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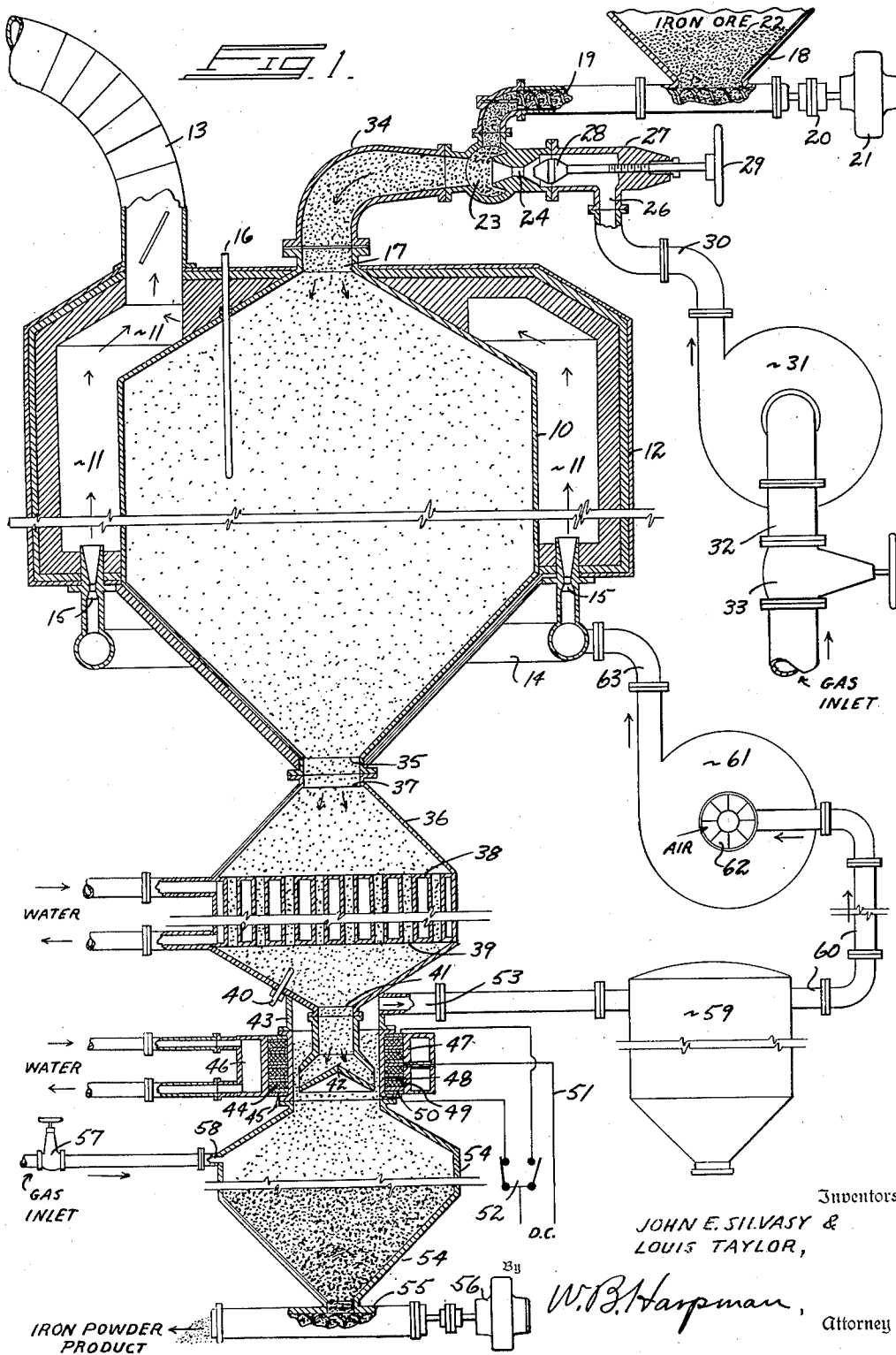
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APPARATUS FOR PRODUCING METAL POWDER

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2 Sheets-Sheet 1



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FIG. 2.

