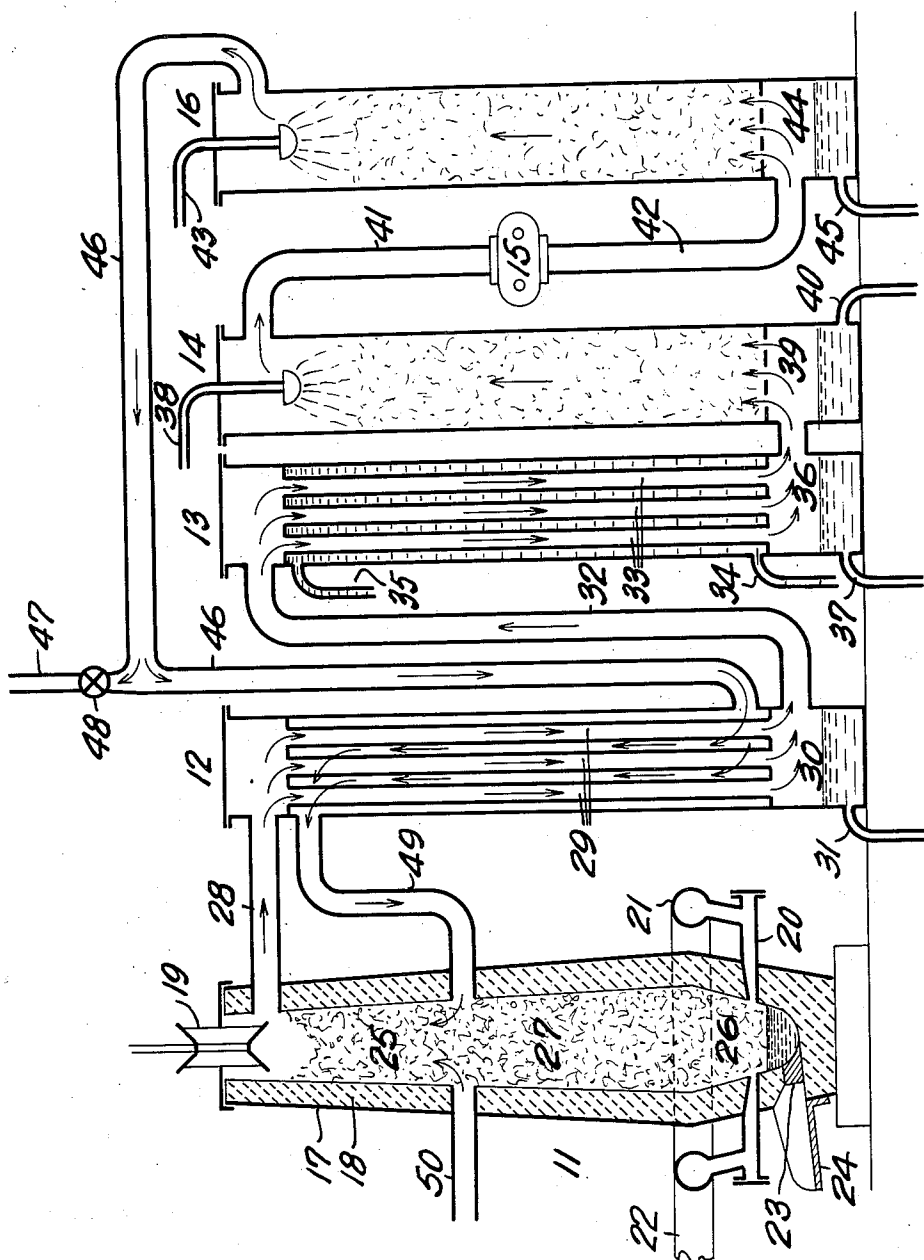


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PROCESS OF AND APPARATUS FOR SMELTING ORES
AND RECOVERING BY-PRODUCTS THEREFROM
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PROCESS OF AND APPARATUS FOR SMELTING ORES AND RECOVERING BY-PRODUCTS THEREFROM

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This invention relates to a process of and to apparatus for the smelting of metals in a blast furnace, and the primary object of the invention is to enable the use of raw fuel containing a high percentage of volatile constituents, such as pine wood or bituminous coal, directly in the blast furnace.

