

Sept. 27, 1955

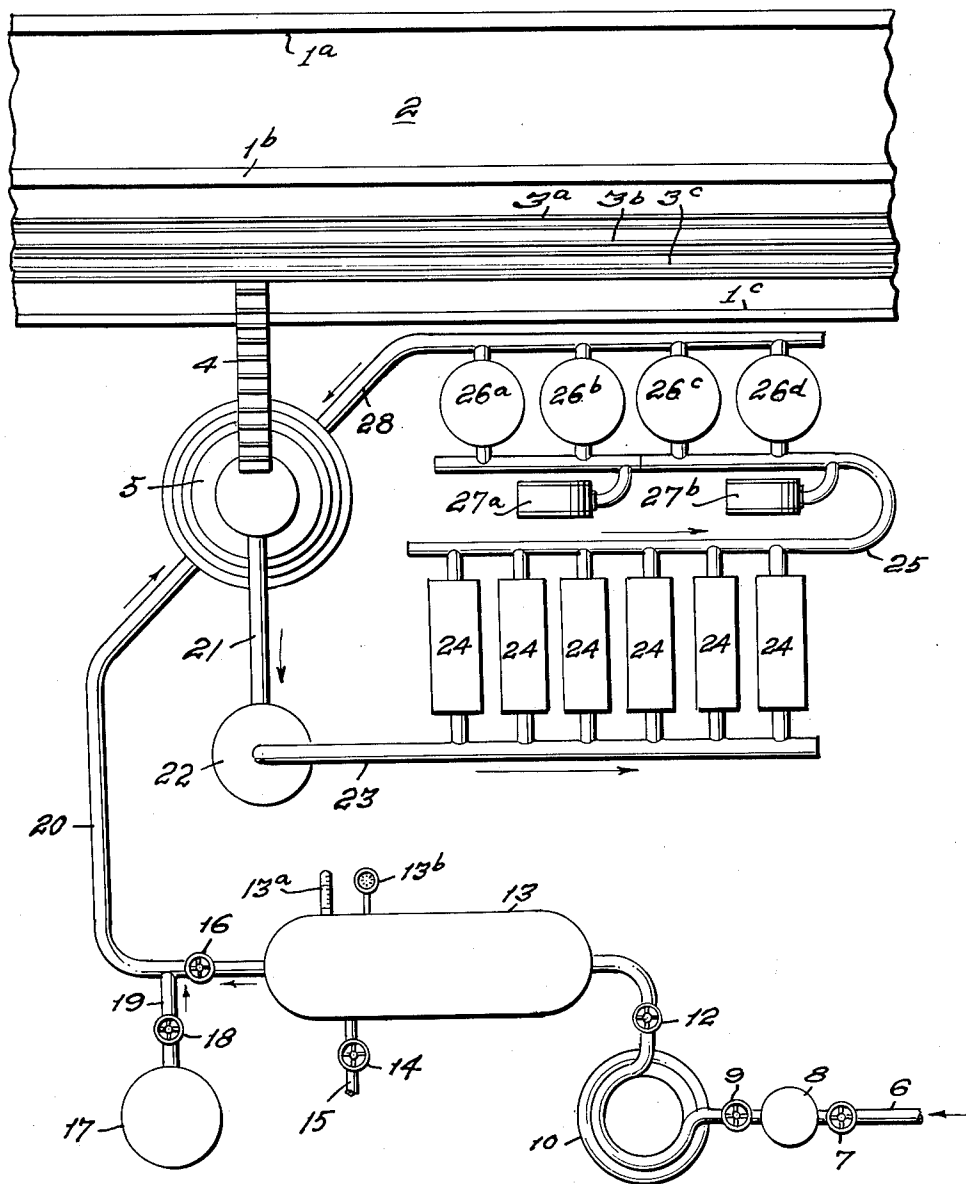
E. S. POMYKALA
SMELTING METHOD

2,719,083

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3 Sheets-Sheet 1

Fig. 1.



