

Dec. 16, 1930.

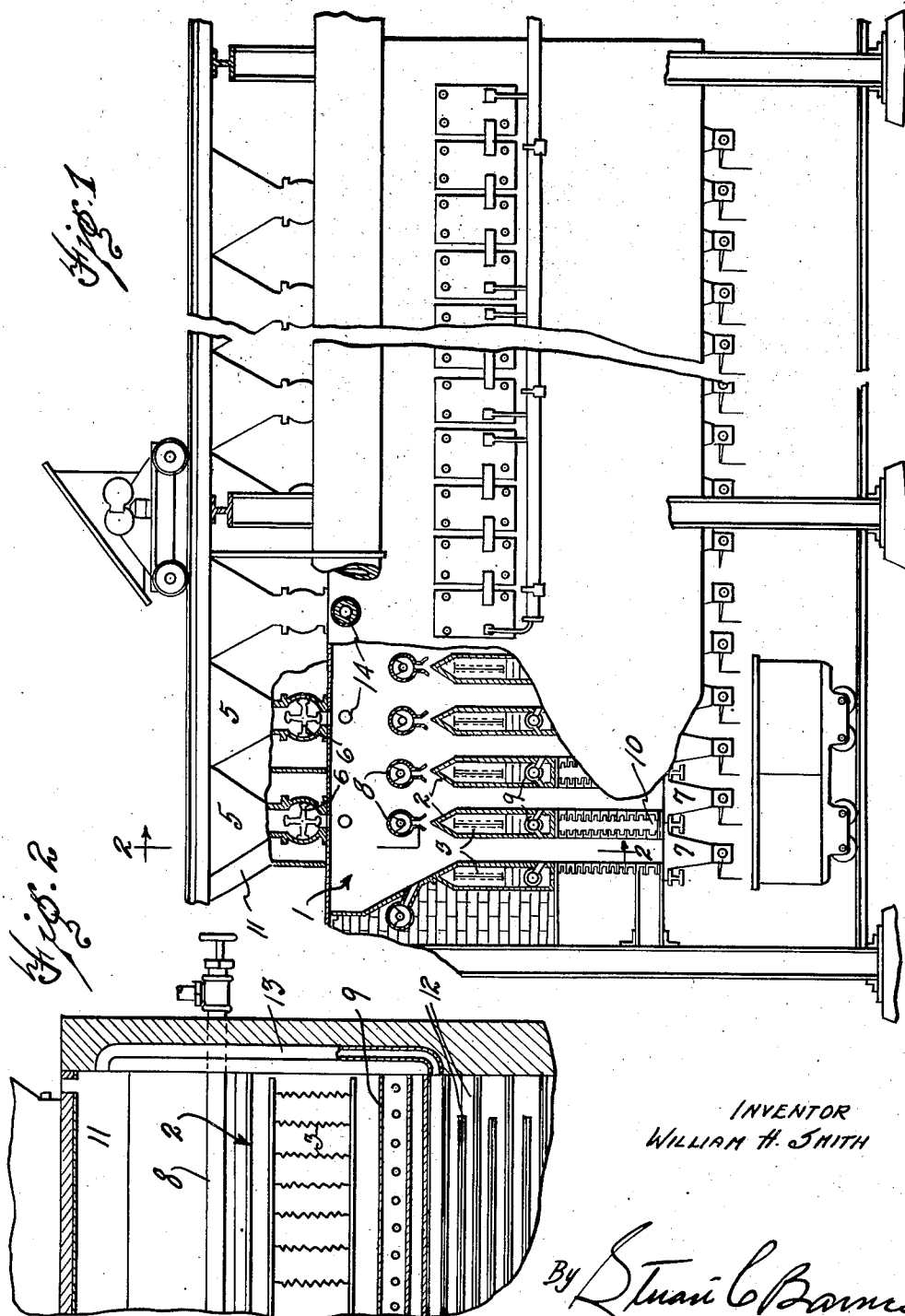
W. H. SMITH

1,785,428

PROCESS OF REDUCING ORE AND CONVERTING HYDROCARBONS

Filed April 4, 1927

4 Sheets-Sheet 1



INVENTOR
WILLIAM H. SMITH

By *Stuart C. Barnes*
ATTORNEY

Dec. 16, 1930.

