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Fig. 1

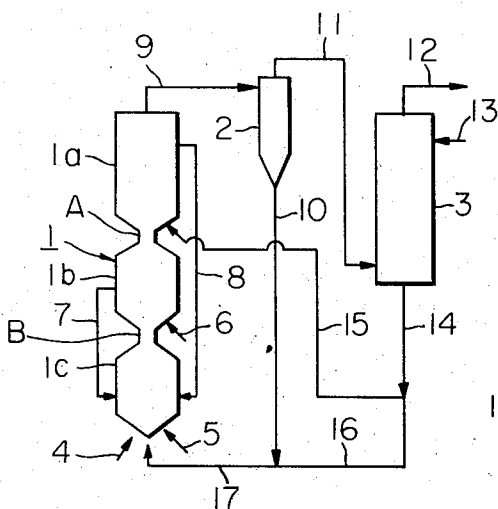
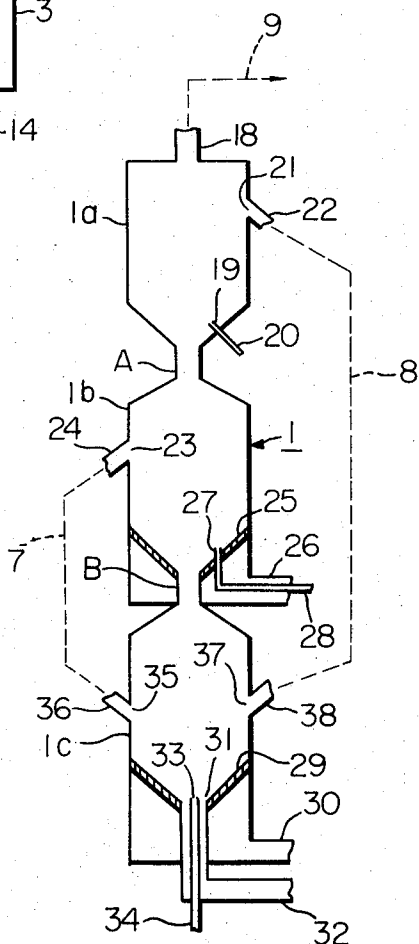


Fig. 2



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3,848,016

PRODUCTION OF CRACKED GASES FROM LIQUID HYDROCARBON

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23 Claims

ABSTRACT OF THE DISCLOSURE

There is provided an improved process and apparatus for cracking liquid hydrocarbon into gases in a new fluidized bed of solid particles, which bed forms a central zone for cracking a starting liquid hydrocarbon, a lower zone for cracking the liquid hydrocarbon of higher boiling point which has been recovered from the cracked hydrocarbon and an upper zone for quenching the cracked gases, the central zone communicating with the neighbouring zones through narrow neck zones formed therebetween, wherein by-produced carbon and tar, heavy oil fraction and the like, which would ordinarily be treated as industrial wastes, are utilized effectively and positively for cracking purposes without exhausting the by-products from the cracking system, thereby producing the cracked gases in a quenched state at an improved yield rate, attaining regeneration of the carbon deposited particles and obviating such environmental pollution as occurs in the conventional process.

The present invention relates to a process for the preparation of gases such as olefins by thermal cracking of liquid hydrocarbon, particularly containing high boiling point constituents, such as crude oil, heavy oil and residue oil in a fluidized bed of solid particles, and further to a furnace for carrying out the cracking process. More particularly, the present invention relates to a process and a furnace for cracking not only a starting liquid hydrocarbon in a specially designed fluidized bed of solid particles, but also the recovery of liquid hydrocarbon of higher boiling point containing carbon and tar in said bed at higher temperature. Said bed consists of an upper zone for quenching cracked gases, a central zone for cracking the starting liquid hydrocarbon and a lower zone for cracking the recovered liquid hydrocarbon which has originated in said bed wherein the solid particles are forced to circulate between said zones according to the predetermined routes. The present invention has as its objective the provision of a process for cracking a starting liquid hydrocarbon without exhausting the by-products produced by the cracking such as carbon and tar, heavy oil fraction and the like, which would ordinarily be treated as industrial wastes, and by utilizing said by-products improving the cracking efficiency and obviating such environmental pollution as occurs in the conventional process, and further, the provision of an improved cracking furnace for liquid hydrocarbon in a compact form which is suitably applicable to the inventive process.

There have been proposed many methods for producing olefins, hydrogen, fuel gas and the like by thermally cracking liquid hydrocarbon in a bed in which solid particles are fluidized. For instance, United States Patent No. 3,238,271 discloses a process for cracking liquid hydrocarbon to gaseous olefins by using two fluidized beds of solid particles which are formed within a cracking furnace and a regenerator separately. This process comprises: cracking the liquid hydrocarbon at a temperature of about

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740° C. in the cracking furnace by applying only the sensible heat of the fluidized solid particles delivered from the regenerator; passing the cracked gases into a cyclone without quenching them; washing the cracked gases by forcing them to flow counter to the liquid hydrocarbon containing higher boiling point constituents separated from the cracked gases by the process set forth below; removing the carbon deposited solid particles from the side wall of the cracking furnace and blowing them with air into the regenerator, thereby burning the carbon deposits with a part of the above-mentioned liquid hydrocarbon containing higher boiling point constituents at a temperature of about 900° C., which results in regenerating and heating the solid particles, and; passing the heated solid particles and steam stream from the regenerator into the cracking furnace at the bottom to crack the liquid hydrocarbon by the sensible heat of the solid particles as described above.

In the above prior art, only the sensible heat of the solid particles heated in the regenerator is applied as the heat source of the cracking reaction. Consequently, it is difficult to maintain the cracking furnace at such a high temperature as about 740° C. The supply of the heat to the cracking furnace necessary for cracking the liquid hydrocarbon requires transporting a large number of heated solid particles by steam. Passing the cracked gases directly from the cracking furnace into the cyclone without quenching them causes carbon and tar to condense and deposit on the wall of the cyclone. This leads to a lower efficiency in capturing the carbon and tar with the result that a great amount of the carbon and tar is passed to the washing tower. Further, the liquid hydrocarbon containing higher boiling point constituents, which has been used for the countercurrent washing process at the time of regeneration of the carbon deposited particles, is treated by combustion only. As a result sulfur contained in the carbon adhering to the solid particles is exhausted from the cracking system. In this connection, the prior art has a disadvantage in that prevention of the sulfur from exhausting to the atmosphere requires an additional process for desulfurization of the flue gas.

In the process for producing olefins from liquid hydrocarbon in a fluidized bed which is disclosed in the specification of Japanese Patent Application Publication No. 2/71, there are substantially the same disadvantages as in the process recited in the above-mentioned U.S. patent specification.