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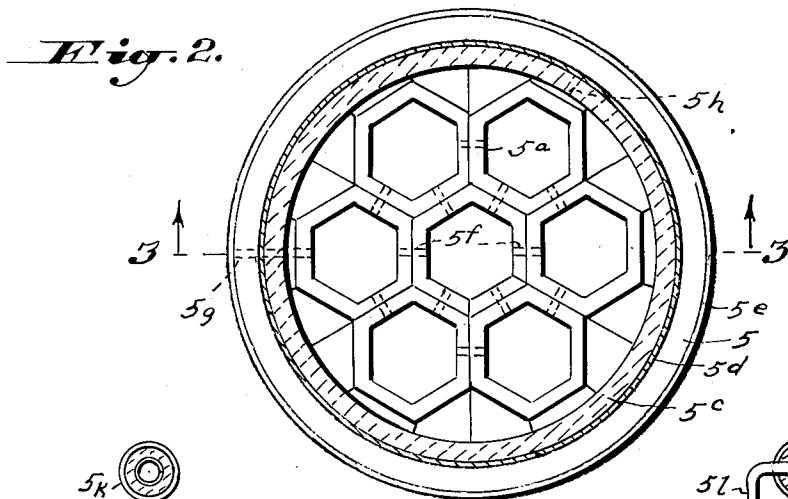
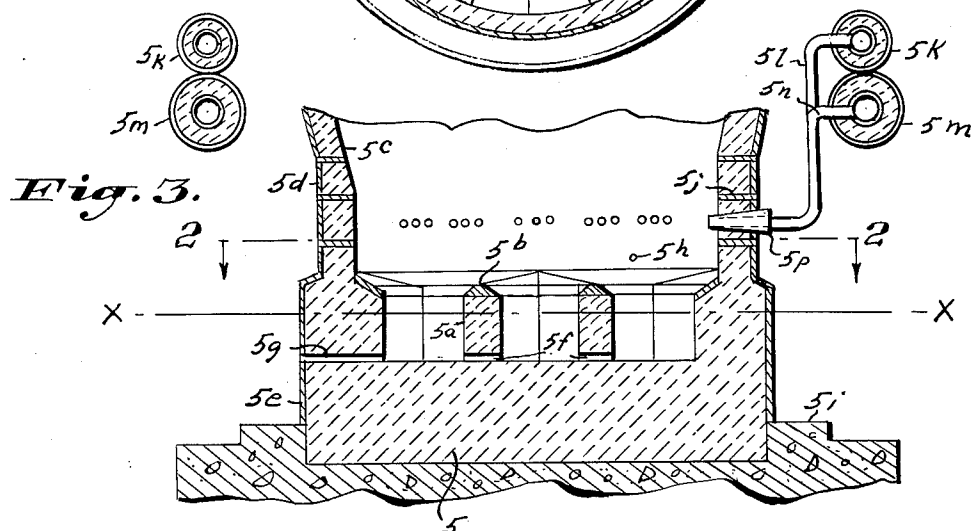
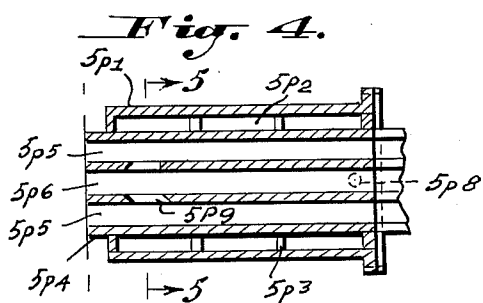
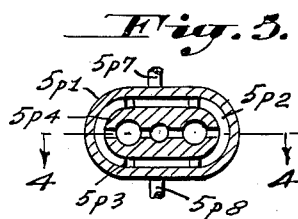
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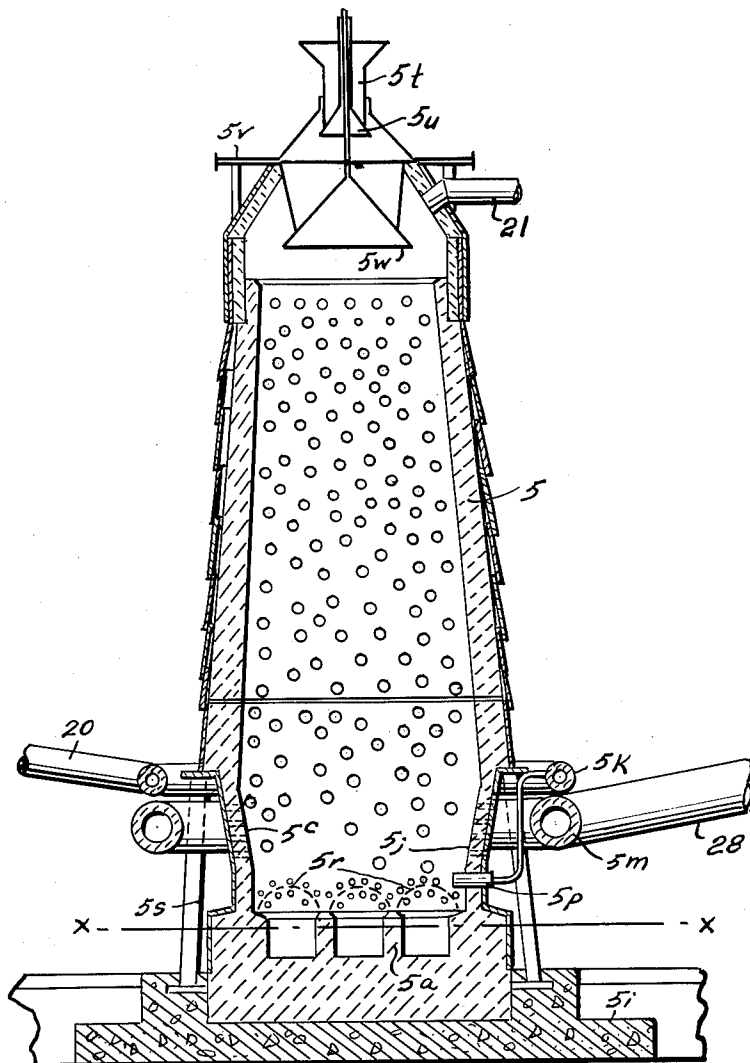
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Fig. 6.



