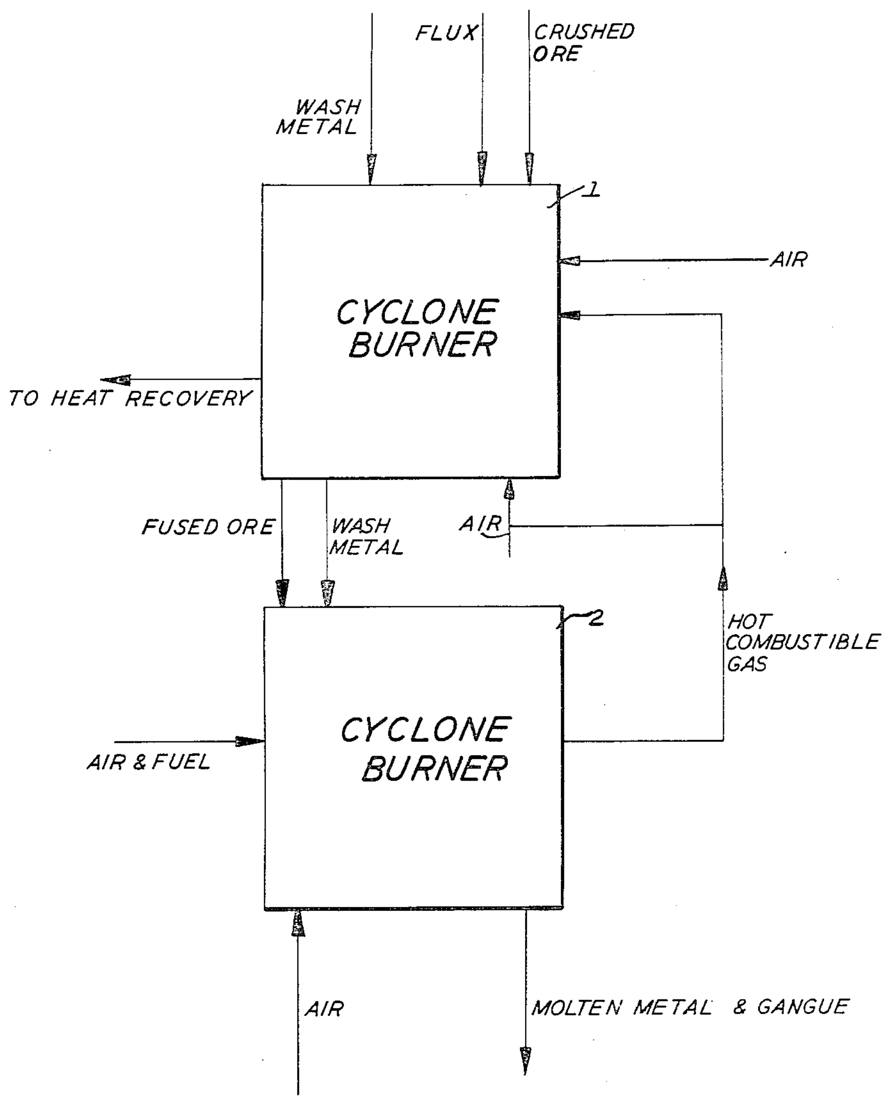
PROCESS OF REDUCING METALLIC ORES WITH GASES

Filed Nov. 21, 1952



T. H. OSTER
INVENTOR

BY E. C. McRae
J. R. Faulkner

ATTORNEYS

United States Patent Office

2,745,737

Patented May 15, 1956

1

2,745,737

PROCESS OF REDUCING METALLIC ORES WITH GASES

Thomas H. Oster, Dearborn, Mich., assignor to Ford Motor Company, Dearborn, Mich., a corporation of Delaware

Application November 21, 1952, Serial No. 321,769

12 Claims. (Cl. 75—91)

This invention is concerned with the art of utilizing fuels and more particularly with a process for the combustion of fuels and the concomitant treatment of metallic ores to recover the metallic values therefrom in a more concentrated condition. This invention is related to my copending application, Serial No. 253,890 filed October 31, 1951, entitled Combustion Process, to my application, Serial No. 317,282 filed October 28, 1952, entitled Combustion Process and to my application, Serial No. 316,708 filed October 24, 1952, entitled Dual Combustion Process.

