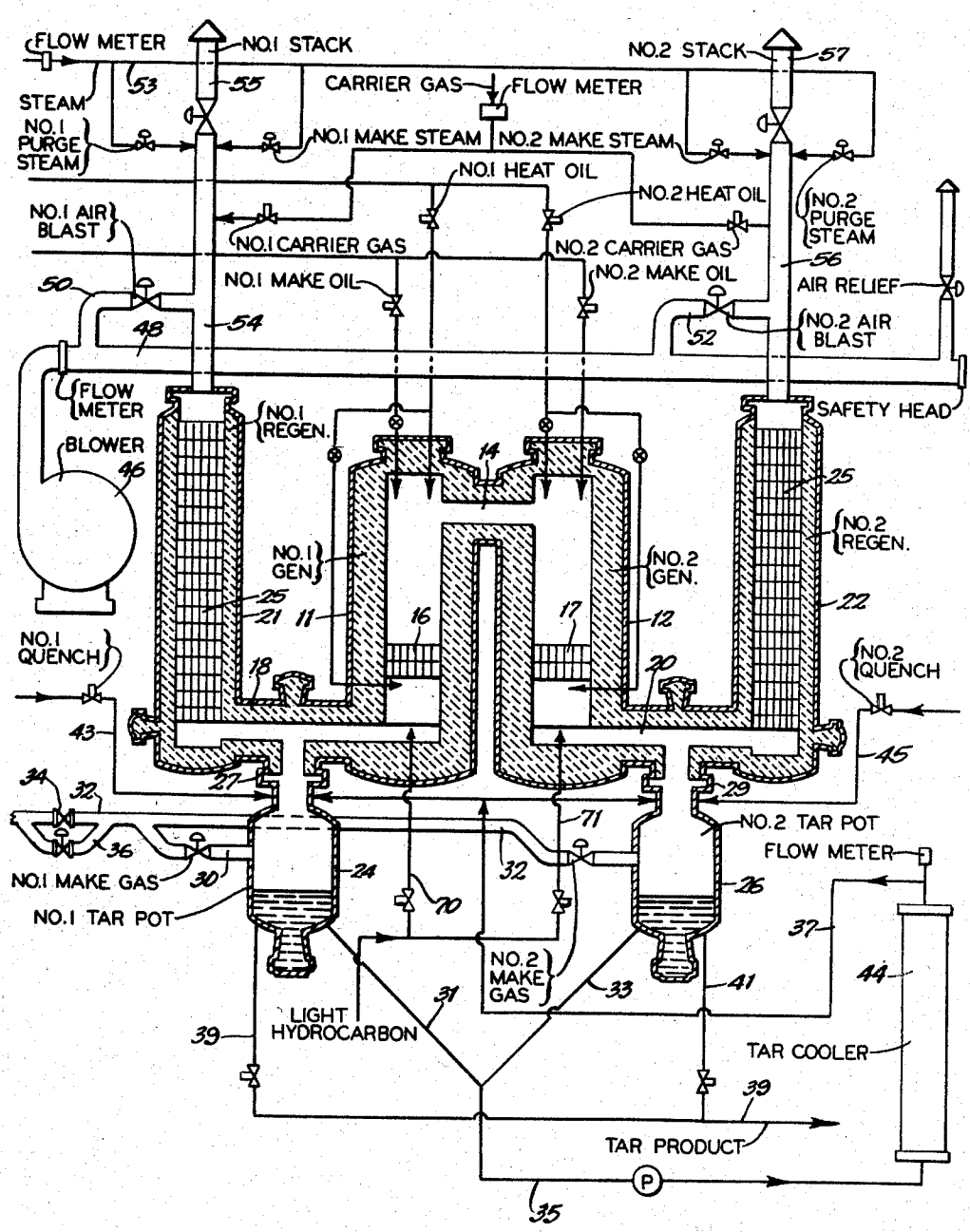
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CYCLIC REGENERATIVE PROCESS FOR CATALYTIC GASIFICATION OF PETROLEUM

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CYCLIC REGENERATIVE PROCESS FOR CATALYTIC GASIFICATION OF PETROLEUM

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This invention relates to a cyclic regenerative process for producing oil gas. More particularly, it relates to a process and apparatus wherein liquid or liquefiable fossil fuels ranging in molecular weight from propane to Bunker "C" oil may be gasified to produce fuel gases completely interchangeable with a variety of manufactured gases, and with natural gas.