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2,719,083

SMELTING METHOD

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9 Claims. (Cl. 75—42)

This invention relates to smelting method. It is primarily devised for smelting iron particularly for localities where suitable coking coal is not readily available but where other fuels such as natural gas or oil are plentiful.

This application is a continuation-in-part of my earlier application Serial No. 287,844, filed May 15, 1952, which is in turn a continuation-in-part of Serial No. 220,864, filed April 13, 1951, now Patent 2,690,333, issued September 28, 1954.

At the present time smelting of iron is done almost exclusively by means of coke. The process consists in blowing highly preheated air through blast pipes called tuyeres into the lower part of a high furnace or stack (about 100 feet high) filled with ore, coke, and a flux, generally of limestone. In the lower part of the furnace opposite the tuyeres, the combustion is intense and temperatures are very high, about 2000° C. and the burden of the furnace at this point is mostly glowing coke, and a little slag and iron in liquid form percolating down. The ore in general is reduced to metal at a point above this level. The ore is reduced mostly by carbon monoxide gas which is formed by combustion or chemical union of hot glowing coke and a blast of air. In the lower part of the stack the temperatures are so high that carbon dioxide (CO₂), usually formed in the combustion of coke, can exist only momentarily and is immediately reduced by the glowing carbon to carbon monoxide (CO).

In the smelting of iron coke has a multiple function.

(1) Coke, by its combustion furnishes heat for the process.

(2) By its combustion, or chemical union with air it forms carbon monoxide (CO) gas, which is the main agent used in the reduction of the ore.

(3) Coke or carbon together with carbon monoxide also protect the reduced iron from oxidation by the blast air.