This invention is more particularly concerned with the utilization of the combustion process described for the recovery of metal values from ores in which the metal value forms only a small portion of the ore as mined or in which the ore is present in a chemical or physical condition which makes its recovery difficult by conventional methods such as pulverization followed by flotation or other differential separation means.

It is contemplated that the process of this invention be carried out in a device known as a cyclone burner. Briefly, this device comprises a water cooled steel cylinder usually placed with its axis slightly inclined from the horizontal and provided at one end with means for the reception of a stream of fuel and primary air and at the other end with an exit for the products of combustion and an exit for molten slag. This type of burner and its operating characteristics are amply and ably described in an article entitled "The Horizontal Cyclone Burner" by A. E. Grunert, L. Skog and L. S. Wilcoxson appearing at page 613 et seq. of the American Society of Mechanical Engineers, Transaction, volume 69, 1947. The term cyclone burner employed in the appended claims is limited to the type of water cooled burner described by Grunert et al.

As the known supplies of high grade metallic ores have become depleted, it has been necessary to resort to leaner and leaner ores for the metals necessary for our day to day life. In these lean ores the desired metallic values are associated with large amounts of worthless gangue. To separate the metallic values from the gangue and obtain the desired high metal concentration, it is usually necessary to resort to crushing and grinding followed by a separation step such as flotation, electrostatic separation, magnetic separation, or other procedure dependent upon chemical or physical differences between the metal desired and the gangue. These concentration procedures are costly and almost invariably involve a sacrifice of metal values. The higher concentration of metal desired the higher is usually the loss of metal values to the tailing pile. The instant invention has been developed to increase the range of ores which may be treated without resort to the usual concentration processes.

As described and claimed in the applications mentioned above, it is possible to operate a cyclone burner with either a solid fuel or fluid fuel, and to introduce a metal ore into the burner and by a judicious choice of the oxidation level in the burner, to recover from the burner either a fused ore or a reduced metal.

In many instances, even when operating with a relatively concentrated ore it is difficult to simultaneously maintain the desired oxidation level within the burner and to maintain a temperature which will keep all materials within the burner except carbon either liquid or gaseous. The great majority of metal ores are predominantly siliceous or combinations of silica with varying amounts of lime and alumina. The upper limit of the temperature necessary to fuse most ores is fixed by the melting point of quartz or about 2600° F. The theoretical melting points of pure silica or the various calcium and aluminum silicates are not attained because of the fluxing action of various impurities and particularly the oxides of iron which are almost inevitably present. To maintain these necessary conditions simultaneously resort must be had either to highly preheating the incoming air, or to enriching the incoming air with oxygen, or to a combination of these expedients. In many instances when the gangue content of the ore is too high, it is impracticable to maintain the necessary temperature and reducing conditions within the burner due to the large amount of energy required to heat and melt the gangue. This energy amounts to approximately one thousand British thermal units per pound. To circumvent this difficulty resort is had to a dual cyclone burner. This method and the associated apparatus are probably best understood by reference to the figure of drawing which is a schematic representation.

In the drawing cyclone burner 1 is shown above cyclone burner 2 and in practice this arrangement should be followed so that molten materials may be transferred by gravity from cyclone burner 1 to cyclone burner 2. It is preferred that practically all of the fuel introduced into the system enter cyclone burner 2 and be introduced along with a stream of primary air or other oxidizing gas such as oxygen enriched air or oxygen of any desired degree of purity. As those skilled in the art will appreciate, the bulk of the air necessary for combustion in cyclone burners is introduced not in the primary air stream but in a rapidly moving stream of secondary air which is injected into the burner tangentially so that a swirling motion is set up therein and any given particle will pass through the burner in a generally helical path. The oxidation level in cyclone burner 2 is adjusted to yield the desired degree of reduction of any metal ore passing through this burner. When the usual fuels such as coal, coke, petroleum or natural or artificial gas is used, the gaseous effluent from cyclone burner 2 will be very hot and contain large quantities of combustible gases such as carbon monoxide and hydrogen. This gaseous effluent of cyclone burner 2 which is rich in both sensible and latent heat is transferred to cyclone burner 1 through a well insulated conduit and preferably serves as the sole fuel for cyclone burner 1. The gaseous effluent from cyclone burner 1 is of necessity very hot and is passed to a steam generator, or air preheater or other device for the recovery of its sensible heat. Cyclone burner 1 may discharge into an ordinary boiler and so produce steam for heat or power purposes. It will often be found to be advantageous to pass the hot gaseous products of combustion of cyclone burner 1 over a mass of crushed ore which is destined for later fusion in cyclone burner 1. This expedient serves the dual function of providing cyclone burner 1 with a preheated supply of ore and of providing an economical method of obtaining preheated air for the cyclone burners. This is accomplished by providing two masses of crushed ore and alternately passing over each mass combustion air and products of combustion. Inasmuch as the products of combustion emanating from cyclone burner 1 are above the melting point of the ore it will usually be necessary to reduce the temperature of these gases slightly either by the use of a small boiler, or by admixing therewith a small amount of relatively cold gas such as air or stack gas.

