 54 formed of refractory material and between the two depending portions of the pipe there is formed a channel 55 through which gas may pass from the furnace to a discharge pipe 56 connected with a dust catcher 57. The interior of the pipe 53 is supplied with cooling water by means of pipe connections 58, 59 extending to the water main 34, as shown in Fig. 5. The water circulating through the pipe 53 protects the pipe against destruction by heat. If desired, the gas discharged through the pipe 56 may be cooled and then reconveyed to the interior of the furnace.

In the form of the invention illustrated in Figs. 9 and 10, the slag discharges into a separate closed vessel 60 and the molten metal into a closed vessel 61. Equal pressure conditions are maintained in both said vessels by means of an equalizing gas connection 62. The vessel 61 for the molten or raw iron is provided with a charging hole 63 for ores and lime, while the vessel 60 is provided with a gas discharge pipe 64 permitting discharge of the evolved gases. Refining of the raw iron may be effected in the closed vessel 61, in accordance with the open-hearth or ore method, by the addition of pure iron ores and a lime stone flux, this resulting in an evolution of carbon monoxid which passes out the gas gas pipe 64. As there is a steady flow of raw iron into the vessel 61, a continuous evolution of gases from the refining process is obtained, thereby maintaining a relation of equilibrium between the gas discharged from the refining process and the supply of molten metal from the blast furnace. When refining by the ore method, it is essential to prevent the furnace slag from entering the vessel 61, in order to prevent

re-absorption of sulfur from the furnace slag, under the oxidizing conditions which prevail in the refining process. This results in a further continuous production of gas of very high calorific value.

The invention as hereinabove set forth may be practised in various ways without departing from the scope of the claims hereinafter made.

I claim:

1. The improvement in the art of reducing iron ores which consists in subjecting the charge of iron ore, basic material, and coke to blast treatment to stratify the molten metal and slag at the bottom of the charge, and continuously withdrawing the reduced metal and slag from such stratified masses, while maintaining the metal and slag strata respectively at constant levels, to effect constant immersion of incandescent carbon in the slag and to maintain a constant flow of molten metal through such slag stratum having an affinity for sulfur, whereby the sulfur is absorbed from the metal; substantially as specified.

2. The improvement in the art of reducing iron ores which consists in subjecting the charge of iron ore, basic material, and coke to blast treatment to stratify the molten metal and slag at the bottom of the charge, and continuously withdrawing the reduced metal and slag from such stratified masses, while maintaining them at the bottom of the charge, to effect constant immersion of incandescent carbon in the slag and to maintain a constant flow of molten metal through such slag mass having an affinity for sulfur, whereby the sulfur is absorbed from the metal; substantially as specified.

3. The improvement in the art of reducing iron ores which consists in subjecting the charge of iron ore, basic material, and coke to blast treatment to stratify the molten metal and slag at the bottom of the charge; continuously withdrawing the reduced metal and slag from such stratified masses, while maintaining them at the bottom of the charge, to effect constant immersion of incandescent carbon in the slag and to maintain a constant flow of molten metal through such slag mass having an affinity for sulfur; and equalizing the pressures on the withdrawn metal and slag with respect to the pressures on the slag and metal masses at the bottom of the charge; substantially as specified.

4. In the art of reducing iron ores by blast furnace operation, the continuous maintenance within the hearth of the furnace, irrespective of slag or reduced-metal discharge, of a slag stratum of substantial mass and in continuous contact with incandescent carbon, to complete the reduction of iron oxid of unreduced ore or reoxidized iron, substantially as specified.

5. In the art of reducing iron ores by blast furnace operation, the continuous maintenance within the hearth of the furnace, irrespective of slag or reduced-metal discharge, of a slag stratum of substantial mass and in continuous contact with incandescent carbon, to render continuously effective the liberation of substances involving an affinity for the sulfur of the iron, substantially as specified.

