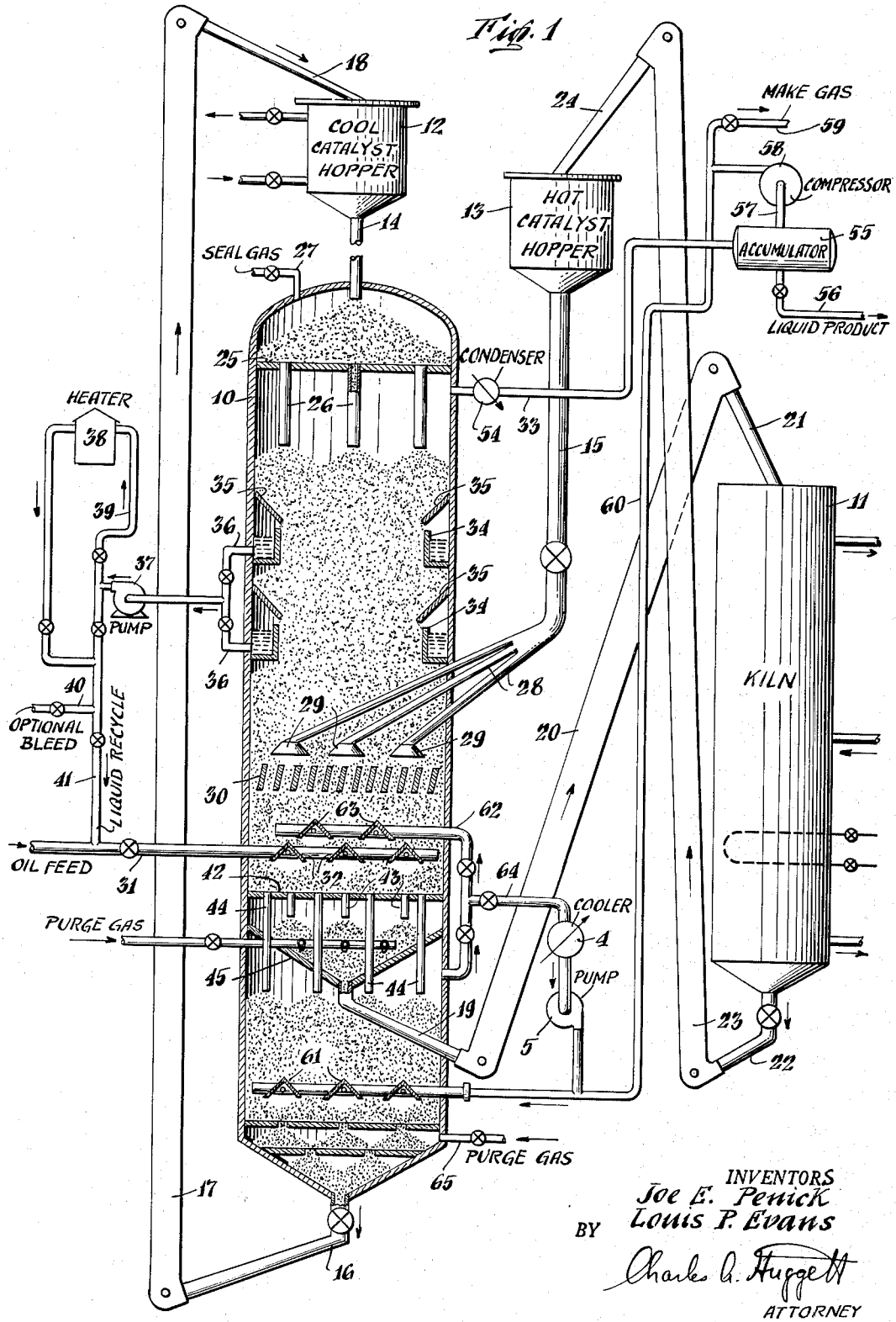
April 10, 1956 L. P. EVANS ET AL 2,741,582