Crushed, but not necessarily pulverized ore is introduced into cyclone burner 1 with, or at least near the point of entrance of the hot fuel gas from cyclone burner 2.

The sensible heat in these hot combustible gases from cyclone burner 2, plus the heat released when they react with the air introduced in cyclone burner 1 maintains the interior of cyclone burner 1 above the melting point of the ore, modified if necessary by the addition of an appropriate flux. The molten ore will form a liquid coating over the interior of the burner and this liquid will describe a helical path towards the discharge end of the burner. The crushed pieces of ore will be hurled to the inner surface of the burner by centrifugal force and trapped in the molten ore layer until they are in turn melted.

The fused ore produced in cyclone burner 1 is transferred immediately to cyclone burner 2 preferably by gravity and through a well insulated conduit to prevent the loss of heat. The air and fuel introduced into cyclone burner 2 are so proportioned that the interior of this cyclone burner will be maintained under conditions reducing to the metal it is desired to recover. The heat of the combustion of fuel in cyclone burner 2 serves to maintain this burner at a temperature necessary to maintain all of the reactants except carbon in either the liquid or gaseous state and to reduce the ore to the metal. The exact temperature to be maintained, and the intensity of the reducing conditions to be established in cyclone burner 2 depend upon such factors as the cost of fuel, the cost of ore, the value of the metal produced, and other strictly local factors so that it is impossible to set these conditions forth quantitatively. They should be determined for each particular operation.

In many instances the operation of this process with air at atmospheric temperatures will be found to be impossible. Under these conditions resort must be had to the use of highly preheated air or oxygen enriched air or both. It is to be understood that preheated air or oxygen enriched air are not strictly alternatives, but can be used either separately or together depending upon the ore and local economic conditions. In any event, the heat introduced into cyclone burner 2 in the fused ore, plus the heat introduced in the air plus the heat of combustion taking place in the burner must equal or exceed the heat leaving the burner in the molten metal and gangue, plus the latent and sensible heat in the hot gas effluent plus the heat losses from the burner through radiation, cooling water, etc., plus the heat necessary for the reduction of the metal.

Similarly in cyclone burner 1, the sensible heat in the hot gases from cyclone burner 2, plus the heat of combustion of these gases, plus the heat brought in in preheated air must equal or exceed the heat necessary to heat and fuse the ore introduced plus the sensible heat in the exhaust gas, plus radiation and cooling water losses from the cyclone burner. Having been given these requirements, the degree of preheat necessary for the air supply to each cyclone burner, or the degree of oxygen enrichment or both may readily be calculated by one skilled in metallurgical and combustion calculations.

In most locations the primary fuel to be used in cyclone burner 2 will be crushed coal, although this is not necessary. The process will operate also upon coke, charcoal, petroleum or gas as the primary fuel. Lignite, brown coal and peat properly dried are workable fuels. Cyclone burner 1 has been described as fired only by gas from cyclone burner 2. However, this is not essential, albeit it is usually economically desirable. Under some circumstances such as where the metal being produced is readily reducible in the presence of large amounts of carbon dioxide and/or water vapor or where there is a

large demand for heat as for steam raising or electric power, it may be more economical to fire cyclone burner 1 with fuel other than the hot gas from cyclone burner 2. The omniverous characteristics of cyclone burners will permit almost any fuel to be employed here, either per se, or as an adjuvant to the hot gas from cyclone burner 2.