Further Japanese Patent Application Publication No. 41,363/70, corresponding to U.S. Pat. No. 3,551,513, discloses a process for producing olefins at a high yield rate by partial oxidation of liquid hydrocarbon in a fluidized bed wherein a forced circulation flow of solid particles is employed. However, there is no suggestion of a possible treatment of the substances such as carbon, tar and heavy oil fraction which are by-produced by thermal cracking of the hydrocarbon.

The inventors thus have sought to realize a new method for thermally cracking liquid hydrocarbon in a fluidized bed of solid particles wherein by-produced carbon and tar heavy oil fraction and the like are utilized effectively and positively for the cracking purpose without exhausting the by-products from the cracking system, and as a result, they have confirmed that the following inventive process avoids the disadvantages in the conventional cracking process and accomplishes the objectives of the present invention.

According to the inventive process, as a unitary fluidizing bed for cracking liquid hydrocarbon, a layer zone of solid particles is formed which involves a central zone for cracking a starting liquid hydrocarbon to gases, a lower zone for cracking the liquid hydrocarbon recovered from the cracked hydrocarbon to gases and an upper zone for quenching the cracked gases, the central zone com-

municating with the upper and lower zones through narrow passages or neck zones formed between the upper and center zones and between the center and lower zones. Oxygen, steam and the recovered liquid hydrocarbon are fed into the lower zone from the bottom to burn the recovered liquid hydrocarbon partially at a temperature of 1050 to 1400° C. thereby cracking the recovered hydrocarbon to gases. The starting liquid hydrocarbon is sprayed into the central zone together with steam, while the cracked gases from the recovered liquid hydrocarbon and the entrained solid particles in the lower zone are spouted into the central zone from the bottom through the narrow neck zone, thereby cracking the starting liquid hydrocarbon in the central zone to gases at a temperature of 700 to 900° C. If the cracking of the starting materials takes place at a temperature below 700° C., it leads to production of increasing light oil fraction according to the decreasing cracking temperature.

Another part of the starting liquid hydrocarbon and/or another part of the recovered liquid hydrocarbon are forced to spray into the upper quenching zone, while the mixture of the steam, the cracked gases from the starting and recovered liquid hydrocarbon and the entrained solid particles in the central zone are spouted into the upper zone from the bottom through the narrow neck zone, whereby the cracked gas mixture is quenched with the result that some carbon and tar and heavy oil which are involved in the cracked gas mixture adhere to entrained solid particles. The resultant gas mixture is then treated to separate the remainder of the carbon and tar and heavy oil. This remainder of the carbon and tar and heavy oil is the recovered liquid hydrocarbon. On the other hand, some part of the solid particles on which carbon has deposited are removed from the upper zone and forced to recycle to the lower zone.

Further, the inventors have investigated the type of cracking furnace suitable for carrying out the above inventive process and have confirmed that the following furnace which is shown in FIG. 2 is the most suitable to the inventive process.

The inventive furnace comprises an upper chamber for quenching the cracked gases, a central chamber for cracking the starting liquid hydrocarbon and a lower chamber for cracking the recovered liquid hydrocarbon, the central chamber at the center of its constricted top communicates with the upper chamber at the center of the constricted bottom thereof, while the central chamber at the center of its constricted bottom communicates with the lower chamber at the center of the constricted top thereof. The upper chamber is provided with a gas exhaust port at the top, an injection opening for the liquid hydrocarbon at the lower portion and a solid particle outlet at the upper portion.

In the central chamber, the constricted bottom is formed by a perforated plate in a funnel form, which opens to the lower chamber. The conical perforated plate of the central chamber is provided with an injection opening for the starting liquid hydrocarbon at the conical portion or shoulder. In the lower chamber, the bottom is formed by a perforated plate in a funnel form, the opening of which receives a gas jet stream. An injection nozzle for the liquid hydrocarbon is located centrally within the conical perforated plate at the inlet, and the lower chamber at the side wall has a solid particle inlet which is connected to the solid particle outlet of the upper chamber.

According to the present invention, as the starting liquid hydrocarbon any kind of liquid hydrocarbon can be used and in particular the cracking of liquid hydrocarbon containing high boiling point constituents, such as crude oil, heavy oil and residue oil is easily attained. In this connection, the present invention is suitable for the production of fuel gas, hydrogen or olefins such as acetylene, ethylene and propylene, and particularly suitable for the production of fuel gas.

The first feature of the present invention is that the unitary fluidized bed used for cracking liquid hydrocarbon involves different function zones which are an upper zone for quenching the cracked gases, a central zone for cracking the starting liquid hydrocarbon and a lower zone for cracking the recovered liquid hydrocarbon, the central zone communicating with the upper zone and the lower zone through the narrow neck passages formed between neighbouring zones, wherein solid particles are forced to fluidize throughout and not only cracking of the starting liquid hydrocarbon but also further cracking of the recovered liquid hydrocarbon from the cracked starting liquid hydrocarbon, which contains high boiling point constituents, are simultaneously carried out, while the cracked gases from the starting and recovered liquid hydrocarbon are quenched.

The second feature is that the sensible heat of the hot cracked gases from the recovered liquid hydrocarbon in the lower zone of the fluidized bed and the sensible heat of a part of the entrained solid particles of high temperature are applied for cracking the starting liquid hydrocarbon.

The third feature of the present invention is that a part of the deposited carbon or contaminated solid particles is removed from the upper quenching zone and is forced to recycle to the lower cracking zone, whereby the deposits are utilized for improving the yield rate of the cracked gases and regeneration of the deposited carbon particles is attained. Further features of the invention will be apparent from the explanation below.

The invention will now be explained in detail by way of preferred embodiments with reference to the accompanying drawings in which:

FIG. 1 is a diagrammatic view showing the outline of an apparatus according to the present invention, and

FIG. 2 is a sectional view showing diagrammatically a cracking furnace for liquid hydrocarbon according to the present invention.

With reference to FIG. 1, the apparatus comprises a cracking furnace for a liquid hydrocarbon 1, a cyclone for separating the materials 2, a distillation column for cracked gases 3 and conduits or lines for passing the materials 4 to 17. The cracking furnace 1 comprises an upper chamber as a quenching chamber for cracked gases 1a, a central chamber as a cracking chamber for starting liquid hydrocarbon and a lower chamber as a cracking chamber for recovered liquid hydrocarbon, the central chamber being connected to the upper and lower chambers by means of narrow necks or constrictions A and B respectively. In this furnace 1, solid particles are filled for forming fluidized beds.

Recovered liquid hydrocarbon is fed into the lower chamber 1c at the bottom through the line 17 and further oxygen and steam are fed into chamber 1c through the lines 4 and 5 respectively, thereby creating a partial combustion of the recovered liquid hydrocarbon for cracking to gases. Within the lower chamber 1c, a cracking zone of the recovered liquid hydrocarbon is then formed in the fluidized solid particles.