By varying the reaction temperature and the compositions of the reactants, it is possible to produce fuel gases having a heating value ranging from 500 to 1000 B.t.u./s.c.f. which can be mixed with, or substituted for, all types of utility gases now in general use such as coke oven gas, carbureted water gas, oil gases and mixtures of these manufactured gases with natural gas, refinery gases or liquefied petroleum gases.

In accordance with the prior art, the production of high B.t.u. oil gases from the lower-cost petroleum products characterized by low hydrogen content, high specific gravity and high coke-forming tendency during thermal cracking operations, such as Bunker "C" oil, resulted in a relatively low conversion to gas. Usually it ranged from 35–50%, with the remainder consisting primarily of tar, pitch and deposited coke.

The primary object of the present invention is to provide a process whereby the lower-cost heavier oils having a molecular weight up to that of Bunker "C" oil may be substantially completely gasified to produce fuel gases having a heating value up to 1000 B.t.u. per standard cubic foot. Liquid by-products associated with the fuel gas from the process of the invention are either limited to small amounts of valuable, low-boiling aromatics, generally identified as light oils, or, when gasifying the highest molecular weight, lowest hydrogen content feedstocks commercially available, are greatly reduced as compared to existing processes. A certain amount of carbon is deposited within the generator during cracking but this is later completely burned off during the blast cycle, the heat serving to satisfy a portion of the process requirements. The tars and pitches which normally form during thermal cracking are gasified by thermal precracking in a hydrogen-rich carrier gas followed by catalytic cracking in the presence of steam.

It is a further object of the present invention to provide an apparatus wherein the liquid feedstock is thermally precracked in one vessel in the presence of highly superheated steam or hydrogen-rich gas, with the cracking being completed in another reaction vessel which also contains a reforming or cracking catalyst. Various forms of an apparatus useful in carrying out the present invention are described in some detail in the application of Pettyjohn and Linden, Serial No. 424,012, filed April 19, 1954, and now U.S. Patent 2,807,528. For purposes of the present invention, the apparatus comprising two interconnected generators described in that application has been modified by incorporation of catalyst beds in both generators. The cyclic regenerative set is further characterized by a direct off-take from the generators for the gaseous and liquid products. Normally, these products are discharged through the regenerators of the cyclic gas generating set, designated normally as superheaters in the prior art, which causes considerable deposition of pitch and carbon in these vessels. The design of the apparatus for the process of this invention permits preheating of steam, carrier gases and air to exceedingly high temperatures because the regenerators are used only for flow of clean gases therethrough. There is no pitch or carbon deposit to insulate the refractory shapes disposed within the regenerator from the fluids flowing therethrough. This cyclic regenerative apparatus can be used in a flexible manner by introducing the liquid feedstock into one generator, or into the other, or into both simultaneously, while introducing carrier gases into the upstream regenerator.