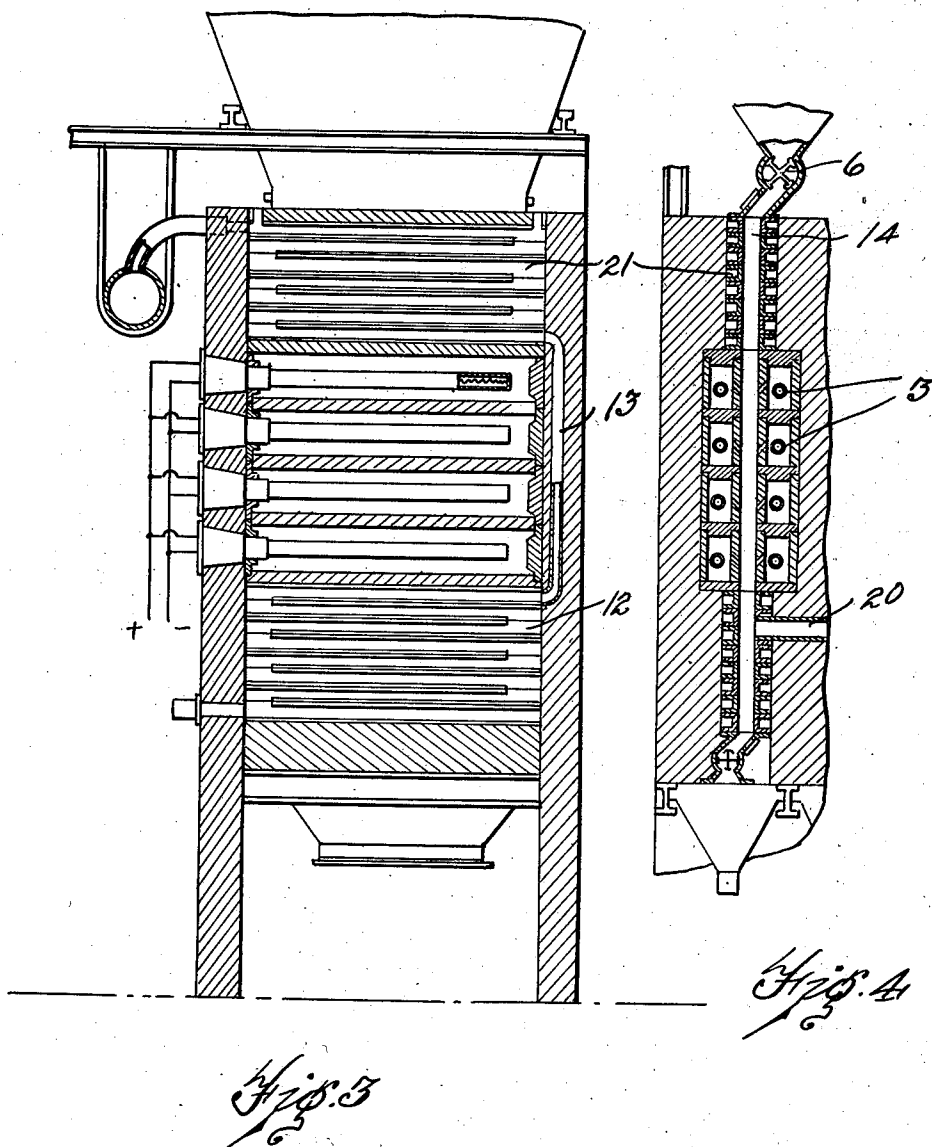
W. H. SMITH

1,785,428

PROCESS OF REDUCING ORE AND CONVERTING HYDROCARBONS

Filed April 4, 1927

4 Sheets-Sheet 2



INVENTOR
WILLIAM H. SMITH

By

Stuart C. Barnes
ATTORNEY

Dec. 16, 1930.

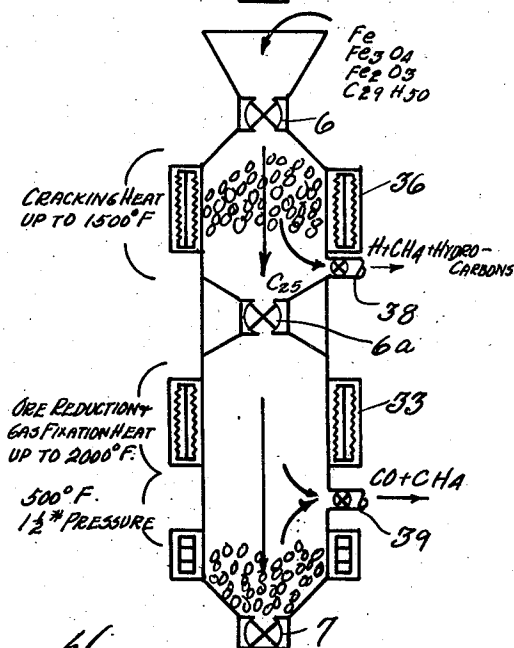
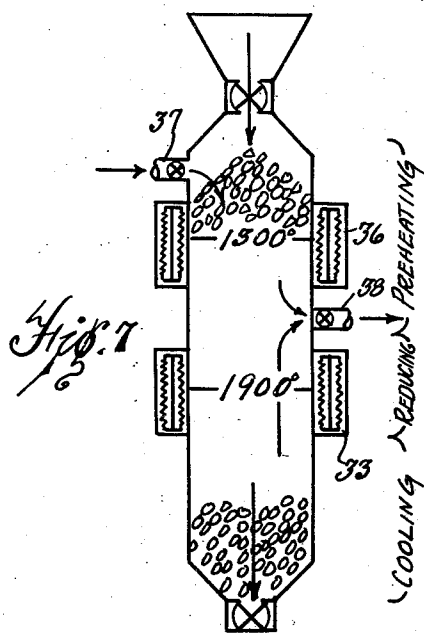
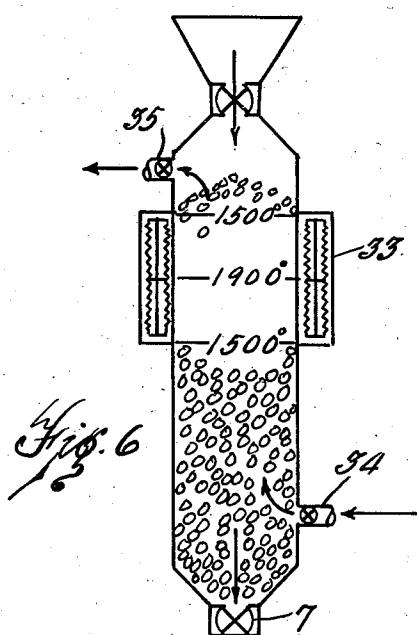
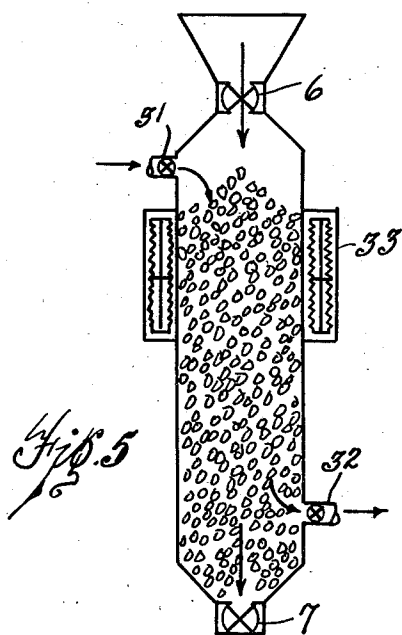
W. H. SMITH

1,785,428

PROCESS OF REDUCING ORE AND CONVERTING HYDROCARBONS

Filed April 4, 1927

4 Sheets-Sheet 3



INVENTOR.

WILLIAM H. SMITH

BY

STUART C. BARNES
ATTORNEY.

Dec. 16, 1930.