CATALYTIC HYDROCARBON CONVERSION PROCESS WITH THE USE OF A MOVING BED AT DIFFERENT TEMPERATURE LEVELS

Filed Sept. 19, 1952 2 Sheets-Sheet 1

Fig. 1



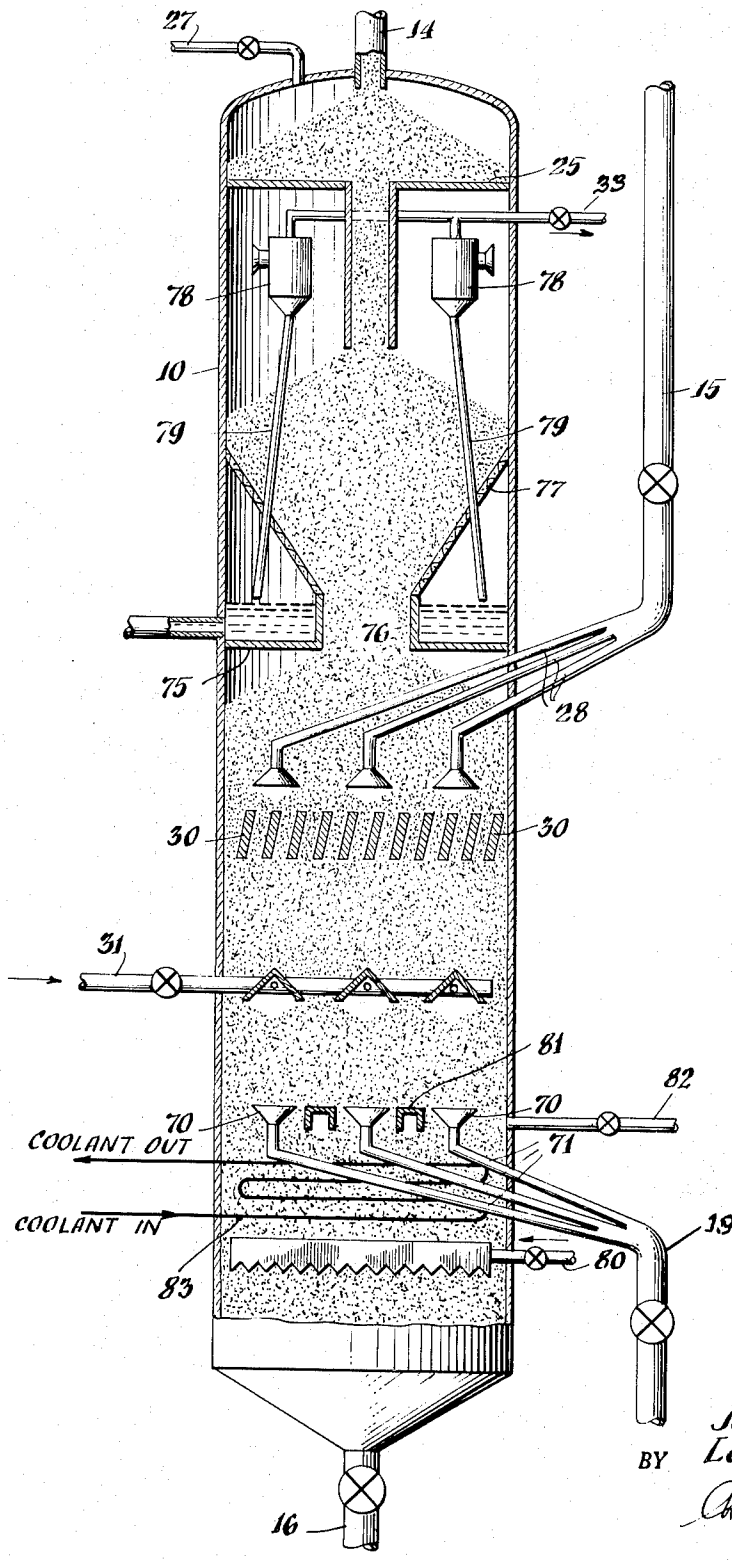
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Fig. 2



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CATALYTIC HYDROCARBON CONVERSION PROCESS WITH THE USE OF A MOVING BED AT DIFFERENT TEMPERATURE LEVELS

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4 Claims. (Cl. 196—52)

This invention pertains to the conversion of high boiling hydrocarbons to lower boiling hydrocarbons in the presence of particle form material. It is particularly concerned with a process for cracking hydrocarbons boiling at a higher temperature than gasoline in the presence of a solid cracking catalyst to produce gasoline.