In the preferred form of the invention, steam is introduced into the upstream generator of the interconnected pair comprising the set, through its corresponding regenerator. A low molecular weight hydrocabron, such as natural gas, propane, butane, LPG, naphtha, gasoline, kerosene or light fuel oil, is fed into the highly superheated steam below the catalyst bed in the upstream generator. The low molecular weight hydrocarbon is catalytically cracked in the presence of the steam to form a gas containing over 50% hydrogen, up to 25% carbon monoxide and various percentages of carbon dioxide and light gaseous hydrocarbons, depending upon the severity of cracking and the steam-hydrocarbon ratio. Normally, a gas containing 70% hydrogen would be produced. The make oil, which may be a low-cost high-molecular weight hydrocarbon such as reduced crude oil or Bunker "C" oil, is introduced into the generator countercurrent to the flow of the hydrogen-rich gas. The mixture is subjected to both hydrogasification, that is, thermal cracking in the presence of hydrogen, and catalytic cracking reactions. Thermal cracking in the presence of hydrogen takes place in the upper portion of the generators and the catalytic cracking occurs in the catalyst bed in the bottom of the downstream generator. The combination of hydrogasification and catalytic cracking results in essentially complete gasification to 700–1000 B.t.u./s.c.f. fuel gas of all but the highest molecular weight, lowest hydrogen content residual oils. The set is preferably maintained at a temperature ranging from 1300°–1800° F. and at a pressure of less than 20 pounds per square inch gauge. The product gases are discharged directly from the downstream generator whereupon they are quenched and given subsequent treatment before being introduced into the transmission lines or storage containers. After cracking, the set is purged with steam followed by an air blast. Heat oil is burned in one or both generators in the presence of excess air to reheat the set and to burn off the carbon and other fouling materials deposited on the catalyst beds. Excess heat from these combustion reactions is stored in one of the highly efficient regenerators for use in preheating of the various gas streams entering the set during subsequent cyclic steps proceeding in the opposite direction.

In an alternate form of the invention, hydrogen-rich gas is supplied from an external source rather than by catalytic cracking of a low molecular weight hydrocarbon and steam in the upstream catalyst bed. In this case the upstream catalyst bed does not serve any function other than imparting additional preheat to the steam and hydrogen-rich gas, which have already been passed through the upstream regenerator, before contacting the make oil in the upper portions of the upstream generator.

In practicing the two major forms of the invention, namely, (1) integral hydrogasification where the hydrogen requirements are provided by catalytic cracking of a low molecular weight hydrocarbon in the upstream catalyst bed and (2) use of an external source of hydrogen

where the upstream catalyst bed is not active in the process, it is essential that the apparatus consist of two interconnecting generators communicating with one regenerator at each end and also communicating with a direct product off-take and quench system at each end, as described in detail in the aforementioned application of Pettyjohn and Linden, Serial No. 424,012, filed April 19, 1954, now U. S. Patent 2,807,528. It will be apparent from the following detailed description of the apparatus and the process that many other configurations and arrangements of the major equipment components are practical other than those depicted in the illustration. In addition to the different methods of practicing the process as indicated, two major methods of operating the apparatus are feasible. These are: (1) use of an air blast period in which the air and combustion products flow through the apparatus in the same direction (up to the point where they leave the downstream generator) as the carrier and product gases in the preceding make period and (2) use of an air blast period in which the flow of air and combustion gases is in the opposite direction of the gas flow in the preceding make period. Further, heat oil can be introduced either in the bottom of a generator below the catalyst bed when the air flow is upwardly, or at the top of a generator above the catalyst bed when the air flow is downwardly. Heat oil may also be simultaneously introduced into the bottom of the upstream generator and into the top of the downstream generator to provide for heating of both catalyst beds. Thus, it can be seen that in the preferred method of operation in which hydrogen is generated by catalytic cracking of a low molecular weight hydrocarbon in the upstream catalyst bed while the higher molecular weight hydrocarbons resulting from thermal precracking of the make oil are catalytically cracked in the downstream catalyst bed, it is desirable to employ two points of heat oil introduction with possible addition of secondary combustion air at the top of the downstream generator so that sufficient heat is stored in both catalyst beds for the subsequent make period. Further, because of the higher heat and steam requirements of the integral hydrogasification operation it is also desirable to blast in the same direction as the preceding make so as to store a maximum amount of heat in the downstream regenerator which will then be able to impart a greater amount of heat to the reaction steam in the reverse make cycle. On the other hand, when using an external source of hydrogen, or when employing only simple steam cracking, it is not necessary to store enough heat in the upstream catalyst bed to provide for the highly endothermic steam cracking reactions. In this case, when the air blast is in the same direction as the preceding make gas flow, heat oil need only be introduced into the bottom of the upstream generator where it will impart the maximum amount of heat to the catalyst bed active in the subsequent make period. However, when choosing to blast in the opposite direction from the preceding make period heat oil need only be introduced into the top of the generator through which the combustion air flows downwardly since this will again impart a maximum amount of heat to the catalyst bed active in the subsequent make period.