6. The art of desulfurizing metals, such as iron and its alloys, which consists in causing molten metal to pass through a desulfurizing bath consisting of a mass of slag in continuous contact with solid incandescent carbon to augment the affinity of the slag for sulfur, and maintaining the slag mass, while withdrawing from the desulfurizing bath the desulfurized metal; substantially as specified.

7. The art of desulfurizing metals, such as iron and its alloys, which consists in causing molten metal to pass in the form of a spray through a desulfurizing bath consisting of a mass of slag in continuous contact with solid incandescent carbon to augment the affinity of the slag for sulfur, and maintaining the slag mass, while withdrawing from the desulfurizing bath the desulfurized metal; substantially as specified.

8. The art of desulfurizing metals, such as iron and its alloys, which consists in effecting a continuous passage of the molten metal through a bath of basic slag which is in continuous contact with solid incandescent carbon to maintain the affinity of the slag for sulfur, and maintaining the slag mass, while withdrawing from the desulfurizing bath the desulfurized metal; substantially as specified.

9. In the art of reducing iron ores by blast furnace operation, the continuous maintenance, during continuous discharging from the furnace, of the slag and molten metal masses at the bottom of the charge respectively at substantially constant levels irrespectively of pressure variations within the furnace; substantially as specified.

10. A blast furnace comprising: a blast furnace chamber; separate discharge means at the bottom of said chamber for the slag and molten metal to permit continuous discharge of molten metal and slag, while maintaining the slag and molten metal strata respectively at constant levels; separate receiving vessels respectively for the material conveyed through said discharge means; and means for equalizing the pressures in said receiving vessels with respect to the interior of the furnace; substantially as specified.

11. A blast furnace comprising: a blast furnace chamber; separate discharge means at the bottom of said chamber for the slag and molten metal to permit continuous dis-

charge of molten metal and slag, while maintaining the slag and molten metal strata respectively at constant levels; separate receiving vessels respectively for the material conveyed through said discharge means; and gas ducts respectively connecting the interior of the furnace with said vessels; substantially as specified.

12. A blast furnace comprising: a blast furnace chamber; means for effecting continuous discharge of the slag and molten metal in the bottom of said chamber, while maintaining masses of slag and molten metal in the chamber; means for receiving the discharged metal and slag; and means for equalizing the pressures in said receiving means with respect to the interior of the furnace, while maintaining said continuous discharge; substantially as specified.

13. A blast furnace comprising: a furnace chamber; twyers for supplying blast to said chamber; and means, operating continuously during slag or metal discharge from the furnace, for maintaining a constant slag level in said chamber above the bottom of the incandescent coke but below the twyers; substantially as specified.

14. A blast furnace comprising: a furnace chamber; twyers for supplying blast to said chamber; means for maintaining a constant slag mass in said chamber above the bottom of the incandescent coke but below the twyers; means for receiving the slag and molten metal discharged from the furnace; and means for equalizing the pressures on the discharged slag and molten metal with respect to the pressures in the furnace; substantially as specified.

15. A blast furnace embodying: a furnace chamber having a stack, a bosh and a hearth; twyers for supplying the blast in the region of the bosh; and means for controlling the temperature in the stack independently of an increase in fuel consumption in the region of the twyers; substantially as specified.

16. A blast furnace embodying: a furnace chamber having a stack, a bosh and a hearth; twyers for supplying the blast in the region of the bosh; and gas outflow means located above the bosh and below the top gas-outlet of the stack for permitting gas from the melting zone to pass directly out of the furnace chamber; substantially as specified.

17. The improvement in the art of blast furnace operation which consists in withdrawing a portion of the gas between the top gas-outlet of the furnace and the twyers to reduce the temperature of the charge above the melting zone; substantially as specified.

18. The improvement in the art of blast furnace operation which consists in withdrawing a portion of the gas from below the top gas-outlet of the stack, to effect the recovery of high-temperature gas having a low content of carbon dioxid and substantially free from sulfur; substantially as specified.

