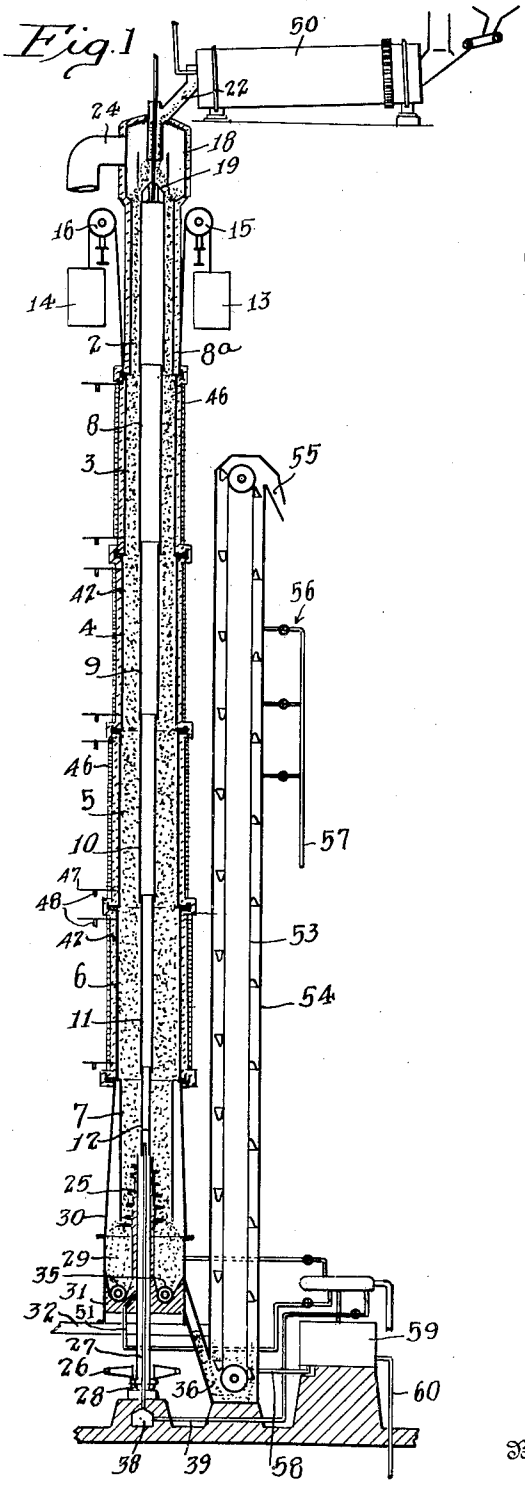
July 28, 1942. W. G. CLARK 2,291,532

ORE REDUCTION APPARATUS

Filed June 10, 1940 2 Sheets-Sheet 1

Fig. 1



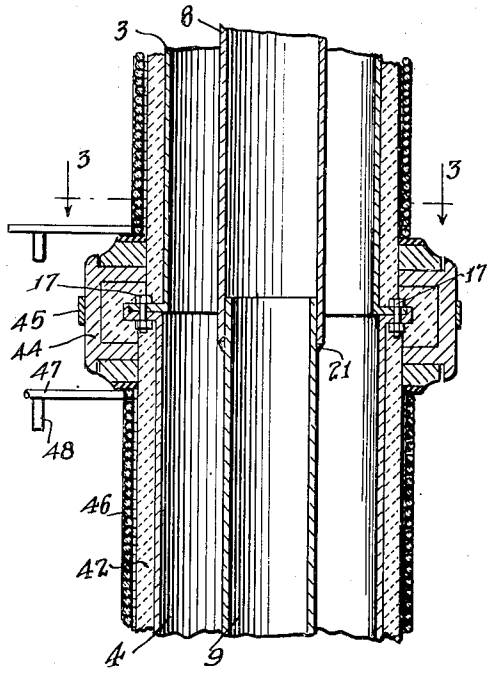


Fig. 2

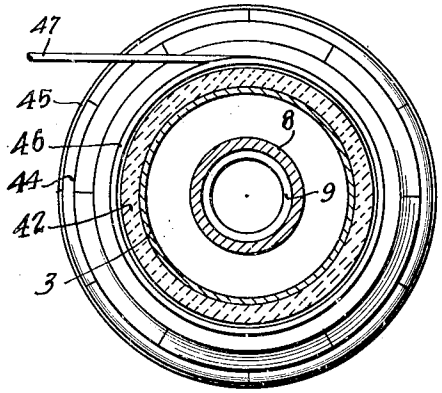


Fig. 3