A large portion of the gasoline used today is obtained by converting suitably selected petroleum stocks, such as gas oil and the like, by contacting the gas oil with adsorbent catalysts at temperatures of the order of 700–1000° F. and pressures usually of about 5–30 p. s. i. gauge. The heavy oil is converted to the lighter gasoline constituents in yields of about 30–50 per cent. It is customary to pass the reactant material, in liquid or vapor form, through a gravitating bed of the contact catalyst in a reaction zone and transfer the products to a separating zone where the gasoline is separated from the gas and heavier oils. The oil is usually heated in a furnace or heat exchanger prior to its introduction into the reactor so that at least a substantial portion of the oil is converted to a vapor before it contacts the catalyst. After the products are removed from the reactor, they are cooled in a suitable heat exchanger before being introduced into the synthetic crude tower for separation. The cracking system requires, therefore, several pieces of complicated and expensive apparatus interconnected into a unitary group. Each piece of apparatus has its own thermal losses and these thermal losses are cumulative. It is desirable to simplify the apparatus required, decrease the number of pieces necessary and make the cracking system more compact.

It is a major object of this invention to provide an improved process in which high boiling liquid petroleum fractions may be converted to gasoline in a confined zone and substantially only gasoline and lighter products removed from said zone.

It is a further object of this invention to provide an improved process for converting high boiling liquid petroleum fractions to gasoline which has high thermal efficiency.

It is a further object of this invention to provide an improved process for converting heavy hydrocarbons in the presence of a suitable contact material and separating substantially only gasoline and lighter material from the contact material.

These and other objects will become apparent from the following detailed description of the invention.

In the preferred form of the invention, a granular contact material is gravitated downwardly as a compact column with a cool contact material being supplied to the top of the column and a hot contact material being introduced into the column at an intermediate level. A high boiling level hydrocarbon charge is introduced into the column below the point of introduction of the hot contact material. The hydrocarbon charge is cracked and passes upwardly through the column to contact cooler catalyst in the upper portion of the column. The flow rate and temperatures of the hot and cold catalyst

streams are adjusted so that substantially all the hydrocarbons heavier than gasoline are condensed and only the gasoline and lighter fractions travel upwardly through the top of the column to be removed therefrom. The condensed liquid hydrocarbons heavier than gasoline are continuously removed from the column and recycled to the hotter portion of the column so that they are eventually converted to coke or gasoline and lighter material. A stream of catalyst is removed from the column at a level below the point of introduction of the hydrocarbon charge and passed to a reconditioning and heating zone for subsequent reuse as the hot catalyst stream. The gasoline and lighter material removed from the top of the column are separated into gas and gasoline fractions and the gas may be recycled to the bottom of the column of catalyst to travel upwardly and extract heat from the catalyst in the lower portion of the column. Heat may also be extracted from the lower portion of the column by means of indirect heat exchange coils. The cooled catalyst is then recycled to the top of the column.

Although a low activity catalyst may be used in the process of this invention, it is preferred to use a catalyst having high cracking activity and high heat capacity. The catalyst may partake of the nature of natural or treated clays or synthetics, such as silica, alumina, chromia, etc. The size range may be about 4–100 mesh Tyler but preferably about 4–20 mesh Tyler.

Suitable apparatus for practicing the process of this invention is shown on Figures 1 and 2 attached.

Figure 1 is an elevational view, partially in section, of a unitary cracking system illustrating the invention.

Figure 2 is a modified form of reactor also illustrating the invention.

Referring now to Figure 1, an elongated vertical vessel **10** serves as the reactor, having any suitable cross-section, such as round, square, rectangular. A kiln **11** is located alongside the reactor **10**. A cool catalyst hopper **12** and a hot catalyst hopper **13** are located above the reactor **10**, the cool catalyst hopper being connected to the top of the reactor **10** by a conduit **14** and the hot catalyst hopper being connected to the reactor at an intermediate level by the conduit **15**. A withdrawal conduit **16** is attached to the bottom of the reactor **10** and connected to the bottom of an elevator **17**. The top of the elevator **17** is connected to the top of the cool catalyst hopper by the conduit **18**. A conduit **19** connects with the reactor **10** at an intermediate level below the point at which the conduit **15** is attached thereto. Conduit **19** connects to the bottom of an elevator **20**. The top of the elevator **20** is connected to the top of the kiln **11** by the conduit **21**. A withdrawal conduit **22** is attached to the bottom of the kiln and connected to the bottom of an elevator **23**. The top of the elevator **23** is connected to the top of the hot catalyst hopper by the conduit **24**.