(4) Finally coke has the important function as a load carrying medium supporting the overburden of ore and fluxing stone in the furnace.

All these functions are important, but I have discovered that part of these functions can be performed advantageously by other fuels which may be more readily available or cheaper in the locality wherein the furnace is situated. Thus, I have found that liquid petroleum stocks can be preheated and cracked to produce hydrocarbon gases and that these gases, admixed with air and/or oxygen, can be introduced into the lower part of a blast furnace with a consequent saving in the amount of coke required. I have also found that if methane is available this can be mixed advantageously with the cracked petroleum gases before introduction into the furnace. Proportions of 1 part methane to 3 parts cracked gases is very satisfactory, for example. My process is operative with hydrocarbon gases whose ratio of carbon to hydrogen varies from 1:4 to 1:1 and, of course, the source of these gases is

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immaterial. Thus gases from cracking stills or natural gas can be used, for example. Gases from liquid petroleum stocks have an ultimate analysis of approximately C₆H₁₂ while aromatics, such as benzene, have a ratio of carbon to hydrogen of 1:1. Such gases are very explosive if not properly handled, and one of the principal objects of this invention is to show how this process may be carried out with safety.

Since in the operation of this new process for smelting iron and other ores, considerable carbon monoxide and hydrogen will flow out of the furnace with the exhaust gases, which will still consist mainly of nitrogen, it is possible to utilize these exhaust gases in the manufacture of ammonia, methyl alcohol, and other chemicals resulting therefrom.

In the operation of this new process coke will still be required in an amount ranging from about 40 to 80% by weight of the total smelting fuel. Smaller amounts of fluxing ingredients will also be required since the amount of impurities needing fluxing will be less.

Another object of this invention is to improve the quality of the product manufactured namely, to reduce the carbon content in the smelted iron.

With these and other objects and advantages in view, the details of construction and operation are further illustrated by having reference to the accompanying drawings wherein:

Fig. 1 is a general schematic plan and arrangement of the apparatus,

Fig. 2 is a sectional plan of the blast furnace or smelting stack taken on line 2—2 in Fig. 3, approximately at the elevation of the tuyeres,

Fig. 3 is a vertical section of the lower part of the blast furnace taken on line 3—3 in Fig. 2,

Fig. 4 is a horizontal section of a tuyere taken on lines 4—4 in Fig. 5,

Fig. 5 is a vertical sectional view of a tuyere taken on lines 5—5 of Fig. 4,

Fig. 6 is a general sectional view of a blast furnace.

In all views similar numerals or numerals and letters designate similar parts.

Numerals 1a, 1b, and 1c, indicate retaining walls in the storage area shown in Fig. 1. A general storage area for ore, coke and limestone is shown at 2. Railroad tracks 3a, 3b and 3c are used for general transportation of smelting burden. Chain conveyor 4 is used for delivering smelting burden from the bins or storage area into the furnace. The blast furnace is shown at 5.

Now starting at the bottom of Fig. 1, numeral 6, indicates the main oil feed line; 7 is a valve in the line; 8 is an oil pump; 9 is another valve on the outlet side of the pump; 10 is a heating coil or heat exchanger; 12 is an outlet valve; 13 is a hot hydrocarbon gas receiver; 13a is a gas temperature indicator; 13b is a gas pressure indicator; 14 is a gas relief valve and 15 is suitable piping for gas relief purposes. Numeral 16 indicates main outlet valve for gas from the receiver 13 into main supply line 20. 17 is a receiver or storage tank for nitrogen or other suitable inert gas. Methane can be stored in this tank if it is to be mixed with the other hydrocarbon gases. 18 is a valve in line 19 controlling the flow of this gas from receiver 17 into main supply line 20. Main supply line 20 feeds the hot hydrocarbon gas into suitable bustle pipe 5k, shown in Figs. 3 and 6. From bustle pipe 5k the hot hydrocarbon gas is led through goose neck pipe 51 into tuyeres 5p whence it is discharged into the furnace on the glowing coke of the furnace charge, through aperture 5p6. The heated air comes from the air heating stoves through main feed line 28, into large bustle

pipe 5m, whence it is directed through goose neck pipes 5n (Fig. 3) into combined tuyeres 5p. The hot air is discharged into the furnace on the glowing charge through nozzles 5p5 and 5p6 (Figs. 4 and 5) since part of the air passes from the air pipes through the apertures 5p9 in the hydrocarbon pipe and thus mixes with the hydrocarbon gases before the latter are discharged through nozzle 5p6. As in existing practice there are multiple number of tuyeres, generally about twelve units for a standard size furnace.