Referring now to the drawing, which is a diagrammatic representation of apparatus suitable for use in practicing the process of this invention, the oil-gas set comprises a pair of generators **11** and **12** which are interconnected by a crossover **14** at the upper ends thereof. A regenerator **21** connects to the lower end of the generator **11** and a second regenerator **22** connects to the lower end of the generator **12**. These connections are through conduits **18** and **20**, respectively. Tar pots **24** and **26** communicate with the conduits **18** and **20**. Quench water may be introduced into the tar pots through the lines **43** and **45**.

The refractory shapes **16** and **17** disposed in the bottom of the generators **11** and **12** contain a cracking catalyst. The preferred catalyst consists of refractory shapes impregnated with 1% to 10% nickel as nickel oxide. One-half to one inch diameter spheres composed of alumina, magnesia or zirconia have been found to be satisfactory. However, it has been found that alumina tends to react with nickel oxide at the temperatures employed to form a less active catalyst. Co-impregnation of alumina with nickel oxide and magnesium oxide has been found to be helpful in maintaining catalyst activity. Other suitable catalysts include other metals of the eighth group of the periodic system, such as cobalt and platinum; also the oxides of magnesium, calcium and aluminum in suitable crystalline forms have catalytic activity without impregnation with metal salts. These oxides may also be used in the form of naturally occurring minerals, such as bauxite, magnesia, magnetite, limestone and dolomite. Chromium and vanadium oxides also have activity in accelerating the desired cracking reactions. The catalysts are known in the art. Refractory shapes may be placed below and above catalyst beds **16** and **17** to provide support, additional heat storage, protection against extreme temperature changes and protection against direct contact with oil and deposited carbon.

Regenerators **21** and **22** are filled with refractory shapes **25** which are capable of absorbing and releasing quantities of heat in exchange with fluids passing therethrough. Stacks **55** and **57** connect to the upper end of regenerators **21** nd **22**, respectively. Suitable sources of steam and hydrogen and other thermally stable carrier gases connect to the stacks **55** and **57** for introduction of these materials into the set through the regenerators. To introduce blast air into the set, a blower **46** is provided which connects to a conduit **48** having branch lines **50** and **52** connecting to stacks **55** and **57**, respectively. It will be noted that stacks **55** and **57** contain valves which may be used to close the stacks so that steam, hydrogen and air introduced into the bottom thereof will flow downwardly through the set rather than out the stack. These valves are open only when flue gases or purge steam are discharged from the regenerators. Make oil and heat oil may be introduced through lines connecting to the top of generators **11** and **12**. Heat oil may also be introduced at the bottom of the generators. These lines have nozzles on the ends thereof projecting into the generator so that the oil can be introduced in the form of a spray. Likewise, nozzles are provided in the lower end of each generator which connect through lines **70** and **71** to a source of low molecular weight hydrocarbons which may be introduced into either one of the generators in the operation of a preferred form of the process of the invention.