Inventor

Walter Gordon Clark

By Lyon & Lyon

Attorneys

July 28, 1942. W. G. CLARK 2,291,532

ORE REDUCTION APPARATUS

Filed June 10, 1940 2 Sheets-Sheet 2

Fig. 4

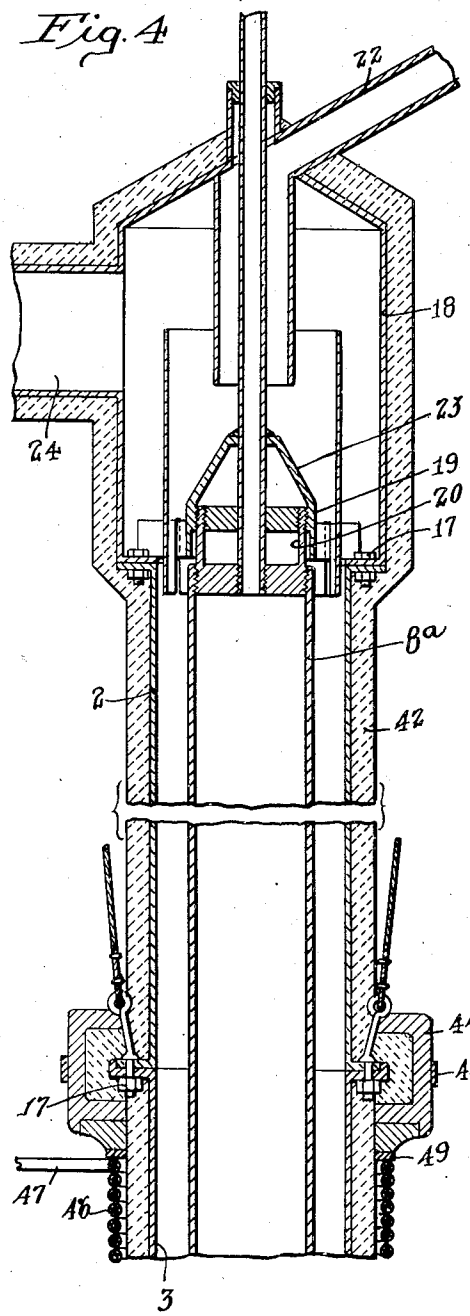
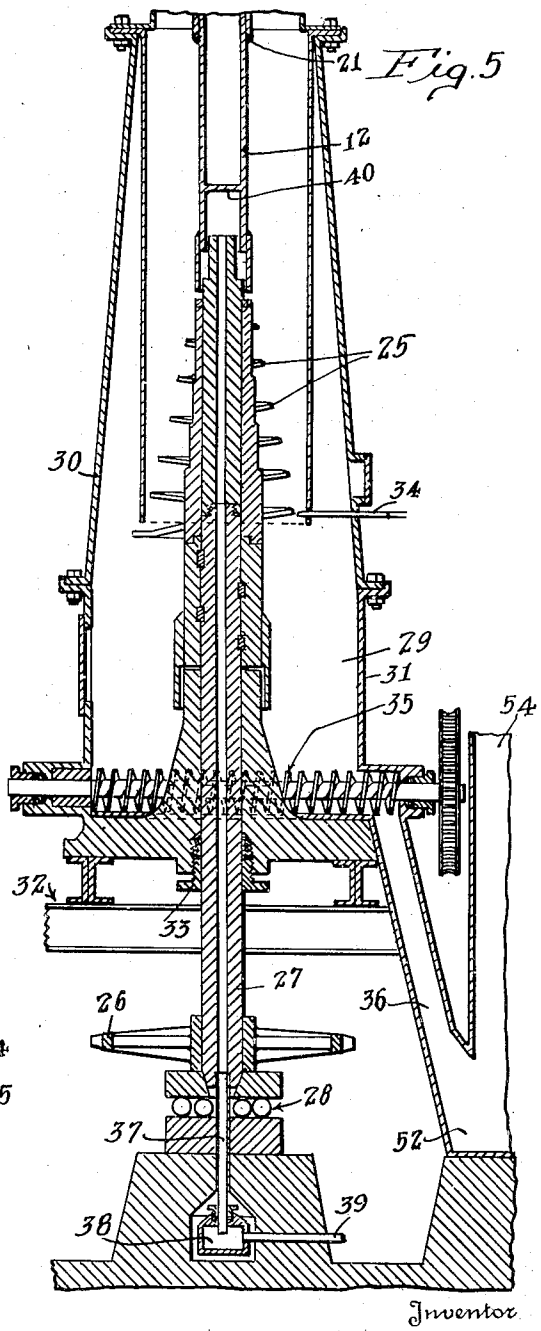