The cracked gases produced at a high temperature flow upwards with a part of the fluidized solid particles and they are spouted into the central chamber 1b at the bottom through the lower narrow neck B, thereby forming a cracking zone of the starting liquid hydrocarbon in the fluidized solid particles within the central cracking chamber 1b.

On the other hand, the starting liquid hydrocarbon, for example, crude oil, heavy oil, residue oil or the like is fed with steam in an atomized state into the central cracking chamber 1b, where the starting material is cracked to gases by the sensible heat of the cracked gases from the recovered liquid hydrocarbon and of the heated solid particles and/or the starting material is burned partially with oxygen which is supplied alternatively to crack the start-

ing material to gases by utilizing its partial combustion, at a temperature of 700 to 900° C.

The cracked gases produced in the central chamber 1b are mixed with the cracked gases from the lower chamber 1c and the mixture is spouted into the upper chamber 1a through the upper narrow neck A with a part of the fluidized solid particles, whereby a quenching zone for the cracked gases is formed within the upper chamber 1a.

The cracked gas mixture spouted at a temperature of 700 to 900° C. is quenched to a temperature of about from 400 to 550° C. by supplying to the upper chamber 1a a recovered liquid hydrocarbon through the line 15 and/or a starting liquid hydrocarbon through a line (not shown) in an atomized state. At this time, a part of the carbon and tar and heavy oil contained in the cracked gases is adhered to the surfaces of the solid particles fluidized in the upper chamber 1a.

The cracked gas mixture is then taken out of the upper chamber 1a through the line 9 to separate the residue of carbon and tar and heavy oil from the mixture, and the separated materials are then supplied to the lower chamber 1c where they are regarded as recovered liquid hydrocarbon.

For example, the cracked gas mixture is introduced through the line 9 to the cyclone 2, where carbon is separated and removed through the line 10. The purified mixture is then introduced through the line 11 to the distillation column 3, where the purified gas mixture is removed at the top through the line 12, while the heavy oil fraction containing tar is removed at the bottom through the line 14. The removed heavy oil fraction is used as recovered liquid hydrocarbon, and one part of it is introduced to the upper quenching chamber 1a through the line 15 with the carbon from the line 10 either in a mixed state or in a separated state, while the other part is introduced to the lower cracking chamber 1c through the line 16 with the carbon from the line 10 either in a mixed state or in a separated state. The line 13 provided in the distillation column 3 at the upper portion is used to force a light oil to circulate within the column. The light oil stems from a part of the heavy oil fraction from the line 14 and/or the purified gases from the line 12 by condensing them by means of a cooling process.

Turning to the solid particles which have been fluidized in the cracking furnace 1, in a process where a starting liquid hydrocarbon is to be cracked by utilizing the partial combustion of it, part of the solid particles in the lower chamber 1c is conveyed to the next central chamber 1b, accompanied by the cracked gases from the recovered liquid hydrocarbon. The conveyed particles are then fluidized in the central chamber 1b and a part of this fluid accompanied by the cracked gas mixture from the starting and recovered liquid hydrocarbons is conveyed further to the upper chamber 1a. In the upper quenching chamber 1a, part of the carbon tar and heavy oil in a condensed state adheres to the solid particles owing to the quenching of the gas mixture, whereby the solid particles are increasingly contaminated. Therefore, in order to burn the carbon, tar and heavy oil to gases and regenerate the solid particles, the contaminated solid particles are returned or recycled to the lower cracking chamber through the line 8. In other words, the solid particles, in this case, are normally recycled through the chambers in the sequence of, the recovered liquid hydrocarbon cracking chamber 1c→the starting liquid hydrocarbon cracking chamber 1b→the cracked gas quenching chamber 1a→the recovery liquid hydrocarbon cracking chamber 1c. Further in the case where the cracking of a starting liquid hydrocarbon is carried out by utilizing only the sensible heat of the cracked gases and the solid particles from the lower cracking chamber 1c, a by-pass route is provided by the line 7, in addition to the above-mentioned recycle system, from which a part of the solid particles in the central cracking chamber 1b is normally removed

from the side wall and is recycled to the lower cracking chamber 1c.

The recycling of the solid particles from the upper quenching chamber 1a and the central cracking chamber 1b to the lower cracking chamber 1c is carried out by adjusting the number of circulating particles by means of an overflow system of valves provided in the lines 7 and 8.

Referring to FIG. 2, the cracking furnace 1 according to the present invention will be explained in more detail. The furnace 1 comprises an upper chamber for quenching cracked gases 1a, a central chamber for cracking a starting liquid hydrocarbon to the gases 1b and a lower chamber for cracking recovered liquid hydrocarbon to gases.

The upper chamber 1a has a bottom of a funnel form and is connected at the bottom to the central chamber 1b at the top of an inverted funnel by means of the conduit-like narrow neck A, while the central chamber 1b is connected at the bottom of a funnel to the lower chamber 1c at the top of an inverted funnel by means of the conduit-like narrow neck B, whereby the furnace is formed as a unit for cracking the liquid hydrocarbon.

In the upper quenching chamber 1a, a gas exhaust port 18 at the top, an injection nozzle 20 having an opening 19 at the lower portion and a solid particle discharging conduit 22 having an outlet 21 at the upper side wall are provided. The injection opening for a liquid hydrocarbon 19 is preferably located at the bottom of the funnel as shown in the drawing. When the liquid hydrocarbon is spouted from the injection opening 19, steam with a starting liquid hydrocarbon and/or recovered liquid hydrocarbon may be fed in a premixed state or an unmixed state. In the case of an unmixed state, the injection nozzle 20 is preferably of a two concentric pipes construction, the liquid hydrocarbon passing through the inner pipe, and the steam passing through the outer pipe.

The central cracking chamber for a starting liquid hydrocarbon 1b is provided with a solid particle discharging conduit 24 having an outlet 23 at the upper side wall and a perforated plate gas distributor 25 which forms the bottom of a funnel, the perforated plate being connected to a conduit 26. In the conical perforated plate 25, one or more injection nozzles for feeding a starting liquid hydrocarbon in an atomized state 28 through an injection opening 27 are provided. From the perforated plate 25, steam fed through the conduit 26 is distributed within the central cracking chamber 1b in order to maintain the solid particles in the starting liquid hydrocarbon cracking zone in a suitable fluidized state and to cause dispersion of the starting liquid hydrocarbon so that cracking of the starting material can be promoted. At this time, if a partial combustion of the starting material is utilized for cracking the material, oxygen is supplied from the perforated plate 25 together with the steam. However the oxygen is not required if the cracking of the starting liquid hydrocarbon can be carried out completely by the sensible heats of the cracked gas and the solid particles spouted from the lower cracking chamber 1c only.

