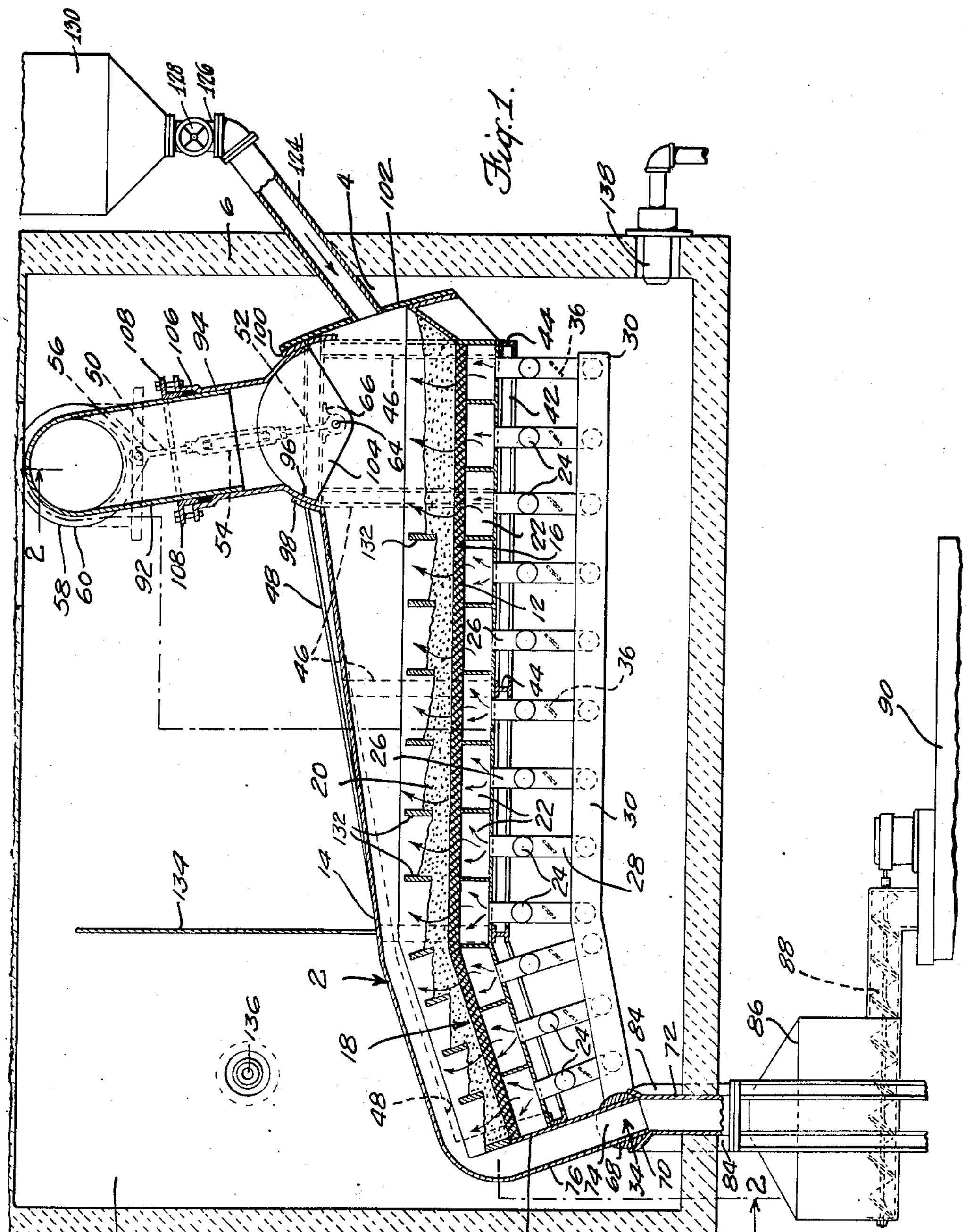
April 13, 1943. H. A. BRASSERT ET AL 2,316,664

PROCESS OF AND APPARATUS FOR FACILITATING AND CONTROLLING CHEMICAL REACTIONS AND PHYSICAL TREATMENTS

Filed Oct. 9, 1940 4 Sheets-Sheet 1



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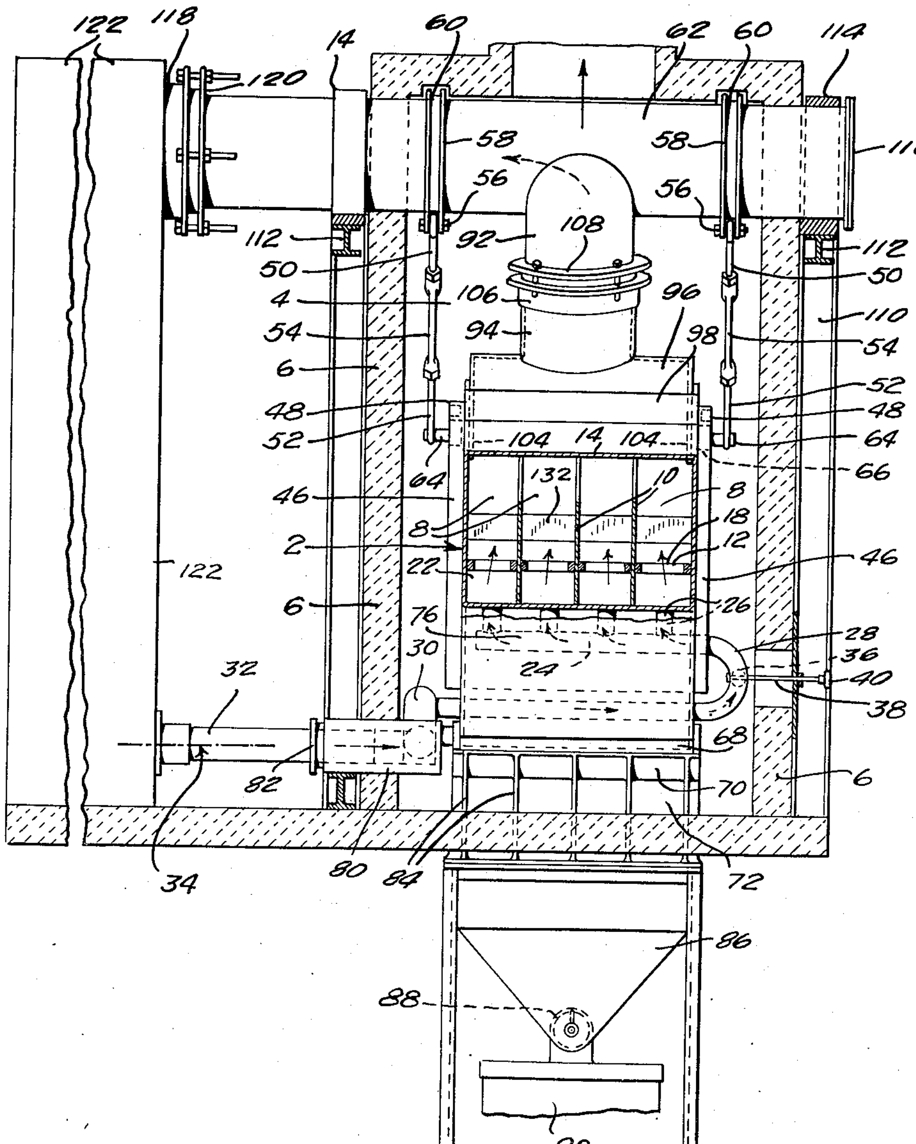
Filed Oct. 9, 1940 4 Sheets-Sheet 2