Fig. 5



Inventor

Walter Gordon Clark

By Lyon & Lyon

Attorneys

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UNITED STATES PATENT OFFICE

2,291,532

ORE REDUCTION APPARATUS

Walter Gordon Clark, Los Angeles, Calif., assignor to Clarkiron, Inc., Los Angeles, Calif., a corporation of Nevada

Application June 10, 1940, Serial No. 339,711

10 Claims. (Cl. 13—26)

This invention relates to a continuous apparatus for reducing ores, in which apparatus a reducing gas is employed. The invention particularly relates to the improvements in the type of apparatus for reduction of ores as described in my United States Letters Patents Nos. 2,144,618 and 2,166,207.

The apparatus for reducing ores described in the aforesaid patents is intended to effect the continuous reduction of ore through movement of the ore to be reduced continuously and counter-currently to the movement of a reducing gas while a suitable reaction temperature is maintained. In order for such a continuous reduction operation to be carried out effectively, it is essential that an accurate control be maintained of the reaction temperature and movement of the materials through the reaction zone.

It is the general object of the present invention to provide an ore reducing apparatus by which the movement of the ore and of the reducing gas through the reaction zone may be controlled in a superior manner.

More particularly, an object of the present invention is to provide an ore reducing apparatus with an improved means for forming the reaction chamber of the apparatus, which means is so constructed as to permit progressively increased areas for occupation by the ore as the ore passes towards the discharge end of the apparatus and to associate therewith an improved means for supporting and regulating the movement of the column of ore undergoing treatment.

Further objects of the present invention are to provide an improved manner of construction and support of the reaction chamber of the apparatus, which improved manner of construction and support is well adapted to allow for the necessary increase due to the accumulation of carbon and to expansion of the elements in the reaction chamber with increased temperature.

A further object of the present invention is to provide an ore reducing apparatus with an improved means for regulating the movement of the desired reducing gas through the reaction chamber and to further provide an improved means for separating gas leaving the reaction chamber from the ore.

The apparatus of the present invention, together with various additional objects and advantages thereof, will best be understood from the description of a preferred form or example of an apparatus embodying the invention. For this purpose, I have hereinafter described a preferred example of the apparatus of the present invention, the description being given in connection with the accompanying drawings, in which:

Figure 1 is an elevation partially in vertical section.

Figure 2 is an enlarged fragmentary elevation of a portion of the reaction chamber.

Figure 3 is a section on the line 3—3 of Figure 2.

Figure 4 is an enlarged view of the upper end of the reaction chamber indicating in particular gas separating means.