Outlets for product gases from tar pots **24** and **26** constitute the conduits **30** and **32**. Upstream of these conduits is a pressure regulator **34** which causes pressure generated by production of gases within the set to build up to the predetermined maximum pressure for which the valve is set. The preferred operating range is below 20 pounds per square inch gauge for maximum gas yields. Higher pressure, say up to 50 pounds per square inch, will provide higher proportions of methane and ethane in the product gas, but the total gas yield will be slightly reduced. A by-pass line **36** around the regulator **34** is provided for operation at atmospheric pressure.

Preheaters for the make and feed oil may be provided, but are not shown in the drawing.

In operating this set, the No. 1 generator **11**, the No. 2 generator **12** and the No. 2 regenerator **22** are first heated by combustion of heat oil. Air is introduced from the line **50** downwardly through regenerator **21** through the conduit **18** and upwardly through the generator **11** where deposited carbon from the previous make oil introduction period is burned off the catalyst **16** and off other refractory surfaces. Heat oil is introduced at the bottom of generator **11** and burned upwardly with the hot products

of combustion passing downwardly through generator 12 and upwardly through the regenerator 22, heating the refractory shapes 25 disposed therein. Additional heat oil and combustion air may be introduced in the top of generator 12 if, under the operating conditions selected, this is necessary to maintain catalyst bed 17 at temperatures above 1300° F.

Following the blast cycle, the make cycle is initiated when steam is passed into the regenerator 21 to superheat it to a temperature of over 1300° F., and preferably 1500°–1800° F. Hydrogen-rich gas is generated within the set by conversion of low-molecular weight hydrocarbon gases or vapors with steam in the upstream catalyst bed 16. Hydrogen from an external source may be introduced into the top regenerator 21 instead of catalytically converting hydrocarbon gases or vapors. If a hydrogen-rich gas from an external source is used, it is not affected by passage through catalyst bed 16. The hydrogen and steam flow upwardly through the generator 11 and meet the spray of make oil which is introduced at the top of the generator. A portion of the make oil can be introduced into generator 12 concurrent with the flow therethrough. The heated hydrogen, steam and the make oil become thoroughly intermixed and thermal cracking is initiated in the presence of these gases in the upper portion of generators 11 and 12. The thermal cracking products mixed with excess steam and hydrogen are then catalytically cracked in catalyst bed 17 in generator 12. The temperature prevailing in the catalyst bed of the generator is from 1300°–1800° F. Preferably, the pressure is below 20 pounds per square inch gauge.

The make gas is discharged from the conduit 20 into the tar pot 26. The temperature of the gas is reduced to less than 800° F. by means of water quench which is introduced into the tar pot in the form of a spray from the line 45. The cooled make gas is discharged from the tar pot 26 into the outlet line 32. The set is then purged by introducing purge steam in the same direction as the make, namely, through the regenerator 21 and out the regenerator 22 with the steam being discharged finally from the stack 57.

After the set has been purged of combustible materials following the make period it is necessary to heat generators 11 and 12 and regenerator 21 so that they are capable of imparting heat to the reactants entering into the second, or reverse flow, make period. This is done by introducing blast air from conduit 52 into regenerator 22. The air flows upwardly through generator 12 to burn off carbon deposited within the generator, particularly on the catalyst. Heat oil is sprayed into the bottom of generator 12 and burned with the air and the hot products of combustion pass upwardly through generator 12, downwardly through generator 11 and then discharge through regenerator 22 where they heat the refractory shapes 25. Here again heat oil and additional air may be introduced into the top of generator 11 to supplement the heat released from combustion of heat oil in generator 12 and from combustion of deposited carbon as discussed in the description of the forward blast period. Instead of heat oil, other fluid fuels such as gas, liquid petroleum gases or liquid by-products may be used.