W. H. SMITH

1,785,428

PROCESS OF REDUCING ORE AND CONVERTING HYDROCARBONS

Filed April 4, 1927

4 Sheets-Sheet 4

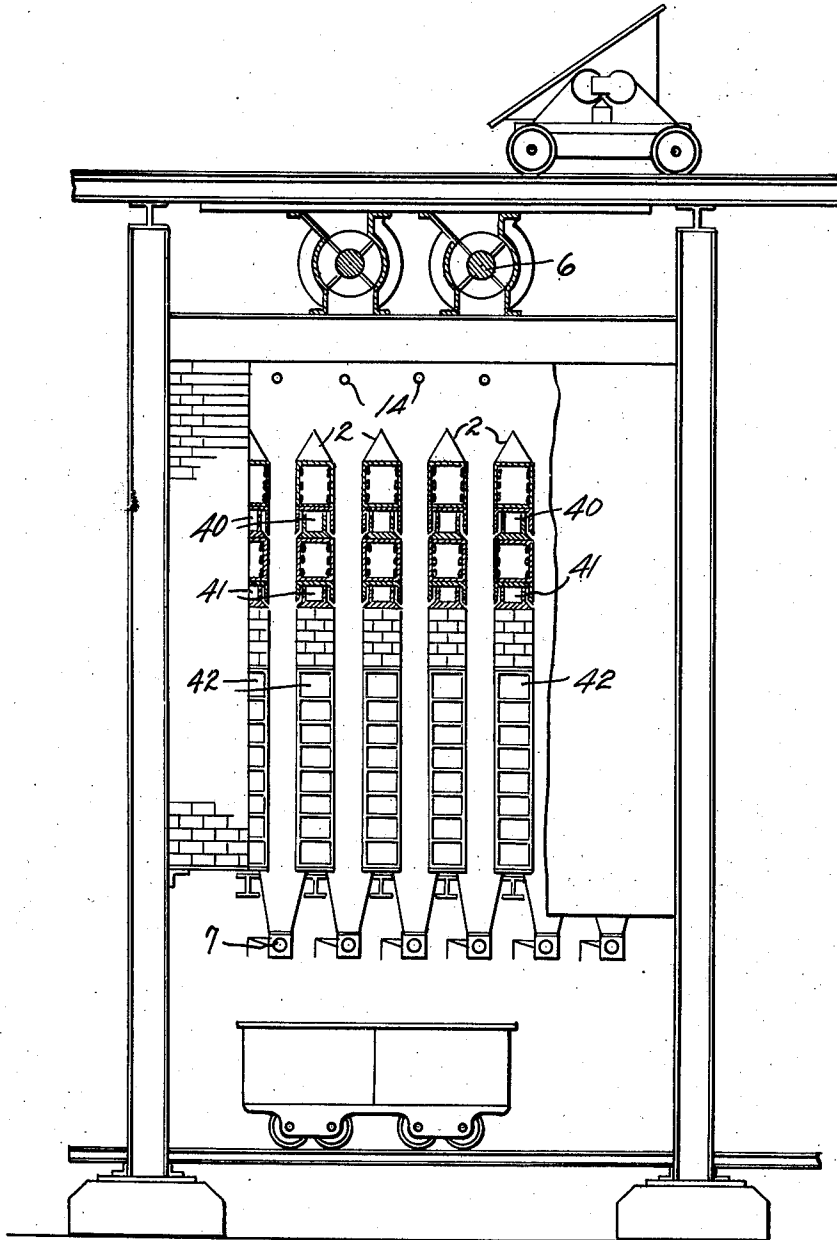


Fig. 9

INVENTOR.

WILLIAM H. SMITH

BY

Stuart C. Barnes
ATTORNEY.

UNITED STATES PATENT OFFICE

WILLIAM H. SMITH, OF DETROIT, MICHIGAN

PROCESS OF REDUCING ORE AND CONVERTING HYDROCARBONS

Application filed April 4, 1927. Serial No. 180,746.

This invention relates to a process of reducing ore and converting hydrocarbons, and has to do particularly with the breaking up of hydrocarbons and the process of reducing iron ore, the reducing and breaking up steps taking place simultaneously and continuously and at relatively low temperatures.

In the past, in the process of reducing ores devices have been designed in an attempt to reduce iron ore, the iron ore being fed through retorts in the presence of reducing agents and at varying degrees of heat. Sponge iron of a good grade has been produced, but at a relatively high cost of manufacture, and in most instances reducing apparatuses and process have been directed solely to the reduction of the ore with the addition of a separate reducing agent utilized entirely as such. On the other hand, in the distilling and cracking of hydrocarbons such as mineral oil, an almost unlimited variety of processes have been utilized which have included the distilling of hydrocarbons with and without cracking, distillation by the novelty of the material treated and cracking of the hydrocarbons in the presence of catalytic material, (in which case the catalytic material quickly becomes poisonous and requires cleaning or removal). These various and almost innumerable processes have usually been accomplished under either relatively high temperatures, or high pressure, or both, and in one or more stages. Such hydrocarbon distilling apparatuses and processes, regardless of the result obtained, have been directed solely to the distillation or cracking process.

It is the object of the present invention to combine ore reducing with hydrocarbon fractionation and distillation, and broadly speaking, it has to do with the process of cracking hydrocarbons in the reduction of iron ore. More specifically, the present invention relates to the method of feeding iron ore in a continuous enclosed stream, applying a relatively low heat to the continuously moving stream of ore by conduction, the temperature being just sufficient to cause reduction of the iron ore without changing the construction of the gangue accompanying same and the addition of hydrocarbons, such as mineral

oils or tars to the enclosed continuously moving ore at a predetermined point or points relative to the reducing zone whereby the hydrocarbons may be vaporized and broken up or cracked in the presence of the ore as a catalyzing influence at a relatively low temperature, without intermission of such catalyzing influence by poisoning or carbon deposit. The poisoning influence of the catalyzers are constantly passing with the ore out of the breaking up or cracking zone of the hydrocarbons and advancing to and through the reduction zone wherein the deposit of carbon unites with the oxygen in the ore to cause the reduction of the iron ore to sponge iron.

The apparatus for effecting this process may comprise a retort or bank of retorts, means for feeding a supply of iron ore continuously or at intermittent periods through said retort or retorts, and means for introducing the hydrocarbons at various points along said retort or retorts into the enclosed mass of iron ore. The retorts for feeding the iron ore are preferably long and narrow in cross section, and arranged in banks whereby to substantially eliminate radiation losses. Accurately controlled heating means are positioned between the retorts and so positioned longitudinally thereof whereby the retort is provided with a preheating, reducing and cooling zone. The introduction of the hydrocarbons to the retort or retorts at the various predetermined points is controlled by the quality of the hydrocarbon products desired and the temperature of the reducing zone. The iron ore passing through the retort or retorts serves as a catalytic agent which is always fresh, and the walls of the retort may be lined with a second catalytic agent, or a second catalytic agent may be passed through with the iron ore. The hydrocarbon derivatives formed by the breaking up of the hydrocarbons in the presence of the lower reducing temperature and the exerting of the catalytic influence, pass off as fixed gases, and the reduced ore discharged after passing the reducing zone and cooled at the discharge ends of the retort or retorts. Various other novel features of this invention will be ap-

parent as this description progresses and will be brought out in the claims appended hereto. The preferred embodiment and apparatus for carrying out my novel process is shown in the accompanying drawings wherein similar characters of reference designate corresponding parts, and wherein:

Fig. 1 is a front elevation partly in section of a combined ore reducing and hydrocarbon converting furnace and showing the preferred manner of forming the retorts and arranging the heating units.

Fig. 2 is a fragmentary transverse section taken on line 2—2 of Fig. 1, the lower part of the structure being shown provided with alternate baffles instead of radiating fins.

Fig. 3 is a transverse sectional view illustrating a modified form of heating elements and flues, and the manner of arranging the same.