The furnace 5 in general follows present standard practice, except for the double bustle pipe, special tuyeres, combined for leading hydrocarbon gas together with standard air blast and special design for the bottom of the furnace at the crucible for giving a better support to the overburden than is the practice at present.

The blast furnace construction is shown in Fig. 6 and the details are shown in Figs. 2, 3, 4 and 5.

In the construction of the crucible a departure is made from the present practice, inasmuch as cross walls 5a are built in. These are arranged in a honeycomb fashion but may follow other patterns. All cross walls are interconnected through holes 5f for discharging molten iron or other metals. Cross walls are capped with metallic coping 5b, like tungsten, tantalum or suitable alloys of these metals which are not fusible at the temperatures existing in the blast furnace. The purpose of these cross walls is to give better support to the coke and overburden than is the practice at present. In the existing furnaces the coke and overburden above is supported partially on the converging walls of the bosh (which is that part of the furnace directly above the crucible) and partially on the bottom. The coke tends to dome over or arch over to the converging walls of the bosh but because of the large spans and also because a great deal of coke is consumed here there is a slippage and a considerable amount of coke below the lines of equilibrium falls and is pressed down into the crucible. This is undesirable since in this manner coke comes in contact with and saturates the molten iron.

It has been found that iron freshly smelted as it percolates down through the glowing coke has a carbon content of about 1½ per cent. After it is in contact with carbon in the crucible the percentage of carbon is raised to about 4.2 per cent. This is not good since nearly all this carbon has to be burned out in making steel, either in the Bessemer converter or the Siemens open hearth furnace. This processing is quite expensive. By placing these cross walls 5a, as shown in Figs. 2, 3 and 6 the spans of any domes of coke are greatly lessened. This is shown as 5r in Fig. 6. Lines of stability are more easily maintained and the small amount of coke that falls below floats in the molten slag which is indicated by the boundary line x—x, between the slag and molten iron in Figs. 3 and 6. By so doing, contact of coke with molten iron is minimized and saturation of iron with carbon is avoided.

The remainder of the details of the furnace follow standard practice. In Fig. 2 5c are walls of the furnace at the bosh, 5d are structural bands at the bosh, 5e are structural bands at the crucible, 5g is outlet hole for molten metal, 5h is slag hole, 5i (Figs. 3 and 6) is a concrete slab foundation, 5j are wall cooling plates, 5s (Fig. 6) are structural columns supporting the main walls of the furnace.

In the upper part of the furnace 5t (Fig. 6) is the chute for loading the burden of the furnace. This burden of coke, ore and flux is lifted by means of a chain conveyor 4 (Fig. 1) and deposited in chute 5t, whence it is lowered by stages into the furnace by means of movable bells, 5u and 5w. 5v is a working platform.

In construction of the tuyeres 5p a departure is made from the existing practice. Where formerly it was one water cooled blow pipe, it now has three apertures or nozzles, one for hot hydrocarbon gas, 5p6, two for hot air blast 5p5. The nozzles are made from one casting

or forging 5p4 and surrounded with a continuous wall 5p1. The whole is so built that it is water-tight. Between 5p4 and wall 5p1 there is a water space 5p2, for circulating cooling water; 5p3 are spacing lugs; 5p7 (Fig. 5) is cooling water inlet and 5p8 is water outlet.

