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METHOD OF REDUCING METALLIC OXIDES TO METAL WITHOUT MELTING

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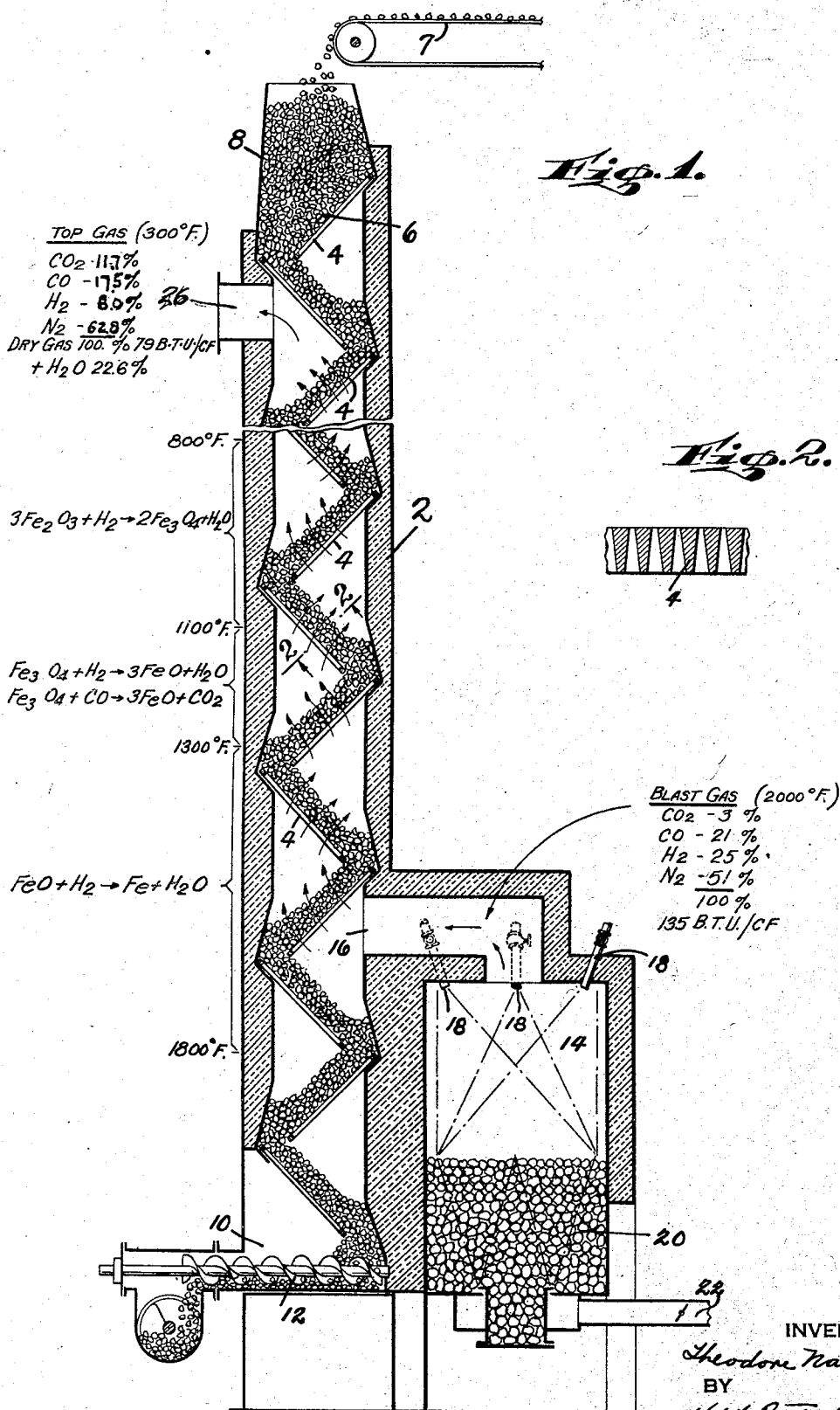


Fig. 2.

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UNITED STATES PATENT OFFICE

2,265,812

METHOD OF REDUCING METALLIC OXIDES
TO METAL WITHOUT MELTING

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Application April 8, 1941, Serial No. 387,451

2 Claims. (Cl. 75-91)

My invention relates to a method for reducing metallic oxide ore to metal.

More specifically my invention is directed to a method for reducing crushed metallic oxide ore to metal wherein the crushed ore continuously slides by gravity downwardly along a series of alternating inclined superimposed chutes enclosed within an air sealed shaft counterflow to a hot reducing gas which is continuously produced adjacent the lower end of the shaft and while confined to the shaft continuously flows upwardly through the shaft and chutes across the paths of the sliding crushed ore so that all of the gas is caused to percolate through the voids of the sliding crushed ore.