Fig. 4 is a fragmentary transverse section taken through one of the retorts formed by the structure shown in Fig. 3.

Fig. 5 is a diagrammatic illustration illustrating one of many ways of introducing the hydrocarbons at different predetermined points into the ore reducing retort.

Fig. 6 is a view similar to Fig. 4 and illustrating diagrammatically the location of the reducing zone relative to the enclosed retort, and the introducing of the hydrocarbons at a point below the reducing zone, and the removal of the gases at a point above the reducing zone.

Fig. 7 is a view similar to Figs. 5 and 6 and diagrammatically illustrating the provision of two positive heating zones, and the manner of passing the hydrocarbons in contact with the ore through only one heating zone.

Fig. 8 is a diagrammatical view similar to Figs. 5, 6 and 7 and illustrating the manner of providing separate preheating and reducing zones, the reducing zone being under positive pressure.

Fig. 9 is a side elevation, partly in section, of an ore reducing and hydrocarbon converting furnace, similar to the structure shown in Fig. 1, but showing specific means for feeding oil shale or similar material through the heating units themselves.

This application is a continuation in part of my application on a combined ore reducing and hydrocarbon refining apparatus, Serial No. 157,225, filed December 27, 1926.

It will be understood that various types of furnaces may be utilized in carrying out my novel process, the main common points of such furnace structures only being that they provide an enclosed retort or retorts for receiving and preferably for continuously feeding ore to be reduced, the provision of means for providing a heating zone and maintaining such heating zone at a relatively accurate predetermined temperature, and means of introducing hydrocarbons at any desired point

in the retort or retorts whereby the hydrocarbons will be distilled and cracked in the presence of the iron ore or reduced ore, and the iron ore reduced in the presence of the hydrocarbons or hydrocarbon deposits. It will be seen that my process relates broadly, therefore, to the method of distilling and cracking hydrocarbons in the process of reducing iron ore, or the broad invention may be stated the other way around, the method of reducing iron ore in the process of cracking and refining hydrocarbons.

The process will probably be more readily understood by the description of apparatus which may be utilized in carrying out the process. In the form of apparatus illustrated in Fig. 1, the retort may be generally designated 1 and it preferably extends the length of the furnace and is open at the top portion whereby to receive a contiguous mass of ore. This retort is preferably of general rectangular shape and divided up into a series of smaller retorts by means of heating units 2 which extend transversely of the main retort 1 so as to divide the mass of ore into separate columns which are relatively long and narrow in horizontal cross section. These heating elements or units 2 may be of any size desired, and arranged in any manner desired so long as the general mass of ore is broken up and the heat applied at intervals in the ore body.

These heating units preferably extend across the furnace and are hollow in the upper portion thereof to receive suitable electric resistance elements which may be designated 3. The ore which is designed to be fed en masse into the furnace to surround the heating units and to be in turn divided up by said heating units 2, is adapted to be fed into the furnace by means of suitable hoppers 5 and suitable revolving valve members 6. Suitable valve members or hoppers 7 are provided at the bottom of each retort formed by the heating elements 2, and both the valve 6 at the top, and the valve 7 at the bottom of each retort are air tight whereby to permit the reduction of the ore, or the distilling and cracking of the hydrocarbons or both under a predetermined pressure if desired. It will be obvious that the feeding valve 6 may be rotated at any speed desired whereby the reduction of the ore and the resulting production may be accurately controlled. It will be understood in the preferred carrying out of my process that the iron ore is preferably continuously fed to the retorts, or at least intermittently, so as to produce a substantially continuous action whereby fresh ore is at all times presented to the incoming hydrocarbons. However, it will be understood that my process may be successfully carried out if the retorts are filled up at relatively infrequent intervals.

In carrying out the introduction of my

hydrocarbons to the retorts I preferably provide a series of valve inlets 8 and 9, the inlets 9 in the drawings being positioned just above the heating zone defined by the electrical resistance elements 3, and the inlets 10 being positioned at the bottom part of such heating zone. It will be understood, however, that any number of inlets may be provided for introducing the hydrocarbons into the long and narrow retorts, and in actual practice where different qualities of hydrocarbons including various oils are available, and where different fractionations and distillations are desired, each retort will be provided with a plurality of valved inlets spaced at different points relative to the reducing zone. The inlets 9 may be positioned within the heating units 2, as clearly shown in Fig. 1, and the hydrocarbons, such as mineral oil, fed into the bottom part of such heating unit, as at 10, and then conducted to the valves 9 whereby to serve as a cooling medium for cooling the reduced ore passing down between the heating units.

The hoppers 5 are preferably enclosed by suitable casings 11 whereby the incoming ore may be preheated if desired. In Fig. 2 I have shown a slightly modified form of furnace, in that the bottom part of the heating unit 2 is divided up into a series of alternately positioned baffles 12. When such a modified structure is used the hydrocarbons are preferably fed directly into the retorts through any one of a series of inlets 8 and 9 without preheating. In this particular arrangement the air is introduced into the baffles 12, forming a part of the heating units 2, and as the air is circulated back and forth by the baffles it serves to cool the reduced ore and to be in turn heated. The heated air is then preferably conducted by means of suitable conduits 13 to surround the hoppers 5 to thus preheat the incoming ore. Suitable outlet conduits 14 are provided to communicate with the interior of the main retort 1. As this retort is entirely closed and the ore and hydrocarbons heated by conduction, it will be obvious that the outlets 14 will conduct away the various gases formed in carrying out my process. Such gases may be conducted to any suitable container, or they may be separated, condensed or otherwise taken care of as desired.

The temperature of the heating units 2 may be accurately regulated and controlled by means of electric resistance units. These units are so positioned so as to accurately apply heat around a certain zone of each retort. The heat at the central or hottest part of this zone may be maintained preferably around 1800 to 2000 degrees Fahrenheit, but the particular heat to which such units are maintained may vary considerably within the desires of the operator, the production required, and the quality of the ore being reduced and

hydrocarbon cracked. The point is, that the heat is applied within the mass of ore and accurately maintained at the correct, relatively low temperature, sufficient to cause reduction of the ore. The separate streams of ore are relatively long and narrow whereby such flat streams are penetrated uniformly and thoroughly by the heat from the resistance units. The ore, when delivered through the hoppers 7, will be comparatively cool through the cooling effect of the air or incoming hydrocarbons whereby such ore may be delivered without being subjected to oxidation.

In carrying out my steps of converting hydrocarbons in the process of reducing ore, the hydrocarbons, such as mineral oil, may be introduced through the valve inlets 8 or 9 or any other point or points as desired, as will be later described. The oxides passing through the retorts to be reduced constitute one catalytic material, and chromium or nickel may constitute another catalytic agent. Such chromium or nickel, or other similar catalyzer may be present as the lining of the retorts or may be introduced together with the introduction of the iron ore in the form of nickel shot, nickel gauze or other similar forms which are easily salvaged after they have been passed through the gas. In some instances I prefer to add a quantity of reduced sponge iron with the iron ore to be reduced whereby to assist the catalytic action in the converting or cracking of the hydrocarbons.