In the event the ore being treated is very lean resort may be had to the addition with the pulverized ore of a metal or metal ore which will follow through the process and which will be referred to as a wash metal. This metal serves the purpose of dissolving the desired metals from the ore as they are reduced and removing them effectually from the scene of the reaction. This wash metal may be introduced either as a metallic compound or ore in the metallic form. It may be either a pure metal or an alloy of metals. Under some circumstances it may be possible to select a wash metal which will be a solvent for the desired metal at the reduction temperature and which will precipitate or partially precipitate the desired metal upon cooling. An example of such a system would be the use of lead as a wash metal for copper bearing ores. In this case the lead and copper are mutually soluble at high temperatures and almost insoluble at low temperatures. As an example of a wash metal in which the metal desired is soluble in all proportions may be mentioned copper for the recovery of nickel from the nickeliferous ores mined in the vicinity of Sudbury, Ontario. These ores contain about three percent nickel and copper combined as well as smaller values in silver, platinum and other metals. In this case a certain amount of copper may be kept circulating through the reduction apparatus acting as a wash metal to secure a more quantitative recovery of nickel, platinum, silver, etc. as a solute in molten copper. It is to be understood that the use of a wash metal is not always necessary and will depend upon the economic conditions prevailing at any given installation and upon such factors as the density of the metal sought, the liquidity of the slag produced and the availability and cost of slagging materials which would serve to reduce the slag viscosity and assist in the operation of the metal and the ore.

Depending upon the nature of the metals sought to be recovered a wash metal may be selected which is either more difficult or less difficult to reduce than the desired metal. Where the metal desired to be reduced is comparatively easy to reduce and of a high value resort may be had to a wash metal more difficult to reduce but of less value. In such case the wash metal should be introduced as metal and into the reducing cyclone and excluded from contact with the oxidizing ambient in the cyclone 1. This metal may be added to reducing cyclone 2 either as a solid, or if the conservation of heat is imperative, in the molten form. An example of such a practice would be the use of cast iron borings as a wash metal in treating copper ores or ores of other metals reducible by iron. Here the molten cast iron serves the dual function as a wash metal and a reducing agent, both functions tending to minimize the loss of copper values in the effluent slag. As a matter of economy where easily reducible metals such as copper are used as a wash metal they may also be introduced in cyclone burner 1 along with the ore to be treated.

Ferrosilicon may also be produced by adding to the second cyclone burner fused silica and iron ore or alternatively fused iron silicates. The production of ferrosilicon requires that the second cyclone be operated very hot and strongly reducing. The hotter the second cyclone is operated and the more strongly reducing conditions are obtained, the higher will be the percentage of silicon in the ferrosilicon.

As an alternative to the use of a wash metal or in conjunction therewith resort may be had to the use of centrifugal force to expedite the separation of minute globules of metal from the molten flux. The use of centrifugal force is particularly indicated where the difference in specific gravity between the metal produced and the slag is insufficient to give a clean separation.

I claim as my invention:

1. In a process for the combustion of fuel and the production of molten metal and a combustible gas, the steps of melting metal ore, transferring this molten ore to a cyclone burner operated under conditions reducing to said metal, adding to said cyclone burner a source of wash metal, said wash metal being a solvent for the metal being reduced, tapping said metals and slag from the cyclone burner, said cyclone being operated at a temperature sufficient to liquefy or gasify all of the products of reaction except carbon, the sensible heat added to the cyclone in the combustion air and fuel, plus the heat added in the molten ore plus the heat of the combustion within the burner being at least equal to the energy of reduction of the metal plus the sensible and latent heat of the gaseous products of combustion plus the heat of the molten metals and slag plus the heat abstracted by radiation and cooling water.

2. In a process for the combustion of fuel and the production of molten metal and a combustible gas, the steps of melting metal ore, transferring this molten ore to a cyclone burner operated under conditions reducing to said metal, adding to said cyclone burner a source of wash metal, said wash metal being a solvent for the metal being reduced at reduction temperatures but not at a lower temperature, tapping said metals and slag from the cyclone burner, said cyclone being operated at a temperature sufficient to liquefy or gasify all of the products of reaction except carbon, the sensible heat added to the cyclone in the combustion air and fuel, plus the heat added in the molten ore plus the heat of the combustion within the burner being at least equal to the energy of reduction of the metal plus the sensible and latent heat of the gaseous products of combustion plus the heat of the molten metals and slag plus the heat abstracted by radiation and cooling water.