The set is now ready for making gas in the reverse direction. Steam is fed through the regenerator 22, whereupon it attains a temperature of above 1300° F., and through conduit 20 into the bottom of generator 12 where lower molecular weight hydrocarbons from line 71 are mixed with the steam as it passes through catalyst bed 17. Oil introduced into the top of generator 12 is thermally cracked in the presence of the hot hydrogen-rich gas formed in catalyst bed 17 in the usual steam-hydrocarbon cracking reactions. Hydrogen-rich gas can again be supplied from an external source, if desired. Precracking is continued in the upper portions of generator 11 and gasification is completed catalytically as the precracked products and excess steam and hydrogen pass downwardly over catalyst bed 16. Make gas is discharged from the conduit 18 into the tar pot 24 and out through the conduit 30 connecting thereto.

The remainder of the process is identical to that disclosed for the forward operation of the cycle, except that it occurs in the reverse direction. Steam is introduced to purge the set, the set is reheated during the blast cycle, and then the third make cycle is begun with cracking taking place initially in generator 11 and being completed in generator 12.

By cracking the make oil thermally in the presence of hydrogen and then catalytically in the presence of steam we are able to convert substantially all of the feed oil to gaseous products. The production of tar and coke is held to a minimum. Thus, the capacity of the set is greatly increased and the operation improved because of the elimination of objectionable coke and pitch deposits.

The flow direction of reactants in the make period can also be the reverse of the direction of air and hot combustion product flow of the preceding blast period. It is apparent that by introduction of heat oil into the bottoms and/or the tops of generators 11 and 12, and by reversing the flow direction of the make period following any given air blast period, it is possible to closely control the temperature levels in catalyst beds 16 and 17 and the upper portions of generators 11 and 12 very accurately to meet the specific operating requirements. For example, when using a low molecular weight hydrocarbon as a source of hydrogen-rich carrier gas, which is a preferred method of operation, it will be desirable to maintain both catalyst beds at temperatures above 1300° F. since they will both be active in highly endothermic reforming reactions. However, when using an external source of hydrogen, the upstream catalyst bed during the make period is not involved in any endothermic steam reforming reactions and serves as a vessel in which thermal precracking and/or hydrogenation reactions are effected. These reactions are considerably less endothermic or may actually be somewhat exothermic in the presence of large amounts of hydrogen. Thus, in this case the upstream generator requires relatively little reheating while the downstream generator requires relatively large amounts of reheating.

The process and apparatus of this invention offer the flexibility required in converting a variety of petroleum and other liquid fossil fuel feedstocks into gaseous products of a critical composition determined by the properties of the send-out gas which has to be substituted or supplemented. Further flexibility is obtained by the suitability of the apparatus for distributing make oil between both generators, thereby reducing the load of deposited carbon to be handled in each catalyst bed.

It is also practical and desirable to introduce the low molecular weight hydrocarbons to be used in hydrogen production in the preferred form of this invention into the upstream regenerator together with the required steam if these hydrocarbons will not undergo substantial thermal cracking. Methane, ethane, propane and butane are examples of hydrocarbons relatively unaffected by the regenerator temperatures.

The catalyst bed 16 in each of the generators is usually deactivated during each make period when sulfur-bearing hydrocarbon feeds are used. However, the catalyst is immediately regenerated by burn-off in the subsequent blast period. The nickel in its reduced form is a catalyst for the highly endothermic steam-hydrocarbon reactions, such as:

$$C_nH_m + nH_2O + \text{heat} \rightarrow nCO + (n + m/2)H_2$$

where n and m are the number of carbon and hydrogen atoms in the hydrocarbon molecule. The nickel also acts as an oxygen carrier. During the blast period, de-

posited carbon is burned off, and reduced or sulfur-poisoned nickel is oxidized:

$$2Ni+O_2 \rightarrow 2NiO+heat$$
$$2NiS+2O_2 \rightarrow 2NiO+SO_2+heat$$

The exothermic heat of these reactions is stored in the catalyst support and thus becomes available for subsequent endothermic cracking reactions. At the start of hydrocarbon introduction, the catalyst is again reduced by reactions of the type:

$$NiO+CH_4 \rightarrow Ni+CO+2H_2+heat$$
$$NiO+H_2 \rightarrow Ni+H_2O+heat$$
$$NiO+C \rightarrow Ni+CO+heat$$

thereby completing the cycle.