Fig. 2.



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Filed Oct. 9, 1940 4 Sheets-Sheet 3

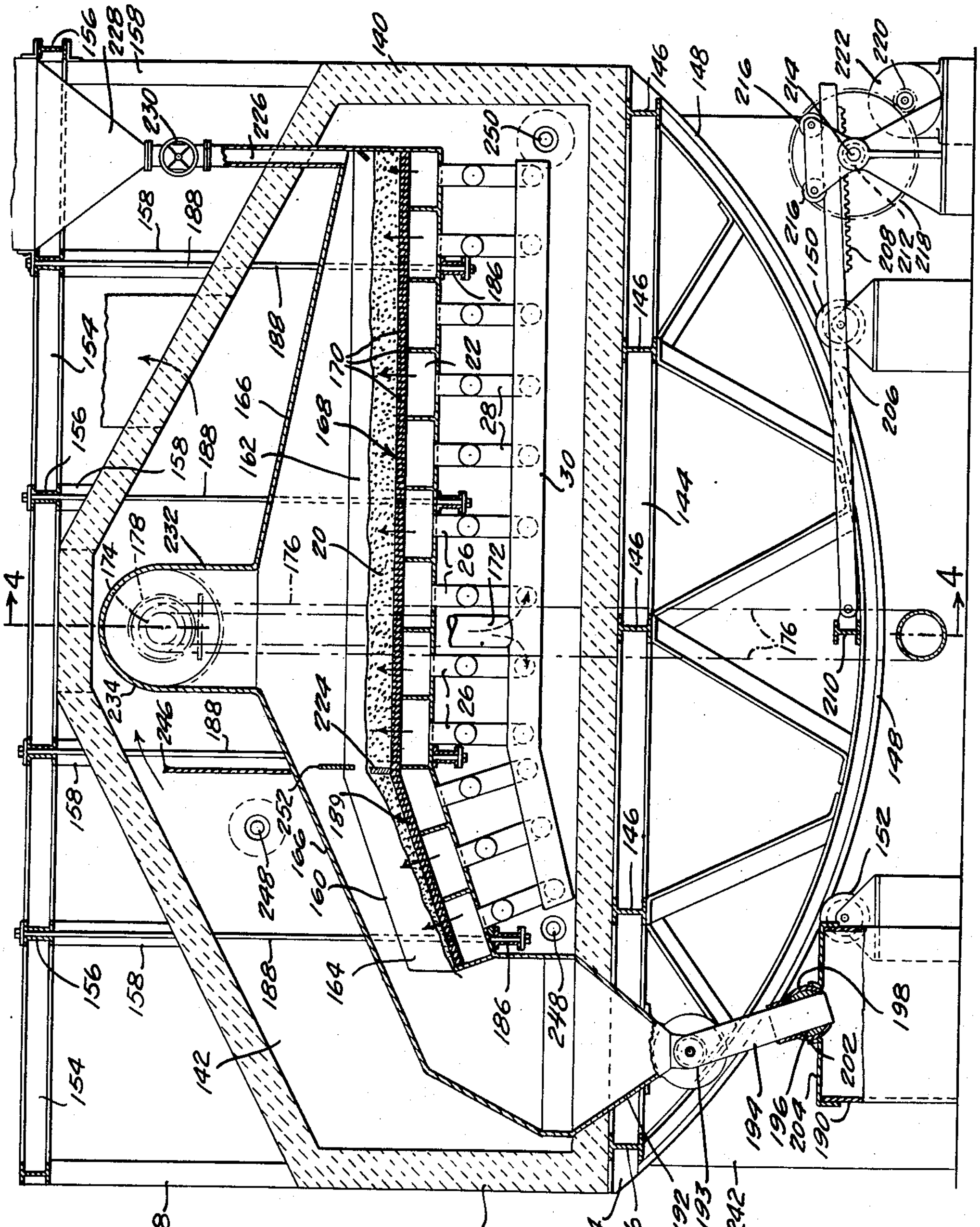

Fig. 3.

