July 29, 1930. W. E. TRENT 1,771,971

PROCESS FOR THE REDUCTION OF IRON ORES

Filed June 16, 1928 2 Sheets-Sheet 1

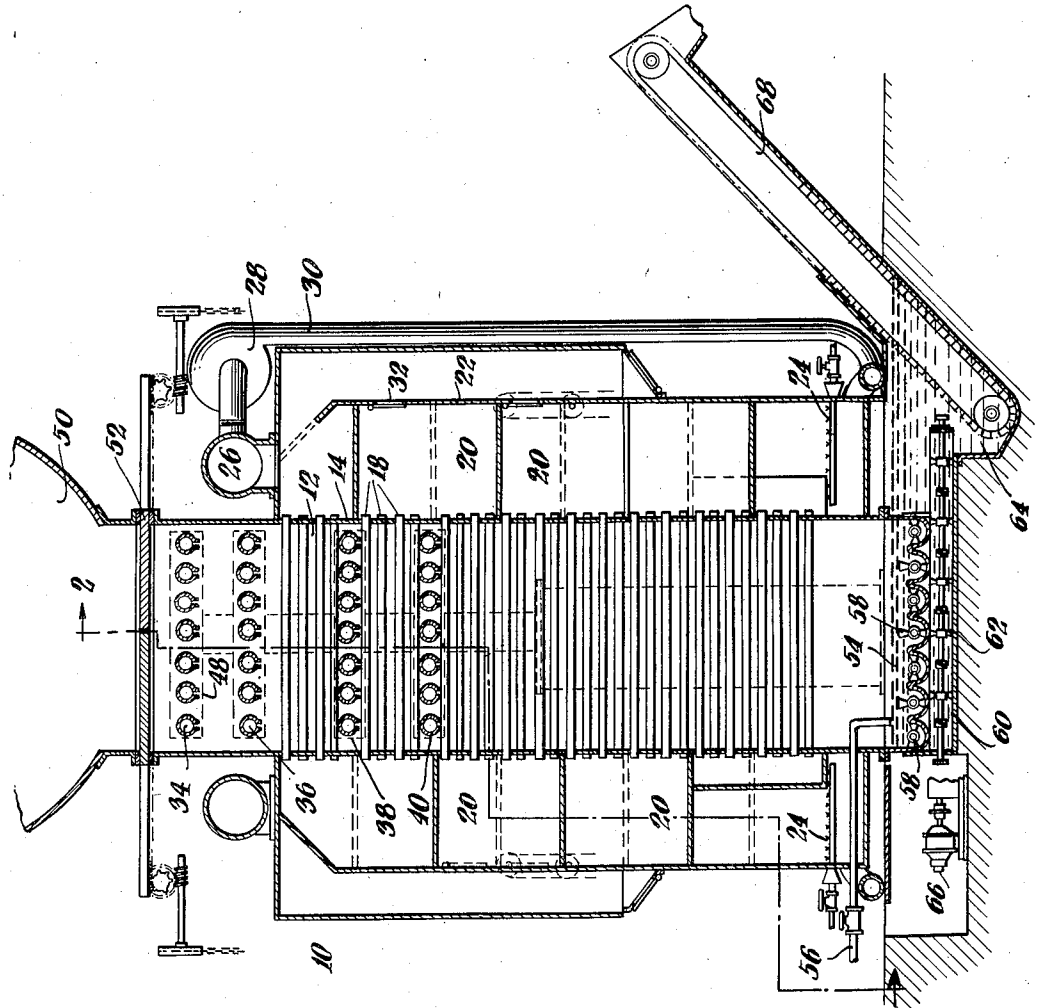


Fig. 1.

