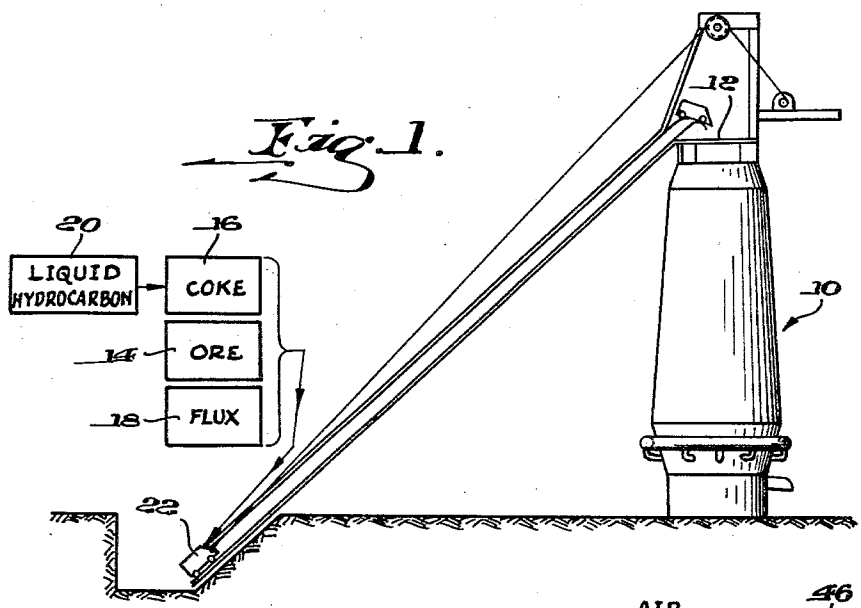
July 20, 1965 K. W. STOOKEY 3,196,002

BLAST FURNACE PROCESS

Filed April 17, 1963

Fig. 1.



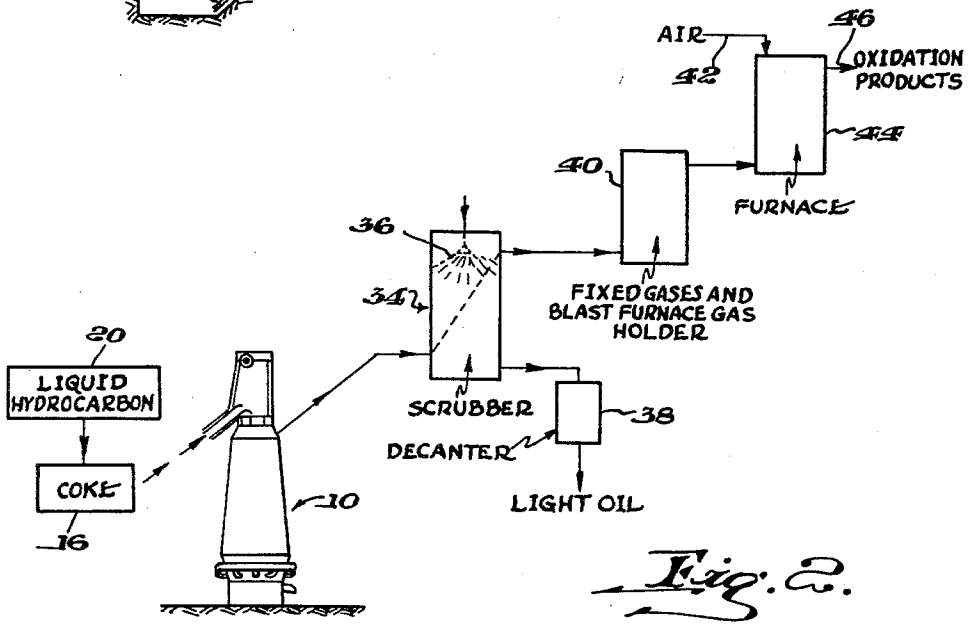


Fig. 2.