Figure 5 is an enlarged fragmentary elevation of the lower end of the reaction chamber indicating more particularly the means for supporting and feeding the column of ore through the apparatus and for introducing the reducing gas.

Referring to the drawings, the reaction chamber of the apparatus is formed by an outer series of tubes 2, 3, 4, 5, 6, and 7, and by a concentric inner series of tubes 8a, 8, 9, 10, 11, and 12. The tubes are preferably constructed of steel or alloy steel. The space between the two series of tubes forms the reaction chamber or reduction tube of the apparatus, by means of which the ore to be treated is caused to pass down the apparatus in the form of a hollow cylinder in contact on each side with metallic tubes which cooperate to insure an even distribution of heat throughout the mass of ore undergoing treatment. The reaction chamber formed by these series of tubes may vary substantially in length as determined by the character of the ore to be reduced. For reducing oxides of iron, I have found, for example, that a reaction chamber approximately 100 feet in length is satisfactory in practice.

The reaction chamber formed between the two series of tubes is increased at intervals between the top and bottom in diameter usually in steps of 7% to 15%. It has been found that by thus increasing the area provision is made for the accumulation of carbon in the space to be occupied by the ore and the movement of the ore through the reaction chamber is more readily controlled. As hereinafter explained during the operation of the apparatus the treated ore becomes mixed with free carbon produced and separated from the reducing gas when a hydrocarbon gas is employed as the reducing agent. This accumulation of carbon in the ore undergoing treatment results in an expansion of the volume and renders it of advantage in the apparatus to provide increasing areas for occupation of the ore and carbon as the ore descends during treatment.

In order to provide for the desired increase in area with the ore undergoing treatment the outer series of tubes 2, 3, 4, 5, 6, and 7 are indicated as each of a succeedingly larger diameter, while the corresponding inner series of tubes 8a, 8, 9, 10, 11, and 12 are indicated as possessing a progressively smaller diameter. Throughout the major part of the reaction chamber the walls of the corresponding inner and outer tubes are parallel, and this is indicated as also true of the bottom or discharge section which, however, may be tapered in certain cases, depending upon the character of the materials undergoing reduction.

In order to allow for the proper support of the outer series of tubes 2, 3, 4, 5, 6, and 7 in such a manner as to properly take care of the expansion of such tubes to be expected in consequence of the rise in temperature during operation, I have found it to be of advantage to suspend this outer series of tubes from near its upper end, as for example by counterweights 13 and 14, supported on lines passing over sheaves 15 and 16 and connected to the series of outer tubes, for example at the lower end of the upper tube 2. The series of outer tubes is indicated as having outwardly extended flanges at their ends, by means of which they may be connected together by bolts 17. The flange of the upper tube is bolted to a housing 18 and to a spider 19, which is threaded to a nipple 20, which is in turn threaded to the upper tube 8a of the inner series of tubes 8a, 8, 9, 10, 11, and 12. In this manner, the series of inner tubes are likewise suspended from their upper ends in order to allow for free expansion thereof upon increase in temperature. The series of inner tubes is preferably welded together, as indicated at 21.

A delivery spout 22 extended to the end 18 to deliver the ore to be treated into a short hopper 23 is supported by the spider. The outlet of the delivery spout 22 is made considerably smaller than the area of the hopper so as to permit the gas rising through the ore to be substantially separated therefrom, which gas is taken by the head 18 and discharged to the gas outlet 24 thereof, the gas discharge being water vapor and excess hydrogen and may leave the apparatus at a temperature of about 1500° F., from which it may be conveyed to a boiler and condenser and gasometer, not shown.