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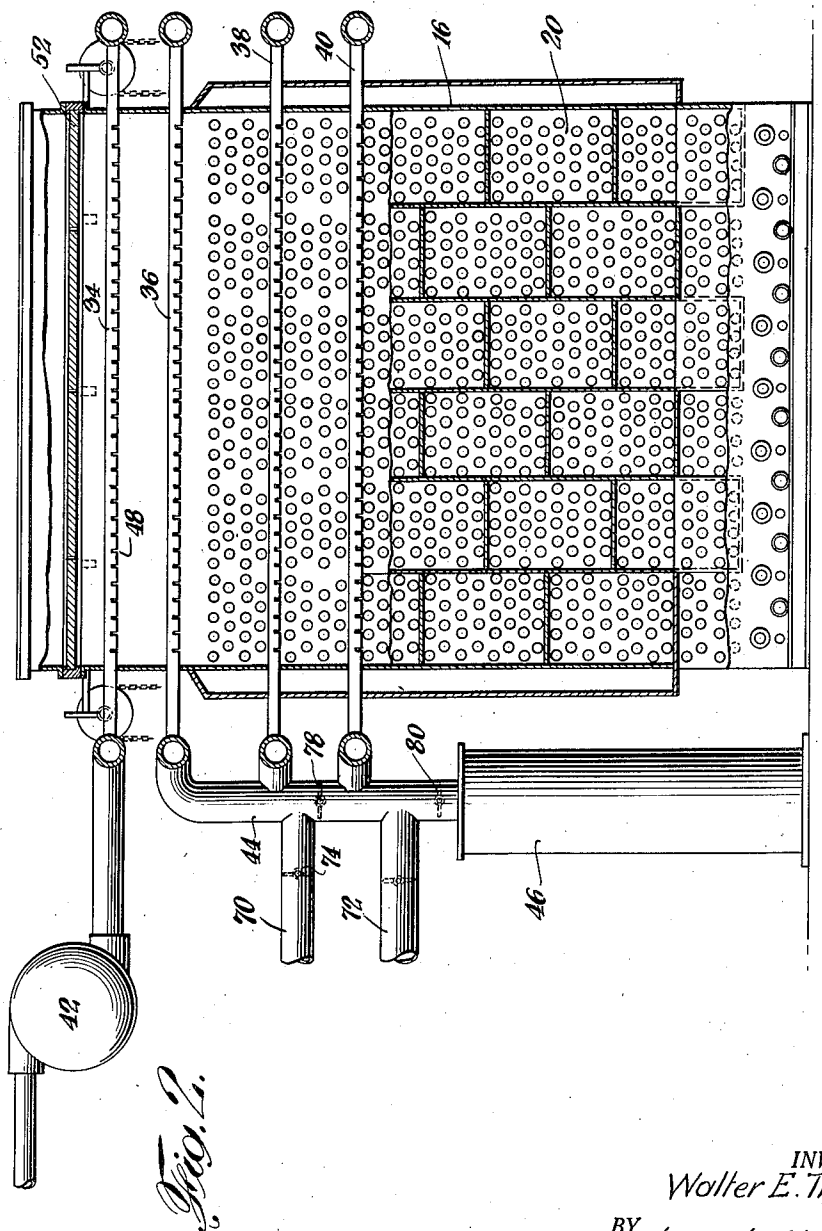


Fig. 2.

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Patented July 29, 1930 1,771,971

UNITED STATES PATENT OFFICE

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PROCESS FOR THE REDUCTION OF IRON ORES

Application filed June 16, 1928. Serial No. 285,953.

This invention relates in general to the reduction of iron ores, and relates more particularly to a process in which the iron is reduced and recovered in the form of finely-divided particles or sponge which may be freely handled or manipulated in the air without danger of reoxidation.

An object of the invention is to quench reduced iron in an oil bath, to prevent its reoxidation after it has been reduced from an ore.

Another object is to recover the residual heat in metallic iron after reduction of its ore, and avoid dissipating and wasting same.

A further object is to utilize the heat residing in freshly reduced iron to vaporize and crack an oil, giving a yield of valuable light petroleum products, which may be rectified to produce gasoline and other commercially important products.

A still further object is to obtain the reduced iron mixed or bonded with the residues of the cracked oil, which furnish fuel for heating the metal in later smelting stages, as well as furnishing the bonding material for briquetting the metal, for convenient handling.