When the starting liquid hydrocarbon is fed from the injection opening 27 of the injection nozzle 28 in an atomized state, it may be injected with steam in a premixed state. Alternatively, the injection nozzle 28 of two concentric pipes construction may be used to feed the starting liquid hydrocarbon through the inner pipe and to feed the steam through the outer pipe. Furthermore three concentric pipes may be used as the injection nozzle 28, wherein the starting liquid hydrocarbon is fed through the inner pipe, the steam is fed through the central pipe and additional steam is fed through the outer pipe. This additional steam feeding improves the atomizing effect markedly.

The cracked gases from the starting liquid hydrocarbon in the central cracking chamber 1b contain, as main compositions, ethylene, propylene, methane and the rest involve hydrogen, carbon monoxide, carbon dioxide, hy-

drogen sulfide, heavy and light oil fractions, carbon and the like.

The lower chamber for cracking the recovered liquid hydrocarbon 1c is provided at the bottom with a perforated plate of an inverted conical or funnel form as a gas distributor 29, the perforated plate being connected to a conduit 30. An injection conduit 32 with an opening for a gas jet stream 31 extends downwards from the lowermost part of the perforated plate 29.

Further an injection nozzle for feeding the liquid hydrocarbon 34 is provided piercing the injection conduit 32 in an arrangement such that an injection opening 33 of the nozzle is located at the center of the gas jet stream opening 31. At the side wall of the lower chamber 1c, solid particle supplying conduits 36 and 38 are provided which have inlets 35 and 37 respectively. The inlet 35 of the lower chamber 1c is connected with the outlet 23 of the central chamber 1b through the conduit 36, line 7 and the conduit 24. This connection is intended to recycle the solid particles from the central chamber 1b to the lower chamber as required thereby heating the solid particles so that the heated particles impart the heat to the starting liquid hydrocarbon sufficient for cracking the starting material to gases. The inlet 37 is connected with the outlet 21 of the upper quenching chamber 1a through the conduit 38, line 8 and the conduit 22. This connection is intended to recycle the solid particles from the upper chamber 1a to the lower chamber 1c, thereby regenerating the contaminated solid particles from the upper chamber 1a. From the inverted cone of the perforated plate 29, steam as a fluidizing gas for the solid particles is fed to the lower chamber 1c along with oxygen which is applied for effecting partial combustion of the recovered liquid hydrocarbon and which may be pure oxygen or oxygen containing a gas mixture, for example, air. From the gas jet stream opening 31 steam is injected as a jet stream at a higher linear velocity than that of the fluidizing gas fed from the inverted conical perforated plate 29. This operation ensures that a desirable fluidized bed where good dispersion of the solid particles takes place is maintained whereby cracking of the recovered liquid hydrocarbon is easily attained.

From the injection opening 33 of the nozzle 34, the recovered liquid hydrocarbon is sprayed together with steam. This injection nozzle 34 may be either a single pipe or a two concentric pipes construction as described before. In the lower chamber for cracking the recovered liquid hydrocarbon 1c, there are produced cracked gases containing hydrogen, methane, carbon monoxide carbon dioxide and the like.

With respect to the cracking furnace 1 according to the present invention, the bottom funnel of the upper quenching chamber 1a, the funnel type perforated plate 25 of the central cracking chamber 1b and the bottom funnel of the lower cracking chamber 1c are preferably of angles of from 60° to 120° respectively. Such design ensures the prevention of the solid particles from stagnating within the whole of the fluidized bed zones formed in the chambers 1a, 1b and 1c, that is, avoids the phenomenon of stagnation of the solid particles in all of the bed zones, and maintains desirable fluidized bed zones.

The narrow neck A and B, that is, passages connecting the central chamber 1b with the upper and lower chambers 1a and 1c may be designed so that the inside diameters of the necks are such that the gas velocities therein are preferably in the range of from 1.1 to 4 times the average linear terminal velocity of the solid particles U_t (m./sec.). These diameters will vary according to the particle size, the rate of the whole gas feed and the like. In general, the lengths of the necks may preferably lie in the range of about 0.2 to 0.4 times the height of the lower cracking chamber 1c.

Nozzles for feeding liquid hydrocarbon to the quenching chamber, the central cracking chamber and the lower cracking chamber may be of a pressurized spray type.

Operational conditions of the cracking furnace according to the present invention will now be explained in detail.

To begin with, for the solid particles used for the present invention, any inert and refractory particles with sufficient mechanical strength, for example particles of refractory inorganic oxide such as alumina, silica, zirconia, titania, alumina-silica, silica-magnesia, silica-titania, alumina-magnesia, alumina-titania, cement clinker, mullite and the like may be employed. Within the above materials, mullite particles belonging to alumina-silica are especially preferred.

The average diameter of the solid particles is preferably of the order of 0.5 to 5.0 mm., and the solid particles of the same size as far as possible are desirable.

As for the number of the solid particles under forced circulation from the cracking zone for a starting liquid hydrocarbon to the cracking zone for a recovered liquid hydrocarbon, it varies to some extent according to factors such as kinds of the starting and recovered liquid hydrocarbons, cracking temperature, and the like, so that it is impossible to determine the number of the circulating solid particles absolutely. However, in general the number circulating must be of an order sufficient to impart to the starting liquid hydrocarbon the sensible heat of the solid particles necessary for cracking the starting material.

Regarding the other solid particles under forced circulation from the quenching zone for cracked gases to the cracking zone for a recovered liquid hydrocarbon, although the number varies in accordance with the extent of contamination of the solid particles and other factors, it may be in the preferable order of about 15% of all of the solid particles per an hour.

Although the entire quantity of steam used as a fluidizing gas and a gas jet stream in the cracking zone for a recovered liquid hydrocarbon depends on the physical properties of the recovered liquid hydrocarbon, it is preferably in the range of 0.5 to 1.2 part by weight relative to the amount of the recovered liquid hydrocarbon sprayed.

The linear velocity of the steam as a gas jet stream U_j (m./sec.), which is recalculated to the velocity at the pressure and temperature at the time of injection, may be preferably in the range of 2 to 10 times the average superficial velocity of the whole of the gas supplied to the cracking zone for a recovered liquid hydrocarbon U_0 (m./sec.), which is recalculated to the velocity at the pressure and temperature in the cracking zone. The quantity of the steam may be preferably within the range of 10 to 30% by volume of the whole amount of the gas supplied to the recovered liquid hydrocarbon cracking zone. The oxygen used as a part of the fluidizing gas must be the amount sufficient to burn the recovered liquid hydrocarbon partially at a desired temperature of 1050 to 1400° C. thereby cracking the hydrocarbon to gases. Although the quantity of oxygen may vary according to the kind and quantity of the recovered liquid hydrocarbon, the cracking temperature, the temperature of the solid particles circulating under force and other factors, it may be generally in a suitable range of 0.5 to 2 parts by weight relative to the recovered liquid hydrocarbon.