The gases discharged from the furnace can be handled in a standard manner. They are discharged to main exhaust pipe or downcomer 21 and are led into dust catcher 22 (Fig. 1). From there they are led by pipe 23 into a battery of dust precipitators 24, thence through another duct 25 which leads a part of the hot gases into regenerative stoves 26a, 26b, 26c and 26d. There the exhaust gases are burned, heating the walls of the stoves to a high temperature. After this heat extraction these gases are discharged and a blast of air is circulated through the stoves by means of air fans or blowers 27a and 27b. This air is thus preheated to a temperature of from about 1000° to 1500° F. and is then redirected to the furnace through main air feed line 28.

Since only a part of the exhaust gases are used for heating the stoves, the remainder of the gases can be put to other uses such as power or preferably making chemicals.

Operation.—In the operation of this process, the furnace is loaded with smelting burden as at present, except that the coke content of the charge constitutes from about 40 to 80% by weight of the fuel required to produce smelting. The remainder of the smelting fuel consists of the hydrocarbon gases which are mixed with air and introduced into the furnace.

In the following table the results obtainable using a conventional charge, given in the first column, are compared with those of two typical charges within the present invention. The hydrocarbon gas used in the charge of column 2 is methane or a gas having the ultimate analysis of CH₄, while in the third column the hydrocarbon gases have an ultimate analysis corresponding to C₃H₈. The air blast in each case has a temperature of approximately 1300° F. The hematite ore contains 52% Fe.

Furnace charges and products recovered

Conventional Charge in Pounds	Charge Including CH ₄ in Pounds	Charge Including C ₃ H ₈ Gases in Pounds
2,000 C 1,000 CaCO ₃ 4,000 Fe ₂ O ₃ 8,000 Air	500 CH ₄ 1,050 C 800 CaCO ₃ 4,000 Fe ₂ O ₃ 6,000 Air	600 C ₃ H ₈ 900 C 800 CaCO ₃ 4,000 FeO ₃ 6,000 Air
Products: 1,000 Slag 2,000 Fe 2,200 CO ₂ 2,900 CO 23 H ₂ 6,500 N ₂ 600 H ₂ O	Products: 800 Slag 2,000 Fe 1,500 CO ₂ 2,000 CO 35 H ₂ 4,700 N ₂ 1,400 H ₂ O	Products: 800 Slag 2,000 Fe 1,500 CO ₂ 2,000 CO 30 H ₂ 4,700 N ₂ 1,300 H ₂ O

The temperature of the hydrocarbon gas used in reducing the charge of column 2 is about 1200° F. while that used in column 3 is about 1100° F. It will be noted that in the runs of columns 2 and 3 the furnace gases contain a much higher content of water vapor than in the case of the run of column 1. This fact, coupled with the use of a lower pressure required to force lighter gases through the furnace burden, results in less dust in the exhaust gases. This constitutes an added advantage of my process.

The coke employed in the charge of column 2 of the above table constitutes about 68% of the total weight of the fuel, while that of column 3 constitutes about 60% of the fuel.

In another specific example using the same operating conditions a furnace charge, consisting of 900 pounds benzene (C₆H₆), 650 pounds coke, 800 pounds lime-

stone, 4000 pounds Fe_2O_3 and 6300 pounds air, is smelted in accordance with my process. In this operation the gaseous products obtained are 1550 pounds CO_2 , 2100 pounds CO , 30 pounds H_2 , 4900 pounds N_2 and 1350 pounds H_2O . 2000 pounds of iron and 800 pounds of slag are obtained. In this example the coke constitutes about 42% by weight of the weight of the fuel. Such low percentages of coke are particularly suitable for smelting easily reducible ores such as copper ores.

At the start of my process the fires are started in the usual manner and the furnace is brought up to smelting temperatures on air blast alone, at about 12 pounds per square inch gage pressure. As this is taking place the generation and heating of hydrocarbon gas is started. This in general follows existing practice in the petroleum industry for making gasoline. Gasoline in the modern practice is largely made from a heavier stock such as gas oil or naphtha generally by one of several crackling processes. The base stock is heated either in the liquid state or injected into a heated chamber in the vapor state and in contact with a suitable catalyst whereby the heavier molecules are broken down into smaller units.