The invention further comprises a continuous process of reducing iron ores in which a mixture of ore and coal or other solid carbonaceous material is fed continuously through an externally heated chamber and progressively subjected to increased heating temperatures while hydrocarbon vapors are led in countercurrent relation to the descending charge in the hotter portions of the chamber, thereby effecting transfer of heat from hot metallized particles leaving the reducing zone to the partially reduced material in the reducing zone, and at the same time bringing the hydrocarbon vapors at cracking temperatures into contact with a maximum exposure of metal surface both of the hot finely-divided reduced metal and heating surfaces through which heat is supplied to the charge from an extraneous source, thus affording optimum conditions for cracking the hydrocarbon vapors.

Other collateral and subsidiary objects will appear as the description proceeds.

While many different types of apparatus may be employed in carrying out my process, I have found the apparatus shown in the annexed drawing to be perfectly suitable, and the process will be described as carried on therein. This apparatus is similar in general details to that disclosed in my copending application, Serial No. 262,472, filed March 17, 1928.

Fig. 1 is a part vertical section and side elevation of the apparatus.

Fig. 2 is a part vertical section and end elevation taken on line 2—2 of Fig. 1.

The apparatus, designated generally at 10 and similar in general respects to that described in the earlier application above mentioned, comprises a vertical reducing chamber 12, formed by side walls 14 and end walls 16. Extending across the chamber 12 are a plurality of tubes 18 which open at their ends into spaces 20 between the side walls 14 and outer walls 22 for the reception of the products of combustion from gas burners 24 disposed near the lower end of the retort.

The spaces 20 are arranged in checkered fashion, as shown in Figs. 1 and 2. Details of this arrangement, designed particularly to secure most efficient gas flow, are immaterial to the present invention, being sufficiently obvious from the drawings, and being described in detail in the copending application above referred to.

It can be seen, however, that the gases of combustion from burners 24 will traverse the tubes 18, heating the same, and providing indirect heat for the contents of the chamber 12. Suitable means are provided, including headers 26, blowers 28, conduits 30, and bypasses 32, for recirculating at will a portion of the partially cooled gases, or to by-pass the gases or a portion of them, thus permitting close control of the temperature of the chamber 12 and making it possible to increase or decrease the amount of heat supplied to the contents of any portion thereof at any stage of the operation. Waste gases are led from headers 26 to an external flue, not shown. A blower 28 and a conduit 30 are provided at the left hand side of the apparatus as viewed in Fig. 1 similarly to those

shown at the right hand side thereof, but are omitted from the drawing.

Extending across chamber 12, horizontally and at right angles to tubes 18, is a series of eduction tubes, 34, 36, 38, and 40. The number of rows of such tubes is not critical, but there may well be at least two; the upper connected to a blower 42 for the purpose of removing air accidentally or unavoidably introduced with the charge to be described later. The lower groups of eduction tubes may feed into a conduit 44, which may, if desired, connect with a condenser shown generally at 46, for a purpose to be later disclosed. These tubes have openings 48 through which gases and vapors may pass from the chamber 12.

At the upper part of the apparatus I have shown a feed hopper 50, and valve slide 52. As an alternative, the structure shown and described in my copending application, Serial No. 284,049, filed June 9, 1928, may be employed, in which event the upper or air eduction group of tubes 34 may be omitted. The specific type of feed is no part of the present invention and may be considered as illustrated conventionally, since many different feeds are known and are satisfactory.

At the lower part of my apparatus is an oil reservoir 54. Oil is fed into this reservoir through pipe 56 from any convenient outside source, as needed. In the floor of this reservoir is a series of parallel screw conveyors 58, all pitched to feed centrally into a double cross trough 60. In this trough rotates a conveyor 62, which is so rotated as to feed into a sump 64. All the conveyors 58 and 62 may be operated from a motor 66.

In order to reduce the iron ore, it is desirable to have a supply of carbon. Accordingly, before introducing the ore into the apparatus, I ordinarily mix it intimately, after suitable crushing, with a suitable solid carbonaceous material. This material may be coke, coal or any similar material. Preferably, I use crushed or finely divided bituminous coal either of a coking or non-coking variety, latter being preferred, although when the process is carried out in an apparatus such as above described the reducing operation may be so conducted that the coking properties of the coal are destroyed before a fusing or coking temperature is reached. While the proportions of coal to ore must necessarily vary with the nature of the raw materials, I find that for a general rule, one ton of iron ore may be mixed with one-half ton of coal. These proportions are not critical or limiting, and are given only to afford an approximate idea of relative amounts used.