3. In a process for the combustion of fuel and the production of molten nickel from nickel ore or concentrates, the steps of melting the ore, transferring this molten ore to a cyclone burner operating under conditions reducing to nickel, tapping said molten nickel and slag from the cyclone burner, said burner being operated at a temperature sufficiently high to liquefy or gasify all of the reaction products except carbon, the sensible heat added to the cyclone burner in the combustion air and fuel plus the heat added in the molten ore plus the heat of combustion within the burner being at least algebraically equal to the energy of the reduction of the nickel plus the sensible and latent heat of the gaseous products of combustion plus the heat of the molten nickel and slag plus the heat abstracted by radiation and cooling water.

4. In a process for the combustion of fuel and the production of molten nickel and a combustible gas, the steps of melting nickel ore, transferring this molten ore to a cyclone burner operated under conditions reducing to nickel, adding to said cyclone burner a source of copper other than that present in the nickel ore, tapping said nickel and copper and slag from the cyclone burner, said cyclone burner being operated at a temperature sufficient to liquefy or gasify all of the products of the reaction except carbon, the sensible heat added to the cyclone in the combustion air and fuel plus the heat added in the molten ore plus the heat of the combustion within the burner being at least equal to the energy of the reduction of the nickel and copper, plus the sensible and latent heat of the gaseous products of combustion, plus the heat of the molten nickel, copper and slag, plus the heat abstracted by radiation and cooling water.

5. In a process for the production of molten nickel the steps of melting the nickeliferous ore in a cyclone burner, transferring this molten ore to a second cyclone burner operated under conditions reducing the nickeliferous ore to nickel and tapping the molten nickel and slag from the second cyclone burner, said first cyclone burner employing as fuel gaseous effluent from the second cyclone burner, the heat introduced into the second cyclone burner in the melted ore, in the air used for the combustion of fuel, in the fuel and by the combustion of fuel therein equaling or exceeding the heat abstracted from said second cyclone burner by the reduction of nickel plus the heat removed by the gaseous effluent plus the heat removed by the molten metal and slag plus the heat removed by radiation and cooling water, and the heat introduced into the first cyclone burner in the hot gaseous effluent from the second cyclone burner plus the heat of combustion in this burner plus the heat of the oxidizing gas used in the combustion equaling or exceeding the heat necessary to heat and melt the ore plus the heat abstracted by radiation and cooling plus the heat removed in the gaseous effluent.

6. In a process for the production of molten nonferrous metal the steps of melting nonferrous ore in a cyclone burner transferring this molten ore to a second cyclone burner operated under conditions reducing to the nonferrous metal and tapping the molten nonferrous metal and slag from the second cyclone burner, said first cyclone burner being fired at least in part by the gaseous effluent from the second cyclone burner, the heat introduced into the second cyclone burner in the melted ore, in the air used for the combustion of fuel, in the fuel and combustion of fuel therein equaling or exceeding the heat abstracted from said second cyclone burner by the reduction of the nonferrous metal plus the heat removed by the gaseous effluent plus the heat removed in the molten metal and slag plus the heat removed by radiation and cooling water, and the heat introduced into the first cyclone burner in the hot gaseous effluent from the second cyclone burner plus the heat of combustion in this burner plus the heat of the oxidizing gas used in the combustion equaling or exceeding the heat necessary to heat and melt the nonferrous ore plus the heat abstracted by radiation and cooling plus the heat removed in the gaseous effluent.