The average superficial velocity of the whole gas in the cracking zone for a recovered liquid hydrocarbon (U_0) (m./sec.) must be of the order sufficient to maintain the fluidized state of the solid particles, and in general it may be varied within a preferable range of 1.3 to 6 times the minimum fluidizing velocity of the solid particles U_{mf} (m./sec.).

By satisfying the above-mentioned conditions, there is attained the desired cracking of the recovered liquid hydrocarbon consisting mainly of heavy oil fractions which contains carbon and tar in the lower cracking zone, and simultaneously it is possible to heat the solid particles from the central cracking zone for the starting liquid hydrocarbon and to regenerate the contaminated solid

particles from the upper quenching zone for the cracked gases. In the above process, the gases produced by cracking the recovered liquid hydrocarbon in the lower cracking zone are forced to flow up to the central cracking zone together with a part of the solid particles through the narrow neck B.

In general the entire quantity of the steam fed to the central cracking zone for the starting liquid hydrocarbon is preferably in the range of 0.1 to 0.5 parts by weight relative to the starting liquid hydrocarbon.

The temperature of the central cracking zone for the starting liquid hydrocarbon should be maintained in the range of 700 to 900° C. For this purpose oxygen may be fed to effect a partial combustion of the starting liquid hydrocarbon as required thereby maintaining the central zone at the above temperature.

The average recalculated superficial velocity of the whole gas in the central zone U_0 (m./sec.) is preferably maintained in the range of 1.3 to 6 U_{mr} . The desired quantity of the starting liquid hydrocarbon and/or the recovered liquid hydrocarbon sprayed into the upper quenching zone for the cracked gases varies according to factors such as the temperature and quantity of the cracked gas mixture produced from the starting and recovered liquid hydrocarbons, so that it cannot be determined absolutely. In practice, it should be adjusted to an amount sufficient for quenching the cracked gases to a temperature of 400 to 550° C. If the quenching temperature is too low, that is, if the cracked gases are quenched to below 400° C., this causes agglomeration of the solid particles owing to adherence of tar contained in the cracked gas mixture and the sprayed recovered liquid hydrocarbon to the solid particles in large quantities. This agglomeration causes the fluidized state of the solid particles in the bed of upper quenching zone and eventually in all of the fluidized bed zones to be degraded. On the other hand, if the quenched temperature is more than 550° C., a desirable quenching effect of the cracked gas mixture cannot be obtained.

The average recalculated superficial velocity of the gas in the cracked gas quenching zone U_0 (m./sec.) is maintained preferably in the range of 1.3 to 4 U_{mr} .

With respect to the cracked gas mixture obtained by the above mentioned operations, carbon and tar, heavy oil fraction and the like may be separated from the gas mixture by a conventional process, for example, by a cyclone and then a distillation column. Further the resultant gas mixture may be refined to remove hydrogen sulfide, carbon dioxide and the like by a conventional process.

According to the present invention, the recovered liquid hydrocarbon, which has been difficult to treat and thus has been a source of environmental pollution, can be cracked easily to gases without exhausting it from the system, and further its energy can be utilized for cracking a starting liquid hydrocarbon. In addition to the above, the present invention provides an advantage in that the cracking of the hydrocarbon, the quenching of the cracked gases and further the removal of a part of carbon and tar, heavy oil fraction and the like can be carried out in a unitary fluidized bed or in a compact apparatus.

The refined gas according to the present invention is suitable as a fuel gas containing no sulfur. A town gas can be produced easily from the refined gas by adjusting the contents of olefin and hydrocarbon, for example by applying a catalytic hydrogenation with nickel.

The present invention is hereinafter explained in more detail by examples.

Example 1

Liquid hydrocarbon was thermally cracked by employing a crack furnace 1 of the same type as shown in FIG. 2, wherein solid particles were fluidized.

The particulars of the furnace were as follows.

Height from the injection opening 31 at the bottom of the lower chamber 1c or the cracking chamber for a recovered liquid hydrocarbon to exhaust port 18 in the upper portion of the upper chamber 1a or the cracked gas quenching chamber		mm.	8450
The cracked gas quenching chamber (the upper chamber) 1a:			
Inside diameter	mm. ϕ	260	
Height	mm.	3300	
Inside diameters of the injection nozzle for a liquid hydrocarbon 19 of two concentric pipes construction (two nozzles of the same size were adopted):			
Inner pipe	mm. ϕ	6.0	
Outer pipe	mm. ϕ	9.3	
Inside diameter of the solid particles outlet 21	mm. ϕ	42	
Angle of the funnel shoulder at the narrow neck A connecting the upper chamber 1a with the central chamber 1b			
	degrees	60	
Inside diameter of same	mm. ϕ	100	
Height of same	mm.	400	
The cracking chamber for a starting liquid hydrocarbon (the central chamber) 1b:			
Inside diameter	mm. ϕ	200	
Height	mm.	1920	
Angle of the funnel shoulder of the perforated plate 25 at the narrow neck B connecting the central chamber 1b with the lower chamber 1c			
	degrees	90	
Inside diameters of the injection opening for a starting liquid hydrocarbon 27 of three concentric pipes construction (two openings of the same size were adopted):			
Inner pipe	mm. ϕ	3.0	
Central pipe	mm. ϕ	8.0	
Outer pipe	mm. ϕ	16.7	
Inside diameter of the solid particle outlet 23	mm. ϕ	76	
Inside diameter of the narrow neck B	mm. ϕ	67	
Height of same	mm.	700	
The cracking chamber for a recovered liquid hydrocarbon (the lower chamber) 1c:			
Inside diameter	mm. ϕ	130	
Height	mm.	2100	
Inside diameter of the injection opening for a gas jet stream 31			
	mm. ϕ	20	
Inside diameter of the injection nozzle for a liquid hydrocarbon 34			
	mm. ϕ	5.8	
Inside diameter of the injection opening 33 of the nozzle 34			
	mm. ϕ	3.0	
Angle of the funnel shoulder of perforated plate 29			
	degrees	90	
Inside diameters of the solid particle inlets 35 and 37			
	mm. ϕ	76, 42	
Residue-oil obtained from Khafji crude oil by normal atmospheric distillation with the following composition and properties was used as the starting liquid hydrocarbon.			
Specific gravity (d_4^{15})		0.9572	
Residue	percent wt.	10.5	
Ash	do.	0.029	
Sulfur	do.	3.7	
Asphaltene	do.	4.9	
C	do.	84.8	
H	do.	11.3	

As solid particles to be fluidized, particles of mullite having an average diameter of 3 mm. in an amount of 130 kg. were used.