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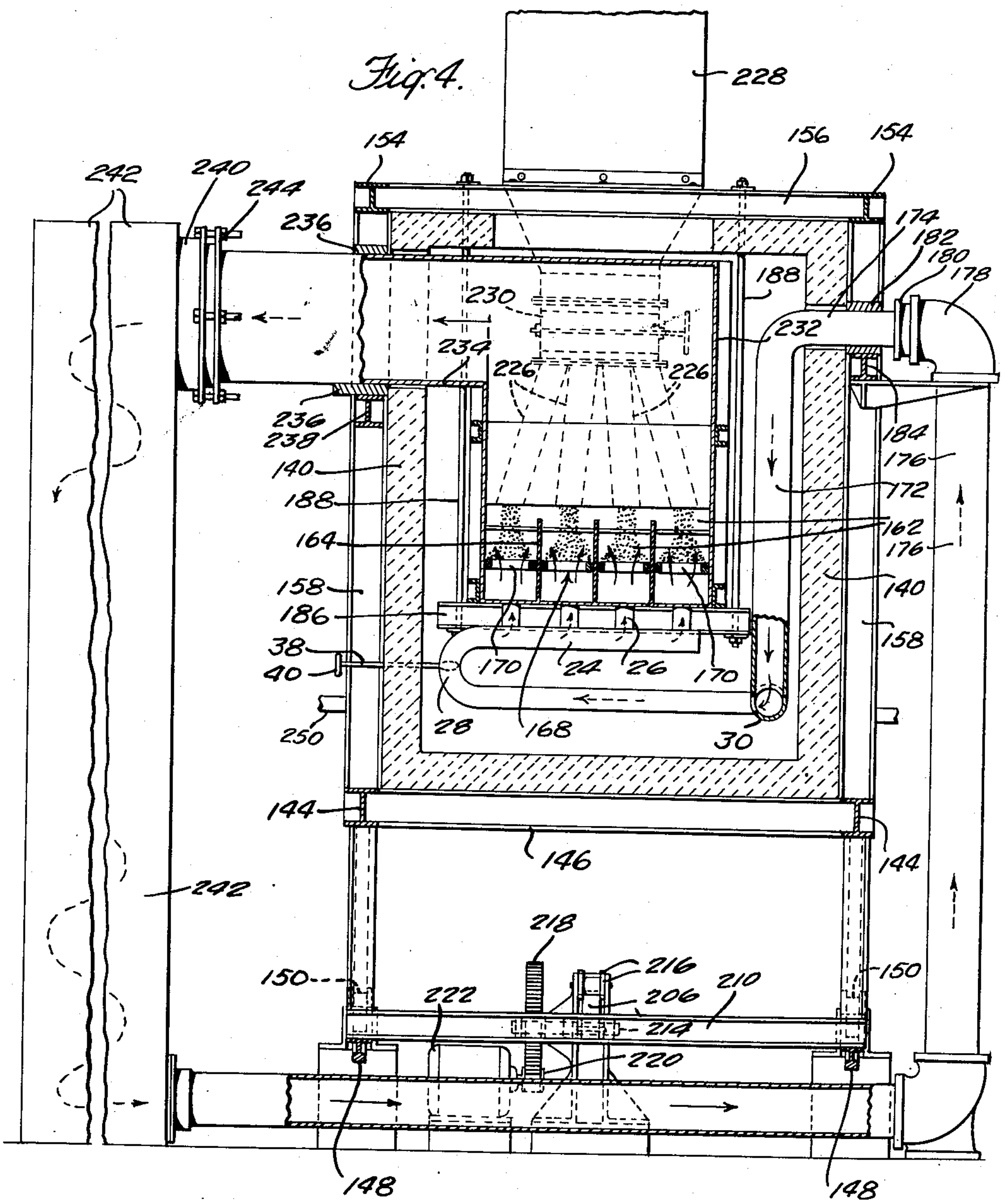
Filed Oct. 9, 1940 4 Sheets-Sheet 4



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Patented Apr. 13, 1943

2,316,664

UNITED STATES PATENT OFFICE

2,316,664

PROCESS OF AND APPARATUS FOR FACILITATING AND CONTROLLING CHEMICAL REACTIONS AND PHYSICAL TREATMENTS

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Application October 9, 1940, Serial No. 360,418

12 Claims. (Cl. 75—91)

This invention relates to processes of and apparatus for facilitating and controlling chemical reactions or physical treatments in which there is an interaction between a solid or solids in a finely divided condition and a fluid or fluids, as illustrated, for example, in the reduction of finely divided ores by reducing gases or in the beneficiation of such ores by oxidizing or other gases.

It has been found in practice that in a chemical reaction or a physical treatment which involves the interaction of a solid or solids in finely divided condition with a fluid or fluids, the required thorough commingling of the particles of the fluid with the particles of the solid and of the particles of the solid with each other can best be obtained by so directing the fluid through the finely divided solid that it effects the desired movements of the particles of the solid in repect to each other and in respect to the particles of the fluid at the same time that it is commingling therewith. As more fully disclosed in the co-pending application of James C. Hartley, Serial No. 338,560, filed June 3, 1940, the fluid in such cases can serve to perform a plurality of functions. If, for example, the fluid be one of the reagents of a chemical reaction, such as the reducing gas in an ore reduction process, the fluid may not only take part in the reaction, but it may also be utilized both to provide the desired physical conditions favoring the reaction, such as temperature control; to effect agitation of the finely divided material in order to expose the particles to reaction or treatment, or to insure catalytic contact in those cases where the finely divided solid is a catalyst; to effect movement of the finely divided material progressively through the reaction zone and to effect movement of the particles of the material into wiping, rubbing or impacted contact with each other in order to keep their surfaces in proper reactive condition and to bring about a mechanical separation of extraneous matter. As further pointed out in said co-pending application, even if the fluid itself be not a chemical reagent, it may be utilized to create or to aid in creating the desired physical conditions favorable to the reaction, such as the required heat and contact conditions, particularly where the reagents are two finely divided solids, and also to effect the agitation and advancing movement of the particles of the finely divided solid, etc.