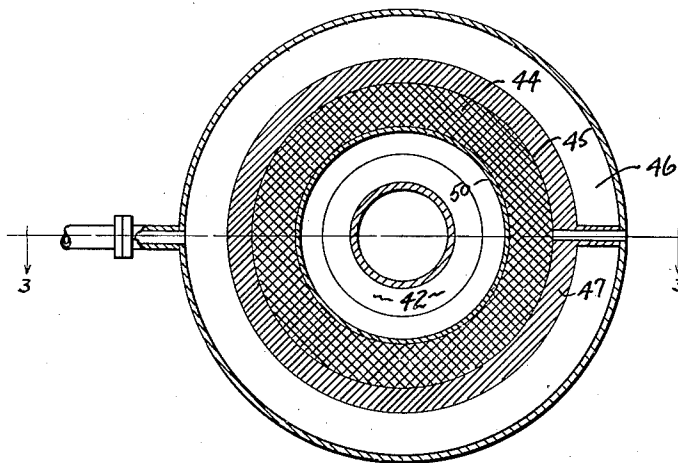
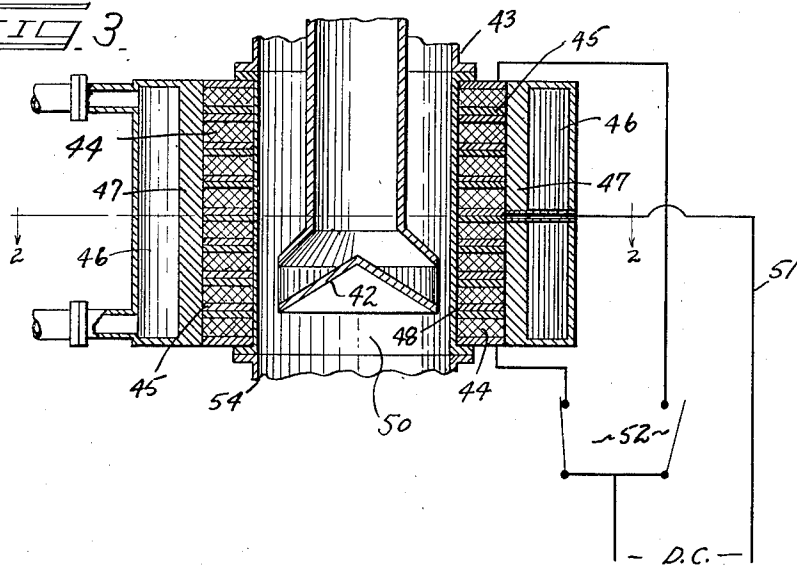


FIG. 3.



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APPARATUS FOR PRODUCING METAL POWDER

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2 Claims. (Cl. 266—24)

This invention relates to the production of metal powders and more particularly to the production of iron powder directly from ore.

The principal object of the invention is the provision of apparatus for the production of metal powders, directly from their oxide ores by a low temperature reduction process.

A further object of the invention is the provision of apparatus for the production of iron powder directly from ore by a thermochemical process.

A still further object of the invention is the provision of a means for producing iron or other metallic powders directly from ore wherein only hydrocarbon gas is added in carrying out the said method.

A still further object of the invention is the provision of apparatus for producing iron powder directly from ore by a thermochemical reduction, and wherein only hydrocarbon gas is added in the process of reduction.

A still further object of the invention is the provision of apparatus for cooling the metallic powder produced and which apparatus constitutes a step in the production of the metallic powder.

A still further object of the invention is the provision of means for separating the metallic powder produced from the gaseous atmosphere in which it has been carried so as to enable its accumulation to facilitate removal of the metallic powders produced.

This invention relates to powder metallurgy and particularly to the production of powdered metal directly from ore suitable for use in various powder metallurgy practices. It has been determined that pulverized ore can be mixed with hydrocarbon gas, as by being fed from a hopper into a mixing chamber into which the hydrocarbon gas is simultaneously admitted, and the hydrocarbon gas and pulverized ore mixture then directed into an externally heated retort, in which the reduction takes place. As the pulverized ore is suspended in the hydrocarbon gas so that individual particles thereof are surrounded by gas, the reduction is accomplished quickly and uniformly by a thermochemical process which depends upon the complete cracking of the hydrocarbon gas wherein the gas separates into its constituent elements, chiefly carbon and hydrogen. The carbon separates as soot in an extremely fine solid state. As iron oxides are reducible by carbon and free hydrogen gas at temperature ranges of between 800–1050 degrees C., the reduction of the ore particles is practically instantaneous, provided the ore is finely pul-

verized. The reduction takes place due to the fact that the large surface area presented by the oxide ore cloud to the hydrocarbon gas affords a very convenient surface upon which the molecular sized carbon particles can settle as they are freed from the hydrocarbon gas. When the ore powder reaches the temperature necessary for reduction the said carbon present will take up the oxygen from the oxide ore and liberate carbon monoxide (CO) gas and free iron powder. The carbon monoxide (CO) gas, being a reducing agent, works on any unreduced oxide converting it to free iron and itself to carbon dioxide (CO₂) gas. The free hydrogen (H₂) liberated by the cracking of the hydrocarbon also aids in the reduction as it liberates free iron and H₂O as vapor. Metal powders other than iron, which metals are reducible by carbon and hydrogen at temperature ranges of 800–1050 degrees can also be produced by the method herein disclosed. Such metal powders are, for example, copper, nickel, cobalt, silver, tungsten and several others of the low melting point group.