Still more specifically the present invention is directed to the process above outlined characterized in that the reducing gas entering the shaft is at such a temperature and the ratio of reducing gas to ore and the relative velocities of the gas and ore are such as to effect reduction of the oxides to metal without melting.

In the accompanying drawing wherein I have illustrated an embodiment of my invention:

Fig. 1 shows in sectional elevation an apparatus suitable for the practice of the invention; and

Fig. 2 is a section on the line 2-2 of Fig. 1.

Referring to the drawing in detail: 2 designates an air sealed vertical shaft, equipped in its interior with a series of superimposed inclined chutes 4. These chutes are disposed in alternating or zigzag fashion so that the crushed metallic oxide ore 6 which is fed from conveyor 7 into a feed hopper 8 on top of the shaft, air seals the top of the shaft 2, the crushed ore being continuously fed by gravity to the series of chutes down which it slides through the shaft to the bottom thereof in inclined alternating paths.

The discharge for the metal and gangue is designated 10 and in the drawing takes the form of an air-sealed screw conveyor 12. It will be appreciated that by controlling the continuous discharge of the reduced ore by this conveyor the continuous movement of the furnace burden downwardly through the shaft 2 along the inclined chutes 4 is regulated.

Adjacent its lower end the shaft 2 is provided with a gas generating space 14 communicating directly with the shaft 2, as shown at 16.

Hydrocarbons are introduced by pressure into this chamber for decomposition to reducing gas through valve controlled multiple nozzles 18.

At the bottom of the space 14 is a porous bed 20 of suitable material such as cobble stones, brick, coke, or other suitable aggregate.

22 designates a damper controlled inlet for air under pressure introduced at the bottom of this porous bed.

The fuel admitted to the space 14 is a hydrocarbon, as above pointed out, and may take the form of a liquid, a vapor or a gas.

The ratio of hydrocarbon to air volume is readily controlled by the nozzle valves and by the air inlet damper, these being so adjusted that after ignition a hot reducing gas will be produced continuously under sufficient pressure to cause the gas continuously to flow upwardly of the reducing shaft 2 through the voids in the charge of crushed ore sliding by gravity downwardly of the shaft.

The reducing gas is produced at a temperature not lower than approximately 1650° F. and contains carbon dioxide in proportion to the combined volume of carbon monoxide and molecular hydrogen approaching not more than 1 to 5, respectively, while the ratio of carbon monoxide to molecular hydrogen does not exceed approximately 1 to 1 by volume.

As the crushed metallic oxide ore slides downwardly through the shaft 2 through the reducing gas flowing upwardly through the shaft, the reducing gas will percolate through the voids of the mass of crushed ore across the paths of the sliding ore. The rate of movement of the ore, as above pointed out, is readily controlled by controlling the rate of discharge of metal and gangue from the bottom of the shaft 2, while the ration of ore feed to the counterflowing gas volume feed is such that the ore will finally attain the temperature at which the final phase of reduction will transfer oxygen from the ore to the active reducing gas.

26 designates an exhaust gas outlet near the top of the shaft 2. The gas exhausting through this outlet is at a temperature above 212° F. and contains carbon dioxide in proportion to the combined volume of more carbon monoxide and molecular hydrogen approaching not more than approximately 1 to 2, respectively.

Partial combustion occurs in the space 14 in the presence of excess carbon with the air which is distributed by percolating upwardly through the voids of the porous bed 20, and the heat required for decomposing the hydrocarbons supplied by the nozzles 18 to molecular hydrogen and carbon is liberated, thereby liberating the carbon required for maintaining partial combustion, the combustion products being carbon monoxide with comparatively smaller volume of carbon dioxide. The resulting gas mixture contains oxidizing gas in proportion to the volume of reducing gas approaching not more than approximately 1 to 5, respectively, and the ratio of carbon monoxide to the volume of molecular hydrogen approaches not more than approximately 1 to 1.

It will be seen, therefore, that in this manner hydrocarbons are continuously converted to a

highly active reducing gas at the temperature required for the final phase of reduction of metallic oxides, after the ore by counterflow heat exchange with the hot gas has been preheated to the temperature required for this final phase of reduction.

Following is an example of the practice of my invention with respect to the reduction of iron ore to metallic iron. It is understood, of course, that this is a mere illustrative example, inasmuch as other oxides may require temperature ranges and ratios of ore feed to gas volume feed different from those presently to be set out.

Let us consider the production of one long ton (2240 lbs.) of iron from two long tons of hematite (Fe_2O_3), this ore, we will assume, contains 50% iron. The temperature range of reduction starts at approximately 800° F. and the final temperature reached by the burden is approximately 1800° F.