When a charge of finely divided material, permeated and agitated by the fluid as hereinabove described, is of substantial depth, that is, when it constitutes an appreciable layer on a hearth, through perforations in which the fluid is projected in a steady stream or when the fluid is created within the bed of solid by decomposition of a solid or a fluid added thereto, the charge of finely divided solid, when the fluid thus becomes thoroughly commingled therewith, takes on more or less of the character of a liquid, that is, the entire mass possesses a fluent mobility, and therefore, if the hearth or grate on which it is supported be inclined, the fluid-permeated finely divided solid material will flow in the direction of the inclination, as would a liquid. In the same manner, even if the hearth or grate be not inclined but there be a constant inflow of finely divided material at one end thereof, there will be a liquid-like flow of the commingled solid and fluid across the hearth.

It is desirable, in the interaction of a fluid with a finely divided solid, in order to insure the desired completeness of the reaction or treatment taking place upon the hearth or grate, that the interaction and commingling of the particles of the fluid with the particles of the solid and of the particles of the solid with each other be continued as long as is necessary to produce the desired result. Naturally, the longer the path of travel across the hearth or grate the higher the speed at which the material can be propelled and still be subjected to the desired amount of reaction or treatment during its travel from the beginning to the end of the hearth or grate as, for example, in cases where the reaction is relatively slow, as in the reduction of ores. It is advantageous, therefore, in order to secure the desired production capacity in apparatus to be employed in the reduction of finely divided ores, to make the travel of the finely divided ore in contact with the reducing gases as long as possible and therefore hearths or grates of considerable length are preferred, it being understood, however, that the rate of travel across the hearth must be such as to give the desired rate of production.

Having in mind the foregoing conditions, one of the objects of the present invention is to provide apparatus particularly adapted for practicing the herein disclosed novel process of facilitating and controlling chemical reactions and physical treatments which, by mere adjustment, will be adaptable for a wide range of uses, particularly in the treatment of materials requiring different rates of travel across the hearth or grate. Examples of such materials are the hematites which, in general, require less time for reduction than the magnetites, and manganese ores which require both more time and higher temperatures than iron ores. To this end, the invention contemplates providing a hearth or grate which can be tilted to different angles to the horizontal to cause increased or decreased rates of flow of the fluid-permeated and liquid-like beds or masses of finely divided solids across the hearth or grate. In this manner, when reducing ores, the amount of reducing gas required to cause the material to progress across the hearth will more nearly approach the theoretical or practicable limit of gas required to complete the reduction of the said ore.

A further important advantage of providing a hearth or grate which can be tilted to different angles horizontally is that, in dealing with certain ores which contain extraneous oxides that it may be desirable to reduce and that reduce more slowly than the basic ore or oxide, such, for instance, as the ores of iron which contain titanium oxide and which are commonly called ilmenites and the chromiferous and nickeliferous ores of iron, if it be desired to produce reduced iron products containing these elements in the reduced or alloyable form, it is only necessary to tilt the hearth back toward the horizontal to provide the additional time element necessary to cause the reduction of these oxides, the temperature conditions, of course, being propitious. Moreover, when, as is often the case, it is desirable to reduce the iron content of such ores without effecting reduction of the extraneous oxides, the desired result can be obtained by tilting the hearth to a greater angle with respect to the horizontal to increase the rate of travel across the hearth thus allowing insufficient time for the more difficultly reducible constituents to react.

In the treatment of some finely divided solids in the apparatus of the present invention, and particularly in the reduction of finely divided ores, it is usually found desirable to provide for a higher degree of heat toward the end of the treatment than at the beginning, which has a tendency usually to affect the flow characteristics of the finely divided solid, and the invention therefore contemplates providing an increased inclination in that part of the hearth which is near the discharge end thereof.

Further to insure the assumption and maintenance by the fluid-permeated mass of finely divided solid of the liquid-like character hereinabove referred to, the invention contemplates so retarding the movement of the entire mass of fluid-permeated finely divided solid across the grate or hearth as to insure both the thorough commingling and permeation requisite to render the mass fluent and the interaction necessary to secure the desired reaction or physical treatment. To this end the invention contemplates the provision of a dam or weir, or a plurality of dams or weirs, so located and of such height as to insure and maintain the desired depth of fluid-permeated finely divided solid upon the hearth or grate.

In the employment of the process and apparatus of the present invention in the reduction of ores, although it is intended that such reduction take place at temperatures below the melting temperatures of the metal constituents of the ores, nevertheless such reducing operations require substantial temperatures which sometimes tend to affect somewhat the flow characteristics of the fluid-permeated finely divided solid or solids. The invention therefore contemplates not only providing for adjustment of the inclination of the grate or hearth to any changed angle of repose of the fluid-permeated solid resulting from the high temperatures, but it also contemplates the mixing with the finely divided solid of substantially inert materials which will serve to prevent any tendency of the particles of the solid not to move freely in respect to each other at the higher temperatures. The invention further contemplates the use, for insuring free movement of the particles of the fluid-permeated solid in respect to each other, of carbon coating of the particles of the finely divided solid or solids or the use of materials such as hydrocarbon or other volatilizable oils, preferably mixed with the finely divided solids in such manner that they will be volatilized, and in some instances partially decomposed, in the course of the interaction of the finely divided solid or solids and the fluid or fluids.

An important advantage of the mixing with the finely divided solid of a decomposable hydrocarbon is that, when the finely divided solid is, for example, a metallic oxide to be reduced, at least a part of the reducing reagent or reagents may thus be supplied in intimate association with the metallic oxide.

Other objects and important features of the invention will appear from the following description and claims when considered in connection with the accompanying drawings, in which

Figure 1 is a longitudinal section through apparatus embodying the structural features of the present invention and particularly adapted to carry out the novel process thereof;

Figure 2 is a section on the line 2—2 of Figure 1;

Figure 3 is a longitudinal section through a modified form of apparatus embodying the structural features of the present invention and particularly adapted to carry out the novel process thereof;

Figure 4 is a section on the line 4—4 of Figure 3.