After mixing the ore and coal, the charge is introduced to the hopper 50, the feed valve 52 being open during operation. Gas burners 24 are started, and the tubes 18 so heated that the temperature within chamber 12 is high enough to reduce the iron oxide in the presence of the carbon of the coal. The charge now feeds slowly down through the chamber 12, becoming of course progressively hotter as it descends. Rate of feed and temperatures must be so regulated that the iron oxide will be completely reduced to the metallic state by the time it has reached the lowermost horizontal row of heating tubes 18.

The hot metallic particles, on leaving the heating zone, will drop immediately into the oil bath 54. The immediate effect of this will be to quench the metal, transferring a large part of its heat to the oil. As a result, the oil will be partially volatilized, and also to a certain degree cracked. These volatile portions will rise through the chamber 12, coming into intimate contact with tubes 18, as well as with the hot descending reduced metal particles, and the partially reduced charge of mixed ore and coal.

As a result of this intimate contact with heated surfaces, particularly the hot surfaces of the metal sponge and the tubes 18, the oil vapors will be further cracked, resulting in the production of considerable proportions of gasoline and gasoline-like fractions. These partially cracked vapors may then be removed through eduction tubes 36, 38, and 40 and conducted to condenser 46, where they are liquefied, to be subsequently redistilled according to the usual refinery practices.

As has been previously suggested, the uppermost row of eduction tubes 34 may be used if desired to withdraw from the system air which has been accidentally or unavoidably introduced together with the ore-fuel charge.

While crushed coal is preferably mixed with the iron ore to cause its reduction when heated, the operation can be effected without the coal. In this case the vapors generated by the hot metal entering the oil bath rise through the charge and effect the reduction of the iron ore.

Since in the reduction of iron ore by means of solid carbonaceous materials the gaseous products of reaction are principally carbon monoxide with smaller proportions of carbon dioxide, the products possess a very considerable fuel value and should be recovered. Instead of withdrawing all of these gases and passing them through the condenser 46 with the cracked oil vapors, thereby making it more difficult to recover all of the available oil fractions, separation of the greater portion of these fixed gases may be obtained by leading the gases withdrawn through the groups of tubes 36 and 38 directly to a suitable place of storage or use. The cracked vapors, on the other hand, will be substantially all withdrawn through the lower group of tubes 40, together with a minor proportion of the fixed gases generated in completing reduction of the ore in the lower portions of

the chamber 12, this mixture of vapors and gases being led through the condenser 46 for recovery of the condensable fractions.

In Fig. 2 of the drawing I have shown bypass lines 70 and 72 connected to the conduit 44 for optionally separating a major portion of the fixed gases evolved in the upper portions of the chamber 12 from the cracked oil vapors, or for leading all of the gases and vapors past the condenser as desired. Valves 64 and 76 are provided in the lines 70 and 72 respectively, and similar valves 78 and 80 are provided in the conduit 44 respectively intermediate the lines 70 and 72 and the line 72 and the condenser 46.

When using a bituminous coal as the solid reducing agent mixed with the ore, it will be understood that distillation of the volatilizable constituents takes place in the upper portions of the chamber 12, and that generally it will be desired to pass these constituents to the condenser to recover the condensable fractions. On the other hand, when using coke or a low volatile coal, the apparatus above described affords a convenient and simple means for recovering fixed gases produced in the reduction of the oil separately from cracked oil vapors and gases without passing the whole gaseous effluent through the condenser.

After the reduced iron is deposited in the oil, and moved by the conveyors 58 and 62 to the sump 64, it may be removed in any convenient manner. I have shown an endless conveyor 68, merely by way of example.

The metal as it leaves the oil bath, will obviously be covered with a coating of oil. This will completely and effectually prevent any reoxidation. The oil adhering to the metal, if sufficiently viscous, may form a binder by which the metal may be briquetted prior to further smelting operations. And, with or without briquetting, the adhering oil will in any event furnish fuel for the subsequent operations, as well as affording a protective coating against atmospheric reoxidation.

