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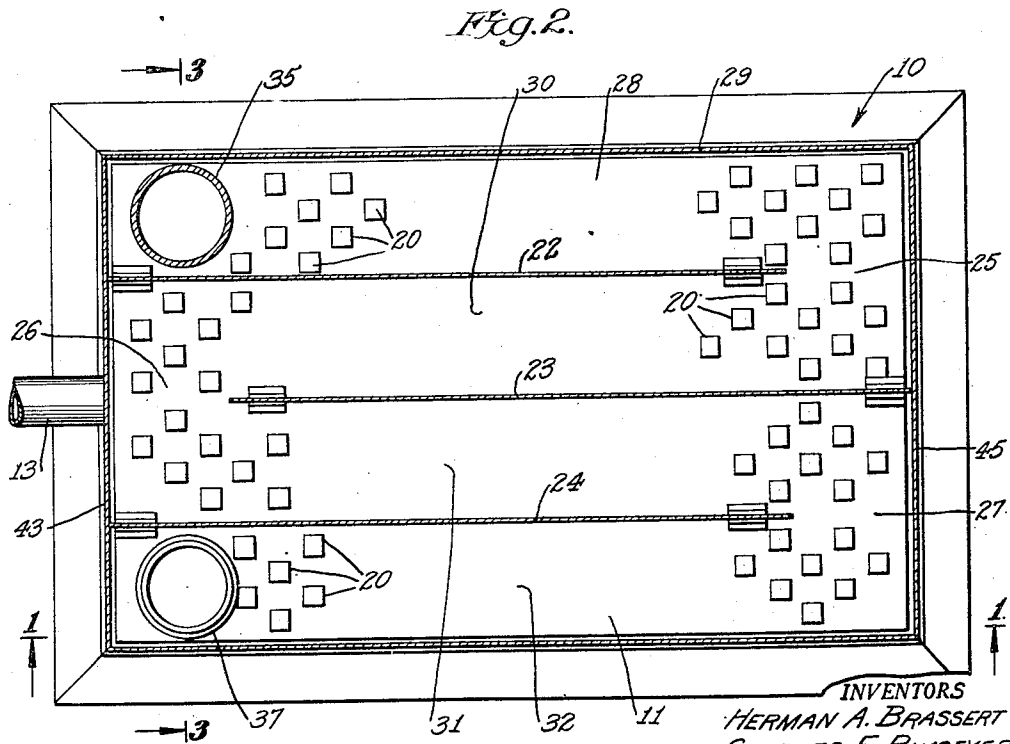
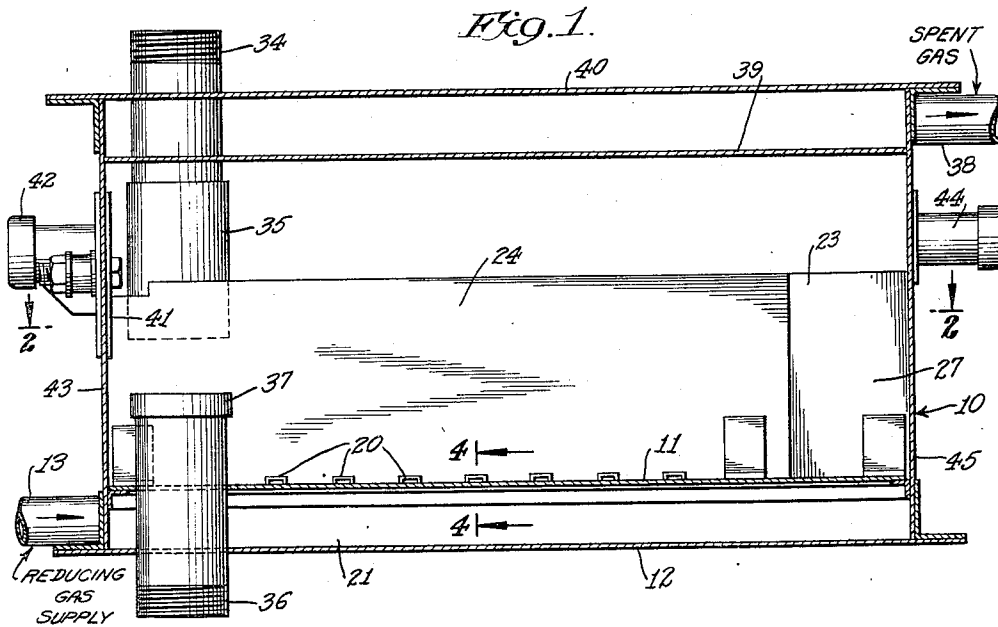
H. A. BRASSERT ET AL

2,389,133

APPARATUS FOR REDUCTION OF METALLIC MATERIAL.