The apparatus which is shown in Figures 1 and 2 of the drawings is particularly adapted, as shown, for the reduction or for the beneficiation of finely divided ores and to this end the chamber 2 in which the ore is treated is itself enclosed in a heating chamber 4 surrounded by refractory walls 6. As shown in Figure 2 of the drawings, there are preferably a plurality of compartments 8 in the chamber 2, these compartments being defined by partitions 10 extending from the hearths 12 part way up to the top plate 14 of the chamber 2.

The hearths 12, like the corresponding hearths of the co-pending application Serial No. 338,560, filed June 3, 1940, may be made either of an iron alloy or a steel alloy or of refractory material, and are each provided with inclined slots or jet orifices 16, these orifices being inclined in the direction of movement of the ore along the hearths. Each of the hearths 12 is preferably provided near its discharge end with a section 18 inclined downwardly with respect to the forward part of the hearth for a purpose set forth hereinafter.

The finely divided ore 20 to be reduced is deposited upon the right hand or front end of each of the hearths 12 in the respective compartments and the reducing gas or other fluid to be used in reducing or beneficiating the ore is caused to pass up through the jet orifices 16 under pressure sufficient to cause it thoroughly to permeate the finely divided ore and to impart to it a fluent mobility. To insure the proper distribution and control of the reducing gas or gases, or other fluid or fluids, the gas or mixture of gases is distributed to groups of orifices 16 in the hearths 12 by means of manifolds 22 arranged beneath the respective groups of orifices, there preferably being corresponding manifolds for corresponding groups of orifices on each hearth. These manifolds 22 are in turn supplied with a gas or mixture of gases by means of cross manifolds 24 connected to the respective orifice group manifolds by pipes 26, the cross manifolds 24 being each connected by U bends 28 to a longitudinal manifold 30 having an intake 32 coaxial with the axis 34 about which the reducing or beneficiating apparatus as a whole is adjustable to vary the inclination to the horizontal of the hearths 12, as hereinafter more fully described. To permit control of the input of the gas or gases to the manifolds 22, a butterfly valve 36 may be provided in each of the U bends 28, said valve having a stem 38 extending to an operating handle 40 on the outside of the casing 6.

The hearths 12 and manifolds 22 are shown as supported upon side channel bars 42 connected by cross channel bars 44, all constituting part of a supporting frame for the reducing apparatus. The side channel bars 42 are connected by upright bars 46 to upper side channel bars 48, the side channel bars 42 and 48 being bent at their ends which support the inclined section 18 of the hearth 12 to correspond with the angle of this section to the main part of the hearth 12. The supporting frame thus formed is suspended at the intake end of the apparatus by links, each comprising an upper eye bolt 50 and a lower eye bolt 52 connected by a turnbuckle 54, the upper eye bolt having its eye received by a pivot bolt 56 extending through the two flanges 58 of a collar 60 on an exhaust pipe 62 extending through the two side walls 6 of the casing of the heating chamber 4. The eye of the lower eye bolt 52 receives a pivot pin or shaft 64 carried by a bracket 66 bolted or riveted to the under side of the upper frame member 48.

The adjustable suspension of the ore treating apparatus thus described permits it to be adjusted about the axis 34, the discharge end of the apparatus being supported by a shaft 68, mounted for oscillating movement in a semicylindrical socket or trough 70 formed in the upper end of the discharge chute 72. Extending throughout a part of the length of the shaft 68 is a transverse slot or passage 74 into which fits the discharge end of the ore treating apparatus, this discharge end comprising a downturned part 76 of the top 14 of the casing and an inner wall 78 extending from the discharge end of the hearth section 18 into the passage 74.

The gas intake 32 is connected to the longitudinal manifold 30 through an elbow 80 having a horizontal portion coaxial with the axis 34 to permit it to turn relatively to the intake 32, a stuffing box, having a gland 82, providing for a non-leaking connection between the elbow member 80 and the intake 32.

The chute 72 may be provided with stiffening ribs 84 to provide for the proper support of the shaft 68 and the ore treating apparatus connected thereto. The chute 72 in turn discharges into a hopper 86 which directs the reduced or otherwise treated ore into a screw conveyor 88 by which it is conveyed to any suitable packaging apparatus indicated generally at 90, this whole operation preferably taking place without exposure to the air.

The gaseous products of the reduction or other ore treating operation are preferably discharged from the chamber 2 at or near the end thereof at which the ore to be treated is introduced into the chamber. To provide for such discharge of the gaseous products of the reaction or treatment taking place in the chamber 2 and at the same time to permit the adjustment of the apparatus about the axis 34 to provide different inclinations to the horizontal of the hearths 12, the connection between the exhaust pipe 62 and the upper part of the chamber 2 comprises the branch or T stem 92 extending downwardly from the exhaust pipe 62 and preferably formed integral therewith. This branch or nipple-like projection from the exhaust pipe 62 is received by a sleeve 94 having an oscillating joint connection with the top wall 14 of the chamber 2. This oscillatable connection, as shown in Figures 1 and 2, comprises a cylindrical segment 96 forming a T with the sleeve 94 and received within cylindrical segment flanges 98 and 100 formed respectively on the top wall 14 of the casing 2 and on the front end wall 102 thereof. At its ends the cylindrical segment 96 is provided with sector-shaped combined closures and supporting members 104, mounted to turn on inward extensions of the pivot pins or shafts 64 so that these sectors, together with the cylindrical segment 96, turn about the axis of the cylinder, the eye bolts 52 turning about the same axis.

A stuffing box 106, formed in the upper end of the sleeve 94 and provided with a gland 108, insures a gas-tight joint between the nipple 92 and the sleeve 94.

The exhaust pipe 62 extends through the two side walls 6 of the casing for the heating chamber 4, which casing is reinforced by I beams 110 and crossbars 112, and said exhaust pipe 62 is mounted for limited oscillating movement in bearings 114 carried by the crossbars 112. At one end the exhaust pipe 62 is provided with a closure 116 and at its other end it is received in a sleeve 118 provided with a stuffing box having a gland 120 that insures a gas-tight connection between the exhaust pipe 62 and the sleeve 118. The sleeve 118 discharges the exhaust gases into any suitable apparatus, such as a checker brick preheater for the intake gases entering the intake 32, this preheater being not shown in detail but being indicated generally by the reference numeral 122.