In operation, a cold catalyst is supplied by the elevator **17**, via conduit **18** to the cool catalyst hopper **12**. The catalyst is gravitated downwardly from the hopper **12** as a compacted column which extends through the conduit **14** and vessel **10** to the bottom of the elevator **17**. A partition plate **25** is located in the upper portion of the reactor. A group of drop pipes **26** are attached to the plate **25** for transferring catalyst from the plate **25** to the top of the bed in the main portion of the reaction zone. A seal gas is introduced into the top of the vessel **10** through the pipe **27** to prevent reactant vapors from rising upwardly through the drop pipes **26**. A stream of hot catalyst is withdrawn from the bottom of the kiln **11** through the conduit **22** and lifted via the elevator **23** to a level from which it flows through the conduit **24** to the hot catalyst hopper **13**. The hot catalyst is gravitated as a compacted column from the hopper **13** through the conduit **15**, and is preferably introduced into the bed of

solids in the vessel 10 through branch conduits 28 which all terminate at about the same elevation. Inverted funnel members 29 are attached to the bottom end of these branch conduits to permit the hot solid streams to enter the reactor freely. Baffles 30 are arranged below the funnels 29 to provide for intimate mixing of the hot stream with the cold stream of solids and thereby provide a uniform catalyst temperature across the column. Oil feed is introduced through the conduit 31 into the column at a level beneath the level at which the hot catalyst is introduced. The inverted channels or angle irons 32 are located across the vessel 10 so as to shield the oil feed introduction pipes. The oil feed, in liquid or vapor form, rises upwardly through the bed of hot solids and is at least partialy cracked to lighter hydrocarbons. When the vapors rise above the level of the point of introduction of the hot catalyst, the vapors are partially condensed. Substantially all the gasoline and lighter fractions remain in the gaseous state and rise upwardly through the column to the catalyst-free region beneath the plate 25. The gasoline and lighter material is withdrawn from the vessel 10 through the conduit 33. The heavier than gasoline fractions condense to droplets. The upward flow rate of the gaseous material may be sufficient to lift and maintain the droplets in the column. Ring type baffles 34 are located in the upper portion of the vessel 10. The baffles 34 have an upwardly directed inner wall which connects to the floor of the baffles to form a suitable trap tray. The storage space of the trap tray is covered by dish-shaped baffles 35, which serve to keep the catalyst out of the trap tray. The dish-shaped baffles are open in the center or bottom, so as to permit free transfer of solids therethrough. The liquid hydrocarbons accumulate in the column and collect in the trap trays. The liquid hydrocarbons are drawn off through the conduits 36. The withdrawn liquids are placed under pressure by the pump 37, and may be heated, if desired, in the heater 38 connected in the line 39. The heavy condensed hydrocarbons may be withdrawn through the conduit 40 or passed downwardly through the conduit 41 to the oil feed line 31 for reuse in the process. Preferably, the liquid condensate is recycled until it is converted to coke or gasoline and lighter products. Where the upward gas flow through the column is not sufficient to hold the droplets of condensed material in the upper portion of the column, the liquid collection system must be arranged to cover a sufficient portion of the cross-section of the vessel so that recycle liquid is collected in large enough quantity. This can be done by use of a sufficient number of trap trays or V-shaped collecting troughs distributed across the vessel, shielded to prevent catalyst from entering the troughs.