Filed April 6, 1943

4 Sheets-Sheet 1



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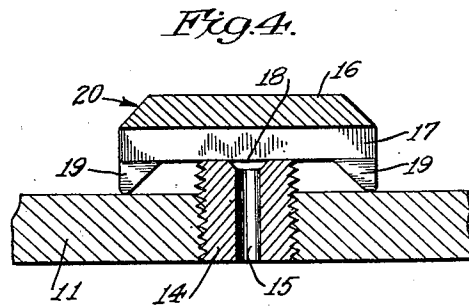
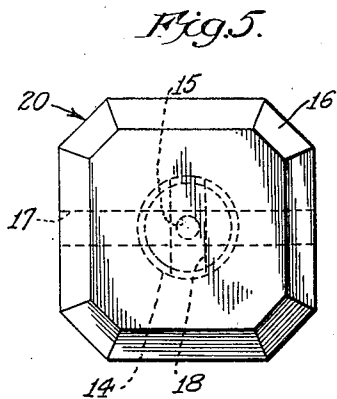
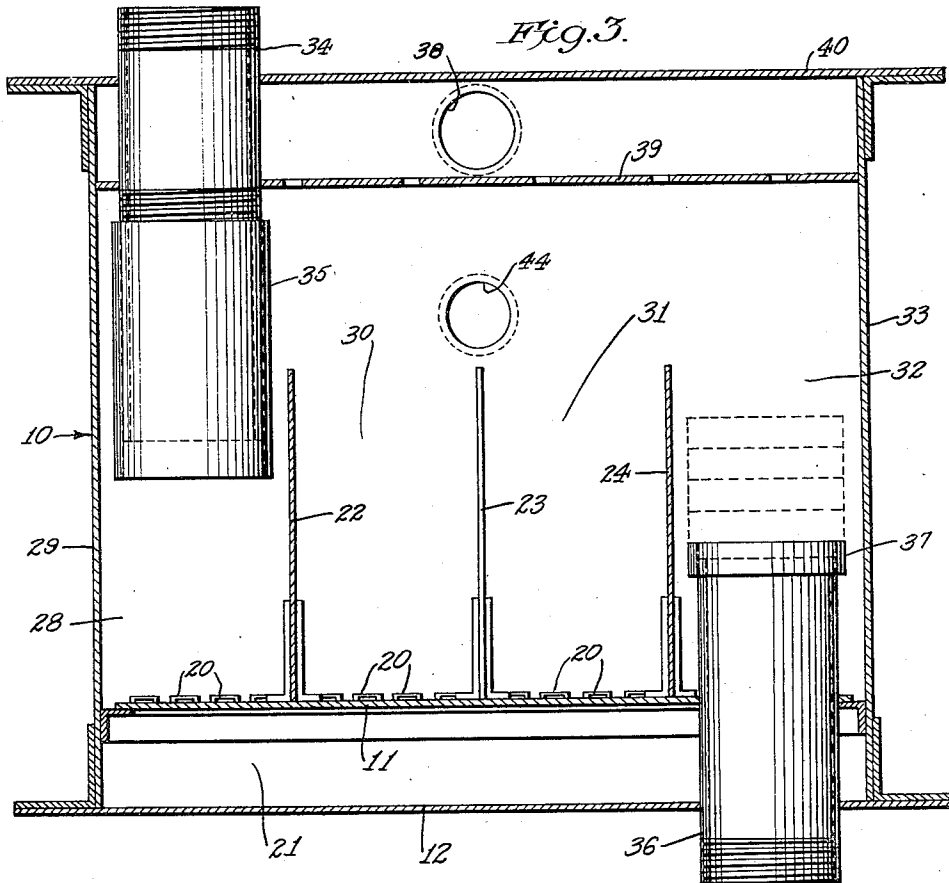
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APPARATUS FOR REDUCTION OF METALLIC MATERIAL

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4 Sheets-Sheet 2



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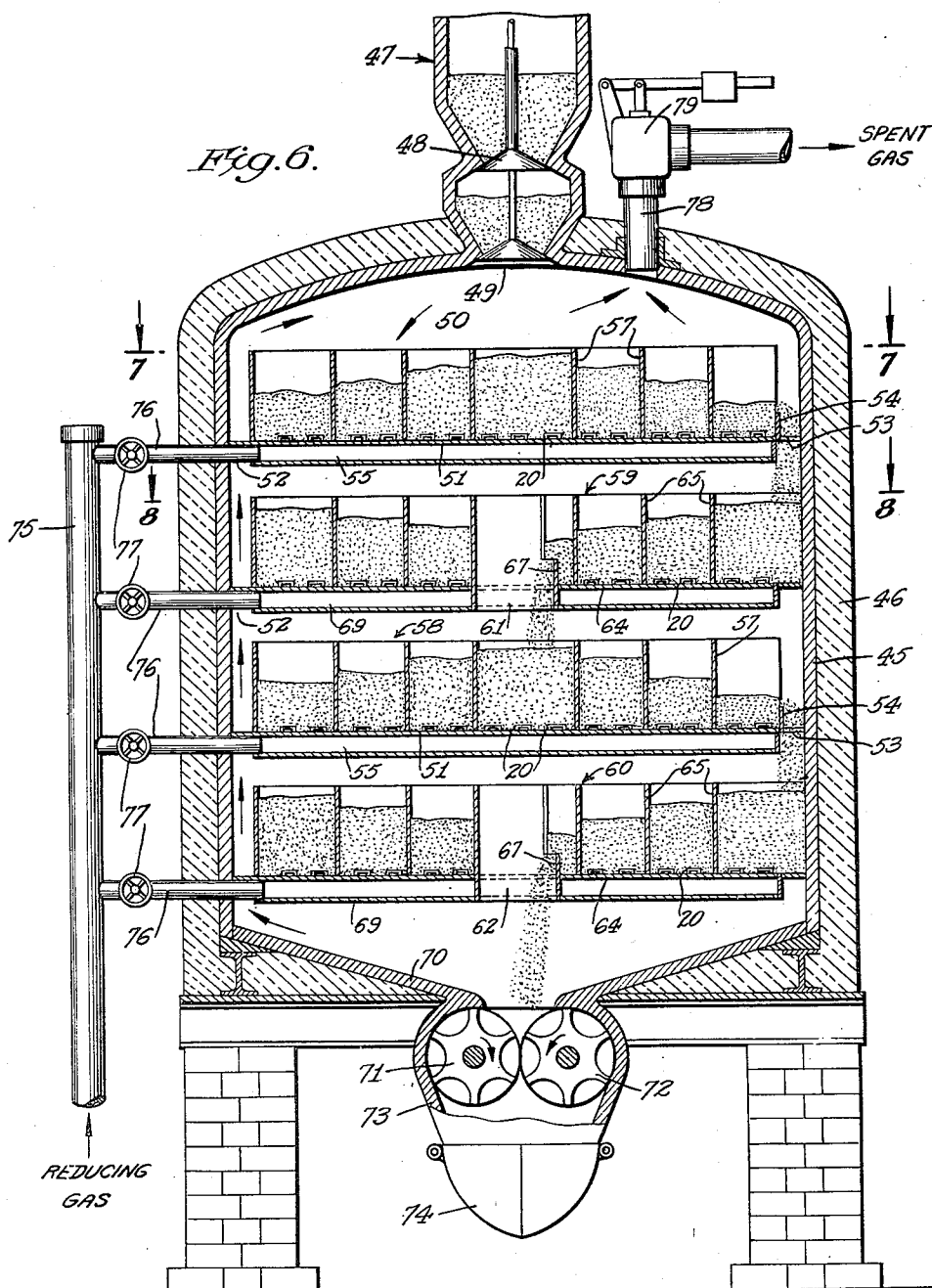
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4 Sheets-Sheet 3