With the foregoing and other objects in view which will appear as the description proceeds, the invention resides in the combination and arrangement of parts and in the details of construction hereinafter described and claimed, it being understood that changes in the precise embodiment of the invention herein disclosed can be made within the scope of what is claimed without departing from the spirit of the invention.

The invention is illustrated in the accompanying drawings wherein—

Figure 1 is a schematic illustration with parts in cross section and with parts broken away illustrating apparatus for practicing the method of making metallic powders directly from ore.

Figure 2 is an enlarged detailed illustration of a magnetic separator forming a part of the apparatus disclosed in Figure 1.

Figure 3 is a cross sectional elevation taken on lines 3—3 of Figure 2.

By referring to the drawings and Figure 1 in particular, it will be seen that a vertical retort 10 which in actual practice is preferably several times greater in height than in width, is provided with a combustion chamber 11 formed thereabout by an enclosure 12 preferably formed of several thicknesses of suitable material. A flue 13 communicates with the combustion chamber 11 so as to provide a vent for the products of combustion. Positioned immediately beneath the combustion chamber 11 there is a fuel supplying

header 14 in communication with a plurality of burner nozzles 15 which extend into the combustion chamber 11. It will thus be observed that fuel supplied through the header 14 and the burner nozzles 15 may be burned in the combustion chamber 11 so as to establish desirable temperatures within the vertical retort 10 about which the combustion chamber 11 is formed. A thermocouple well 16 is positioned partially within the vertical retort 10 in a gas-tight manner so that suitable instruments may be employed in connection therewith to control the temperature within the vertical retort 10.

In order that a mixture of pulverized metallic ore and suitable hydrocarbon gas such as natural gas may be supplied to the vertical retort 10 as by way of an opening 17 at the uppermost end thereof, means has been provided for supplying suitably pulverized metallic ore and a hydrocarbon gas and suitably mixing the same and delivering the mixture of ore particles and gas to the vertical retort 10 through the opening 17 in the top thereof. Such means may consist, for example, of a hopper 18 equipped with a screw type conveyor 19, which conveyor 19 is driven through a flexible coupling 20 by a suitable power source 21 such as an electric motor. Finely pulverized iron ore, indicated by the numeral 22, in the hopper 18, is delivered by the screw type conveyor 19 to a Venturi tube type mixing chamber 23 into which the hydrocarbon gas is admitted through a Venturi jet 24 from a regulating valve chamber 26 in a regulating valve 27, the regulating element of which is indicated by the numeral 28 and is shown adapted for manual regulation by means of a hand wheel 29, it being obvious that automatically regulated valves can be employed at this point. Hydrocarbon gas under suitable pressure is supplied to the valve chamber 26 by way of tubular connections 30 which in turn communicate with a suitable pump or compressor 31, hydrocarbon gas being supplied to the pump or compressor 31 by way of tubular connections 32 in which a control valve 33 is preferably located.

By again referring to the mixing chamber 23 it will be observed that hydrocarbon gas passing through the Venturi jet 24 enters the mixing chamber 23 and will carry the pulverized ore particles being introduced thereto by the conveyor screw 19 into an elbow 34 which is affixed to and communicates directly with the interior of the vertical retort 10 by way of the opening 17 therein. It will thus be observed that the finely divided ore particles in a practical suspension of hydrocarbon gas are introduced into the uppermost portion of the vertical retort 10 from whence the natural tendency will be to settle downwardly to the lowermost section thereof. As a suitable reducing temperature is maintained in the vertical retort 10 by means of fuel burning in the combustion chamber 11 which surrounds the vertical retort 10, the reduction of the metallic ore is accomplished.

The pulverized ore is suspended in the hydrocarbon gas so that the individual particles thereof are quickly and uniformly reduced by a thermochemical process which depends upon the complete cracking of the hydrocarbon gas thereby separating the gas into its constituent elements, chiefly hydrogen and carbon. The carbon separates as a soot in an extremely fine solid state. As iron oxides, for example, are reducible by carbon and hydrogen gas at temperature ranges

of between 800 and 1050° C., the oxide ore particles are reduced practically instantaneously as the surface area presented by the oxide ore particles affords a very convenient surface upon which the molecular sized carbon particles can settle as they are freed from the hydrocarbon gas. The pulverized ore rapidly reaches the temperature necessary for reduction (approximately 1000°). The carbon present takes up the oxygen from the oxide ore and in turn liberates carbon monoxide (CO) gas and free iron powder. The gas (CO) being a reducing agent, works on any unreduced oxide and converts it to free iron and itself to carbon dioxide (CO₂) gas. Free hydrogen (H₂) is liberated by the cracking of the hydrocarbon and this also aids in the reduction of the pulverized ore as it liberates free iron and water vapor.