19. In the reduction of iron ores, maintaining substantially constant the zone of dipping of the carbon into the pool of slag, to render continuous the direct reduction effected in such zone; substantially as specified.

20. In the reduction of iron ores, maintaining the dipping of the carbon into the pool of slag, to render continuous the direct reduction effected in the region of such contact of the slag and carbon; substantially as specified.

21. In the art of reducing iron ores, the continuous maintenance of the slag and molten metal masses at the bottom of the charge at a constant slag level, to prevent sudden sinking of the charge; substantially as specified.

22. A blast furnace comprising: a furnace chamber; twyers for supplying blast to said chamber; and means, operating continuously during slag or metal discharge from the furnace, for maintaining continuously a slag level in said chamber above the bottom of the incandescent coke but below the twyers; substantially as specified.

23. A blast furnace comprising: a furnace chamber, twyers, a slag over-flow means below the level of the twyers, an over-flow means for the molten metal below said slag overflow means, receiving means for the metal and slag discharge from the furnace, and means for maintaining the atmosphere in said receiving means in substantially continuous aerostatic equilibrium with respect to the atmosphere within the furnace chamber; substantially as specified.

24. In the art of blast furnace operation, the continuous maintenance of the slag and the molten metal masses at the bottom of the charge respectively at constant levels, to prevent sudden sinking of the charge, combined with the withdrawal of a portion of the furnace gas between the top gas outlet of the furnace and twyers, to check fusion in the stack part of the furnace and to insure gradual sinking of the charge into the melting zone; substantially as specified.

25. A blast furnace comprising; a furnace chamber; twyers for supplying blast to said chamber; means for maintaining continuously a slag level in said chamber above the bottom of the incandescent coke but below the twyers and gas out-flow means located above the bosh and below the top gas outlet of the stack for permitting gas from the melting zone to pass directly out of the furnace chamber; substantially as specified.

26. In the art of blast furnace operation, the continuous maintenance of the molten

metal in the hearth of the furnace at a constant level, with a mass of slag above said level, combined with the accumulation of the excess metal in a receiver exterior to the furnace and the continuous maintenance of equalized gas pressures on the top surfaces of the metal in the hearth and in the receiver, whereby metal may be drawn off from the receiver without changing the level of metal or slag in the hearth of the furnace; substantially as specified.

27. A blast furnace comprising: the main furnace chamber including the hearth, an auxiliary receiver for the molten metal, a molten-metal overflow means from the hearth to said receiver, a slag overflow means connected with said hearth, and means for maintaining the pressure of the atmosphere in the receiver in substantial aerostatic equilibrium with respect to the furnace pressure; substantially as specified.

28. In a blast furnace, in combination: a furnace chamber; twyers for the blast thereto; reservoir means for molten material discharged from the furnace chamber; means for maintaining pressure in said reservoir means in substantial aerostatic equilibrium with pressure variations in the furnace chamber; and discharge means connecting the furnace chamber with the reservoir means and providing for continuous gravity overflow of the molten material from the furnace chamber into the reservoir means; substantially as specified.

29. In a blast furnace, in combination: a furnace chamber; twyers for the blast thereto; reservoir means for molten material discharged from the furnace chamber; means for maintaining pressure in said reservoir means in substantial aerostatic equilibrium with pressure variations in the furnace chamber; and discharge means connecting the furnace chamber with the reservoir means and providing for continuous outflow of the molten material from the furnace chamber into the reservoir means; substantially as specified.

30. In the art of reducing iron ores by blast furnace operation, the continuous gravity overflow discharge from the furnace of the molten material into an atmosphere maintained continuously in substantial aerostatic equilibrium with respect to pressure variations within the furnace; substantially as specified.

31. In the art of reducing iron ores by blast furnace operation, the continuous outflow from the furnace of the molten material into an atmosphere maintained continuously in substantial aerostatic equilibrium with respect to pressure variations within the furnace; substantially as specified.

HEINRICH KOPPERS.