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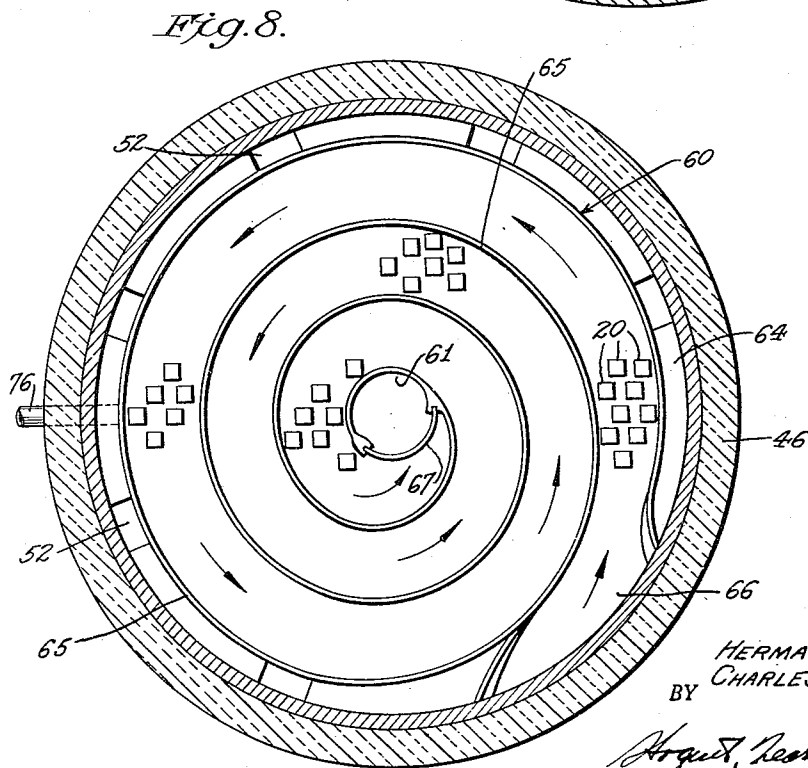
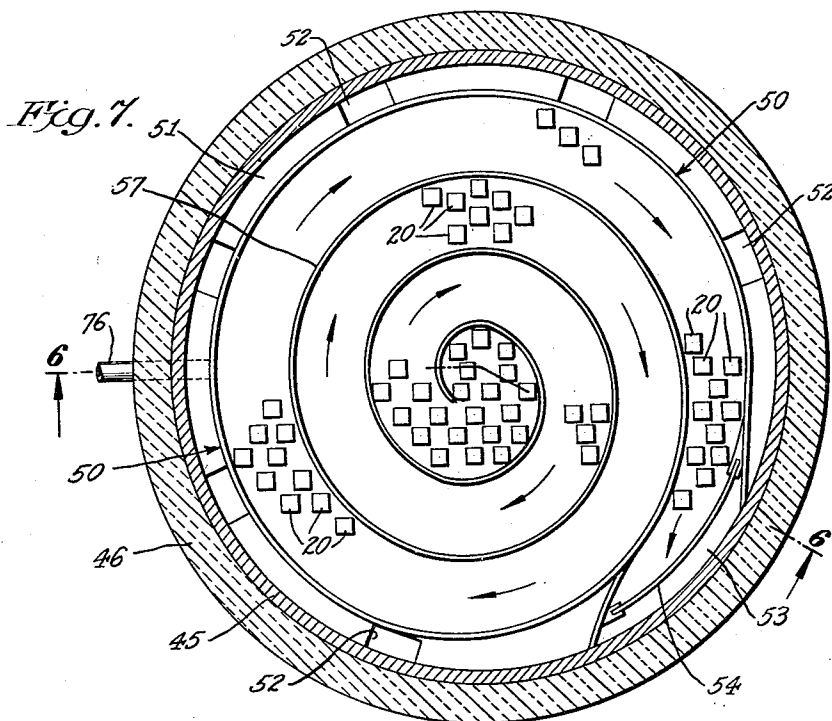
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APPARATUS FOR REDUCTION OF METALLIC MATERIAL

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4 Sheets-Sheet 4



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UNITED STATES PATENT OFFICE

2,389,133

APPARATUS FOR REDUCTION OF METALLIC MATERIAL

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Application April 6, 1943, Serial No. 481,968

4 Claims. (Cl. 23—277)

This invention relates to the production of metals and has particular reference to methods and apparatus for effecting reduction of finely-divided metallic ores or other oxides or sulphides, such as iron ore, pyrites, mill scale, and other ferrous oxides, although the invention is not limited to ferrous metals, but may also be used for producing non-ferrous metals.