Near the bottom of the reaction chamber there is provided one or more vertically disposed spiral feed screws 25 (one here shown), the turns of which are preferably broken, and the turns of which are tapered to contract upwardly. This feed screw 25 operates to carry the weight of the ore undergoing reduction in the reaction chamber. The feed screw 25 is rotated from its lower end, as by means of the sprocket 26, and controls the rate of delivery of the reduced material and/or accompanying carbon from the reaction chamber. It is understood, however, that various forms of vertically disposed spiral feed screws may be used in substitution for that shown. The feed screw 25 is indicated as supported on the hollow shaft 27, the lower end of which is provided with the sprocket 26, and supported by a ball thrust bearing 28 capable of carrying the weight of the feed screw, plus the weight of the ore in the reaction chamber which rests on the feed screw. The lower end of the reaction chamber delivers the reduced ore to a discharge chamber 29 formed by a tapered shell 30, indicated as bolted to the upper end of the tube 7, and by a base member 31 bolted to the shell 30 and supported by a suitable frame 32. The packing gland 33 is indicated between the member 31 and the hollow shaft 27.

The discharge chamber is indicated as preferably provided with temperature indicating elements, such as a thermal couple 34 and additional thermal couple indicators (not shown) may be located at intervals in each heating zone. Positioned at the bottom of the discharge chamber is a pair of screw conveyors 35, by means of which the reduced ore may be delivered to a chute 36. The hollow shaft 27 is indicated as connecting with a tube 37 leading to a gas chamber 38, and thence by lines 39 to a gas manifold system (not shown), by means of which the desired reducing gas may be introduced into the apparatus. The hollow shaft 27 extends up into the lower inner tube 12 of the reaction chamber and loosely engages the same to center the inner series of tubes in the apparatus, the tube 12 being closed, as indicated at 40, to direct incoming reducing gas into the ore undergoing treatment.

The outer series of tubes 2, 3, 4, 5, and 6 are enclosed by suitable heat insulating couplings 42 and the connecting flanges of the tubes covered by additional rings of heat insulating material, which are received in split ceramic blocks 44 held together by metal straps 45. In this manner, the necessary expansion of the joints of the tubes is provided for. The outer series of tubes 3, 4, 5, and 6 are indicated as each surrounded by the spirals of a conductor 46, preferably in the form of a hollow pipe so as to be capable of being water-cooled as by water inlets 47. These conductors 46 are indicated as provided with contacts 48, by means of which the same may be supplied with an alternating electrical current of proper frequency. The reaction chamber is thus provided with a plurality of induction coiled heating sections. These electrical coils 46 are preferably held slightly spaced from the insulation 42 of the outer tubes, as by spacing means 49. These electrical coils when carrying an alternating current establish a magnetic couple with the inner and outer series of tubes of the reaction chamber and the ore and/or reduced metal also enters into the magnetic couple between the inner and outer series of tubes whereby the tubes and conduits thereof are caused to become heated and by means of which a precise temperature control indicated by thermal couples located in each zone of the reactions taking place within the reaction chamber may be maintained by the operator.

At the upper end of the reaction chamber there is indicated as provided a means 50, such as a rotary drum roaster, for preliminarily roasting the ore to dry and remove water, including combined water therefrom, before the ore is discharged therefrom into the inlet spout 22 of the apparatus. The preliminary roaster provides a means for preliminarily heating the ore before it is introduced into the reaction chamber, for example, to a temperature of about 1550° F. The reducing gas not only enters the apparatus through the hollow shaft 27 where it serves to limit the temperature of the shaft 27, but also enters the apparatus through lines 51 entering near the end of the screw conveyors 35 where it serves to cool the discharge material, the reducing gas in turn being heated.

The reduced ore and accompanying carbon are discharged into the chute 36 of an elevator 53,

which is surrounded with a tube **54**, which tube may be filled with water to a desired height. The elevator **53** carries the reduced ore and/or accompanying carbon through the water seal to an appropriate discharge outlet **55**, from which the same may pass to suitable carbon separating means (driers, not shown), and thence to an apparatus for grinding or melting the reduced product. The manifold control means **56** is shown for controlling the height of the water maintained within the tube **54** surrounding the elevator **53** and connected with the line **57**. The lower end of the tube **54** surrounding the elevator is connected by a line **58** to a tank **59** of sufficient capacity to hold the volume of water maintained in the tube, which tank **59** is connected by a line **60** to a source of water supply. By the means thus described, i. e., the water column surrounding this conveyor **53** in association with the manifold connections therefor, the flow of reducing gas through the reaction chamber may be accurately controlled by controlling the head of water maintained. The tank **59** provides a means by which, when the apparatus is shut down, the water column may be withdrawn therefrom so that the same will not enter the reaction chamber.