In the general carrying out of my process the iron ore together with other catalytic agents such as nickel chromium or reduced sponge iron is fed into the retorts. Cooling, reducing, preheating zones are maintained around each retort and the iron ore is fed downwardly in such retorts and progressively through the preheating, reducing and cooling zones, the maximum heat at the reducing zone being relatively low compared with ordinary blast furnace practice. The hydrocarbons, in the form of oils or other forms, are introduced into the respective retorts at predetermined points, and due to the presence of catalytic agents, the breaking up of the hydrocarbons is accomplished at relatively low temperatures, and the precipitated carbon in such fractionations of the hydrocarbons will pass with the material to be reduced to the higher temperatures (but still relatively low, approximately 1800° F.) and react with the oxides present to reduce the ore and form a (CO) gas.

In the general introduction of hydrocarbons into the retorts, the heavier hydrocarbons will be vaporized and broken up and changed into lighter liquids or into gases forming lighter liquids in the presence of a catalyzer or catalyzers to prevent them from combining with the oxygen at the lower tem-

peratures of ore reduction to form water vapors. In this manner lighter hydrocarbons are formed at relatively lower heat temperatures than take place in the so-called cracking process of refining hydrocarbons, as a stronger active catalytic agent will be present in the continuously passing ore, being mixed with the ore or formed in the walls of the retort. The iron oxide, as it passes through the reducing zone, will release its oxygen to the carbon or hydrogen present and be reduced to sponge iron, the oxygen combining with the excess carbon deposits from the hydrocarbons to form carbon monoxide. As a result of this arrangement and catalytic reaction the hydrocarbons, if introduced at the proper point, will be fractionated or cracked, some hydrogen will be released at the same time and will combine with carbon, which may be released by the cracking process to form a fixed gas, such as methane (CH_4) due to the presence of catalyzers. It will thus be seen that by continuously passing the oxides through the closed retorts and adding heavy hydrocarbons, such as mineral oil or tars, that I am able to convert or crack the heavier hydrocarbons, preferably into lighter hydrocarbons and also to produce a higher and richer gas as containing hydrogen or hydrogen compounds, and gases such as methane, illuminates and saturates. It will be understood, however, that this cracking of the hydrocarbons and the forming of resultant gases may take place to a certain extent in the presence of finely divided iron or iron ore only as a catalyzer, but I prefer magnetite Fe_3O_4 , or ore with nickel or chromium to increase the catalytic reaction. When hydrogen and carbon are present in my retorts, in the presence of sponge iron, nickel and other catalytic agents at a temperature around 500°F ., and a pressure around $1\frac{1}{2}$ pounds, the carbon will combine with the hydrogen to form CH_4 , which is approximately 97% fixed. It will thus be seen that with the liberating of hydrogen and carbon in the reducing zone that as such hydrogen and carbon pass downwardly through the cooling zone they will combine, in the presence of the catalytic agent or agents to form methane (CH_4).

In the use of the modified form of apparatus illustrated in Figs. 3 and 4, in carrying out my novel method, the retorts are formed as individual retorts from the point of entrance to the point of discharge. It will be obvious that suitable inlets may be provided at different points along each retort in such bank of retorts for introducing the hydrocarbons at different points relative to the reducing zone represented by the resistance elements 3. It may be desired, however, to pass the ore to be reduced through one retort and in the next adjacent retort to feed the reducing material or hydrocarbons, particularly so when such reducing materials are

associated with undesirable gangue such as oil shale. When such reducing materials or other combined materials are added to the separate retorts and heated by conduction, I preferably provide a suitable passageway 20 between the respective retorts whereby the gases from the reducing material or other hydrocarbons will be conducted to the ore carrying retort whereby to serve as a reducing material. Some of the hydrocarbon gases formed will be subjected to catalytic action and be broken up to form various lighter hydrocarbons. All the gases formed will pass upwardly and out through the outlet 14. In Fig. 3, a conduit 13, similar to that shown in Fig. 2, is provided for conducting the heated cooling gases or air from the cooling zone, around the reducing zone and up to the preheating zone, which may be designated 21.

In Figs. 5, 6 and 7 I have illustrated diagrammatically several different methods of introducing the hydrocarbons to the continuously moving stream of ore or catalytic material. In Fig. 5 the retort, diagrammatically illustrated, may include the intake port for the hydrocarbons 31, the outlet port 32, and the heating unit as 33. If the heating unit 33 in this modification is maintained at reducing temperature, approximately 1900°F ., and the hydrocarbons introduced at point 31 pass downward under increasing temperatures in the direction of the reducing zone, end fractions of the hydrocarbons result, and as the hydrocarbons encounter the rising temperatures in the reducing zone hydrocarbons and hydrogen are liberated and residue carbon proceeds downwardly into the reduction zone to react with the oxygen in the ore to form a CO gas. The hydrocarbons added are preferably such as to produce an excess of carbon to insure a positive formation of the CO gas. It will also be understood that some of the hydrogen liberated will combine with the ore as a reducing agent forming, as a result, H_2O . The carbon and hydrogen released as a result of the heating of this hydrocarbon will continuously pass downwardly and in the presence of the sponge iron or other catalyzer in the form of either nickel or chromium, etc., will, when a temperature around 500°F . is reached, combine to form methane (CH_4). In this process, due to the presence of catalyzers, the gases formed are released through the port 32, the reduced ore and other catalysts continuously passing through the retort at all times to present constant, fresh catalytic material. In this particular process pressure in the retort will be beneficial to increase the reducing action and the forming of the gases; therefore, I preferably maintain a slight pressure within the retort by inherent reaction of the materials or by mechanical means.

In the modification illustrated in Fig. 6,

the hydrocarbons enter the retort at the point 34 and are removed at the point 35. The heating means 33 is preferably maintained at reducing temperature, as illustrated, and the hydrocarbons enter the reduction chamber below the point of reduction of the iron oxides, and the hydrocarbons become broken to minor fractions by the higher temperatures encountered in the reducing zone. The hydrocarbons being broken up into minor fractions by the passage through the reduction zone will, in the presence of the catalytic agents present, pass off as illuminating gases, such as H_2 , CH_4 , and CO gas. If desired, the temperature of the heating element 33 in Fig. 5 will be maintained at approximately 1000° F. whereby to produce cracking of the hydrocarbons and no appreciable reduction of the iron ore. In this case the unreduced ore and carbon will be discharged through the valve 7 and can then be passed through the retort shown in Fig. 6, in which case the carbon will serve as a reducing agent when the carbon and ore pass through the reducing zone maintained at the higher temperatures. Otherwise, when the ore is introduced into the retort shown in Fig. 6, the hydrogen liberated in the hydrocarbons will serve as a reducing agent or a separate reducing agent must be introduced with the introduction of the iron ore.