These reactions are typical of the non-precious metals of the eighth group of the periodic system (nickel, cobalt and iron) and are well known and widely applied. The stable oxide catalysts act differently and require higher temperatures to be active in the steam-hydrocarbon cracking reaction. They are primarily carbon oxidation catalysts and have been widely used for this purpose. The reactions occurring with these materials are best characterized by the system:

$$C_nH_m+heat \rightarrow nC+m/2H_2$$
$$nC+nH_2O+heat \rightarrow nH_2+nCO$$

The first step is simply thermal cracking and may lead to methane and other lower hydrocarbon production at suitable severities of cracking. The second step is the one catalyzed by the stable oxides (CaO, Al_2O_3, MgO, Cr_2O_3, etc.), particularly in the presence of alkaline promoters. It appears that carbon deposited on these catalysts is more reactive to conversion with steam.

In the preferred form of the invention make steam is introduced through one of the regenerators to superheat it to a very high temperature, say 1300° F. or higher. A low molecular weight hydrocarbon, such as natural gas, propane, butane, LPG, naphtha, gasoline, kerosene or distillate oil, is introduced into the highly superheated steam through the spray nozzle in the lower end of generator **11** or **12**, depending upon the direction in which the make cycle is taking place. The steam reacts with the light hydrocarbon in the presence of the catalyst to catalytically convert the hydrocarbon to a gas containing over 50% by volume of hydrogen and up to 25% by volume of carbon monoxide plus carbon dioxide and light gaseous hydrocarbons, depending upon the severity of cracking and the steam-hydrocarbon ratio. Normally, a gas containing 70% hydrogen would be produced. This hot hydrogen-rich gas and any unreacted excess steam then flow upwardly through the generator where they are intermingled with make oil, such as high molecular weight Bunker "C" or crude oil, which flows countercurrent thereto. Thermal cracking begins to take place in the upper end of the generator and is completed in the presence of the catalyst as the products pass through the second generator. The heating value of the make gas can be adjusted by varying the ratio of the hydrogen-rich carrier gas and the make oil and by controlling the amount of excess process steam available for catalytic cracking reactions of the make oil. For example, if the light hydrocarbon is fed at a rate of 0.5 to 1.0 pound per gallon of make oil and steam is fed at a rate of 5 to 10 pounds per gallon of make oil (equivalent to 12–24 standard cubic feed of natural gas per gallon of make oil), a product gas having a heating value of from 700 to 1000 B.t.u./s.c.f. will be produced. The thermal capacity of a four-shell set operating in this manner would be substantially higher than in conventional high B.t.u. oil-gas operation on cyclic catalytic cracking operation.

It will be seen that the process described provides for simultaneous hydrogasification and catalytic cracking which results in greatly improved conversions of oil to gas and essentially complete gasification of all but the heaviest Bunker "C" oils to high heating value gases.

The composition of a typical product gas made in accordance with this process, using Bunker "C" oil as a feedstock, is as follows:

Composition of gas, percent

CO_2	3
CO	8
H_2	27
CH_4	27
C_2H_6	3
C_2H_4	21
C_3H_6	5
C_6H_6	1
N_2	5

Operating conditions

[1500° F., 5 lbs. steam/gal., 12.5 s.c.f. natural gas/gal. of oil.]

The temperature set forth in the table above is the cracking temperature.