In the operation of the apparatus of the present invention the reaction chamber is filled with the ore to be reduced, which may be previously roasted. Electrical currents of the proper frequency and potential are caused to flow through the water-cooled tubes surrounding the reaction chamber, and the spiral is rotated thereby controlling the rate at which the ore moves downwardly through the reaction chamber. A reducing gas is caused to enter the reaction chamber at its lower end, thereby cooling the discharged material, and through heat exchange heating the gas. The reducing gas then moves upwardly in counterflow to the descending ore.

The reducing gas may be hydrogen or a hydrocarbon gas capable of being broken into hydrogen and carbon at the available temperature maintained within the reaction chamber; or the reducing gas may be carbon monoxide or a mixture of carbon monoxide and/or hydrogen and/or hydrocarbon gas, or either of them. The reducing gas passes upwardly through the descending heated oxide ores, bringing about a reduction of the oxide to metal, a typical reaction being the conversion of iron oxide by hydrogen to iron with the liberation of water when hydrogen or hydrocarbon gas is employed as the reducing agent. When carbon monoxide is employed as the reducing agent, a typical reaction may be the conversion of iron oxide by carbon monoxide to iron and forming carbon dioxide gas. When hydro-carbon gas is employed the reduced metal, for example iron, at the lower end of the reaction chamber acts to catalytically convert the hydrocarbon gas to free carbon suitable for carbon black or lamp black and generating hydrogen. The carbon freed by this reaction intermingles with the discharged ore, from which it may be later separated. The resulting water or vapor or carbon dioxide, or any mixture thereof, plus any excess of unchanged gas which should always contain an excess of reducing agent, moves upwardly to the top of the reaction chamber. Within the reaction chamber the ores may be gradually heated to the desired reaction temperatures, which may be up to about 1850° to 1900° F. (during the treatment of hematite ores), as described more particularly in my aforesaid Letters Patents Nos. 2,144,618 and 2,166,207.

I claim:

1. An apparatus for reducing ore, comprising a reaction chamber formed between concentric inner and outer tubes, electric induction heating coils surrounding said reaction chamber, a vertically disposed spiral feed screw mounted near the lower end of said reaction chamber for supporting and controlling the movement of a column of ore through said reaction chamber, and means for counter-currently passing a reducing gas through said reaction chamber.

2. An apparatus for reducing ore, comprising a reaction chamber formed between concentrically disposed inner and outer tubes, said reaction chamber expanding in cross-sectional area downwardly, electric induction heating coils surrounding said reaction chamber, a vertically disposed spiral feed screw mounted at the lower end of said reaction chamber for supporting and controlling the movement of the column of ore through said reaction chamber, and means for counter-currently passing a reducing gas through the reaction chamber.

3. An apparatus for reducing ore, comprising a reaction chamber formed between a series of outer and inner vertically extending concentric tubes, electric induction heating coils surrounding said reaction chamber, means for suspending said tubes from their upper portions to allow for heat expansion, a vertically disposed spiral feed screw mounted at the lower end of said reaction chamber for supporting and controlling the movement of the column of ore therethrough, and means for counter-currently passing reducing gas through said reaction chamber.