In the modification shown in Fig. 7 I have illustrated two separate heating elements, one, 33, representing the reducing zone, and the other, 36, representing a preheating zone. It will be understood, however, that only one heating means 33 may be provided and the outlet ports positioned at points above the heating means. The intake port for the hydrocarbons may be designated 37 and the outlet port 38, but it will be obvious that such ports may be reversed and the same results obtained. By placing the ports as shown it will be obvious that the hydrocarbons may be introduced into the continuously moving stream of ore without encountering the higher temperatures present in the reducing zone, of approximately 1900° F., which temperatures would break up the hydrocarbons into minor fractions. The heating element 36 may be maintained at a temperature, say, of 1300° F., in which case the hydrocarbons passing through this zone will be broken up into major fractions in the presence of the catalytic materials, part of the hydrocarbons may be broken up into CH_2 , CH_4 , C_2H_6 or other major hydrocarbon fractions. The temperature of the heating element 36 is not fixed and may be varied as desired, or in practical conditions the positioning of the outlet port or inlet ports above the reducing zone may be varied whereby to produce fractions of saturated or unsaturated hydrocarbons in major or minor fractionations, as desired. It will further be obvious that an excess of carbon

will be precipitated or formed as residue in the cracking of the hydrocarbons. This carbon will proceed downwardly with the ore to act as a reducing means, and as the reduction of the ore is accomplished the carbon, being present in excess, will combine with the oxygen from the reduced ore to form a CO gas which will be recovered by passing the same out of the ports 37 or 38, in accordance with the particular operation.

It will thus be obvious that by providing a plurality of different ports at various points along my retorts for introducing and taking out the hydrocarbons before and after conversion, that I have provided a process whereby the hydrocarbons may be added to the iron ore or other metallic oxides, preferably containing additional catalyzers in the form of nickel or chromium, at any desired point relative to the reducing zone, up to approximately 1900° F., in accordance to the hydrocarbon products desired by the reaction. In other words, speaking in general terms, when heavier oils and liquids are required, the hydrocarbons are added to the retort to encounter lower temperatures up to 1000° F.; when olefins and gasolines are required, the hydrocarbons are added to encounter temperatures in the retort up to 1500° F.; when excess hydrogen or CH_4 are required, the hydrocarbons are added to the retort so as to encounter temperatures up to 1900° F. These steps indicate major possibilities, but it will be understood that the hydrocarbons may be added to and taken from the retorts in many different ways so as to encounter an almost infinite number of reactions at different temperatures.

In Fig. 8 I have illustrated a further modified form of apparatus for carrying out my novel process of converting hydrocarbons in the reduction of metallic oxides. The various retorts may be provided with separate heating zones maintained at predetermined temperatures by electrical resistance units 33 and 36, or by any other desired means. Between the two heating zones which may be designated a preheating and reducing zone I have provided a suitable air tight valve member 6a, similar to the valve 6, whereby pressures may be maintained at one part of the retort without affecting the reactions or operations in the other parts of the retorts. In operating the structure such as diagrammatically illustrated, the materials fed into the top of the separate retorts may consist of iron ore in the form of magnetite or hematite, with which may be added a certain amount of reduced iron together with the hydrocarbons to be converted, and as shown in the drawings, they may consist of California oils (such as $C_{26}H_{50}$). The preheating temperature maintained by the heating element 36 or the zone between the valve 6 and 6a preferably has a maximum heat under 1500° F.

This temperature of course may be varied in accordance with the fractionating of the hydrocarbons desired, but regardless of the temperature at which the hydrocarbons are cracked, the feeding of the combined ore and the hydrocarbons through the preheating zone will result in the cracking of the hydrocarbons in the presence of temperature up to 1500°, and in the presence of catalysts such as iron ore and the iron or other added catalytic agents. The cracking process will result in the liberating of hydrogen, methane and other hydrocarbons in accordance with the temperatures maintained. The carbon residue from the cracking process will pass on down through the reducing zone with the preheated iron and through the valve 6a together with the part of the hydrogen given off in the cracking process. This carbon will combine with the preheated iron ore in passing through the reducing zone to react with the iron ore and thereby reduce the same to sponge iron. The carbon being in excess will form CO instead of CO₂ and will pass out through the outlet 39. Hydrogen being present, in the presence of the carbon will unite with the carbon to form a fixed gas (CH₄) when such carbon and hydrocarbon reach a cooler part of the zone at approximately 500° F., in the presence of a catalytic agent which may be the reduced iron or other added catalyst. The iron, together with whatever gangue there may be, will be passed outwardly through the outlet valve 7. In this reducing of the iron ore and in the formation of the fixed gas or gases some positive pressure is preferable, and this positive pressure may be the result of the reaction and the expanding of the gases themselves in the reducing zone, or may be established by mechanical means.

In Fig. 9 I have illustrated a further modification of an apparatus for carrying out my novel combined process of reducing ore and converting hydrocarbons. This apparatus, or furnace, is quite similar to the structure illustrated in Fig. 1 with the exception that I have provided suitable transverse conduits 40 and 41 which extend transversely of the furnace or longitudinally of the heating units 2. These conduits are enclosed and are preferably provided with suitable feeding means (not shown) at each end thereof, whereby suitable oil shale or other oil burning rock or material may be introduced and fed through these conduits. The heating elements in the separate heating units 2 are so arranged as to not only heat the streams of ore by conduction but to also heat the material being fed through the conduits. As shown, the conduits 40 are positioned at approximately centrally of the heating elements, defining the reduction zone, and the conduits 41 are positioned at the bottom of such zone. It will be under-

stood that any number of conduits of 40 and 41 may be provided at different heights whereby to introduce the gases resulting from the heating of the oil shales, or other hydrocarbons into the ore stream at different points relative to the temperatures maintained in the reducing zone. Each conduit 40 or 41 is provided with suitable apertures which are spaced longitudinally of the conduits 40 whereby to feed the gases emitting from the oil shale into the thin flat stream at various points transversely of said stream or streams. The bottom parts of the heating units 2 may be provided with suitable flues 42, similar in construction to flues shown in Fig. 2, whereby said suitable baffles are provided for baffling the incoming gases or air to cool the reduced ore. As shown, the gases formed from the heating of the oil shale and from the catalytic action between the ore and gases will be taken out through the outlet ports 14, but it will be understood, that suitable outlet ports may be provided at any height desired whereby to remove the gases from the retorts at any point in the travel of the iron ore. It will thus be obvious that I have here provided means for removing the hydrocarbons from the oil shale, or similar material, utilizing such liberated hydrocarbons to act as a reducing agent for the iron ore, and to either crack the hydrocarbons or pass the same through the highest temperature zone to merely form illuminating gases in the presence of the iron ore, or other material, as a catalytic agent.