As the volatilized oil passes upwardly through chamber 12, it will come in contact with the hot tubes 18. Cracking will result, and there may be some tendency for carbon to deposit upon these tubes. But this tendency is completely overcome by the scouring action of the downwardly flowing ore-fuel charge, and the partially reduced iron. In this way, the heating and cracking tubes are kept completely free of carbon, with a resulting increased efficiency of heat transfer, and also thereby avoiding the necessity of tearing down the apparatus periodically to remove the cracked carbon residues. By keeping the heating tubes and other metal surfaces of the retort chamber free from carbon, the maximum catalytic cracking effect which takes place when hydrocarbon vapors contact with heated metal surfaces at cracking temperatures is insured.

Another advantage which must be emphasized in my invention is the saving of heat. The iron is of course very hot as it leaves the reducing zone. Ordinarily, this heat would be entirely wasted. Most of this waste heat I recover by carrying on the simultaneous distillation and cracking steps of my process.

While I have described my process as carried out in a particular type of apparatus, it is understood that the process is independent of any specific apparatus, and is to be considered as limited only by the prior art and the scope of the appended claims.

I claim:

1. A process comprising heating a mixture of iron ore and carbonaceous material to reduce the ore and depositing the freshly reduced metal while hot into an oil bath.

2. A process comprising heating a mixture of iron ore and carbonaceous material to reduce the ore, immersing the reduced metal in finely divided form while hot and before exposure to an oxidizing atmosphere, in a bath of liquid hydrocarbon to coat the metal particles with a protective layer of hydrocarbon material, and removing the coated metal particles from said bath.

3. A process comprising heating a mixture of iron ore and carbonaceous material to reduce the ore, depositing the freshly reduced metal substantially without prior heat loss into a body of oil, thereby volatilizing and cracking a part of said oil, and in subsequently recovering the vapors from said oil.

4. A process comprising heating a mixture of iron ore and carbonaceous material to reduce the ore, depositing the freshly reduced metal into a body of oil, thereby volatilizing and cracking a part of said oil, and passing the vapors so formed through a body of partly reduced metal, ore and carbon, further to crack said oil vapors, and subsequently condensing and recovering the condensible fractions of said cracked vapors.

5. A process comprising heating a mixture of iron ore and carbonaceous material to reduce the ore, depositing the freshly reduced metal into a body of oil, thereby volatilizing and cracking a part of said oil, passing the vapors so formed through a body of partly reduced metal, further to crack said vapors, and subsequently condensing and recovering said vapors, and removing said reduced metal mixed with and covered by the residue from the cracked oil, to prevent atmospheric oxidation and to provide fuel for smelting said metal.

6. A process comprising applying indirect heat to a mixture of iron ore and carbonaceous material to reduce the ore, depositing the freshly reduced metal into a body of oil, to quench the metal, transfer its heat to the oil and protect the reduced metal from at-

mospheric reoxidation, and submitting the vapors from the oil to the same source of indirect heat as the ore, thereby cracking said oil vapors, and recovering the partially cracked vapors.

7. A process comprising heating a mixture of iron ore and carbonaceous material to reduce the ore, depositing the freshly reduced metal into a body of oil, to quench the metal, transfer its heat to the oil and crack and volatilize same, thereby protecting the reduced metal from atmospheric reoxidation, passing the vapors from the oil through heated and partly reduced ore, further to crack said vapors, and condensing and recovering said partially cracked vapors.

8. A process for reducing iron ore comprising heating a mixture of iron ore and carbonaceous material by indirect heat to reducing temperature, maintaining the reaction mixture and the freshly reduced metal in non-oxidizing atmosphere, and depositing the reduced metal while hot into a body of oil.

9. A process for reducing iron ore comprising heating a mixture of iron ore and carbonaceous material by indirect heat to a reducing temperature, maintaining the reaction mixture and the freshly reduced metal in an atmosphere of hydrocarbon vapors and depositing the reduced metal into a body of oil to supply said vapors.

10. A process for reducing iron ore comprising subjecting a mixture of ore and carbonaceous material to reducing conditions and protecting the reduced metallic particles from atmospheric oxidation by coating them with a liquid residue from a cracked hydrocarbon oil.