4. An apparatus for reducing ore, comprising a reaction chamber formed between concentric vertically disposed inner and outer tubes, a gas discharge head connected to the upper end of said reaction chamber, ore inlet tubes extending through said gas discharge head to above the reaction chamber and providing an annular space between said head and ore inlet tubes thereby maintained substantially free of ore, a gas discharge outlet connecting with said annular space, an electric induction heating coil surrounding said reaction chamber, means at the lower end of said reaction chamber for supporting and controlling the movement of a column of ore in said reaction chamber, and means for counter-currently passing a reducing gas through said reaction chamber.

5. An apparatus for reducing ore, comprising a reaction chamber formed by the concentric inner and outer tubes, electric induction heating means surrounding said tubes, gas discharge head at the upper end of said reaction chamber and ore inlet tubes extending through said head substantially to said reaction chamber and providing an annular space between said head and walls of said ore inlet tubes thereby maintained substantially free of ore, said gas discharge head having a gas discharge outlet of relatively large cross-section compared with the cross-section of the ore inlet, a vertically disposed spiral feed screw positioned at the lower end of said reaction chamber for supporting and controlling the movement of a column of ore through said reaction chamber, and means for introducing a reducing gas into said reaction chamber.

6. An apparatus for reducing ore, comprising a vertically extending reaction chamber, electric induction heating means surrounding said

reaction chamber, means at the upper end of said reaction chamber for feeding ore into the reaction chamber for separating gas from ore and discharging said gas, means at the lower end of said reaction chamber for supporting and controlling the movement through said reaction chamber of a column of ore, means for introducing a reducing gas into the lower end of said reaction chamber, an elevator into which the ore is discharged from said reaction chamber, a housing for said elevator communicating with said reaction chamber and capable of enclosing a water column, said housing extending to an elevation equal to the elevation of the major portion of the reaction chamber, and means for maintaining and regulating the height of a water column in said housing and surrounding said elevator whereby to determine the pressure of gas in said reaction chamber.

7. In an ore reducing apparatus, a vertical reaction chamber through which the ore is to descend during treatment, means for feeding the discharging ore from said reaction chamber, means for counter-currently passing a reducing gas through said reaction chamber, a reduced ore elevator having a housing communicating with said reaction chamber, said housing extending to an elevation equal to the elevation of the major portion of the reaction chamber, means for supplying said housing with water, and means for controlling the height of the water column maintained within said housing during the operations of said reaction chamber to thereby control the pressure and movement of gas through said reaction chamber while continually discharging the reduced material through the communication between said housing and reaction chamber to said ore elevator.

8. An apparatus for reducing ore, comprising a narrow reaction chamber formed by a series of vertical inner tubes and a series of vertical outer tubes suspended from near their upper ends, said tubes being spaced from each other to define between the same the reaction chamber, the diameters of the inner tubes decreasing downwardly and the diameters of the outer tubes increasing downwardly, induction heating coils surrounding said reaction chamber, a vertically disposed spiral feed screw positioned below the reaction chamber effective for supporting and controlling the movement of a column of ore through said reaction chamber, and means for counter-currently passing a reducing gas through the reaction chamber.

9. An apparatus for reducing ore, comprising a reaction chamber formed between concentrically disposed inner and outer tubes, said reaction chamber expanding in cross-sectional area downwardly, electric induction heating coils surrounding said reaction chamber, a vertically disposed spiral feed screw mounted below said reaction chamber for supporting and controlling the movement of the column of ore through said reaction chamber, said feed screw being provided with a hollow shaft, and means for passing a reducing gas through said hollow shaft into said reaction chamber.

10. An apparatus for reducing ore, comprising a reaction chamber formed between concentrically disposed inner and outer tubes, said reaction chamber expanding in cross-sectional area downwardly, electric induction heating coils surrounding said reaction chamber, a vertically disposed spiral feed screw mounted below said reaction chamber for supporting and controlling the movement of the column of ore through said reaction chamber, said feed screw being provided with a hollow shaft, means for passing a reducing gas through said hollow shaft into said reaction chamber, a reduced ore discharge, and means for counter-currently passing a reducing gas through said discharge into said reaction chamber.

WALTER GORDON CLARK.