The finely divided ore to be treated upon the hearths 12 of the respective compartments 8 may be introduced into the respective compartments through chutes 124, one for each compartment, these chutes being connected to a common chute 126 having therein a star valve feeder 128, the common chute 126 being in turn connected to a hopper 130 into which the finely divided ore is delivered, preferably in a preheated condition.

The ore having been discharged by the chutes 124 upon the respective hearths 12 of the compartments 8 in the chamber 2 and the reducing or other gases with which it is to be reduced or otherwise treated being forced through the jet orifices 16 with sufficient pressure to cause them thoroughly to permeate the mass of ore 20 upon each hearth 12, the mass 20 of gas permeated finely divided ore will soon assume a condition of fluent mobility, in which condition it will behave more or less like a liquid, with the result that, as the gas continues to flow into and through the fluent mass and as additional ore is charged upon the mass at the right hand end of Figure 1, the mass will gradually move toward the left, being partly impelled in that direction by the inclination of the jet orifices 16.

Preferably the force of the gas entering the mass 20 of ore upon the hearth 12 through the jet orifices 16 and the amount of the gas thus introduced into the mass 20 will be sufficient not only thoroughly to permeate it and impart to it a fluent mobility, but it will also be sufficient to effect a considerable agitation, somewhat in the nature of boiling, of the mass, with the result that there will be a considerable tendency for rapid movement of the fluent mass across the hearth, if not otherwise restrained. This might have a tendency to leave too thin a layer of the finely divided ore upon the hearth for the most effective treatment. To impede too rapid movement across the hearth and at the same time to insure the desired average depth of the fluid-permeated mass of finely divided ore upon the hearth, baffles 132 are preferably interposed in the upper zone of the path of movement of the finely divided ore 20 across the hearth, these baffles, as shown in Figure 1, preferably extending across the hearths 12 between the partition walls 10 and having their bottom edges sufficiently above the hearths 12 to permit the desired flow of the fluid-permeated finely divided ore therebeneath, the baffles acting to retard the upper surface of the fluent mass sufficiently to insure maintenance of the desired depth over each section of the hearth.

When the process being carried out in the apparatus is, for example, the reduction of a finely divided ore, such as an iron ore, by means of a reducing gas, it is usually desirable, in order to insure a complete reduction before discharge of the material at the discharge end of the hearth, to increase the temperature conditions surrounding the reaction near the discharge end. Such increase of temperature, particularly after the ore has been reduced and while the iron is in somewhat of a nascent state, tends to reduce somewhat the fluent mobility of the fluid-permeated mass, apparently partly by reason of the tendency of the particles of the substantially nascent iron to adhere to each other, and it is therefore also usually desirable to provide means for insuring both the desired movement of the mass across the hearth and the movement of the particles with respect to each other. To this end, as herein shown, the hearth 12 near the discharge end is provided with a section 18, hereinabove referred to, which is inclined downwardly with respect to the forward parts of the hearth.

As above suggested, provision is preferably also made for increasing the heat applied to the reaction chamber 2 at this end of the ore-treating apparatus. As herein shown, the heating chamber 4 is provided with a partition 134, stopping short of the top wall thereof, so that the part of the chamber 4 to the left of the partition 134 in Figure 1 can have imparted thereto a higher degree of heat. For this purpose burners 136 may supply to the part of the heating chamber to the left of the partition 134 a greater degree of heat than is supplied by the burners 138 to the part of the chamber 4 on the right hand side of the partition 134.

It will be obvious that by means of the butterfly valves 36, operated by the handles 40, the amount and force of the gas projected through the orifices 16 in the inclined section 18 of the hearth 12 may be so adjusted as to insure the desired fluent mobility and movement of the reduced mass along the inclined section 18 of the hearth 12.

In the modified form of apparatus embodying the characteristic structural features of the present invention and designed to practice the novel process of the present invention, which is illustrated in Figures 3 and 4, reliance is had principally upon the fluent mobility of the fluid-permeated mass of finely divided solid for effecting the movement of the solid along the hearth upon which it is being treated, provision being made also, however, for so tilting the hearth as to secure the rate of flow best suited for the particular fluid-permeated finely divided solid which is being treated and for the treatment which is being carried out.

As shown in Figure 3, the walls of refractory material 140 which enclose and define the heating chamber 142 for supplying outside heat to the apparatus in which the reaction or treatment is carried out are supported upon a frame comprising longitudinal channel members or I-beams 144, connected by cross beams 146. The supporting frame for the heating chamber is itself mounted upon rockers 148 supported upon bearing rollers 150 and 152 to permit rotary movement of the rockers 148 about an axis in the center of their curvature.

To provide for support of the reaction or treatment chamber within the heating chamber 142 and also for suitable reenforcement of the side walls 140 of the heating chamber, there is carried upon and connected to the supporting frame base, which is made up of the beams 144 and 146, an upper frame comprising longitudinal channel members or I-beams 154 and cross beams 156, the upper frame being connected to the lower frame by vertical channel members 158.

The reaction or treatment chamber 160 of the form of the invention illustrated in Figures 3 and 4 is, like the apparatus shown in Figures 1 and 2, divided into a plurality of compartments 162 by partition members 164 which preferably stop short of the top plate 166 of the chamber 160. Each of the compartments 162 has a hearth 168 similar to the hearths 12 of the apparatus shown in Figures 1 and 2, except that the jet orifices 170 of the hearths 168 are not shown as inclined to the surfaces of the hearths but are substantially normal thereto so that they do not contribute directly to the movement of the mass of finely divided ore or other solid material 20 along said hearths, when the hearths lie in a horizontal position as shown in Figure 3. Except that the jet orifices 170 are not so inclined to the supporting surfaces of the hearths 168 as to tend to advance the material 20 along said hearths toward the discharge ends thereof, the functions of the orifices 170 in the form of the invention shown in Figure 3 are substantially the same as the functions of the jet orifices 16 of the form of the invention shown in Figures 1 and 2.