A concomitant object is the elimination of the usual preliminary and externally performed steps of charcoal or coke making which are resorted to chiefly for the removal of volatiles from the raw fuel.

A further object of the invention is the recovery of a larger amount than usual of the volatiles of the raw fuel.

A still further object is to reduce the cost of smelting not only by the larger recovery of volatiles and the elimination of expensive charcoal or coking installation, together with their cost of operation, but by effecting a more rapid reduction of the ore and a greater reduction per unit weight of fuel used.

Various other objects and advantages of the invention may be ascertained from the following description.

Briefly, the invention resides in circulating through the upper or distilling zone of a blast furnace in a direction opposite to the movement of the charge, a stream of gas free from condensable volatiles, which will mix with the gaseous products of combustion rising from a lower zone and enable substantially completed distillation of the fuel to be effected at a temperature below its fusing temperature. The relatively large volume of gas is also circulated through condensing and washing apparatus for recovery of entrained vapors and gas. After separation of an amount of cleaned gas equal to the unfixed gas produced from the charge, the remainder of the gas, which is a substantially constant amount, is reheated in the condenser and returned to the furnace at the bottom of the distilling zone thereof.

If pine wood or bituminous coal is used directly in the usual way in the current types of blast furnaces, the furnace operator is confronted by two alternative difficulties. If the gases leaving the furnace top are too low a temperature, some of the volatile matter

which has evaporated in the gas will condense out again and deposit as a more or less gummy coating on the incoming charge. This deposited condensate both sticks the pieces of the charge together, interfering with its movement, and also chokes up the passages between the pieces interfering with the passage of the gases. If, in an endeavor to avoid such condensation, the furnace is operated with hot top gases, another form of sticking is encountered. Raw fuels with high volatile content have rather low fusing temperatures, many bituminous coals fusing at 650° F. Higher temperature operation causes fusing of the fuel. Such fusing interferes both with the movement of the charge and the passage of the gas in exactly the same way as does the premature condensation. Attempts to avoid either of these effects operate to prevent the cure of the other.

My invention avoids this difficulty by increasing the volume of the top gases through the introduction into the furnace of a gas free from condensable volatiles and additional to that resulting from the distillation and combustion of the fuel at any moment in the furnace. This increase in the volume of the gas which mixes with the vapors of the condensable volatiles reduces the condensation temperatures of the vapors due to the correspondingly reduced partial pressures of such volatile vapors. By introducing enough gas, the condensation temperatures of even the high boiling volatiles can be reduced well below the fusing temperature of the fuel.

It is the present practice to distil such volatile carrying raw fuels in coke ovens or charcoal kilns, and introduce only the solid residue into the smelting furnace. It happens that conditions are extremely favorable for doing such distillation directly in the smelting furnace, thus not only avoiding a considerable part of the expenditure and operating costs of an outside distillation plant, but also materially increasing the yield of the by-products of the distillation, by concurrently carrying on the distilling and the smelting in the same furnace. Furthermore, the presence of the additional reducing gas

aids materially in the reduction of the ore, which reduction is especially rapid in the presence of the volatile hydrocarbon vapors.

The average bituminous coal carries some 11½% by weight of nitrogen. If this nitrogen could all be recovered as ammonia, it would enable a possible production of about 130 pounds of ammonium sulphate per ton of coal. Good coke oven practice produces about 26 pounds of the possible 130 pounds of sulphate, being a recovery of about 20%. The principal cause of this low extraction is that most of the nitrogen remains in the coke and its combination with hydrogen as ammonia is prevented by the high temperature used to finish the coke. Where bituminous coal is used directly in the furnace, in accordance with this invention, the lower temperature conditions permit the recovery of a large part of the contained nitrogen as ammonia. A recovery of 100 pounds of ammonium sulphate per ton of coal used becomes practicable. This increased recovery of ammonia is largely aided by the fact that the usual smelting furnace charge contains lime, introduced to flux the silica of the ore. This lime takes up the organic acids with which part of the ammonia is usually combined and releases that ammonia to go forward with the furnace gases.