It is known that finely-divided solid behaves as a fluid, and particularly so when continuously aerated. This phenomenon has been utilized in reducing finely-divided ores or other oxides by means of hot reducing gases caused to flow through a bed of the ore under such conditions that the bed assumes a state equivalent to fluidity, and accordingly flows along the hearth from the charging to the discharging point while the ore is being reduced. This method is disclosed in application Serial No. 338,560, filed June 3, 1940, by J. C. Hartley, and a variant thereof is disclosed in application Serial No. 422,930, filed December 15, 1941, by C. J. Westling. In each case the hot reducing gas is percolated through the bed of ore from below, the hearth being provided with perforations or similar apertures for that purpose.

In utilizing prior perforated hearths for reducing fine ores, the gas is supplied at sufficient volume to effect reduction and flows through the ore bed at sufficient velocity to obtain the desired fluid condition, but frequently channeling takes place, owing to temporary clogging of some of the hearth apertures, or because the bed happens to be thinner at one point than another. Channeling and consequent bursting of large gas bubbles at the surface of the bed results in dusting, uneven flow, and non-uniform reduction.

We have found that the number of the gas apertures may be increased and the size of the gas apertures through the hearth may be reduced still further so that there is no tendency toward channeling, and that an adequate supply of gas for effecting complete reduction may be nevertheless supplied by maintaining a relatively high gas pressure at the upstream ends of the apertures without any undue disturbance in the bed. We employ a hollow hearth containing between its upper and lower decks a volume of reducing gas under sufficient pressure so that the amounts of gas flowing through each aperture are substantially the same or remain in constant relationship one to the other. An adequate volume of gas may be supplied to the gas chamber for effecting reduction and the desired fluidity, even in very deep beds, without any concomitant

jetting effect tending to cause channeling. The hearth is arranged horizontally and is preferably made of heat-resistant metal for lightness and strength. The gas apertures are preferably arranged vertically and the gas travels perpendicularly or normally to the general direction of movement of the bed and, notwithstanding its high emergence velocity, is effectively distributed uniformly over the hearth surface by a cap placed over each aperture so that the gas is diffused under the edges of the caps and bubbles up through the bed from the enclosed gas chamber coextensive with the hearth which forms the upper surface of the gas chamber.

The chamber is supplied with gas at proper temperature and pressure to effect the reduction and any number of such complete self-contained hearths may be enclosed in a housing, preferably one above the other, although each hearth is independent of the other. Gas may be fed independently to each one of those hearths, and the gas can be fresh in each instance or partly or wholly spent gas, particularly in the upper hearths. The depths of the ore beds on the hearths and the reducing power of the gas and its velocity, temperature and pressure can be so varied that the spent gas leaving each hearth may be as close to equilibrium as possible, thus realizing the optimum reducing power of the gases. A relatively thin bed of the fresh ore at the top of the furnace will have the same effect on the reducing gases as a much thicker bed of almost completely reduced ore near the bottom.

Enclosing a plurality of hearths in a single housing not only saves space and heat, but also enables feeding of the material from one hearth to another for progressive reduction in a manner similar to the Herreshoff furnace, although rabbling arms and a control shaft are not required since the material flows from the charging to the discharging end of the hearth in the manner of a fluid while being reduced. Also the entire reducing operation may be maintained under superatmospheric pressure to promote reduction, since the supply of reducing gas is more concentrated under these conditions and pressure speeds up the reaction.

In a preferred form of furnace embodying the present invention, the elongated hearth may be spirally arranged so as to further conserve space and heat, and this may be conveniently done by providing a circular plate-like hearth with a spiral partition to which the material may be fed, either at the center or at the periphery, and when such hearths are arranged one above the

other the material is supplied alternately at the center and periphery of the successive hearths.

For a more complete understanding of the invention, reference may be had to the accompanying drawings, in which:

Figure 1 is a longitudinal section as seen along the line 1—1 of Fig. 2 through the straight form of reducing furnace embodying the improvements and utilizing the process of the present invention;

Fig. 2 is a horizontal section therethrough as seen along the line 2—2 of Fig. 1, and illustrates the arrangement of the hearth surface;

Fig. 3 is a transverse section therethrough as seen along the line 3—3 of Fig. 2;

Fig. 4 is an enlarged section through the hearth as seen along the line 4—4 of Fig. 1 and illustrates the construction of one of the bubble caps;

Fig. 5 is an enlarged plan view of one of the bubble caps;

Fig. 6 is a vertical section through the preferred circular form of reducing furnace, as seen along the line 6—6 of Fig. 7;

Fig. 7 is a horizontal section therethrough as seen along the line 7—7 of Fig. 6 and illustrates the arrangement of the first or upper hearth; and

Fig. 8 is a horizontal section at 8—8 of Fig. 6 and illustrates the second hearth.