In the various apparatuses disclosed for carrying out my novel process of reducing ore and converting hydrocarbons, I find that whenever excess carbon remains it is carried forward or downward with the stream of oxides and reducing material to form CO gas. In this reaction the catalysts do not become poisoned by the deposit of carbon or the presence of poisonous gases, as the catalytic powers of iron and its oxides are always in excess of the catalytic effects required, and by their cleanliness in the reaction and the reduction, and because of the continuously moving mass of oxides and reducing materials through the retorts, excess deposits of carbon or poisonous gases cannot remain in the catalytic areas. It will be seen that this process differs materially from other processes where catalysts are used and where iron oxides are used as permanent catalytic agents, being only changed or removed when poisoned with gas or carbon. It also differs from other processes in that use is not made of water vapors as a means of sweeping or cleaning the catalysts.

In carrying out my process of reducing metallic oxides in forming fixed gases, the walls of the reduction chamber may be formed of catalytic materials or catalysts

may be associated with the oxides to be reduced. In actual practice, however, I preferably utilize the several catalytic powers of iron and its oxides. I have found that iron ore in the form of magnetite, because of its magnetic influence, is active as a catalyst up to 1400° F., and that up to such temperature of 1400° F. is more active as a catalyst than hematite. In some cases also I may prefer to add certain proportions of reduced iron to the hematite or magnetite ore being fed into the reducing retorts.

It will be understood that in carrying out my process in some instances pressure will be beneficial in carrying out the action, while in other instances positive pressure will have no beneficial action whatsoever. As I have enclosed my retorts by means of the air tight valves at each end it will be obvious that I may maintain any desired pressure within the retorts whereby to carry out the particular reaction desired, such pressure resulting from the reactions within the retort or from mechanical means.

Attention is also called to the fact that when hydrocarbon oils are introduced into the moving stream of ore that such oils mix with the particles of ore or catalytic material with a turbulent or tortuous motion, thus increasing the catalytic action by effecting greater contact between particles.

What I claim is:

1. In the art of reducing metallic oxides and cracking hydrocarbons without melting the charge, the steps of preparing a charge containing the oxides to be reduced, adding a heavy hydrocarbon to the charge, continuously feeding the charge through a fixed temperature zone maintained at a temperature sufficient to crack the hydrocarbons in the presence of the materials of the charge removing the cracked hydrocarbons at a predetermined point, relative to said zone and completely reducing the ore without melting during the same operation by a reducing agent present in the charge.

2. In the art of reducing metallic oxides and cracking hydrocarbons, the steps of preparing a charge containing the oxides to be reduced, adding a heavy hydrocarbon to the charge, continuously feeding the charge through a zone heated to a temperature sufficient to crack the hydrocarbons in the presence of the materials of the charge, feeding the ore and a reducing agent liberated in the cracking of the hydrocarbons through a reducing zone to reduce the charge, and removing the cracked hydrocarbons during said reducing action and at a point spaced from said reducing zone.

3. In the art of reducing metallic oxides and cracking hydrocarbons in an enclosed retort, the steps of preparing a charge containing the oxides to be reduced, continuously adding a heavy hydrocarbon to the charge,

continuously feeding a fresh charge of oxides through a zone heated to a temperature sufficient to crack the hydrocarbons in the presence of the continuously fresh materials of the charge to produce gases and vapors and carbon, feeding the charge through a reducing zone removing the gases and vapors formed, and reducing the ore by the carbon present in the charge.

4. In the art of reducing metallic oxides and cracking hydrocarbons, the steps of preparing a charge containing the oxides to be reduced, continuously adding a heavy hydrocarbon to the charge, continuously feeding the charge through a zone heated to a temperature sufficient to crack the hydrocarbons in the presence of the materials of the charge to produce gases and vapors and carbon, feeding the charge through a reducing zone, removing the gases and vapors formed at a predetermined point relative to the reducing zone, and reducing the ore by the carbon resulting from the cracking of the hydrocarbons.

5. In the art of reducing metallic oxides, the steps of preparing a charge containing the oxides to be reduced, continuously feeding the charge through an enclosed retort, maintaining a reducing zone at a constant predetermined temperature, adding hydrocarbons to the charge and simultaneously cracking the hydrocarbons and reducing the metallic oxides by continuously feeding the mixture so as to subject the hydrocarbons to a temperature sufficient to crack the same in the presence of the materials of the charge, and reducing the metallic oxides by a reducing agent as the charge passes through the zone of predetermined temperature.

6. In the art of reducing metallic oxides, the steps of preparing the charge containing the oxides to be reduced, continuously feeding the charge through an enclosed retort and through a zone maintained at a fixed positive reducing temperature, adding heavy hydrocarbons to the charge at a predetermined point relative to said fixed zone whereby to heat the hydrocarbons to a temperature sufficient to crack the hydrocarbons in the presence of the materials of the charge, this temperature being sufficient to form hydrogen during the cracking process, removing the hydrogen and hydrocarbons formed, and utilizing the carbon residue from the cracked hydrocarbons as a reducing agent for the metallic oxide.

7. The process of fractionating hydrocarbons and reducing metallic oxides, which comprises preparing a charge of oxides to be reduced, maintaining a reducing zone at a temperature sufficient to reduce the oxide in the presence of a reducing agent without melting, continually passing such charge through said reducing zone, adding the hydrocarbons to the continually moving

charge at a point in advance of the reducing zone to effect cracking of the hydrocarbons in the presence of the materials of the charge and a temperature less than said reducing temperature taking off the cracked hydrocarbons at a predetermined point or points relative to the reducing zone, and reducing the oxides by a reducing agent liberated in the cracking of the hydrocarbons.

8. In the art of reducing metallic oxides without melting, the steps of preparing a charge containing the oxides to be reduced, adding a heavy hydrocarbon to the charge, continuously feeding the charge through a cracking zone heated to a temperature below 1500° F., continuously cracking the hydrocarbons in the presence of the materials of the charge in said zone, and completely reducing the ore without melting by passing the charge through a fixed temperature reducing zone in the presence of a reducing agent liberated in the cracking of the hydrocarbons.