Coke is characterized by the fusion of the coal and the blowing up of the fused mass into a sponge form by the entrapped gas bubbles. When enough top gas is circulated in contact with raw coal fed into a blast furnace, the volatiles are distilled off below the fusing temperature of the coal. With the volatiles removed, the fusing temperature of the solid residue becomes so high that no fusion takes place. In place of the sponge formation of ordinary coke, the solid product of such distillation with gas resembles anthracite coal, but under close examination is seen to be full of fine fissures, separating the laminations of original vegetable matter from which the coal was formed. This product is more free burning than coke with the consequence that a blast furnace using it works faster.

This invention applies to any metallurgical process adapted to be carried out in stack type furnaces, and may be illustrated by its application to the smelting of iron ore for the production of pig iron.

The accompanying drawing shows a diagrammatic view of a plant including a blast furnace 11, a first condenser or heat exchanger 12, a second condenser 13, an oil washing tower 14, an exhauster 15, an ammonia washing tower 16, together with the gas and liquid pipes connecting and serving these pieces of equipment.

The blast furnace comprises a gas-tight shell 17 lined with refractories 18. A feeder 19 is arranged to feed ore, flux and fuel into

the furnace without allowing the escape of gas. Near the base of the furnace air is blown into the furnace through tuyères 20, supplied with air from a bustle pipe 21 and a blast main 22. The molten metal and slag resulting from the smelting action of the furnace are periodically tapped out through a taphole 23 and a spout 24.

As the charged metallic ore sinks down in the furnace it is heated by the upcoming gas. The ore is also acted on chemically, the oxygen of the ore being taken over by the gas. This reducing action occurs largely in the upper half of the furnace, designated 25 and termed the reducing zone. At the bottom of the furnace in the section of highest heat is the melting zone, designated 26. In between these zones is a heating zone, designated 27, in which the reduced materials are raised in temperature preparatory to melting.

The gases resulting from the smelting leave the top of the furnace through a pipe 28 and pass through the tubes 29 of the heat exchanger 12. As the gases cool in the exchanger, part of the volatiles absorbed from the fuel condense and run down the insides of the exchanger tubes and are collected in a reservoir 30 in the base of the exchanger, from which they are removed through a pipe 31. The partially cooled gases pass through a pipe 32 into the condenser 13 and down through the tubes 33. These tubes are surrounded by water, entering cold through a pipe 34 and leaving them hot through a pipe 35. The volatiles which condense as a result of this further cooling of the gas, accumulate in a reservoir 36 in the base of the condenser from which these condensed volatiles are removed through a pipe 37.

The cooled gas leaving the condenser still carries a considerable amount of vapors of light oils with low boiling temperatures. Most of these are recovered by passing the gas from the condenser through the oil washing tower 14, where the gas is washed with an absorbing oil sprayed into the oil washer through the pipe 38, and collected in a reservoir 39 in the base of the oil washer and removed through a pipe 40. A small part of the oils remain in the gas and are returned to the furnace, where they are especially effective in reducing the last of the oxygen from the ore. Leaving the oil washer through a pipe 41, the cooled and cleaned gases pass through the exhauster 15, which sends them forward through the pipe 42 into the ammonia washer 16. The work done on the gas in the exhauster 15 heats the gases about 10° F. This heating prevents moisture from condensing out of the gases in the ammonia washer.