Referring to Figs. 1, 2 and 3 of the drawings, the furnace 10 comprises a rectangular housing preferably formed of welded 4% to 6% chrome steel or other suitable heat-resistant metal provided with a double bottom formed by a horizontal upper deck 11 spaced above the lower deck or bottom 12 so as to form a sealed chamber into which a reducing gas supply pipe 13 leads. The upper deck 11 forms the horizontal hearth of the furnace and is perforated, the perforations being spaced from two to six inches apart and each containing a plug 14 shown in Fig. 4, preferably threaded into the perforation in the hearth 11 as shown, or it may be force-fitted therein. Each plug 14 is provided with a relatively small central orifice 15, for example, of $\frac{1}{8}$ to $\frac{1}{4}$ inch diameter, or of a suitable diameter determined by capacity for the particular furnace to be employed. A plate 16 is secured as by welding to the upper end of the plug 14. This plate is provided with a transverse slot 17 shown particularly in Fig. 5, and the upper end of the plug 14 is provided with a transverse notch 18. Gas emerging from the upper end of the orifice 15 impinges against plate 16 and traverses notch 18 and slot 17 so that the gas flows beneath the edge of the plate 16, which is preferably also spaced above the upper surface of hearth 11 by means of integral studs 19. The whole plug and cap-plate organization 14—16 just described may be conveniently termed a bubble-cap, and is designated 20. Accordingly, the entire hearth 11 is studded with bubble-caps 20 supplying gas from the gas chamber 21 beneath the hearth 11.

The upper surface of hearth 11 is subdivided by several parallel vertical partitions 22, 23 and 24. Partition 22 extends from the lefthand end of the hearth 11, as shown in Fig. 2, but stops short of the righthand end thereof, so as to leave an end passage 25. The center partition 23 extends from the righthand end of the hearth 11 but stops short of the lefthand end thereof, leaving an end passage 26. Partition 24, like partition 22, extends from the lefthand end of the hearth 11 but stops short of the righthand end

thereof, leaving the passage 27. It will be observed that these partitions provide a zig-zag channel of substantial length within a small space, equivalent to a long tunnel-like furnace.

The effective hearth begins with the channel 28 between partition 22 and the side wall 29 of the furnace leading through end passage 25 to channel passage 30 between partitions 22 and 23, leading through end passage 26 to channel 31 between partitions 23 and 24, leading through end passage 27 to channel 32 between partition 24 and side wall 33. It will be understood that this zig-zag channel is supplied through its entire extent by reducing gas from gas chamber 21 through the bubble-caps 20. As shown particularly in Figs. 1 and 3, the partitions 22, 23 and 24 stop short of the top 40 of the furnace and may be welded or otherwise secured to the upper surface of hearth 11.

Discharging into the closed end of channel 28 at the lefthand upper corner of Fig. 2 is the supply pipe 34 for charging the furnace 10 with the finely-divided oxides to be reduced. Pipe 34 is preferably welded to the top 40 of the furnace 10 and its lower end is threaded and carries an adjustable collar 35. By screwing collar 35 upwardly or downwardly on pipe 34, the level of discharge of the material to the hearth may be adjusted.

At the discharge end of the zig-zag channel on hearth 11 is a discharge pipe 36 welded to the bottom 12 of the furnace and extending through the gas chamber 21 above the surface of the hearth 11. The upper end of discharge pipe 36 is also threaded for the reception of one or more collars 37, whereby the level of the bed at the discharge end of the zig-zag passage may be adjusted. Collars 37 screw into each other as shown and may be increased or decreased in number to obtain the desired depth of bed at discharge, which is always lower than the depth of the bed at the feeding end, so that a head of the material is maintained in order that it may flow in the manner to be described. The discharge pipe 36 may lead directly to a briquetting machine, not shown, for compacting the reduced material into briquettes while still hot from the reducing operation and while still in a reducing atmosphere, in the manner described in Patent No. 2,287,663, issued June 23, 1942, to H. A. Brassert. If desired, the reduced material may be further concentrated before briquetting, also as described in said patent.

Leading from the upper end of the furnace 10 is a spent gas discharge pipe 38 which may conduct the gas to a reforming or recovering plant for effecting reuse of the gas. A perforated plate 39 is preferably suspended in spaced relation to the top 40 of the furnace, so that the spent reducing gas diffuses uniformly therethrough and its velocity retarded so that it does not carry out of the furnace any substantial amount of fines that may result from dusting.

An access door 41, preferably fitted with a peep tube 42 is provided in the lefthand end 43 of the furnace 10, and a similar peep tube 44 may be provided at the righthand end 45 of the furnace 10.

In operation, in accordance with the process of this invention, the furnace 10 is supplied with iron ore or other oxide through supply pipe 34, the material being previously ground to 20 to 150 mesh and concentrated to substantially remove the gangue according to known methods. The depth of the bed at the discharge end is deter-

mined by the number of rings 37 on a discharge pipe 36, but as previously mentioned, the height of the upper end of the discharge pipe 36 above the deck 11 is always less than the height of the lower end of the collar 35 above the deck 11, so that a head of the finely-divided material is maintained at the feed end, the differential depending upon depth of bed desired, fineness of the ore, nature of reducing gas, temperature, etc.

The reducing gas, preferably pre-heated to have a temperature in the bed of from 1100 to 1500° F., is supplied by pipe 13 to the chamber 21, below the hearth 11, and at a pressure of say thirty pounds per square inch above the internal furnace pressure. At this temperature the gas readily reduces the oxide but is not high enough to cause the particles to agglomerate and frit together, so that they remain separate and distinct throughout the operation and hence retain the fluid-like flow when permeated by the gas in the manner to be described.