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BLAST FURNACE PROCESS

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1 Claim. (Cl. 75—41)

This invention relates to a new and improved process for operating a blast furnace, or shaft type furnace, into which liquid hydrocarbon materials are introduced into the top of the furnace, in addition to the conventional materials of ore, coke and flux. These hydrocarbon materials may be refinery bottoms, Bunker oils, pitches, tars and the like, and the purpose of which is to crack their complex molecules into gases, lower boiling point liquids and carbon. Heat of the furnace, a large part of which will be waste heat carried by the top gases, will supply the thermal energy required to decompose these hydrocarbons and will be assisted by the catalytic effect of the iron oxide.

Similar materials, including gases and coals, are now being introduced through the tuyeres at the hearth zone of the blast furnace, mainly for more restricted reasons and with much different results than is the objective of my invention. The basic purpose of bottom injection of supplementary fuels is to substitute lower priced fuels for the higher priced blast furnace coke. This aids in the economics of production but there are still problems associated with it that have need of solution.

A major one is related to the drop in the B.t.u. value of the top gas as the temperature of the hot blast is increased to accommodate the injection of maximum amounts of supplementary fuels. Any of these injectants have an endothermic effect on temperatures and reactions in the hearth zone and would cool the hearth to a point that smooth furnace operation is adversely affected so their use must be accompanied by a related rise in the temperature of the hot blast. Because of the additional thermal energy supplied by the hotter blast, hearth flame temperatures are increased but less coke is required for direct reduction to produce a ton of hot metal. However, as less coke is consumed, there is less CO produced for indirect reduction and there is less left in the top gas or, what is generally better known as blast furnace gas. CO is the main fuel constituent of these gases so that heating, or thermal, value drops in relation to the reduction of the CO. As hotter blast temperatures are used, and the trend is in this direction, the blast gases will become even more lean.

Because of the great volumes of blast gases evolved in the production of pig iron, it is an economic necessity to utilize this gas for plant fuel needs. Large quantities of it are used to heat the blast furnace stoves, which in turn heat the blast air, for plant boiler firing, gas engine fuel, furnace heating, etc. Approximately 100,000 cubic feet of these gases are generated in the production of each ton of pig iron, the historical B.t.u. of which has ranged from 90 B.t.u. to 100 B.t.u. To state it more graphically, from 8,000,000 to 12,000,000 B.t.u. of gaseous energy is contained in the top gas from each ton of hot metal produced. This is roughly equivalent to the energy in ⅓ ton or more of coke and consequently, plant fuel balances are equated with this energy.

As the trend to higher hot blast continues, more of this gas is required to heat the blast air which leaves less for other purposes. Also, with the use of hotter blast, less coke is required and therefore less coke must be produced which in its turn will result in less coke oven gas being produced and available for plant fuel. In many cases, this will require the use of supplementary fuels in the plant energy balance.

In integrated, foreign steel works, it is becoming the

practice to sell coke oven gas to local domestic utility distribution systems to which its value is greater than for steel mill use. This makes it attractive for the mills to sell all the gas to the utilities that can be made available and use supplementary and less expensive fuels for their own use, to the greatest extent possible. Since most of these plants are designed to use gaseous fuels, adaptation for supplementary liquid or solid fuels imposes added costs and difficulties. It would be advantageous to be able to convert any of these supplementary fuels to gas phase materials if it can be done, easily and economically.

Further, the combustion of blast furnace gas, even under the best condition is difficult because of its low B.t.u. content and high percentage of inerts and a combustible, mixture of this gas and ambient air will not maintain ignition in the open. Consequently, provision must be made to increase the mixture temperature to get acceptable flame speed and heat release in combustion work through the use of recuperation or regeneration. In certain applications, the mixture can be impinged on refractory walls or targets which aid in maintaining ignition. An example of this latter, is the conventional stove combustion system in which the mixture is injected tangential to the chamber wall in such a way that it strikes the wall and spirals upwardly through the combustion chamber.

As is well known, because of its high inert content the gas has a low flame temperature since the heat required to heat the inerts leaves little thermal energy for the work when furnace temperatures exceeding 2000° F. are required. Preheating for these conditions is an absolute need but is a substantial problem in itself.