In my new process great precision is not required and a greater variety of size of molecules can be used. What is required is a hot hydrocarbon gas heated to a temperature within the range of from about 700° to 1400° F. or preferably heated to about 1200° F. (650° C.), and at approximately 12 pounds gage pressure. Small molecular size is desirable but not essential mainly since gas of smaller molecular structure causes less expansion in the products of combustion. This heating and cracking process can be performed in a hot coil 10 (Fig. 1) and a heated chamber 13 operating in the neighborhood of the temperature and pressure indicated above. When methane is used as the hydrocarbon gas the preheating temperature should be roughly 100° F. higher than that used in the case of hydrocarbon gases having an ultimate analysis of C_3H_8 or with higher ratios of carbon to hydrogen. I prefer a preheating temperature range of from about 900° to 1400° for methane and from about 700° to 1300° for the other hydrocarbon gases.

When the smelting furnace is well heated and operating on full blast, it may then be switched over to hydrocarbon gas fuel. This is done in the following manner. The lines 20 conducting the hot hydrocarbon gas from the receiver 13 have to be first flushed with inert gas preferably nitrogen which may be stored in tank 17. Nitrogen gas can be secured and purified from the exhaust gases issuing from the regenerative heating stoves 26a to 26d if desired.

After the lines are flushed, the hot hydrocarbon gas can be let in through valve 16. As valve 16 is opened, the nitrogen valve 18 is closed. The hydrocarbon gas is forced in the lines at 12 pounds per square inch gage pressure. This hot gas at a temperature of from about 700° to 1400° F. drives out the nitrogen and is forced into the furnace through tuyeres 5p. Just before issuing from the nozzle 5p6, it is mixed partially with the air blast which is blown at slightly higher pressure than the hydrocarbon gas. This mixing is done by means of apertures 5p9 and the hydrocarbon gas is burned partially at the tip of the nozzle 5p6. The quantity of air introduced is controlled so that the gases issuing from the furnace are reducing in character. Sufficient air must be introduced, of course, to consume the coke present in the charge and incompletely to burn the hydrocarbon gases. The latter are not burned completely as is evident from the above table. The effluent gases contain sufficient carbon monoxide and hydrogen so that they have a substantial heating value and can be burned wherever desired or sent to storage. All of the air required can be introduced through the tuyeres 5p together with the hot hydrocarbon gases or part of the air can be introduced into the bosh of the furnace through separate nozzles at the same level or at a level slightly below that of the tuyeres 5p.

In my new process the temperatures at the level of the tuyeres are slightly less than those produced in the conventional process and average from about 2000° to 3600° F. However at higher levels the interior temperatures in the furnace are higher than conventional temperatures and average from about 2 to 5% above these conventional temperatures. These higher temperatures result in a higher efficiency of reduction of the ore and enable the reduction of other oxide ores which are difficult to smelt in the conventional process. Reduction with hydrogen would tend to lower the carbon content in the molten iron.

In the interest of safety it should be mentioned that the pipe lines leading from the hydrocarbon receiver to the furnace should always be flushed with nitrogen whenever the furnace is closed down. The operation is similar to but in the reverse to that used when the furnace is started on hydrocarbon gas.

As shown in the above table the gases as they issue from the top of the furnace contain nitrogen as the main component, as well as carbon monoxide, carbon dioxide, hydrogen, water vapor and a trace of impurities. These gases can be treated to separate and recover nitrogen and hydrogen, this mixture being then converted into ammonia by known processes. Or if desired a mixture of carbon monoxide, hydrogen and nitrogen can be separated and by using suitable converters and different catalysts can be converted to methanol by known methods. Also nitrogen necessarily used in this process can be most easily obtained by suitable treating and separating spent flue gases from the heating stoves.

Having described the general features of the process and apparatus of this invention, it is felt others skilled in the art may make changes in arrangement of parts and details without departing from the spirit of this invention or the scope of the appended claims.