The gas accordingly flows at substantial velocity through the orifice 15 of each bubble-cap 20 and impinges against the cap plate 16 thereof so as to be diffused below its edge into the finely-divided material on the deck 11. Under these conditions, the volume and velocity of gas flowing into the bed from each bubble-cap 20 is substantially the same, so that the action of the gas throughout the bed is uniform. The gas is supplied in adequate volume to effect reduction at the temperature given and to produce the desired fluidity described, and usually, particularly where relatively deep beds are employed, the amount of gas necessary to obtain the desired fluidity of the bed is in excess of that theoretically necessary to deoxidize the ore. Accordingly a surplus of reducing gas is supplied which may be recovered and recirculated. For example, if hydrogen is used, the water vapor resulting from the reaction may be washed out to leave hydrogen for recirculation. Similarly where carbon monoxide is used, the resulting carbon dioxide may be washed out with alkaline water and when mixtures of hydrogen and carbon monoxide are used the washing treatment removes both the water vapor and carbon dioxide. Other recovering means for purifying the unused oxidizing gas may be used so that it may be recirculated. Although at the beginning of the operation, all of the finely-divided material is located only at the feed end of the zig-zag hearth channel under feed pipe 34, the fluidity imparted thereto by the gas causes it to rapidly flow along the hearth 11 between the partitions and to level out until it begins to flow out of the discharge pipe 36.

It will be observed that the general direction of flow of the gas issuing from bubble-caps 20 is perpendicular or normal to the general direction of movement of the bed on the horizontal hearth 11, and this action coupled with the even distribution of the gas over the entire surface of the hearth 11 without jetting results in an even, steady flow of the material along the hearth without formation of large gas bubbles or channeling and consequently there is little or no dusting. The entire bed is accordingly in a fluid-like state and each particle is suspended in the gas which reduces it while maintaining it so suspended, the spent reducing gas rising to the top of the bed and being immediately replaced by fresh reducing gas entering the bed from below so that reduction is rapid and continuous, augmented by the rubbing between the particles in

the bed, which aids in removing the spent reducing gas which tends to cling to the surface thereof. The spent reducing gas is immediately removed through pipe 38.

5 The furnace 10 is preferably so constructed that two or more may be stacked in vertical relation whereby the reduction is progressive in a downward direction, beginning with partial reduction in the upper one, which discharges into the next lower section, which continues reduction and in turn discharges into the one below, and so on until complete reduction is obtained. In this way the throughput on a furnace may be increased materially over the use of one furnace alone, although it is to be understood that by proper control one furnace unit 10 will effect the complete reduction, but at a slower rate.

When several furnace units 10 are so superimposed, it will be observed that in each unit 20 fresh gas is supplied to the material from the hollow hearth, so that reduction is expedited and more efficient operation is obtained, although, if desired, the partially spent reducing gas, containing an excess of unoxidized gas, may be delivered from the lowest hearth to the upper 25 - hearth, and the like, since only partial reduction is effected on the top hearth. Whether one or more units 10 are so used, the furnace is preferably jacketed with insulating material or mounted in an insulating enclosure to conserve heat, which is also conserved when two or more units are mounted together, since heat is transmitted from one unit to another. Heat may also be conserved by partially pre-heating the fresh reducing gas in a heat-exchanger by means of the sensible heat in the spent reducing gas withdrawn by pipe 38. By withdrawing the spent reducing gas from 38 by means of a suction pump, the interior of the furnace 10 may be maintained under a slight vacuum to expedite the purging of the spent reducing gas, although as will be described, it is preferred that the furnace be maintained under pressure to expedite the reducing action.

45 Instead of employing straight hearth channels in the manner described, they may be arranged spirally, as shown in Figs. 6, 7 and 8. Referring to Fig. 6, the furnace preferably comprises a cylindrical housing 45 of steel or other suitable heat-resistant metal, enclosed in suitable heat insulation 46 and capable of withstanding internal superatmospheric pressures on the order of 15 to 30 pounds per square inch gage. The upper portion of the housing is provided with a centrally 50 located double bell and hopper arrangement 47 including the separately-operated upper feed bell 48 and lower sealing bell 49. This arrangement serves as a pressure lock, enabling feeding of the finely-divided metallic oxide to be reduced into the housing 45 without losing pressure during the opening of the feed bell 48.

Located within the housing 45 and positioned one above the other is a series of independent, self-contained hearths, four of which are shown 65 in Fig. 6, but more or less may be used, depending upon requirements. As before, each hearth is preferably composed of heat-resistant metal. The upper unit 50 comprises a hearth deck 51 extending across the housing and having spaced peripheral spent gas slots 52 and one peripheral discharge slot 53 for the material under treatment. The hearth 51 has a gas chamber 55 beneath it and this slot 53 having a dam 54 extending across its mouth.

75 The hearth deck 51 is studded with bubble-caps

20 illustrated in Figs. 4 and 5, and as described in connection with Figs. 1, 2 and 3, they supply diffused reducing gas into the finely-divided material constituting the charge on each hearth.

Secured on the upper surface of the top hearth 51 is a spiral partition 57 of heat-resisting steel. The length of the spiral partition 57 from the center, to which the material is discharged from the double bell and hopper feed 47, to the discharge passage 53 at the periphery, depends upon the volume of material to be treated and the rate of its travel necessary to secure the desired reduction. For instance, for a twenty-foot inside diameter hearth the total ore travel from feed to discharge should be, under normal operating conditions, equal to about 188 feet, and accordingly the length of the spiral partition 57 must be such to provide a length of travel of that distance.

The third hearth from the top, designated 58, is identical to the top hearth 50, but the second hearth from the top, designated 59, and the lower hearth, designated 60, are constructed differently from hearths 50 and 58, and have center discharge passages 61 and 62, respectively, instead of peripheral discharges, since these two decks receive the material from the corresponding upper decks at their periphery, for travel spirally inwardly to the center. The second and lower hearths, 59 and 60, are identical, and description of one of them, 59, will suffice, and is illustrated in Fig. 8. The top of hearth deck 64 is fitted with a spiral partition 65 leading from the periphery at 66 to the center discharge opening 61 filled with the dam 67. Also, like upper hearth 50, the second hearth 59 is provided with an enclosed bottom gas chamber 69, as is like lower hearth 60.