The cracking operations adopted and the results obtained are as follows.

A recovered liquid hydrocarbon separated from a cracked gas mixture, which will be described later at a feed rate of 39.8 kg./hr. was atomized into the recovered liquid hydrocarbon cracking chamber 1c from the injection opening 33 along with super heated steam at 400° C. at a feed rate of 4.8 kg./hr. Simultaneously another super heated steam at 400° C. at a feed rate of 11.8 kg./hr. was injected into chamber 1c from the injection opening 31 as a gas jet stream, while a gas mixture involving super heated steam at 400° C. at a feed rate of 17.7 kg./hr. and oxygen at a feed rate of 45.6 Nm³/hr. were fed into chamber 1c from the perforated plate 29 of funnel form. By the above operations, the recovered liquid hydrocarbon was burned partially and cracked to gases. At the same time, the cracked gas accompanied by a part of the solid particles was injected into the cracking chamber for the starting liquid hydrocarbon 1b, while steam at a feed rate of 9.0 kg./hr. was supplied to chamber 1b from the perforated plate 25 and starting liquid hydrocarbon of 137.5 kg./hr. was forced to flow into chamber 1b from the two injection openings 27 in an atomized state along with super heated steam at 400° C. at 19.3 kg./hr., whereby the starting liquid hydrocarbon was cracked to gases at a temperature of about 850° C. Simultaneously solid particles of 770 kg./hr. at 850° C. were forced to circulate to the cracking chamber for the recovered liquid hydrocarbon 1c from the solid particle outlet 23 by the method of over-flowing. During the above operations, a recovered liquid hydrocarbon of 334 kg./hr. was atomized into the cracked gas quenching chamber 1a from the two injection nozzles 19, accompanied by super heated steam at 12.6 kg./hr. at 400° C., whereby the cracked gas mixture injected from the bottom of the upper quenching chamber 1a was quenched to a temperature of about 500° C. Simultaneously the solid particles to which carbon and tar, heavy oil and the like had adhered were forced to circulate at a rate of 41 kg./hr. from the solid particle outlet 21 to the cracking chamber for the recovered liquid hydrocarbon 1c where they were regenerated for recycling. From the gas exhaust port 18 of the cracked gas quenching chamber 1a, a cracked gas mixture in a yield of 190 Nm³/hr. (dry gases) was obtained.

Composition of the yielded gas mixture is shown in Table 1 below. The gas mixture contained heavy and light oils and the like comprising carbon and tar in addition to the shown composition.

TABLE I

Composition			Composition		
	Vol. percent	Kg./hr.		Vol. percent	Kg./hr.
H ₂	21.7	3.64	CO ₂	12.4	45.64
CH ₄	14.1	18.99	N ₂	2.1	5.00
C ₂ H ₂	0.9	2.01	H ₂ S.....	1.8	5.18
C ₂ H ₄	15.1	35.58	Organic sulfur.....	0.06	0.15
C ₂ H ₆	1.3	3.28	Benzene, xylene and toluene..	1.9	12.19
C ₃ H ₈	3.4	12.11			
C ₃ H ₆	0.1	0.52			
C ₄ H ₁₀	1.0	4.43			
C ₄ H ₈	0.6	2.84			
CO.....	23.5	55.19			

The cracked gas mixture was then introduced into the cyclone 2, where carbon of 1.6 kg./hr. was separated out and the remainder of the mixture was then fed to the distillation column 3, where heavy oil fraction of 38.2 kg./hr. containing tar and light oil fractions was separated out. The mixture of the separated carbon and the heavy oil fraction was fed as a recovered liquid hydrocarbon in an atomized state from the injection opening 33 to the lower cracking chamber for the recovered liquid hydrocarbon 1c. The stored mixture of the carbon and the heavy oil fraction separated out by the cyclone and the distillation column was sprayed into the cracked gas quenching chamber 1a for recycling at a feed rate of 334 kg./hr.

In the cracking zone for a recovered liquid hydrocar-

bon within the lower chamber 1c, the average superficial velocity of the gas in the fluidized bed which was recalculated to the gas velocity at the temperature in the bed (U_0) was 8.0 m./sec., the linear velocity of the gas jet stream (steam) (U_j) was 30 m./sec., and the minimum fluidizing velocity of the solid particles (U_{mf}) was 1.7 m./sec. In the cracking zone for the starting liquid hydrocarbon within the central chamber 1b, the average recalculated superficial velocity of the gas in the fluidized bed (U_0) was 7.1 m./sec. In the quenching zone for the cracked gas in the upper chamber 1a, the average recalculated superficial velocity of the gas (U_0) in the fluidized bed was 3.7 m./sec. The linear velocity of the cracked gas from the recovered liquid hydrocarbon passing through the narrow neck B between the lower chamber 1c and the central chamber 1b was 30 m./sec., while the linear velocity of the cracked gas mixture passing through the narrow neck A between the central chamber 1b and the upper chamber 1a was 28 m./sec.

With respect to the quantity of the solid particles retained in each chamber, that is the number of the solid particles remaining in each chamber, the respective quantities in the upper chamber 1a, the central chamber 1b and the lower chamber 1c were about 80 kg., 35 kg. and 15 kg.

The recovered liquid hydrocarbon in an atomized state fed to the upper and lower chambers 1a and 1c had the following composition and properties:

Specific gravity (d_4^{15})	1.2
Sulfur	percent wt. 7.3
C	do. 87.2
H	do. 5.1

Example 2

Liquid hydrocarbon was thermally cracked to gases by using the same furnace as in Example 1 under different conditions, wherein solid particles of a quantity of 130 kg. were fluidized.

The solid particle outlet and inlet 23 and 35 were not provided.

	Mm. ϕ
Inside diameter of the narrow neck A connecting the upper chamber 1a with the central chamber 1b.....	146
Inside diameter of the central chamber 1b.....	230
Inside diameters of the injection opening for the starting liquid hydrocarbon 27 of three concentric pipes construction:	
Inner pipe	3.0
Central pipe	6.3
Outer pipe	21
Inside diameter of the injection opening for the gas jet stream 31	21
Inside diameter of the injection nozzle for the liquid hydrocarbon 34	6
Inside diameter of the injection opening 33 of the nozzle 34	3

As liquid hydrocarbon and solid particles, the same materials as in Example 1 were employed respectively.