In the ammonia washer, the gases are sprayed with an acid solution of ammonium sulphate supplied through a pipe 43 and collected in a reservoir 44 and removed through

a pipe 45. The ammonia free gases pass through a pipe 46, part going back to the exchanger 12 and part, being the excess gas from the furnace, being removed from the system for use elsewhere through the pipe 47 controlled by the valve 48. The part of the gas returned to the exchanger passes around the outside of the exchanger tubes and is reheated. Due to the fact that the amount of gas passing from the furnace through the tubes is much larger in amount than the gases passing outside the tubes, this return gas can be heated nearly to the temperature at which the gas leaves the furnace. This reheated gas is returned to the furnace through a pipe 49, which delivers the gas into the furnace at a point in the shaft below the reducing zone 25.

The amount of gas returned to the furnace at the base of the reducing zone is sufficient to carry all the volatiles from the raw fuel out of the furnace without condensing at a temperature below the fusing temperature of the raw fuel. As this gas returns to the furnace substantially at the temperature at which it leaves the furnace, little heat is absorbed in this circulation. Because of the reduction in the partial pressures of the volatiles resulting from the larger amount of gas circulated, the volatiles distil from the raw fuel at much lower temperatures than would obtain under atmospheric conditions and the heat saving due to such lower vaporization temperatures is more than the heat lost in the circulation of the returned gas. In addition, all cracking of the volatiles is prevented, resulting in a by-product yield larger than the yield from outside coke ovens and kilns, which products are of higher selling values.

The presence of the returned gas reduces the average temperature of the gases in the reducing zone. This increases the reduction effect of the gases on the ore and shortens the time required and increased the capacity of the furnace. It also reduces the amount of fuel required per unit weight of metal, due to the increased reducing ability of each unit of carbon at the lower temperature. As the returned gas is introduced above the heating and melting zones of the furnace, this lowered temperature of the reducing zone is obtained without lowering the temperatures in the heating and melting zones. When raw fuel decomposes, a considerable amount of heat is liberated. Where the fuel is distilled directly in the stack furnace, this exothermic heat is utilized and less fuel is required for stack heat. Where coke is made in outside ovens, the sensible heat of the hot coke is lost. When the coal is distilled directly in the blast furnace, the sensible heat of the hot solid residue is saved and less fuel is required for the smelting. Thus, according to this invention, there are three separate and distinct fuel economies which in the aggregate enable a

very considerable reduction to be effected in the cost of smelting, in addition to the reductions resulting from lower investment and operating costs and from the increased yield of by-products of higher value.

Where condensing water is available, it is more economical to condense the steam exhausted from the blowing engines furnishing the air blast for the smelting furnace. Where this exhaust steam cannot be condensed, it may be used in part as the gases returned to the furnace, being blown in through a pipe 50 at the base of the reduction zone.

Having thus described my invention, what I claim is:—

1. In a process of smelting ore with fuel containing a substantial proportion of volatile constituents, the step of passing in contact with the mixed ore and fuel a current of reducing gas sufficient in amount to lower the partial pressures of volatile constituents of the fuel to such a degree that they will evaporate into the gas at temperatures below the normal fusing temperature of the fuel and will remain in vapor state in presence of cold fuel and ore.

2. A method of smelting ore which comprises charging the ore into the top of a stack furnace along with fuel containing volatile constituents, distilling from the fuel while in the upper part of the furnace substantially all the volatile constituents thereof at a temperature below the normal fusing temperature of the fuel and while passing in contact with the fuel a current of gas derived from previous distillation and combustion and the hot gaseous products of combustion of previously distilled fuel burning in a lower part of the furnace, the amount of the combined gases and vapors being such as to reduce the partial pressures of volatile constituents of the distilling fuel to such an extent that the evaporating temperatures of such constituents are brought below the normal fusing temperature of the fuel, and blowing air into the lower part of the furnace for combustion of non-volatile distillation products to provide heat for melting the metal and for said distilling operation.