As the reduction of coke consumption accompanies improvements in blast furnace operating techniques and the B.t.u. of the top gases continues to deteriorate, the problems and difficulties in the use of blast gases are compounded. Problems are also extended to the plant fuel balance.

The gases can be cold enriched with some other gas that is richer in thermal value or by vaporizing some liquid hydrocarbon to the extent its vapors will remain as a fixed gas in relation to the partial pressures and temperatures existing. Typical of this practice, is the growing custom in Europe to saturate this gas with naphtha vapors. The B.t.u. of the naphtha is relatively expensive but it has offsetting advantages in that it calls for little capital expenditure, reduces the problems in combustion, etc.

Accordingly, it is one of the objects of the present invention to enrich the blast gas by thermally cracking a low cost feed stock within the furnace to obtain fixed gases.

Another object of the invention is to replace a part of the blast furnace coke by free carbon which is contained in the low feed stock and is produced as a byproduct of the cracking process.

Another object of the invention is to produce a quantity of light oil from the less valuable feed stock which is in the form of very heavy Bunker "C" oil or the like. This valuable light oil byproduct can then be used as desired.

A still further object of the invention is to utilize the low cost feed stock as a means for retarding fluidization of fines and, also, for cooling the upper part of the blast furnace instead of using water or the like.

It is an important feature of the present invention that I have caused the top portion of the furnace to serve as a modified oil gas generator in order to obtain gasification of oil. Since the oils, are, in many locations of the world, less expensive than coke, it is possible to achieve a multiple purpose in using the oils as a part of the burden, and in converting the upper part of the blast furnace to an oil gas generator, among these purposes are those of: (1) enriching the blast furnace gas, (2) replacing higher

priced coke with lower priced Bunker "C" oil coke or other equivalent oil coke, (3) obtaining a valuable source of light oils which are condensed and separated from the original charge stock.

Other objects and features of the present invention, will become apparent from a consideration of the following description, which proceeds with reference to the accompanying drawings wherein:

FIGURE 1 is a schematic view of a blast furnace illustrating the flow of materials in accordance with the present invention; and,

FIGURE 2 illustrates in block diagram form the passage of solid materials, liquid phase oil, gasified materials, condensed oils and fixed gases.

In accordance with the present invention, the blast furnace **10** receives, at the top **12** of the blast furnace the usual raw materials comprised of ore **14**, coke **16** and flux **18** constituting the burden of the blast furnace **10**. There is combined with these materials, a quantity of liquid phase hydrocarbon material **20** which may be in the form of refinery bottoms, Bunker oils, pitches, tars and the like and which is hereinafter referred to under the generic term "oils."

The liquid phase hydrocarbon oil is added into the top of the furnace along with the conventional charge materials, preferably the coke, because of its greater porosity and surface area and before it is raised by the skip **22**. Alternatively, the oil may be injected onto the coke in the charging bell. It is not recommended, however, to inject the oil on the burden after charging because of the high rate of mechanical carry-over of oil into the gas downcomers and gas cooling-and-cleaning equipment by the velocity of the rising gases and before the oil has been thermally and catalytically processed. Moreover, in the method of introducing the oil, it is necessary that it be evenly distributed through the burden in order to get uniformity of treatment and maximum benefits of the invention.

In contrast with previous proposals of converting heavy oils by involving expensive plants and other complicated operating control mechanisms, there is proposed in the present invention a utilization of the top portion of the furnace as an oil gas generator to obtain reforming of the oil. As the burden descends, together with oil, it is exposed to successively greater temperature and the heavy complex oil molecules are broken down into simpler ones which make up light oil, and gasified fractions. Volatilized portions of the heavy oil are broken down into fixed gases, some into light oils, and still other parts of the oil are converted to petroleum coke, which adheres as a lamination to the outer surface of the coke and thereby serves as substitute for the coked coal and its function as a reducing agent for the ores.

Portions of the volatilized heavy oil will recondense on the surfaces at the upper end of the burden and will then be carried back to the hotter zones for further processing. There is therefore a pronounced distillation effect of the cracked products in which all of the oil is ultimately converted either to petroleum coke or to gasified product, or to light oil, these products being sufficiently volatile so that they will not recondense at higher parts of the blast furnace.