As in the form of the invention shown in Figures 1 and 2, groups of orifices 170 in each hearth are supplied by manifolds 22 which in turn are supplied by cross manifolds 24 connected to the orifice manifolds by pipes 26, the manifolds 24 each having U bends 28 provided with butterfly valves 36 and each being connected to a longitudinal manifold 30 which, instead of having an elbow connecting it with an intake concentric with the axis about which the apparatus is adjustable, as in the form of the invention shown in Figures 1 and 2, has, instead, a vertical T branch 172 having a horizontal portion 174 which is concentric with the rocker 148. This arrangement permits the manifold 30 to move bodily with the hearths 168 as they are adjusted to different angles of inclination to the horizontal, without disturbing the connection between the manifold 30 and the gas supply pipe 176. From Figure 4 of the drawings it will be seen that the end of the horizontal portion 174 of the T connection 172 to the manifold 30 enters the elbow joint 178, with which it has a non-leaking connection permitting it to turn in the elbow, this non-leaking connection being provided by a stuffing box of which a part of the gland 180 is shown. A bearing ring 182 for supporting the horizontal portion 174 of the T connection, and in which it can turn when the hearths 168 are to be adjusted to a different angle of inclination to the horizontal, is carried upon a horizontal frame member 184 extending between two of the vertical frame members 158.

The hearths 168 and manifolds 22 are supported by crossbars 186 which are in turn suspended by rods 188 from the crossbars 156 of the upper frame. The hearths 168, like the hearths 12 of the form of the invention shown in Figures 1 and 2, have near their discharge ends sections 189 inclined downwardly in respect to the forward parts of said hearths but rigidly connected thereto so that they take part in all adjustments of the hearths about the center of curvature of the rockers 148.

To provide a constant discharge connection between the chamber 160 and any suitable closed receptacle 190, in all of the different angular positions of the hearths 168, a hopper 192, rigidly connected to the walls of the chamber 160 and into which the material 20, after it has been treated on the hearths 168, 189, is discharged, has a hinged connection 193 with a chute 194 slidable in a transverse slot 196 in a cylindrical member 198 mounted to rock in a correspondingly shaped bearing 200 formed in the cover 204 of the receptacle 190. It will thus be seen that the combination of the hinged joint 193 and the sliding connection between the chute 194 and the rocking member 198 permits adjustment of the hearths 168 about the center of curvature of the rockers 148 without disturbing the air-tight connection between the chute 192 and the container 190.

To effect the desired movement of the rockers 148 on the rollers 150 and 152 about the center of curvature of the rockers 148, a link 206, having at one end a rack 208, is pivotally connected at its other end to a crossbar 210 between the two rockers 148. The rack 208 meshes with a pinion 212 on a shaft 214 and is held in engagement with the pinion 212 by bearing rollers 216 engaging the upper side of the link 206. Reducing gears 218 and 220 connect the shaft 214 with an electric motor 222 or any other suitable means for effecting rotation of the pinion 212 and thereby movement of the rockers 148 about their center of curvature to bring about an adjustment of the hearths 168 to any desired inclination to the horizontal.

In order to insure a predetermined average depth of the material 20 upon the hearths 168, a dam 224 may be located on each hearth 168, the illustrated dam being shown as located at the junction between the forward part of the hearth and the inclined section 189. The dam 224 preferably rests upon the hearth 168 thus forcing the fluid-permeated material to flow over the top thereof after it has received the required treatment.

The finely divided ore is fed into the chamber 160 and deposited upon the right hand end of the hearth 168 as shown in Figure 3 of the drawings, the illustrated means for charging the finely divided ore or other finely divided solid upon each of the hearths 168 comprising a series of chutes 226 connected to a hopper 228 between which and the chutes is a star valve or valves 230 for effecting a measured delivery of the finely divided solid material from the hopper 228 to the chutes 226.

The gaseous products of the reaction or other treatment effected upon the hearths 168 pass up through a stack 232 connected to or integral with the top 166 of the chamber 160, the stack 232 having a horizontal section 234 concentric with the center of curvature of the rockers 148, whereby the horizontal portion 234 of the stack may turn in a ring bearing 236 mounted upon a cross beam 238 between two of the vertical beams 158 and may also turn in a sleeve connection 240 to a checkerwork gas preheater or other device not herein illustrated but indicated generally by the reference numeral 242. A stuffing box, of which a part of the gland 244 is shown in Figure 4, may provide a gas-tight connection between the horizontal portion 234 of the stack and the sleeve 240.

As hereinabove suggested in connection with the description of the form of the invention illustrated in Figures 1 and 2, it is usually desirable to provide a higher temperature for that part of the treatment or reaction which takes place on the inclined section 189 of the hearth 168. To this end a partition member 246 may be provided in the chamber 142 so that burners 248, supplying heat to the part of the chamber 142 on the left hand side of the partition 246, may provide a higher degree of heat to the part of the chamber 160 adjacent to the inclined section 188 of the hearth 168 than is supplied by the burner 250 to the part of the chamber 142 on the right hand side of the partition 246. Further to insure the desired temperature differential within the chamber 160, a partial partition 252 may be provided between the part of the chamber over the more nearly horizontal parts of the hearths 168 and the part of the chamber over the inclined sections 189.

From the foregoing description of the illustrated two forms of apparatus which may be employed in practicing the novel process of the present invention, it will be seen that in each provision is made for so introducing the gas or other fluid into a mass of finely divided solid to be treated thereby, for example, the reducing gas to be used in reducing a finely divided metal oxide, that the gas or other fluid not only thoroughly permeates and renders fluently mobile the mass of oxide but it also brings about an effective agitation thereof. Moreover, it will also be seen that, in the form of the invention shown in Figures 1 and 2, the fluid is so directed as to assist in the movement of the oxide over the hearth.