A partition plate 42 is located across the vessel 10 beneath the level at which the oil feed is introduced into the column. Drop pipes 43 and 44 are attached to this plate. The pipes 43 conduct catalyst onto a funnel-shaped collection member 45 which connects at its lower end to conduit 19. This permits the removal of a stream of solids from the column for transfer via the elevator 20 and conduit 21 to the top of the kiln 11. The longer drop pipes 44 are passed through the collection member 45 and transfer the remaining catalyst to the bottom of the vessel 10. The gasoline and lighter material removed from the top of the vessel 10 through the conduit 33 is cooled in the cooler 54 and separated in a simple accumulator 55. Liquid product is drawn from the bottom of the accumulator 55 through the conduit 56 and the gas is taken overhead via the conduit 57 to the compressor 58. Some gas may be withdrawn as make gas via the conduit 59. The remaining gas under pressure, is recycled via the conduit 60 to a level near the bottom of the catalyst column in the vessel 10. The gas is introduced under the channels 61 and travels upwardly through the bed of catalyst. The gas is substantially cooler than the catalyst and undergoes heat exchange with the catalyst, thereby serving as a cooling fluid. The cooled catalyst is withdrawn from the bottom of the column and recycled to the top of the cool catalyst hopper 12. The heated cycle gas is withdrawn from the vessel 10 beneath the collection member 45. Some of this gas may be conducted via the conduit 62 to a level about the same as that at which the oil charge is introduced into the column and introduced under the channels or angle irons 63. The remainder of the cycle gas may be withdrawn from the system through the conduit 64, cooled in the cooler 4, and pumped via the pump 5 back into the lower portion of the column for reuse as coolant fluid. It is possible to use liquid recycle as a coolant in this process. The recycle is separated into heavy and light material. The heavy recycle is then introduced into the column just below the level of hot solids withdrawal through conduit 19. The light recycle is introduced at a lower level. A suitable purge gas is introduced into the bottom of the column via the pipe 65.

An alternate arrangement of apparatus for practicing the invention is shown on Figure 2. The reactor 10 is supplied cool catalyst by the conduit 14 and hot catalyst by the conduit 15 and branch conduits 28. Liquid charge is introduced via the conduit 31 at a level substantially below the mixing baffles 30 and substantially above the level of a series of funnel-shaped cups 70. The cups are distributed uniformly across the vessel and are connected to the conduits 71 for removal of a side stream of the solids via the conduit 19 to a kiln, not shown. A trap tray is shown in the upper portion of the vessel having a floor 75 and vertical wall 76. The top of the wall is connected to the inner wall of the vessel 10 by a conical screen 77, suitably selected to prevent the solid material from entering the trap tray. In place of the single screen shown, a double screen may be provided with provisions for injecting steam therebetween to clean the screens when desired. The liquid condenses in the upper portion of the column. The upward gas flow may be just sufficient to suspend the droplets at the level of the trap tray or the tray may be designed to catch the droplets as they fall. The liquid flows through the screen 77 into the trap tray and is removed therefrom as recycle stream in a manner similar to that shown on Figure 1. Alternatively internal conduits may be used to transfer the recycle stream downwardly from the trap tray through the column to a discharge level in the reaction portion of the bed. The gasoline and lighter material enters the cyclone separators 78 in the catalyst-free area beneath the partition plate 25. Any entrained liquid in the vapor stream is separated in the cyclone separators and passed through the drop legs 79 into the trap tray. The gas is withdrawn from the vessel 10 via the conduit 33. The remainder of the system may be similar to that shown on Figure 1 and is, hence, not shown in this figure. Recycle gas, which has been cooled, may be introduced into the bottom of the column via the conduit 80 to travel upwardly through the bed of solids. The recycle gas cools the solids, before they are transferred via the conduit 16 to the cool catalyst hopper. The gas is withdrawn from the column via the channels 81 and conduit 82. Additional cooling may be obtained by cooling coils 83. Alternatively all the cooling may be effected by use of the cooling coils 83.

As an illustration of the invention, a gas oil, having a boiling range of about 450 to 1000° F., may be introduced into a continuous gravitating bed of chrome bead contact catalyst at an intermediate level at a flow rate of about 7,500 barrels per day. Cool catalyst is added to the top of the column at a temperature of about 280° F. and flow rate of about 280 tons per hour. The hot catalyst is introduced into the column at about 10 feet below the top thereof at a temperature of about 950° F. and flow rate of about 430 tons per hour. The height of the column is about 45 feet and the cross-section about 260 square feet. The side stream of solids for the kiln is withdrawn from the column at a level about 10 feet above the bottom of the column. Condensate is recycled at a flow rate of about 7,500 barrels per day and gas is recy-

cled to the bottom of the column at a flow rate of about 175,000 cu. ft. per hour, and temperature of about 110° F. The products withdrawn from the top of the column contain 56 weight per cent gasoline, 39 weight per cent material lighter than gasoline and 5 weight per cent heavier than gasoline.