The product which passes out of the furnace in vapor phase is led to gas cooling and scrubbing equipment designated generally by reference numerals **34**. At this point, light oils are condensed and separated from the blast furnace gas and the resulting product is in the viscosity range of No. 3 oil. The blast furnace gas, comprised of carbon monoxide and nitrogen is enriched by fixed gases such as methane, ethane, etc., and which accompany the blast furnace gas flow and are indistinguishable from the blast furnace gas to greatly increase its B.t.u. value from 90 B.t.u./ft.^{3} to an appreciably higher value.

The light oil which has been produced, is about 1.7 times the cost of the high carbon/hydrogen ratio heavy oil fuel which was originally added to the top of the blast furnace. Therefore, the low cost oil is greatly upgraded at a very slight cost.

The following analyses of two different Bunker oils and an estimate of their breakdown into the three product streams, is as follows:

	Sample No. 1 Flash Cracked Residuum	Sample No. 2 Low Level Cracked Residuum
API. Gravity	8.6	22.0
Sp. Gr. @ 60°	1.011	0.0218
Lbs./Gallon	8.423	7.680
Percent Bottom Sediment	1.00	0.20
Pour Point, ° F	25	Below 0
Viscosity, Furol Sec	25 @ 122°	14 @ 77°
Sulphur	0.56	0.05
Carbon	88.9	87.4
Hydrogen	9.80	11.1
Undetermined	0.74	1.03
Conradson Carbon	14.0	6.0
Carbon: Hydrogen Ratio	9.2:1	7.87:1
B.t.u./Lb	18,277	18,788
B.t.u./Gallon	153,947	144,215

The cracking results obtained with these two products are summarized as follows:

	Sample No. 1	Sample No. 2
Carbon, B.t.u	43,106	29,500
Gas, B.t.u	51,316	52,380
Light Oil, B.t.u	59,525	62,335
	153,947	144,215

The cracking results are influenced by the size of furnace operated and the amount of oil added is adjusted in order to give best results for iron production, which remains, of course, the basic purpose of the blast furnace and it is intended that the present invention will in no way detract from that principal purpose. There is a limit to the amount of oil which the blast furnace can receive without affecting its operation. The upper limit of usable oil is dictated by the amount of waste heat contained in the top gas and available as energy to crack the oil. If the oil addition exceeds that at which waste heat is available to effect conversion, the blast furnace operation will slow down and force the indirect reduction zone farther down in the furnace. While this result can be tolerated to some extent, it is essential that the direct reduction zone is not directly penetrated by the oil.

The present invention, is especially suitable where Bunker oil by virtue of the economics of availability, can be used as a substitute for the coke which it replaces at least in part to reduce the costs of operation. Bunker "C" oil is less expensive than coke in many places where, owing to cost of transportation and availability, the Bunker "C" oil represents a savings in cost per B.T.U. For example, Bunker oils by salt water, delivered in small tanker lots to many parts of the world represent a savings when compared with coke on a B.T.U. basis. Therefore, when any quantity of it can be substituted for coke, savings will be obtained.

Referring to FIG. 2, the blast furnace gas which is enriched by the addition of fixed gases, is led to a scrubber **34** having a water spray **36** which condenses the light oils and separates them from the fixed gases and blast furnace gas. The light oils are then separated by a decanter **38**. The blast furnace gas and fixed gases are then led to a gas holder **40** and can then be mixed with air from line **42** to corm a combustible mixture which is burned within a furnace **44** and the oxidation products are vented to atmosphere through line **46**.

While the oil is descending with the burden within the blast furnace, its conversion is catalyzed by the iron ore. That is, the iron oxide or other metal oxides which form a part of the burden facilitate decomposition of the heavy

oils to petroleum coke fixed gases and volatilized hydrocarbon. Therefore, the uprising hot blast gas is put to the useful purpose of converting the Bunker "C" oil and such sensible heat is not merely dissipated as was previously the case with the practice of putting water into the top of the furnace to protect the furnace against exposure to heat. Now the oil serves the function of a coolant in place of such water.