7. In a process for the production of molten nickel the steps of melting together in a cyclone burner nickeliferous ore and a source of copper transferring the molten mixture to a second cyclone burner operated under conditions reducing the nickeliferous ore to nickel and tapping the molten nickel copper alloy and slag from the second cyclone burner, said first cyclone burner being fired at least in part by the hot gaseous effluent from the second cyclone burner, the heat introduced into the second cyclone burner in the melted mixture, in the air used by the combustion of fuel, and in the fuel and by the combustion of fuel therein equaling or exceeding the heat abstracted from said second cyclone burner by the reduction of the material, plus the heat removed by the gaseous effluent plus the heat removed in the molten metal and slag plus the heat removed by radiation and cooling water, and the heat introduced into the first cyclone burner in the hot gaseous effluent from the second cyclone burner plus the heat of combustion in this burner plus the heat of the oxidizing gas used in the combustion equaling or exceeding the heat necessary to heat and melt the ore plus the heat abstracted by radiation and cooling plus the heat removed in the gaseous effluent.

8. In a process for the production of a molten alloy of iron and nonferrous metal the steps of melting together in a cyclone burner a mixture of iron ore and an ore of the nonferrous metal, transferring this molten material to a second cyclone burner operated under conditions capable of reducing to metal the most difficultly reducible ore, tapping the molten alloy and slag from the second cyclone burner, said first cyclone burner employing as fuel gaseous effluent from said second cyclone burner, the

heat introduced into the second cyclone burner in the melted ores, in the air used for the combustion of fuel, in the fuel and by the combustion of fuel therein equaling or exceeding the heat abstracted from said second cyclone burner by the reduction of the metals plus the heat removed by the gaseous effluent, plus the heat removed in molten metal and slag plus the heat removed by radiation and cooling water, and the heat introduced into the first cyclone burner in the hot gaseous effluent from the second cyclone burner plus the heat of combustion in this burner plus the heat of the oxidizing gas used in the combustion equaling or exceeding the heat necessary to heat and melt the ores plus the heat abstracted by radiation and cooling plus the heat removed in the gaseous effluent.

9. In a process for the production of a molten alloy of iron and silicon, the steps of melting iron ore and silica, adding these molten materials to a cyclone burner operated under conditions capable of reducing to metal at least a portion of the silica, tapping the molten alloy and slag from the second cyclone burner, the heat introduced into the cyclone burner in the melted ore, in the air used for the combustion of fuel, in the fuel and by the combustion of fuel therein equaling or exceeding the heat abstracted from the cyclone burner by the reduction of the metals plus the heat removed by the gaseous effluent, plus the heat removed in the molten metal and slag plus the heat removed by radiation and cooling water.

10. In a process for the production of a molten alloy of iron and a nonferrous metal the steps of melting an ore of iron and the nonferrous metal, introducing this molten material into a cyclone burner operated under conditions capable of reducing to metal the most difficultly reducible ore and tapping the molten alloy from the cyclone burner, the heat introduced in the cyclone burner in the melted ores, in the air used for the combustion of fuel, in the fuel, and by the combustion of fuel therein equaling or exceeding the heat abstracted from said cyclone burner by the reduction of the metals plus the heat removed by the gaseous effluent plus the heat removed in the molten metal and slag plus the heat removed by radiation and cooling water.

11. In a process for the production of a molten alloy of iron and copper, the steps of melting an ore of iron and copper, introducing this molten material into a cyclone burner operated under conditions capable of reducing iron to metal and tapping the molten iron copper alloy from the cyclone burner, the heat introduced in cyclone burner in the melted ore, in the air used for the combustion of fuel, in the fuel, and by the combustion of fuel therein equalling or exceeding the heat abstracted from such cyclone burner by the reduction of the metals plus the heat removed by the gaseous effluent plus the heat removed in the molten metals and slag plus the heat removed by radiation and cooling water.

12. In a process for the production of a molten alloy of iron and copper, the steps of melting together metallic iron and copper ore, introducing this molten metal into a cyclone burner operated under conditions capable of reducing oxides of iron to metal and tapping the molten iron copper alloy from the cyclone burner, the heat introduced into the cyclone burner in the melted ore and iron, in the air used for the combustion of fuel, in the fuel, and by the combustion of fuel therein equalling or exceeding the heat abstracted from such cyclone burner by the reduction of the metals plus the heat removed by the gaseous effluent plus the heat removed in the molten metals and slag plus the heat removed by radiation and cooling water.

References Cited in the file of this patent

UNITED STATES PATENTS

861,593	De Laval	July 30, 1903
1,815,888	Baily	July 28, 1931
2,530,078	Ramsing	Nov. 14, 1950
2,581,597	Nissim	Jan. 8, 1952