In general, the cool catalyst may be introduced onto the top of the gravitating column at a temperature of about 150 to 450° F., but preferably should be about 200 to 350° F. The hot catalyst may be introduced into the column at a temperature of about 900 to 1,200° F. but preferably should be about 950 to 1,050° F. The separation of the hydrocarbons in the upper portion of the column should be broadly such that the gasoline and lighter material is not less than 75 weight per cent of the products removed from the top of the column and preferably should be such that not less than 90 weight per cent of the product is gasoline and lighter material.

The process of this invention has many advantages over the prior practices, such as for example:

(1) Since substantially all the product removed from the catalyst column is gasoline or lighter, no synthetic crude fractionating tower need be provided.

(2) The cracked products are continuously removed from the cracking zone and the heavier than desired products are continuously recycled, resulting in improved overall yields of gasoline and decreased gas and coke formation.

(3) Since it is only necessary to supply heat to the process equivalent to the heat of cracking plus the heat of vaporization of the net product plus radiation losses, the thermal efficiency is high.

(4) Since no heaters, vaporizing furnaces, synthetic crude towers, cracked vapor heat exchangers need be provided, the cost of apparatus for practicing the invention is low.

It is intended that the scope of this invention be considered broadly to cover all changes and modifications of the examples of the invention herein chosen for purposes of disclosure which do not constitute departures from the spirit of the invention.

We claim:

1. A process for the catalytic cracking of hydrocarbons to form a gasoline-containing product, which comprises: maintaining a downwardly gravitating, substantially compact bed of solid, granular adsorptive catalyst within a confined zone; supplying a stream of cool granular adsorptive catalyst to the upper section of said bed at a temperature within the range about 150° F. to 450° F.; supplying a stream of hot granular adsorptive catalyst at a temperature within the range about 900 to 1200° F. to an intermediate level in said bed in sufficient quantity that a substantial portion of said bed therebelow is maintained at an average temperature within the range of about 700 to 1000° F.; introducing hydrocarbon charge into the bed below the level of hot catalyst supply and passing the charge through the bed to effect cracking thereof below the level of hot catalyst supply; passing vapors resulting from the cracking conversion upwardly through the upper section of said bed above the level of hot catalyst supply to effect heating of the catalyst in that section and cooling of the vapors to a point where condensation occurs to the extent that of the remaining uncondensed vapor at least 75 per cent boils within the gasoline boiling range and below; removing a vapor product, at least 75 per cent of which consists of material boiling within the gasoline range and below, from the upper section of said confined zone; continuously removing catalyst from the lower section of the bed as a mixture of catalyst particles initially supplied to the upper section of the bed and catalyst particles supplied at the intermediate level in the bed; passing a portion of the catalyst so removed to a confined regeneration zone and regenerating the catalyst therein to recondition it for re-use in the reaction zone; returning catalyst from the regeneration zone to the bed as the hot

catalyst stream; passing a second portion of the catalyst removed from the bed into and through a cooling zone and returning said second portion to the reaction zone as the cool catalyst stream.

2. A process for the catalytic cracking of hydrocarbons, which comprises: maintaining a downwardly gravitating, substantially compact bed of solid adsorptive catalyst within a confined zone; supplying a first stream of solid adsorptive catalyst to the upper end of said bed at a temperature within the range 150 to 450° F.; supplying a second stream of solid adsorptive catalyst at a temperature within the range about 900 to 1200° F. to an intermediate level in said bed to mix with the catalyst in said bed at said level, said second stream being of sufficient quantity that a substantial portion of said bed below the level of its supply is maintained at an average temperature within the range about 700 to 1000° F.; supplying a hydrocarbon charge to the bed at a level below the level of supply of said second stream and passing said charge upwardly through the bed to effect cracking thereof; passing the vapors resulting from the cracking conversion upwardly through the portion of the bed above the level of supply of said second stream, whereby heat transfer occurs and a substantial portion of the products of conversion are condensed so that there remains as a vapor, material at least 75 per cent of which boils within the gasoline boiling range and below; withdrawing as vapor product said material remaining in the vapor state after said condensation; withdrawing material condensed in the upper section of said bed from said confined zone separately of the vapors withdrawn; re-introducing a portion of the vapor product withdrawn into said bed at a level adjacent the lower end of the bed and cooling catalyst by means of said portion of the vapor product; withdrawing catalyst as a mixture of the catalyst particles initially supplied from said first and second streams from said bed at a level above the level of supply of said portion of the gaseous product and below the level of supply of said second stream and regenerating the catalyst so withdrawn and returning it to said bed as said second stream; also removing catalyst as a mixture of catalyst particles initially supplied through said first and second streams from the lower end of said bed after it has been cooled by the introduced portion of the vapor product and returning said cooled catalyst to the upper end of said bed as said first stream.