3. In a metallurgical process adapted to be carried out in a furnace in which the incoming charge is gradually and continuously heated by gases, the improvement which comprises charging the furnace with ore and a solid fuel containing hydrocarbon constituents adapted to be distilled by heat, prior to such heating, mixing the products of the combustion of the non-volatile combustible portions of said fuel with additional reducing gas allowing the resulting gas mixture to contact with the incoming fuel to absorb said volatiles and fractionally condensing most of said volatiles from said mixture after removal from said furnace, and returning said gas with the remainder of said volatiles

to said furnace for the further reduction of said ore.

4. A process of smelting ore with fuel containing volatile constituents, which comprises blowing air through a hot mixture of fuel and partially reduced ore for combustion of the fuel, cooling the gaseous and vaporous products of such combustion by addition of a reducing gas and passing the combined gases through a mixture of fuel and ore to partially reduce the ore and to evaporate from the fuel its volatile constituents.

5. A process of smelting ore with fuel containing volatile constituents, which comprises blowing air through a hot mixture of fuel and partially reduced ore for combustion of the fuel, cooling the gaseous and vaporous products of such combustion by addition of a reducing gas and passing the combined gases through a mixture of fuel and ore to partially reduce the ore and to evaporate from the fuel its volatile constituents, the volume of the combined gases being such that the partial pressures of volatile constituents of the fuel are lowered sufficiently for their evaporation at a temperature below the normal fusing temperature of the fuel and for their maintenance in vapor state in presence of cold fuel and ore.

6. A metallurgical process which comprises charging oxide ore into a furnace with an alkaline flux and a fuel from which ammonia can be distilled, passing through said charge reducing gas and removing said gas and its contained ammonia from said charge through the last charged portions thereof, treating said gas with acid for the separation of said ammonia and returning such ammonia free gas to said furnace at a zone in which said fuel is substantially free of ammonia constituents.

7. In a metallurgical process, feeding to a furnace a charge of iron ore, a lime flux and a coal containing volatile constituents, recovering ammonia from said coal by passing through said charge reducing gas in excess of the products of the combustion of the non-volatile portions of said coal, passing the gas containing said ammonia in contact with acid and returning to said furnace and to further contact with said fuel a portion of such gas from which said ammonia has been removed.

8. In a metallurgical process, feeding into a furnace successive charges of ore, lime flux and bituminous coal and recovering ammonia from the coal by passing the gaseous products of the combustion of a previously distilled portion of said fuel into contact with said fuel in the presence of said flux, after cooling said gaseous products below a temperature of 1000° F. by admixture with similar gaseous products previously passed from which the ammonia has been previously absorbed.

9. A process of smelting ore which includes charging a mixture of ore and distillable fuel into the top of a stack furnace and circulating upwardly through an upper distilling zone of the furnace a substantially constant volume of reducing gas additional to the gaseous products of combustion rising from a lower zone of the furnace, the temperature and amount of the circulating gas being such as to so reduce the partial pressures of the volatiles in the fuel that the volatiles will evaporate into the combined gases at temperatures below the fusing temperature of the fuel and will remain in the vapor state in presence of cold ore and fuel.

10. A process of smelting ore which includes charging a mixture of ore and distillable fuel into the top of a stack furnace and circulating through an upper distilling zone of the furnace and through fractional condensing apparatus a substantially constant volume of reducing gas, whereby volatile constituents of the fuel are extracted, removed from the furnace and collected.

11. A process of smelting ore which includes charging a mixture of ore and distillable fuel into the top of a stack furnace and passing a reducing gas through an upper distilling zone of the furnace, along with the gaseous products of combustion rising from a lower part of the furnace, passing the mixed gases carrying gaseous and vaporous products of distillation through condensing and washing apparatus for recovery of distillation products, removing a portion of the mixed gases substantially equal to the gas production of the distillation and the gaseous products of combustion and returning the remainder of the gas to the distilling zone of the furnace.