The amounts of pulverized ore and hydrocarbon gas being regulated in the mixing chamber 23 are present in proper amounts for carrying through the process of reduction and the result is, therefore, a completely reduced iron powder. The process also produces a relatively small quantity of unreduced non-metallic particles, consumed gas consisting of carbon monoxide (CO) gas, carbon dioxide (CO₂) gas, free hydrogen (H₂) and water vapor in small percentages which prevent reoxidation of the iron powder.

The free iron powder together with the gases resulting from the reduction process and minute quantities of unreducible foreign particles pass from the vertical retort 10 by way of an opening 35 in the lowermost portion thereof directly into a heat exchanger 36 by way of an opening 37 in the top thereof. In the heat exchanger 36 a circulating water cell heat exchanger unit 38 is positioned which is supplied with circulating cooling water and is so formed that a plurality of tubular openings are positioned vertically therethrough and which vertical openings are indicated by the numerals 39. The iron powder and gases are thereby caused to descend through the tubular openings 39 in the heat exchanger 36 and give up a considerable amount of the heat retained from the reduction process. A thermocouple well 40 is provided in the heat exchanger so that suitable controls may be effected depending upon the temperatures therein.

The iron powder and gases pass from the heat exchanger 36 by way of an opening 41 in the lowermost portion thereof and into a radial distributor 42 which in turn is positioned within a depending enclosure 43, a portion of which consists of a magnetic separator 44 which is circular in shape and positioned about the delivery opening of the radial distributor 42 through which the iron powder is delivered. The magnetic separator is, as may be seen by referring to Figure 2, formed of a plurality of alternate layers of flat, circular coils and soft steel plates, the coils being indicated by the numerals 46 and the steel plates by the numerals 45. A circular water jacket 46 is positioned around the outer surface of the magnetic separator and is adapted to convey circulating water as a cooling agent thereabout. The soft steel plates 45 are provided for the magnetic circuits which are completed through a shell 47 and the gaps 48. Individual magnetic circuits 49 are established. A thin shell 50 is placed in the inside bore of the magnet, the shell being formed of a non-magnetic material so that the flux spreads out from one pole to an-

other bridging the gaps and attracting the iron powder and holding it against the non-magnetic shell 50. The magnetic separator is divided into two or more circuits, one of each being connected to a common D. C. power line 51, the other circuit lines are independently controlled by switches 52 which indicate that one or more circuits are on while another is open thus dropping the iron powder accumulated thereby.

It will be obvious that certain modifications of the apparatus disclosed will permit the reduction of non-magnetic powdered metals. Such modifications consist of substituting conventional dust collectors for the magnetic collector so as to separate non-magnetic metal powder from the gas present. Such devices are well known in the art.

The switches 52 are used to alternate the energization of the two or more magnetic circuits of magnetic separator and thereby serve to collect and hold the iron powder delivered through the radial distributor 42 and permit the gas in which they have been carried to pass outwardly from the area about the radial distributor 42 through a tubular channel 53. The iron powder collected by the magnetic separator is dropped from time to time upon the alternate energization of the two or more circuits of the magnetic separator heretofore described, directly into a receiving hopper 54 which is of sufficient size to permit a sufficient quantity of the iron powder to be maintained therein to effect a gas seal with respect to a screw type conveyor 55 driven by a motor 56 which communicates with the hopper 54 at the bottom thereof and which is adapted to deliver the iron powder therefrom. The powder delivered therefrom constitutes the product of the method and apparatus of this invention.

In order that additional hydrocarbon gas may be added to the gaseous mixture being separated from the metal powder in the magnetic separator 45, a gas inlet, controlled by a valve 57, communicates with the uppermost portion of the receiving hopper 54 by way of an opening 58 therein and hydrocarbon gas introduced therein flows upwardly through the magnetic separator 45 and joins the gases therein and leaves the area of the magnetic separator by way of the tubular channel 53. The tubular channel 53 communicates with a gas cleaner 59 where such non-magnetic particles as may have been carried along with the gas mixture are separated therefrom. The gas cleaner is similar to a conventional dust collector and is known in the art. A clean gas mixture leaves the gas cleaner 59 by way of a tubular channel 60 and is carried thereby to a pump or compressor 61 which is also provided with an air inlet 62 so that a proper combustible mixture may be formed and delivered therefrom by way of a tubular channel 63 at a desirable pressure to the header 14 from whence it will flow through the burner nozzles 15 into the combustion chamber 11 formed about the vertical retort 10. The combustion taking place in the combustion chamber 11, therefore, utilizes the remaining gaseous by-products of the actual metal reduction process thereby eliminating waste and adding to the efficiency of the method.