The oils which are contemplated in the present invention, include more than the Bunker oils, and the particular oil selected will depend upon the delivered cost which will of course vary throughout the world. The variation is due primarily to availability and the cost of transportation. Normally, Bunker "C" oil is considered a difficult material to handle unless it is heated but it can be transported in substantial quantity by water transport and is less costly in many areas of the world where blast furnace operations take place.

The blast furnace gas produced by the present invention is enriched, and provides a ready source for heating the hot air blast to the temperatures required for modern blast furnace operation. The higher air blast temperatures conserve the quantity of coked coal and therefore the Bunker "C" oil is useful not only as a direct replacement for coked coal but also during operation, by virtue of increasing the temperature of the hot blast this also contributes to reduced coked coal consumption.

In operation, the Bunker "C" oil or its equivalent is added in liquid phase either with the coke or mixed with the burden generally, prior to charge at the top of the blast furnace. The blast furnace operation continues according to conventional operation, except that the volatilized product which is obtained from the top of the blast furnace (FIGURE 2) is led to a light oil recovery system which includes cooling and scrubbing equipment, settling and decantation tanks.

The light oil is removed and the fixed gas which is formed as a byproduct of conversion of the Bunker "C" oil is mixed and is indistinguishable from the blast furnace gas, upgrading its B.t.u. content. The light oil can be used for numerous heating applications and is much more adaptable to use than the Bunker "C" oil and is substantially more valuable.

The particular quantity of Bunker "C" oil added to the coke will depend upon the operation of the furnace. What dictates the upper limit of oil used is the available quantity of waste heat in the top gas and is available as thermal energy to convert the oil. In other words, since the top portion of the blast furnace is used as a converter, the amount of heat available for such conversion must not be exceeded by the quantity of oil introduced to the blast furnace; otherwise, the oil will tend to slow down the preheat of the burden and force the indirect reduction zone farther down in the furnace.

All of the oil which is added to the top part of the furnace, is converted to petroleum coke, light oil or fixed gas as it moves downwardly with the burden. The petroleum coke in turn serves as a direct replacement for the original charge of coke, the fixed gas forms a part of the blast furnace gas and to that extent upgrades its B.t.u. value; and, the light oil is separately recovered as a valuable byproduct of the conversion system and, being substantially more valuable than the coke, provides an incidental valuable material generally useful in steel producing facilities at no additional cost. It has further been found, that the original charge of Bunker "C" oil added at the top of the blast furnace, tends to retard fluidization of fines and therefore precludes contamination of the atmosphere which often occurs by the upflowing stream of gas within the blast furnace.

Although the present invention has been illustrated in connection with certain selected example embodiments, it will be appreciated that these embodiments are only illustrative of the invention and are by no means restrictive thereof. It is reasonably to be expected that those skilled in the art can make numerous revisions and adaptations of the invention to suit individual design requirements and it is intended that such revisions and adaptations of the invention which incorporate the herein disclosed principles, will be included within the scope of the following claim, as equivalents of the invention.

I claim:

In combination with a blast furnace operation utilizing a hot air blast, the steps comprising: charging at the upper end of the blast furnace a quantity of ore-flux material-and-coke which is combined with a liquid phase heavy hydrocarbon material, internally cooling the blast furnace charge solely with said hydrocarbon material which is added to the charge of ore-flux material-and-coke to effect such cooling internally of said blast furnace at the upper end thereof, progressively heating such hydrocarbon material to effect its thermal decomposition into petroleum coke and volatilized hydrocarbon byproduct, removing and cooling such volatilized hydrocarbon byproduct, condensing the removed volatilized hydrocarbon byproduct and separating such condensed material from the uncondensed hydrocarbon which is volatilized.

References Cited by the Examiner

UNITED STATES PATENTS

1,565,689	12/25	Van Slyke	75—42
2,124,905	7/38	Bratasianu	75—41
2,593,257	4/52	Bradley	75—42

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