11. A continuous process for the simultaneous reduction of iron ore and cracking of oil comprising continuously feeding by gravity a charge of coal and iron ore through an indirectly heated reduction chamber, depositing the reduced metal by gravity into a bath of oil, thus quenching the metal and partially volatilizing and cracking the oil, passing the vapors from the oil in countercurrent relationship to said charge, removing said quenched metal mixed with residues from the oil, and in continuously supplying fresh oil to replace that which has been removed.

12. A continuous process for the simultaneous reduction of iron ore and cracking of oil comprising continuously feeding downward by gravity a charge of carbonaceous material and iron ore through a reducing chamber, in a countercurrent stream of hydrocarbon vapors, indirectly heating said charge in the course of its progress, thus partially cracking the hydrocarbon vapors, withdrawing and condensing said partially cracked vapors, and continuously supplying fresh hydrocarbon vapors to replace those removed.

13. A continuous process for the simultaneous reduction of iron ore and cracking of oil comprising continuously feeding downward by gravity a charge of carbonaceous material and iron ore, through a reducing chamber, in a countercurrent stream of hydrocarbon vapors, indirectly heating said charge in the course of its progress, thus reducing the ore and partially cracking the vapors, and utilizing the heat of the reduced metal to generate a continuous stream of hydrocarbon vapors from a body of liquid hydrocarbon.

14. A continuous process for reducing iron ore comprising indirectly heating a charge of iron ore and coal to reducing temperatures, in passing the hot reduced metal into a liquid hydrocarbon, partially to crack and volatilize said hydrocarbon, in passing the vapors through the heated charge, further to crack said vapors, and in withdrawing and recovering both the vapors from the liquid hydrocarbon and the vapors extracted from the coal of the charge when heated.

15. A continuous process for reducing iron ore comprising indirectly heating to reducing temperatures a charge of iron ore and coal, passing the hot reduced metal into a liquid hydrocarbon oil, partially to crack and volatilize same, passing the resulting vapors through the heated charge, further to crack said vapors, withdrawing and recovering said vapors, and separately withdrawing vapors produced from the coal of the ore-coal charge when the latter is heated.

16. A process for the reduction of an oxide ore, comprising heating the ore in the presence of a carbonaceous reducing agent to reduce the ore, contacting the reduced metal while hot with a hydrocarbon oil bath, and leading oil vapors generated thereby to the reducing zone to reduce additional ore therein.

17. A process for the reduction of iron ore, comprising heating iron ore in the presence of hydrocarbon vapors to reduce the ore, immersing the reduced metal while hot in a hydrocarbon oil bath, and leading oil vapors generated thereby to the reducing zone to reduce additional ore therein.

18. A process for the reduction of an oxide ore, comprising passing the ore and hydrocarbon gases in countercurrent reactive relation in a reducing zone, indirectly heating the mixture in said zone to effect reduction of the ore, contacting the reduced metal while hot with liquid hydrocarbons to crack the same and to generate vapors and gases therefrom, and leading gases so generated to the reducing zone to react upon additional ore therein.

19. A continuous process for the simultaneous reduction of an oxide ore and crack-

ing of oil comprising feeding the ore through a reducing zone in reactive relation with a current of hydrocarbon gases, heating said charge in the course of its progress to effect reduction, leading the reduced metal from said zone and immersing it while hot in a body of liquid hydrocarbons, thereby effecting cracking of the hydrocarbons and generating gases, and leading gases so generated to said reducing zone.

20. A process for the reduction of iron ore comprising heating iron ore in the presence of hydrocarbon vapors to reduce the ore, depositing the reduced metal while hot in a hydrocarbon oil bath, thereby volatilizing and cracking a part of said oil, and subsequently recovering the vapors evolved from said oil.

21. A process for the reduction of iron ore which comprises heating the ore in the presence of carbonaceous material to reduce the ore, contacting the freshly reduced metal substantially without prior heat loss with hydrocarbon oil, thereby volatilizing a part of said oil, and subsequently recovering the vapors evolved from said oil.

In testimony whereof, I have signed my name to this specification.

WALTER E. TRENT.