12. A process of smelting ore which includes charging a mixture of ore and distillable fuel into the top of a stack furnace and passing a reducing gas through an upper distilling zone of the furnace, along with the gaseous products of combustion rising from a lower part of the furnace, passing the mixed gases carrying gaseous and vaporous products of distillation through condensing and washing apparatus for recovery of distillation products, removing a portion of the mixed gases substantially equal to the gas production of the distillation and the gaseous products of combustion and returning the remainder of the gas to the distilling zone of the furnace, and passing the returned gas through a part of the condensing apparatus as a cooling agent and for the return of heat to the furnace.

13. A method of smelting ore, which comprises distilling volatiles out of fuel admixed with ore and at the same time reducing the ore, the distilling and reducing operations being effected by the heat and gases of a smelting operation together with addition-

al non-oxidizing gas in such amount and at such temperature that the distillation is effected without cracking condensable volatiles of the fuel, and then admitting air to the solid distillation residue and reduced ore while the same are still hot from the distilling and reducing operation to smelt the ore.

14. A method of smelting ore, which comprises distilling volatiles out of fuel admixed with ore and at the same time reducing the ore utilizing the heat and gases of a smelting operation, passing a current of reducing gas of lower temperature than the smelting gases in contact with the admixed fuel and ore during the distilling and reducing operations, the amount of said gas of lower temperature being such that the volatiles will be evaporated out of the fuel at temperatures below the fusing temperature of the fuel, and then burning the solid residue of the distillation with air to smelt the admixed reduced ore.

15. A method of smelting ore, which comprises distilling volatiles out of fuel admixed with ore and at the same time reducing the ore utilizing the heat and gases of a smelting operation, circulating a substantially constant amount of reducing gas additional to the smelting gases in contact with the mixed fuel and ore, the temperature and amount of said additional gas being such that the partial pressures of the vapours of volatiles in the fuel will be so lowered that the volatiles will evaporate out of the fuel into the stream of combined added and smelting gas at temperatures below the melting temperatures of the volatiles, and burning the solid residue of the distillation with air to smelt the admixed reduced ore.

16. A method of smelting ore, which comprises distilling volatiles out of fuel admixed with ore and at the same time reducing the ore utilizing the heat and gases of a smelting operation, circulating a substantially constant amount of reducing gas additional to the smelting gases in contact with the mixed fuel and ore, the temperature and amount of said additional gas being such that the partial pressures of the vapours of volatiles in the fuel will be so lowered that the volatiles will evaporate out of the fuel into the stream of combined added and smelting gas at temperatures below the melting temperatures of the volatiles, treating the combined added and smelting gases after passage through the distilling fuel and reducing ore for removal of volatiles of the ore, reheating the cleaned gas for subsequent use, removing cleaned gas from the circulation at approximately the rate of production of gas in the smelting operation, and burning the solid residue of the distillation with air to smelt the admixed reduced ore.

17. A method of smelting ore, which comprises distilling volatiles out of fuel admixed with ore and at the same time reducing the

ore utilizing the heat and gases of a smelting operation, preventing sticking or agglomeration of the fuel and ore during the distilling operation by passing in contact with the fuel and in admixture with the smelting gas a stream of non-oxidizing gas and at such rate and temperature that the volatiles are evaporated out of the fuel at temperatures below their melting temperatures, and burning the solid residue of the distillation with air to smelt the admixed reduced ore.

18. A method of smelting ore, which comprises distilling volatiles out of fuel admixed with ore and at the same time reducing the ore utilizing the heat and gases of a smelting operation, moving the solid distillation residue and reduced ore while still hot from the distilling and reducing operations into a smelting zone and subjecting the fuel and reduced ore to an air blast for combustion of the fuel and smelting of the ore, transferring the hot products of combustion into contact with distillable fuel and unreduced ore, and adding to the hot products of combustion an accumulation of similar gas at such rate and temperature that the volatiles in the fuel are evaporated at temperatures below their melting temperatures, treating the gas for separation of volatiles and removing treated gas at substantially the rate of production of gas in the smelting operation.

In witness whereof, I have hereunto set my hand.

FREDERICK T. SNYDER.