Thus, the material discharged from upper hearth 50 falls on the periphery 66 of the next hearth 59, travels spirally inwardly for a distance determined by the length of the spiral partition 65, and discharges at the center through passage 61 upon the center of the next hearth 58. On deck hearth 58 the material travels outwardly from the center to discharge through peripheral passage 68 to the lower hearth 60 on which it travels inwardly to discharge centrally at 62. Since the partitions of all hearths 50, 59, 58 and 60 are spiral in shape, the aggregate length of their convolutions determines the effective hearth length of the furnace. For example, in the furnace illustrated, each hearth is designed to have the same length and accordingly travel of the material on each deck is approximately 188 feet, making a total hearth length of about 750 feet for the four hearths.

The lower or discharge end of the furnace housing 45 converges into a discharge cone 70 feeding to a pair of driven briquetting rolls 71 and 72, which are enclosed within a casing 73 fitted with a normally closed pressure valve or discharge hopper 74, this hopper 74 and the briquetting rolls 71 and 72 constituting a form of gas pressure lock.

Located along one side of the furnace housing 45 is a manifold 75 for supplying reducing gas by pipes 76 to each of the gas chambers 55 and 69 of the several hearths 50, 59, 58 and 60. The flow of the reducing gas to each hearth may be regulated by means of a separate valve 77. The reducing gas, preferably cleaned and desulphurized if necessary, is pre-heated to such temperatures as to be delivered to the discharge ends of the orifices in the bubble caps 20 at a reducing

temperature of between 1100 and 1500° F., below the fusion point.

Furnace 45 is pressure-sealed as described, at the charging feed hopper 47 and at the discharge end, at the briquetting rolls 71 and 72 and discharge hopper 74. The spent gas discharge pipe 78 leading from the furnace 45 is preferably fitted with a pressure responsive valve 79, set to the internal pressure desired for the furnace 45, so that the internal pressure will remain substantially constant at, say 15 to 30 pounds per square inch gage.

In operation, in accordance with the process of this invention, the furnace 45 is supplied with iron ore or other oxide from hopper 47, the material being previously ground to 20 to 150 mesh and concentrated to substantially remove the gangue according to known methods. The reducing gas, preheated as described, is supplied from manifold 75 to the several independent gas chambers 55 and 69, within each double-deck hearth at a pressure of say five pounds per square inch above the internal furnace pressure. Thus, if the internal furnace pressure is fifteen pounds per square inch, the gas is then supplied to these gas chambers at twenty pounds per square inch. The gas accordingly flows at substantial velocity through the bubble-caps 20 for flow into the material which lies on the upper deck 51 of top hearth 50 within the spiral partition 57.

The material discharged on the top deck 50 by the feed bell 47 falls on the center thereof, but owing to the fluidity imparted thereto by the gas percolating therethrough, the material rapidly level out, although a higher level or head is maintained at the center than at the dam 54 at the periphery of the spiral partition 57 as is indicated in Fig. 6. Because the gas emerging from beneath the bubble-caps 20 imparts thereto a condition equal to fluidity in the manner described, the head maintained at the center of the spiral 57 causes the material to flow from the center around the spiral to discharge over dam 54 into passage 53 at the periphery, meanwhile being reduced at least to a certain extent.

The partially reduced material then falls to the next deck 59 at the periphery thereof and again flows spirally around it within partition 65, owing to the fluid condition imparted thereto by the gas flowing thereinto from the bubble-caps and the head maintained at the periphery, as indicated. However, in this instance the flow is inward from the periphery to the center. The fresh reducing gas supplied to the hearth 59 from the gas chamber 69 therein further reduces the material and when it discharges over dam 67 into the center passage 61 to the center of the hearth 58 below, it is largely reduced. Further reduction takes place in the same way on hearth 58, by means of a fresh supply of reducing gas supplied thereto, the material being received at the center and flowing spirally outwardly to discharge over the dam into peripheral passage upon the periphery of the last hearth 60. There the reduction is completed by means of the fresh supply of gas furnished to lower hearth 60.

The completely reduced material discharged from the center opening 62 of the last hearth 60 into the cone 70 is fed by gravity to the briquetting rolls 71 and 72, which immediately compact it while still hot from the reducing operation into self-sustaining briquettes before the material has any opportunity for contamination, the briquetting operation being conducted in the reducing atmosphere, as described in said Patent

No. 2,287,663. The completed briquettes collect within the hopper 40 and may be periodically removed.

The spent reducing gas is effectively purged from the surfaces of the particles by friction and attrition as the particles fall freely from one hearth to another, so that by the time they reach the hearth below their surfaces are substantially freed of spent reducing gas, and fresh gas may readily attack the unreduced portions. Also, as previously described, the particles rub against each other in the bed and the spent reducing gas is in that fashion further purged from the bed and is carried out by the fresh reducing gas. By maintaining the entire furnace under internal superatmospheric pressure in the order of 15 to 30 pounds gage, the reducing gas is supplied in more concentrated form to the particles and thus reduction is promoted. The straight type furnace shown in Figs. 1 to 3 may also be placed under pressure in the same way, if desired.

The spent reducing gas passes from each hearth through openings 52 at the periphery of each hearth into the annular space 80 for exit through the gas discharge pipe 78 for recovery and recirculation of the unoxidized reducing components thereof in the manner described.