9. A process of simultaneously fractionating hydrocarbons and reducing metallic oxides without melting, which comprises enclosing and continuously feeding a mass of iron ore, passing said ore through a reducing zone maintained at a temperature sufficient to reduce the ore without melting, introducing hydrocarbons to said mass of ore at a predetermined point relative to the reducing zone, the temperature at said point being sufficient to fractionate the hydrocarbons in the presence of the iron ore and reducing the iron ore by a reducing agent liberated in the fractionating of the hydrocarbons.

10. A process of fractionating hydrocarbons, which comprises enclosing and continuously feeding a mass of iron ore, passing said ore through a reducing zone maintained at a positive fixed temperature sufficient to reduce the ore without melting, introducing hydrocarbons to said mass of ore at a predetermined point relative to the reducing zone, the temperature at said point being sufficient to fractionate the hydrocarbons in the presence of the iron ore and reducing the iron ore by a reducing agent liberated in the fractionating of the hydrocarbons.

11. In the art of reducing metallic oxides, the steps of preparing a charge containing the oxides to be reduced, adding a heavy hydrocarbon to the charge, continuously feeding the charge through an enclosed retort having a cracking zone of positive fixed temperature sufficient to crack the hydrocarbons in the presence of the materials of the charge, removing the cracked hydrocarbons at a fixed point relative to said zone and completely reducing the ore without melting by continuously passing the charge through an enclosed

reducing zone in the presence of a reducing agent present in the charge.

12. In the art of reducing metallic oxides, the steps of preparing a charge containing the oxides to be reduced, adding a heavy hydrocarbon to the charge, continuously feeding the charge through a cracking zone of positive fixed temperatures sufficient to crack the hydrocarbons in the presence of the materials of the charge, maintaining a positive fixed reducing zone, adjacent said cracking zone, at a temperature sufficient to reduce the oxides without melting, and reducing the ore by a reducing agent liberated in the cracking of the hydrocarbons.

13. In the art of reducing metallic oxides, the steps of reducing the oxides and forming a fixed gas of high methane content which comprises preparing a charge containing the oxides to be reduced and a catalyst, adding heavy hydrocarbon to the charge, continuously feeding the charge through a zone heated to a temperature sufficient to crack hydrocarbons in the presence of the materials of the charge, and passing released hydrogen through a relatively low temperature zone in the presence of carbon and the catalyst and the charge to form a fixed gas of high methane content.

14. In the art of fractionating hydrocarbons in reducing iron ore, the steps of forming a fixed gas of high methane and hydrogen content, which comprises preparing a charge containing the oxides to be reduced, adding a heavy hydrocarbon to the charge, continuously feeding the charge through a zone heated to a temperature sufficient to crack the hydrocarbons in the presence of the materials of the charge whereby to form hydrogen and carbon, passing said hydrogen and carbon through a zone of relatively low temperature in the presence of a catalyst to form said fixed gas.

15. In the art of fractionating hydrocarbons in reducing iron ore, the steps of forming a fixed gas of high methane and hydrogen content, which comprises preparing a charge containing the oxides to be reduced, adding a heavy hydrocarbon to the charge, continuously feeding the charge through a zone heated to a temperature sufficient to crack the hydrocarbons in the presence of the materials of the charge whereby to form hydrogen and carbon, feeding the charge through a reducing zone, passing said hydrogen and carbon through a zone of relatively low temperature in the presence of a catalyst to form said fixed gas and maintaining an excess of carbon in the reducing zone whereby the carbon will unite with the oxygen of the ore to form a CO gas.

16. The steps of fractionating hydrocarbons in the process of reducing metallic oxides, which comprises preparing a charge

containing the oxides to be reduced, adding a heavy hydrocarbon to the charge, continuously feeding the charge through a zone heated to a relatively low temperature sufficient to crack the hydrocarbons in the presence of the materials of the charge, said charge being maintained under pressure, and reducing the ore by a reducing agent liberated in the cracking of the hydrocarbons.

17. In the art of reducing metallic oxides and fractionating hydrocarbons, the steps of preparing a charge containing the oxides to be reduced, maintaining a reducing zone at a temperature sufficient to reduce the metallic oxides without melting, maintaining a lower heating zone below approximately 1500° F., and introducing hydrocarbons to said zone of lower temperature whereby the hydrocarbons will be cracked in the presence of the materials of the charge to form H and C, and then utilizing said H and C liberated in the cracking process to reduce the metallic oxides as they are continuously passed through the reducing zone.

18. In the art of reducing metallic oxides in fractionating hydrocarbons, the steps of preparing a charge containing the oxides to be reduced, maintaining a reducing zone at a temperature just sufficient to reduce the oxides with carbon, maintaining another zone at a lower temperature sufficient to crack the hydrocarbons in the presence of the materials of the charge, continuously feeding the charge through said reducing zone, adding hydrocarbons to the charge at the zone of lower temperature whereby to crack the same and removing the hydrocarbon derivatives from the retort at a point which is at a temperature lower than the temperature of the reducing zone.

19. The process of fractionating hydrocarbons in the reduction of metallic oxides, which comprises preparing a charge containing the oxides to be reduced, maintaining a reducing zone sufficient to reduce the oxides without melting, maintaining a lower temperature zone below approximately 1500° F., continuously feeding the charge through said zones, adding heavy hydrocarbons to the charge at a point adjacent said zone of lower temperature whereby to crack the hydrocarbons in the presence of the materials of the charge to form major fractions, removing the major fractions at a point or points relative to the reducing zone and reducing the ore by a reducing agent liberated in the cracking of the hydrocarbons.

20. In the art of reducing metallic oxides, the steps of fractionating hydrocarbons to form minor fractions which comprise preparing a charge of the oxides to be reduced, maintaining an enclosed fixed temperature reducing zone sufficient to reduce the oxides to metals without melting, continuously feeding the charge through said reducing zone

and adding heavy hydrocarbons to the continuously moving charge whereby the hydrocarbons will pass through said reducing zone, cracking the hydrocarbons in the presence of the materials of the charge to form minor fractions and removing the cracked hydrocarbons at a point or points spaced from the reducing zone.

21. In the art of reducing metallic oxides, the steps of fractionating hydrocarbons to form minor fractions which comprise preparing a charge of the oxides to be reduced, maintaining a reducing zone sufficient to reduce the oxides without melting, continuously feeding the charge through said reducing zone and adding hydrocarbons to the continuously moving charge whereby the hydrocarbons will pass through a temperature zone above 1500° F. to crack the hydrocarbons in the presence of the materials of the charge to form minor fractions and passing the minor fraction hydrocarbons such as C and H₂ through a temperature zone of approximately 500° F. in the presence of a catalyst and through a maintained pressure to effect the bonding of the carbon and hydrogen present to form CH₄ as a fixed gas.

In testimony whereof I affix my signature.
WILLIAM H. SMITH.