It will thus be observed that two materials, ore in a pulverized state and hydrocarbon gas, such as natural gas, are supplied the apparatus for the reduction of the ore into a metallic powder and that there are practically no waste products as the hydrocarbon gas used in the thermochemi-

cal reduction process is utilized for heating purposes in the apparatus.

It will thus be seen that a practical and efficient method of producing metal powders directly from their ores has been disclosed as has apparatus suitable for carrying out the method. It has been determined that the reduced metallic powder is prevented from agglomerating into larger particles by the surrounding gas and it is also prevented from sticking to the walls of the vertical retort 10 by radiation pressure from the walls which action is further assisted by the fact that the ore is rapidly moving downwardly carried by the gas. As has been stated, natural gas is preferred as the hydrocarbon reducing agent and fuel where available. However, manufactured hydrocarbon gas can be used if freed from sulphur compounds. The apparatus can be operated continuously as long as suitable ore is deposited in the hopper and suitable hydrocarbon gas is supplied the mixing chamber, and the magnetic powder produced is removed from the receiving hopper. It will be observed that the supplementary gas supplied through the gas inlet communicating with the receiving hopper is admitted in controllable quantities therethrough for the dual purpose of further cooling the powder held by the magnetic separator and to provide additional fuel for heat in the combustion chamber 11 to supplement the partially consumed gas coming from the vertical retort so that the required temperature may be maintained in the vertical retort 10. In actual practice pyrometer and electrically controlled valves are employed and the mixing and measuring of the ore and gas are accurately controlled. Flow meters, pressure gauges, fuel gas analyzers and other conventional items of furnace equipment are not shown or described as the same are well known in the art and their application to the apparatus disclosed is readily understood by those familiar with the art.

It will thus be seen that as illustrated the apparatus can reduce magnetic metals and separate them by the magnetic type separator shown. The apparatus can be modified to reduce and separate any similarly reducible non-magnetic metal. It will be observed that powder of any particle size can be produced as the easily controlled particle size of the ore entering the hopper 18 is maintained throughout the process. Powder produced will be of a spongy texture which is desirable in further processing of the powder directly or indirectly into articles. The magnetic powder produced is of exceptional high purity, while the cost of producing the metallic powder is very low. The process is rapid and continuous.

Having thus described our invention, what we claim is:

1. Apparatus for reducing metallic oxide ores to pure metallic powder, said apparatus consisting of a closed retort, means for mixing pulverized ore and hydrocarbon gas so as to cause the pulverized ore to be carried in a gaseous suspension, means for introducing the gaseous suspension of pulverized ore into the said retort and means for externally heating the said retort so as to establish reduction temperatures therein, means in communication with said retort for receiving the reduced metallic powder and gaseous by-products for cooling the same and means in connection with the said cooling means for separating the metallic powder from the gaseous by-products, means in connection with the said

separating device for receiving the separated metallic powder and means in communication with the said separating device for receiving the by-products, and means for directing the said by-products for fuel for the external heating of said retort.

2. Apparatus for continuously producing free iron powder from iron ore, said apparatus including a retort having a combustion chamber formed thereabout for the purpose of establishing suitable temperatures within the said retort; a mixing device in communication with the said retort, means for supplying the said mixing device with pulverized iron ore and with a hydrocarbon gas, the said mixing device for creating a gaseous suspension of the said iron ore particles and introducing the same into the said retort, a heat exchanger in communication with the said retort for receiving the reduced iron powder and gaseous by-products of reduction for cooling the

same, a separator in communication with the said heat exchanger for separating the said iron powder from the said gaseous by-products of reduction and a hopper for collecting the said separated iron powder; a gas cleaner in communication with the said separator for further treating the said gaseous by-products and a compressor in communication with the said gas cleaner for the purpose of removing gaseous by-products therefrom and forcibly supplying them to the said combustion chamber by way of a plurality of burner nozzles in association therewith, a flue in association with the combustion chamber for removing the products of combustion and a supplementary fuel gas inlet in communication with the said apparatus for supplying supplementary fuel gas to the said combustion chamber.

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