Three barrels of fuel oil decompose to 91,000 cubic feet (S. T. P.) 135 B. t. u. fuel value per cu. ft. gas, the gas having a temperature of 2000° F. Top gas 91,000 cu. ft. (S. T. P.), wet gas exhausted at 300° F., is composed of approximately 16,800 cu. ft. steam and approximately 74,200 cu. ft. dry gas of approximately 79 B. t. u. fuel value per cu. ft. Under the above conditions the heat balance as shown on drawing Fig. 1 approximates:

FURNACE CHARGE, REACTIONS AND HEAT BALANCE

Furnace burden.—4480 lbs. ore (2240 lbs. $\text{Fe}+960$ lbs. O_2+1280 lbs. gangue (rock))

Furnace blast.—91,000 cu. ft (S. T. P.) 135 net B. t. u./C. F.

Highly active reducing gas at 2000° F.

Heat input 15,750,000 B. t. u.

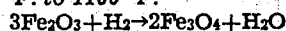
Gas analysis

CO_2 -----	3% by volume
CO -----	21% by volume
H_2 -----	25% by volume
N_2 -----	51% by volume

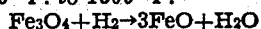
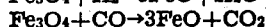
100% 135 net B. t. u./C. F.

Gaseous reduction reactions of Fe_2O_3 to Fe

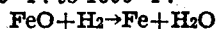
800° F. to 1100° F.



1100° F. to 1300° F.



1300° F. to 1800° F.



Furnace heat balance

	B. t. u.
Fuel gas to furnace 91,000 cu. ft.	+12,300,000
Sensible heat 2000° F.	+ 3,450,000
	+15,750,000
4480 lbs. ore to 1800° F. requires	- 2,530,000
Reduction to Fe requires	- 7,100,000
Gas reactions generate	+ 6,540,000
Top gas fuel exhaust	- 5,860,000
Top gas sensible heat 300° F. exhaust	- 455,000
Furnace heat loss+excess blast	- 6,345,000
	-15,750,000

FURNACE PRODUCTS

2240 lbs. $\text{Fe}+1280$ lbs. gangue (rock)

91,000 cu. ft. (S. T. P.) top gas at 300° F., 6,315,000 B. t. u.

(74,200 cu. ft. dry+16,800 C. F. H_2O (Steam))

Dry gas analysis

CO_2 -----	11.7% by volume
CO -----	17.5% by volume
H_2 -----	8.0% by volume
N_2 -----	62.8% by volume

100% 79 net B. t. u./C. F.

In the above example oil has been taken as the hydrocarbon from which the desired highly reactive hot reducing gas is produced by atomizing a controlled supply of oil into a hot gas which is continuously generated by partial combustion of carbon with air in the gas generating space of the furnace, the carbon being liberated through decomposing the oil to molecular hydrogen and carbon most of which carbon supplies the fuel for the above mentioned partial combustion.

It is to be understood that the process above described may be varied as to its details without departing from the spirit and scope of my invention.

What I claim is:

1. The method of reducing metallic oxide ore to metal, which method comprises continuously sliding crushed metallic oxide ore by gravity in controlled flow in inclined alternating paths through an air-sealed shaft, simultaneously and continuously producing a hot $\text{CO}+\text{H}_2$ reducing gas under pressure near the lower end of the said shaft, and while confining the gas to the shaft flowing all of the gas upwardly through the voids of the mass of crushed ore across the paths of said sliding crushed ore, the gas temperature, the ratio of gas to crushed ore and the relative velocities of the gas and crushed ore being such as continuously to effect progressive reduction of the ore to metal without melting as the temperature of the crushed ore progressively increases.

2. The method of reducing metallic oxide ore to metal, which method comprises continuously sliding crushed metallic oxide ore by gravity in controlled flow in inclined alternating paths through an air-sealed shaft, simultaneously and continuously producing a reducing gas near the lower end of the shaft, the gas being produced under pressure at a temperature not less than approximately 1650° F. and containing CO_2 in volume relative to $\text{CO}+\text{H}_2$ not more than approximately 1 to 5, respectively, and CO in volume relative to H_2 not more than approximately 1 to 1, and while confining this gas to the air-sealed shaft flowing all of the gas upwardly through the voids of the porous mass of crushed ore across the paths thereof, the gas temperature, the ratio of gas to ore and the relative velocities of the gas and ore being such that the gas after thus flowing through the voids of the mass of crushed ore will be at a temperature above 212° F. and contain CO_2 in volume relative to $\text{CO}+\text{H}_2$ of not more than approximately 1 to 2, respectively, and progressive and continuous reduction of the ore to metal without melting will be effected as the temperature of the sliding crushed ore progressively increases.

THEODORE NAGEL.

CERTIFICATE OF CORRECTION.

Patent No. 2,265,812.

December 9, 1941.

THEODORE NAGEL.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 1, second column, line 30, for "ration" read --ratio--; line 39, strike out the word "more"; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 13th day of January, A. D. 1942.

(Seal)

Henry Van Arsdale,
Acting Commissioner of Patents.