The cracking operations and the results are as follows. A recovered liquid hydrocarbon separated from a cracked gas mixture, which will be explained hereafter, at a feed rate of 28.0 kg./hr. was forced to flow into the recovered liquid hydrocarbon cracking chamber 1c in an atomized state from the injection opening 33 along with super heated steam at 400° C. at 5.3 kg./hr. Simultaneously, another super heated steam at 400° C. at 9.5 kg./hr. was injected into chamber 1c from the injection opening 31 as a gas jet stream, while a gas mixture of super heated steam at 400° C. of 14.2 kg./hr. and oxygen of 19.9 Nm³/hr. was fed to chamber 1c from the perforated plate of funnel form. By the above-mentioned operations, the recovered liquid hydrocarbon was burned partially and cracked to gases. At the same time, the cracked gas accompanied by a part of the solid particles was injected

into the starting liquid hydrocarbon cracking chamber 1b, while a gas mixture of steam at 39.5 kg./hr. and oxygen at 48.9 Nm.³/hr. was supplied to chamber 1b from the perforated plate 25 and the starting liquid hydrocarbon at 184.7 kg./hr. was forced to flow into chamber 1b from the two injection openings 27 in an atomized state along with super heated steam at 400° C. at 34.4 kg./hr., whereby the starting liquid hydrocarbon was cracked to gases at a temperature of about 850° C. Further, a circulating recovered liquid hydrocarbon at 334 kg./hr. was forced to flow into the cracked gas quenching chamber 1a in an atomized state from the two injection openings 19 accompanied by super heated steam at 400° C. at 34.4 kg./hr.; whereby the cracked gas mixture injected from the bottom of the upper chamber 1a was quenched to a temperature of about 500° C. Simultaneously, the solid particles to which carbon and tar, heavy oil and the like had adhered were taken out of the solid particle outlet 21 and forced to circulate at a rate of 48 kg./hr. to the cracking chamber for the recovered liquid hydrocarbon 1c where the carbon deposited solid particles were regenerated for recycling.

From the gas exhaust port 18 of the cracked gas quenching chamber 1a, a cracked gas mixture of a yield rate of 242.8 Nm.³/hr. (dry gas) was obtained.

Composition of the yielded gas mixture is shown in Table 2 below. The gas mixture contained heavy and light oils and the like involving carbon and tar in addition to the composition shown.

TABLE 2

Composition			Composition		
	Vol. percent	Kg./hr.		Vol. percent	Kg./hr.
H ₂	21.8	4.82	CO.....	20.1	61.97
CH ₄	12.5	22.11	CO ₂	21.3	103.46
C ₂ H ₂	0.9	2.44	O ₂	0.1	0.35
C ₂ H ₄	12.9	39.94	N ₂	1.6	4.82
C ₂ H ₆	1.1	3.69	H ₂ S.....	1.8	6.69
C ₃ H ₆	2.7	12.58	SO ₂	0.1	0.81
C ₃ H ₈	0.1	0.57	Organic sulfur.....	0.05	0.20
C ₄ H ₆	0.8	4.99	Benzene.....		
C ₄ H ₈	0.6	3.45	xylene and toluene.....	1.5	13.08

The cracked gas mixture was then introduced into the cyclone 2, where carbon of 2.7 kg./hr. was separated out and the remainder of the mixture was then fed to the distillation column 3, where a heavy oil fraction of 25.3 kg./hr. containing tar and a light oil fraction of 16.7 kg./hr. were separated out.

The separated carbon and the separated heavy oil fraction were mixed and the mixture was sprayed into the recovered liquid hydrocarbon cracking chamber 1c from the injection opening 33, while the recovered liquid hydrocarbon was sprayed for recycling into the cracked gas quenching chamber 1a from the injection opening 19.

In the cracking zone for a recovered liquid hydrocarbon within the lower chamber 1c, the average superficial gas velocity in the fluidized bed, which was recalculated to the gas velocity at the temperature in the bed (U_0) was 8.0 m./sec., the linear velocity of the gas jet stream (steam) (U_j) was 30 m./sec., and the minimum fluidizing velocity of the solid particles (U_{mf}) was 1.7 m./sec. In the cracking zone for the starting liquid hydrocarbon within the central chamber 1b, the average recalculated superficial velocity in the fluidized bed of the gas (U_0) was 8.1 m./sec. In the quenching zone for the cracked gas within the upper chamber 1a, the average recalculated superficial velocity in the fluidized bed of the gas (U_0) was 4.6 m./sec. The linear velocity of the cracked gas from the recovered liquid hydrocarbon passing through the narrow neck B between the lower chamber 1c and the central chamber 1b was 20 m./sec., while the linear velocity of the cracked gas mixture passing through the narrow neck A between the central chamber 1b and the upper chamber 1a was 28 m./sec.

The recovered liquid hydrocarbon in an atomized state fed to the upper and lower chambers 1a and 1c had substantially the same properties as in Example 1.

What we claim is:

1. In a process for cracking liquid hydrocarbon into gases in a fluidized bed of solid particles, the improvement comprising;

(a) forming a unitary fluidized bed of solid particles having a central zone for cracking a starting liquid hydrocarbon to cracked gases, an upper zone for quenching said cracked gases, and a lower zone for cracking liquid hydrocarbon recovered from said cracked gases, said central zone communicating with said lower zone and said upper zone through narrow passages or neck zones formed therebetween;

(b) spraying said starting liquid hydrocarbon and a first portion of steam as a fluidizing gas into central zone, while passing a second portion of steam, cracked gases from recovered liquid hydrocarbon, hereinafter described, and entrained solid particles from said lower zone into said central zone from the bottom thereof through said narrow neck zone, thereby cracking said starting liquid hydrocarbon in said central zone to gases;

(c) spraying a liquid hydrocarbon selected from the group consisting of a said starting liquid hydrocarbon and said recovered liquid hydrocarbon into said upper zone, while passing a second gas mixture comprised of said first and second portions of steam, said cracked gases and entrained solid particles from said central zone into said upper zone from the bottom thereof through said narrow neck zone, whereby said cracked gas mixture is quenched and a portion of the carbon, tar and heavy oil fractions which are contained in said cracked gas mixture adhere to said entrained solid particles;

(d) removing said cracked gas mixture from said upper zone and treating said cracked gas mixture to separate said carbon, tar and heavy oil fractions, which comprise the recovered liquid hydrocarbon, referenced hereinbefore, to be fed to said bed, while a portion of said entrained solid particles are removed from said upper zone and recycled to said lower zone; and

(e) feeding oxygen, said second portion of steam as a fluidized gas and said recovered liquid hydrocarbon into said bottom of said lower zone to fluidize said solid particles throughout and partially burn said recovered liquid hydrocarbon, thereby cracking said recovered liquid hydrocarbon to said cracked gases.

2. A process for cracking liquid hydrocarbon into gases according to Claim 1, further comprising forcing some part of said entrained solid particles in said central zone to recycle to said lower zone.