What I claim is:

1. In the smelting of iron and other metal oxide ores with the simultaneous generation of reducing gases carbon monoxide and hydrogen in a blast furnace equipped with multijet tuyeres having a central nozzle between adjacent side nozzles, the process which comprises charging such a blast furnace with a mixture of metal oxide ore, coke and slag-forming components, smelting the charge and passing it downwardly through the furnace while supplying smelting heat and simultaneously generating said reducing gases by introducing at the bottom thereof through the central nozzles of said multijet tuyeres gases consisting of hydrocarbons having a ratio of carbon to hydrogen ranging from about 1:4 to 1:1 and preheated to temperatures within the range of from about 700° to 1400° F., mixing the hydrocarbon gases just before they enter the furnace with preheated air blown through said central nozzles, and impinging the mixture on the surface of the glowing charge to produce surface combustion of the gaseous mixture and blowing additional air through said side nozzles, the total air introduced into the furnace being sufficient to consume the coke but insufficient completely to burn the hydrocarbon gases, the amount of coke in the charge being sufficient to supply from about 40 to 80% of the smelting fuel while the remainder of the smelting fuel comprises the hydrocarbon gases which are mixed with the air and introduced into the furnace.

2. The process of claim 1 wherein the air is preheated to temperatures within the range of from about 1000° to 1500° F.

3. The process of claim 1 wherein the oxide ore is hematite.

4. The process of claim 1 wherein the hydrocarbon gas is methane preheated to temperatures within the range of from about 900° to 1400° F.

5. The process of claim 1 wherein the hydrocarbon gases have an ultimate analysis corresponding approximately to C_3H_8 these gases being preheated to temperatures within the range of from about 700° to 1300° F.

6. In the smelting of iron and other ores with the simultaneous generation of ultimate reducing gases carbon monoxide and hydrogen in a blast furnace equipped with multijet tuyeres having a central nozzle between adjacent side nozzles, the process which comprises charging a blast furnace with a mixture of ore, coke and flux, preheating and cracking a liquid hydrocarbon stock to temperatures within the range of from about 700° to 1400° F., supplying smelting heat and generating the required reducing gases carbon monoxide and hydrogen by introducing through said central nozzles of the multijet tuyeres the cracked and preheated hydrocarbon gas mixed with air, and from the side nozzles additional blast air, the total quantity of air introduced being insufficient for complete combustion, the gas mixture introduced through said central nozzle being burned essentially on the surface of glowing carbon while the major heat of combustion is supplied by burning the bulk of the charge by air introduced through the side nozzles of the tuyere.

7. The process of claim 6 wherein the air is preheated to temperatures within the range of from about 1000° to 1500° F.

8. The process of claim 6 wherein methane is mixed with and forms a part of the hydrocarbon gases introduced into the furnace.

9. In the smelting of iron and other metal oxide ores with the simultaneous generation of reducing gases carbon monoxide and hydrogen in a blast furnace equipped with multijet tuyeres, the process which comprises charging said blast furnace with a mixture of metal oxide ore, coke and slag-forming components, smelting the charge

and passing it downwardly through the furnace while supplying smelting heat and simultaneously generating said reducing gases by introducing at the bottom of the furnace jets of hydrocarbon gases preheated to temperatures from about 700 to 1400° F., mixing the hydrocarbon gases in said jets with preheated blast air immediately before the jets enter the furnace and impinging the jets on the glowing charge to produce surface combustion of the gaseous mixture, introducing additional blast air into the furnace in the immediate vicinity of the hydrocarbon-air jets, the blast air so introduced being sufficient to produce more intense combustion and higher heat in the immediate vicinity of the hydrocarbon-air jets, the total blast air introduced being sufficient to consume the coke but insufficient completely to burn the hydrocarbon gases, the amount of coke in the charge being sufficient to supply from about 40 to 80% of the smelting fuel while the remainder of the smelting fuel comprises the hydrocarbon gases which are mixed with the air and introduced into the furnace.

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