It will further be seen that in both forms of apparatus provision is made for maintaining a predetermined average depth of the finely divided oxide upon the hearth and that in both forms provision is also made for insuring the optimum rate of travel of the oxide over the hearth by so inclining the hearth as to facilitate such movement without too much dependence upon the fluid, thereby permitting an approximation of the gas or other fluid consumption to the theoretical minimum required to effect the reaction or treatment.

It will be observed that the gas or other fluid which is to take part in the reaction or treatment may be preheated before it enters the manifold 30 in any suitable manner and that it will also receive further preheating before entering the reaction chamber by reason of the exposure of the manifolds 30, 24 and 22 to the heat generated in the heating chamber 4. In this manner, as in the apparatus of the co-pending application Serial No. 338,560, a large part of the heat required for the reaction or treatment will be delivered to the point at which the reaction or treatment takes place by means of the gas or other fluid which takes part therein.

It will be understood that the jet orifices 16 or 170 are of substantially uniform dimensions, at least in each group, and that during operation of the apparatus the gas or other fluid is continuously delivered thereto at a substantially constant pressure so that in any group of orifices the gas or other fluid will be distributed equally among the orifices of that group and uniformly throughout the mass of finely divided solid served thereby. In practice, it has been found desirable to have the jet orifices of uniform dimensions throughout the extents of the hearths 12 and 168 and to control the distribution, rates of flow and pressure drops of the gas or other fluid by means of the valves 36 governing these factors in the connections 26 between the longitudinal manifold 30 and the cross manifolds 24.

From the foregoing it will be seen that where there is a tendency to a change in the fluent mobility of a fluid-permeate finely divided ore by reason of the partial reduction of the ore in the early stages of its travel across the hearth 12 or 168, this may be compensated for by providing different conditions of treatment in the later stages such as rate of gas flow, pressure drop through the mass, inclination of the rear part of the hearth, etc.

What is claimed as new is:

1. Apparatus for facilitating and controlling the reduction of finely divided ores or other oxides of metals by fluid reagents, said apparatus comprising, in combination, a hearth, lateral walls and an end dam for laterally confining to a predetermined and substantial depth upon said hearth a substantially continuously replenished charge of finely divided ore which is to be caused both to react with a fluid reagent and to travel continuously along said hearth and past said dam, at least one of the surfaces which engage said charge and direct the movement thereof being provided with jet orifices, means for continuously supplying a fluid reagent under a substantially constant pressure and means, comprising a plurality of manifolds each supplying a separate group of orifices, for positively distributing said fluid reagent among successive groups of said jet orifices, said distributing means being so controllable and said fluid agent supplying means providing sufficient fluid pressure so that there is insured a continuous discharge of fluid reagent from each group of jets at the desired constant pressure for said group and with sufficient force to permeate throughout and to render fluent the charge of finely divided ore on said hearth and thus, while reacting therewith, to insure, as an incident to the continuous replenishment of the ore, the movement of the entire charge over the hearth.

2. Apparatus according to claim 1 in which the hearth is inclined to insure flow of the fluid-permeated finely divided solid thereacross and in which a series of dams provides the desired depths of the fluid-permeated finely divided solid at different points along the inclined path of flow.

3. Apparatus according to claim 1 in which the hearth, toward its discharge end, has a section of like construction and function downwardly inclined in respect to the forward parts of said hearth.

4. Apparatus according to claim 1 in which the hearth, adjustable to different inclinations to the horizontal, is provided toward its discharge end with a section downwardly inclined in respect to the forward portions of said hearth in all positions of adjustment thereof.

5. Apparatus according to claim 1 in which the hearth is provided toward its discharge end with a section downwardly inclined in respect to the forward portions of said hearth, said downwardly inclined section being provided with baffles for maintaining the desired average depth of the fluid-permeated finely divided solid upon said inclined section.

6. Apparatus according to claim 1 in which the hearth, toward its discharge end, has a section downwardly inclined in respect to the forward parts of said hearth and in which there are means for providing a higher temperature for the reaction or treatment on said inclined section.

7. That improvement in the art of facilitating and controlling the reduction of finely divided ores, or other oxides of metals, by fluid reagents which consists in positively and uniformly distributing the fluid reagent throughout a charge of finely divided ore which is being substantially continuously replenished at one end and which is laterally and endwise confined but has an unconfined top surface and also provision for discharge of reduced metal past the confining wall at the end remote from the point of replenishment, said fluid reagent being supplied throughout one of the confined faces of the charge in quantity and at a pressure sufficient to cause it to permeate the mass of finely divided ore so thoroughly and uniformly and in such amount as to render the charge completely fluent, whereby a continuous flow of the entire fluent charge across the field of action of the fluid reagent, from the point of replenishment to the point of discharge, takes place and an intimate and reactive contact of each particle of finely divided ore with the fluid reagent is insured.

8. A process according to claim 7 in which the fluid reagent is preheated to produce the desired physical conditions for the reaction and in which inert material is mixed with the finely divided ore to insure the fluency thereof under the desired physical conditions.

9. A process according to claim 7 in which the reaction takes place at a high temperature and in which the particles of the finely divided ore are coated with carbon to maintain the fluency of the fluid-permeated mass at such high temperature.

10. A process according to claim 7 in which a lubricant, volatilizable under the physical conditions provided for the chemical reaction, is mixed with the finely divided ore.

11. A process according to claim 7 in which a hydrocarbon, comprising constituents, some of which are volatile and some of which are decomposable under the physical conditions surrounding the reaction, is mixed with the finely divided ore.

12. A process according to claim 7 in which a hydrocarbon, decomposable under the conditions surrounding the reaction, is mixed with a finely divided oxide and serves both to contribute to the fluency of the mass of oxide and to provide at least a portion of a reducing reagent.

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