Where it is desired to produce a fuel gas having a heating value of less than 700 B.t.u./s.c.f., the apparatus of the invention may be operated without hydrogen, either integrally generated or supplied from an external source. In such case only highly superheated steam from the upstream regenerator is passed into the upstream generator of the interconnecting pair comprising the set. The liquid feedstock is introduced into the first generator countercurrent with the flow of superheated steam and/or the second generator, concurrent with the flow of superheated steam. The feedstock may constitute any liquid fossil fuel having a molecular weight up to that of Bunker "C" oil. Partial thermal cracking occurs in the first and second generators to produce a gas containing low molecular weight saturated and unsaturated hydrocarbons and hydrogen, and tar vapor consisting of higher molecular weight hydrocarbons, mostly of the aromatic type. Carbon will also deposit in the generators. The partially cracked feedstock and excess steam then pass through the catalyst disposed in the second or downstream generator. Cracking is completed in the presence of the catalyst, which permits the substantially complete conversion of hydrocarbons to gaseous products. The hydrocarbon materials normally polymerizing to tar and pitch constituents are reacted with steam in presence of the catalyst to form carbon monoxide and hydrogen by the reaction:

$$C_nH_m+nH_2O \longrightarrow nCO+\left(n+\frac{m}{2}\right)H_2$$

where n is the number of carbon atoms and m is the number of hydrogen atoms in a molecule of any of the tar and pitch-forming hydrocarbons.

Much higher temperatures, 1500°–2000° F., must be used to obtain complete gasification in the absence of hydrogen since none of the oil is converted to gas by means of hydrogasification reactions. This necessitates a greater proportion of conversion by means of catalytic steam reactions. As a result, the heating value of the product gas is considerably lower, because of conversion of the high heating value gaseous hydrocarbons formed in the thermal precracking step into carbon monoxide, hydrogen and deposited carbon. This type of operation is typical of the prior art in which there exists only a choice between complete conversion to low heating value gases or partial conversion to high heating value gases. However, use of the apparatus disclosed in this invention greatly improves the thermal efficiency and operability of the conventional cyclic catalytic steam cracking processes.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A cyclic regenerative process for producing a high B.t.u. oil gas in a gas generating set including a first and

a second generator, each containing a cracking catalyst and being interconnected to a first and second regenerator, respectively, comprising heating the first regenerator and both generators, passing a mixture of steam and a hydrocarbon gas taken from the group consisting of natural gas, propane and butane through the first regenerator to heat it to over 1300° F. and thence through the catalyst bed of the first generator to reform said hydrocarbon gas into a hydrogen-rich gas, introducing make oil into said first generator countercurrent to the flow of said hydrogen-rich gas-steam mixture to initiate thermal cracking of said oil in said first generator at temperatures of 1300° to 1800° F., permitting the partially cracked products to flow into said second generator together with any unreacted steam to complete cracking in the presence of catalyst at temperatures of 1300° to 1800° F. thereby converting substantially all said make oil to a gas having a heating value in excess of 700 B.t.u.'s per standard cubic foot, and discharging the make gas from the set directly from the downstream end of the second generator.

2. The process of claim 1 wherein said hydrocarbon gas is introduced at a rate of 0.5 to 1.0 pound per gallon of make oil and said steam is introduced at a rate of 5 to 10 pounds per gallon of make oil.

3. A process for making a fuel gas which comprises heating a light hydrocarbon in admixture with excess steam to a temperature above 1300° F., said hydrocarbon being taken from the group consisting of natural gas, propane, butane, liquefied petroleum gas, naphtha, gasoline, kerosene and light fuel oil, passing said heated mixture over a catalyst to form a hydrogen-rich gas containing more than 50% hydrogen, introducing make oil having a molecular weight up to and including that of Bunker "C" oil into said heated mixture to partially thermally crack said oil in the presence of said hydrogen-rich gas and excess steam at a temperature of 1300° to 1800° F. and causing the partially cracked products to flow over a catalyst to complete cracking, thereby converting substantially all of said make oil to a fuel gas having a heating value in excess of 700 B.t.u.'s per standard cubic foot, said light hydrocarbon and said steam being added at a rate of one-half to one pound per gallon of make oil and five to ten pounds per gallon of make oil, respectively.

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