It will be seen that the method and apparatus of this invention enables fresh reducing gas to be supplied to any number of hearths to carry on a progressive reduction of metallic oxides in an economical and efficient fashion. Because the gas orifices are small, although numerous, and the gas is diffused from a relatively large reservoir of gas under relatively high pressure, the tendency to channeling and consequent dusting and irregular flow and reduction is avoided. Also, the spent gas is removed from each hearth as it is discharged from the material being treated, and is not re-used without reformation and cleaning, but, instead, a supply of fresh reducing gas is used for that purpose. The depth of the ore beds on the hearths are adjusted by raising and lowering the discharge dams, and the reducing power of the gas and its velocity, temperature and pressure can be so varied that the spent gas leaving each hearth is as close to equilibrium as possible. Thus, the fresh ore on the upper hearth in Fig. 6 deoxidizes the gas to a greater degree than the nearly completely reduced material on the lower hearth and, therefore, a thinner bed on the upper hearth is preferred so that the gas emerging therefrom is no more deoxidized than that emerging from the lowest hearth, with progressively greater depths and proportionate results from the intermediate hearths. Furthermore, in the two types of furnace described the temperatures and pressures may be maintained, and adjusted if desired, in accordance with operating requirements, so as to obtain most efficient and complete reduction within a small space and with a minimum of parts to the exclusion of any moving parts except those used for briquetting purposes.

Although the invention has been illustrated and described in connection with straight and circular furnaces, it may also be constructed in other forms with one or more decks as desired, and other changes in the method and apparatus of this invention may be made within the scope of the appended claims.

We claim:

1. In apparatus for reducing finely-divided metallic material, the combination of a housing, a horizontal hearth therein having a multiplicity

of substantially uniformly distributed, pressure-reducing gas apertures therethrough, said apertures being less than one-quarter inch in diameter, partition means on said hearth to provide a long path for travel of material along said hearth, a casing forming a gas chamber beneath said hearth communicating with said apertures, a pipe leading from the exterior of said housing into said chamber for supplying preheated gas under pressure thereto, means on said hearth overlying said apertures for diverting the gas issuing from said apertures laterally in all directions to fluidize said material without propelling said material along said hearth and to prevent said material from entering said apertures by gravity, means extending into said housing and disposed adjacent one end of said hearth for feeding said finely-divided material upon the hearth for reduction by the gas emerging from said apertures, and means in said housing for discharging said reduced material from said hearth, said discharging means having an outlet at a lower level than the level of the material at said one end of the hearth whereby said fluidized material moves along said hearth by gravity flow.

2. In apparatus for reducing finely divided metallic material, the combination of a housing, an elongated horizontal hearth therein having a multiplicity of substantially uniformly distributed apertures therethrough, said apertures being less than one-quarter inch in diameter, a casing forming a gas chamber beneath said hearth communicating with said apertures, a pipe leading from the exterior of said housing into said chamber for supplying preheated gas under pressure thereto, means on said hearth overlying said apertures for diverting the gas issuing from said apertures laterally in all directions to fluidize said material without propelling said material along said hearth and for preventing said material from entering said apertures by gravity, a plurality of spaced partitions extending alternately in opposite directions part way across said hearth to form an elongated relatively narrow zig-zag path for movement of the material along said hearth, means extending into said housing and disposed adjacent one end of said hearth for feeding said finely-divided material to the hearth for reduction by the gas emerging from said apertures, and means in said housing for discharging said reduced material from said hearth, said discharging means having an outlet at a lower level than the level of the material at said one end of the hearth whereby said fluidized material moves along said hearth by gravity flow.

3. In apparatus for reducing finely-divided metallic material, the combination of a substantially circular horizontal hearth having a multiplicity of substantially uniformly distributed, spaced, pressure-reducing gas apertures therethrough, said apertures not exceeding one-quarter inch in diameter and being of substantially uniform size, a casing forming a gas chamber beneath said hearth communicating with said apertures, a pipe connected to said chamber for supplying preheated gas under pressure thereto, means on said hearth overlying said apertures for diverting the gas issuing from said apertures laterally in all directions to fluidize said material without propelling said material along said hearth, and for preventing said material from entering said apertures by gravity, a spiral partition on the upper surface of said hearth providing an elongated relatively narrow path for the material, means for feeding the finely-divided material upon the

hearth at one end of the spiral for reduction by the gas emerging from the apertures in said hearth, and means in said housing for discharging said reduced material from said hearth, said discharging means having an outlet at a lower level than the level of the material at said one end of the spiral whereby said fluidized material moves along said hearth by gravity flow.

4. In apparatus for reducing finely-divided metallic material, the combination of a housing, a plurality of substantially circular horizontal hearths arranged in spaced superimposed relation in said housing, a spiral partition on each hearth providing an elongated narrow path for movement of the material along said hearth, each hearth having substantially uniformly distributed, spaced, fine pressure reducing apertures therein not exceeding one-quarter inch in diameter, means on said hearths overlying said apertures for preventing said material from entering

5 said apertures by gravity, a casing secured beneath each hearth forming therewith a gas chamber for supplying gas to said apertures, alternate hearths having a discharge passage at the periphery of the corresponding spiral for discharging material by gravity to the hearth below, and the remaining hearths each having a discharge passage leading to the hearth below from the center of the corresponding spiral, means extending into said housing for feeding the material to be reduced to the uppermost hearth at the end of the spiral path opposite the discharge passage, and means for supplying preheated reducing gas independently to said gas chambers of the several hearths for emergence at reduced pressure from the apertures thereof to diffuse through the material thereon to reduce the same.

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