3. A process for cracking liquid hydrocarbon into gases according to Claim 1, further comprising feeding another part of oxygen to said central zone to effect a partial combustion of said starting liquid hydrocarbon, thereby cracking said starting material or promoting the cracking of said starting material.

4. A process for cracking liquid hydrocarbon according to Claim 1, wherein said cracked gas mixture from said upper zone is separated by a cyclone into purified gases and carbon, and said purified gases are further separated by a distillation column into refined gases and a heavy oil fraction, said separated carbon and heavy oil fraction being recycled to said bed as said recovered liquid hydrocarbon.

5. A process for cracking liquid hydrocarbon into gases according to Claim 1, wherein partial combustion of said recovered liquid hydrocarbon in said lower zone is carried out at a temperature of 1050 to 1400° C., the thermal cracking of said starting liquid hydrocarbon in said central zone takes place at a temperature of 700 to 900° C.,

and said cracked gas mixture is quenched to a temperature of 400 to 550° C.

6. A process for cracking liquid hydrocarbon into gases according to Claim 1, wherein the average superficial velocity of the whole of the gas recalculated at the pressure and temperature in said lower zone U_o (m./sec.) is adjusted within the range of 1.3 to 6.0 times the minimum fluidizing velocity of the solid particles U_{mf} (m./sec.).

7. A process for cracking liquid hydrocarbon into gases according to Claim 6, wherein the average recalculated superficial velocity of the whole gas U_o in said central zone is in the range of 1.3 to 6.0 times the minimum fluidizing velocity of the solid particles.

8. A process for cracking liquid hydrocarbon according to Claim 6, wherein the average recalculated superficial velocity of the whole gas U_o (m./sec.) in said upper zone is in the range of 1.3 to 4.0 times the minimum fluidizing velocity of the solid particles U_{mf} (m./sec.).

9. A process for cracking liquid hydrocarbon according to Claim 6, wherein the gas velocities in said narrow neck zones are in the range of 1.1 to 4 times the average linear terminal velocity of the solid particles U_t (m./sec.).

10. A process for cracking liquid hydrocarbon into gases according to Claim 1, wherein the quantity of steam used as a fluidizing gas in said lower zone is in the range of 0.5 to 1.2 parts by weight relative to the amount of said recovered liquid hydrocarbon sprayed into said lower zone.

11. A process for cracking liquid hydrocarbon into gases according to Claim 10, wherein the quantity of oxygen supplied to said lower zone for effecting fluidization of the solid particles and a partial combustion of said recovered liquid hydrocarbon is in the range of 0.5 to 2 parts by weight relative to the amount of said recovered liquid hydrocarbon sprayed in said lower zone.

12. A process for cracking liquid hydrocarbon into gases according to Claim 10, wherein the entire quantity of the steam fed to said central zone is in the range of 0.1 to 0.5 parts by weight relative to the amount of said starting liquid hydrocarbon feed.

13. A process for cracking liquid hydrocarbon into gases according to Claim 6, wherein a linear velocity of the steam recalculated at the pressure and temperature of the steam passing through the injection opening of said lower zone U_j (m./sec.) is adjusted within the range of 2 to 10 times the average recalculated superficial velocity of the whole gas U_o in said lower zone, and said steam is in the range of 10 to 30% by volume of the whole amount of the gas supplied to the lower zone.

14. A process for cracking liquid hydrocarbon into gases according to Claim 2, wherein said solid particles under forced circulation from said central zone to said lower zone are of an order sufficient to impart to said starting liquid hydrocarbon the sensible heat of said entrained solid particles necessary for cracking the starting material.

15. A process for cracking liquid hydrocarbon into gases according to Claim 1, wherein the carbon deposited solid particles under forced circulation from said upper zone to said lower zone are on the order of about 15% of all of the solid particles per hour.

16. A process for cracking liquid hydrocarbon into gases according to Claim 1, wherein said solid particles used are inert refractory particles with sufficient mechanical strength.

17. A process for cracking liquid hydrocarbon into gases according to Claim 1, wherein said solid particles used are of a size in the order of 0.5 to 5.0 mm.

18. A furnace for cracking liquid hydrocarbon into gases, having three portions formed in a fluidized bed of solid particles therein comprising:

- (a) a central chamber for cracking a starting hydrocarbon, said central chamber having constricted top and bottom portions and containing a first perforated plate gas distributor of the funnel type for a

fluidizing gas, said first gas distributor having a first injection nozzle for a starting liquid hydrocarbon located within the conical portion thereof, said injection nozzle being of dual concentric pipe construction having an inner pipe for feeding said starting liquid hydrocarbon and an outer pipe for feeding steam;

- (b) a lower chamber for cracking a recovered liquid hydrocarbon, said lower chamber having a constricted top portion communicating with said bottom portion of said central chamber and containing a second perforated plate gas distributor of the funnel type for a fluidizing gas, said second gas distributor having an injection opening formed within the conical portion of said second gas distributor for passage of a gas jet stream of fluidizing gas and a second injection nozzle for said recovered liquid hydrocarbon located coaxially within said injection opening, said injection nozzle being of dual concentric pipe construction having an inner pipe for feeding said recovered liquid hydrocarbon and an outer pipe for feeding steam; and

- (c) an upper chamber for quenching cracked gases, said upper portion provided with a gas exhaust port in the top portion, a constricted lower portion and a third injection nozzle for liquid hydrocarbon located within said constricted lower portion of said upper chamber, said third injection nozzle being of dual concentric pipe construction having an inner pipe for feeding said liquid hydrocarbon and an outer pipe for feeding steam, said upper chamber also communicating with said lower chamber through a first bypass means for recycling solid particles.

19. A furnace for cracking liquid hydrocarbon into gases according to Claim 18, wherein said first injection nozzle in said central chamber is of a triple concentric pipe construction having an inner pipe for feeding said starting liquid hydrocarbon, a middle pipe for feeding steam, and an outer pipe for feeding additional steam.

20. A furnace for cracking liquid hydrocarbon into gases according to Claim 18, wherein said constricted bottom portion of said upper chamber is connected to said constricted top portion of said central chamber by a conduit-like narrow neck, while said constricted bottom portion of said central chamber is connected to said constricted top portion of said lower chamber by another conduit-like narrow neck.

21. A furnace for cracking liquid hydrocarbon into gases according to Claim 20, wherein said narrow necks are of a height of about 0.2 to 0.4 times the height of said lower chamber.

22. A furnace for cracking liquid hydrocarbon into gases according to Claim 18, wherein said constricted bottoms of said upper, central and lower chambers are conically shaped having an angle formed thereby within a range of about 60° to 120°.

23. A furnace for cracking liquid hydrocarbon into gases according to Claim 18, wherein said lower chamber also communicates with said central chamber through a second bypass means for recycling solid particles.

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