3. The process for the catalytic cracking of hydrocarbons, which comprises: maintaining a downwardly gravitating, substantially compact bed of solid adsorptive catalyst of a size within the range 4 to 100 mesh within an elongated confined zone; supplying a first stream of catalyst to the upper end of said bed at a temperature within the range 150 to 450° F.; supplying a second stream of catalyst at a temperature within the range 900 to 1200° F. to an intermediate level within said bed to mix with the catalyst there; supplying a hydrocarbon charge to the bed at a level below the level at which said second stream is introduced and passing said charge upwardly through the bed to effect cracking thereof; maintaining said bed between the level of supply of said second stream and the level of hydrocarbon introduction at an average temperature within the range about 700 to 1000° F.; passing the vapors resulting from the cracking conversion upwardly through the portion of the bed lying above the level of introduction of said second stream to effect heat transfer between vapors and catalyst, whereby a sufficient portion of the vapors are condensed so that there remains as a vapor a material at least 75 per cent of which boils in the gasoline range and below; removing vapor product, consisting of at least 75 per cent of material boiling within the gasoline range and below, from said zone at a level above said bed; withdrawing condensate formed in the upper section of said bed from the upper section of said bed

and returning it to said bed at a level below the level of supply of said second stream, removing catalyst as a mixture of particles initially supplied from both of said streams from the lower section of said bed; regenerating a portion of the catalyst so removed and returning it to said bed as said second stream and cooling another portion of the catalyst so removed and returning it to said bed as said first stream.

4. A process for the catalytic cracking of petroleum hydrocarbons, which comprises: maintaining a downwardly gravitating, substantially compact bed of solid adsorptive catalyst of a size within the range about 4 to 100 mesh Tyler within an elongated confined zone; supplying a first stream of said catalyst at a temperature within the range about 200 to 300° F. to the upper end of said bed; supplying a second stream of said catalyst at a temperature within the range about 900 to 1200° F. to said bed at an intermediate level to mix with the catalyst in said bed at said level; supplying a petroleum hydrocarbon charge boiling within the range about 450 to 1000° F. to said bed at a level below the level of supply of said second stream; maintaining the average temperature of said bed between the level of hydrocarbon charge supply and the level of supply of said second stream within the range about 700 to 1000° F.; passing hydrocarbon charge upwardly through the bed to effect cracking thereof in the region of the bed below the level of supply of said second stream; passing the vapors formed from said cracking upwardly into the upper portion of said bed above the level of supply of said second stream to effect heat exchange between catalyst in that portion of the bed and the vapors to condense sufficient of said vapors so that at least 90 per cent of the material boiling above the gasoline boiling range is condensed; withdrawing as a vapor product from the upper section of said bed a vapor stream in which at least 90 per cent of the material boils within the gasoline boiling range and below; removing condensate formed in the upper section of said bed from said bed at a level below that at which the vapor product is withdrawn and recycling at least a portion of the condensate so removed to said bed at a level below the level of supply of said second stream; cooling said vapor product so as to condense higher boiling portions thereof while lower boiling portions remain in the gaseous phase; and introducing at least a portion of said gaseous phase material into said bed at a level adjacent the lower end thereof and passing said gaseous phase material upwardly through the lowermost regions of said bed to effect cooling of the catalyst there; removing catalyst from said bed at a level a substantial distance above the level at which said gaseous phase material is supplied and below the levels at which hydrocarbon charge and recycled condensate are introduced to the bed; withdrawing the gaseous phase material from said bed at a level substantially above its point of introduction but below the level of withdrawal of catalyst and re-introducing at least a portion of this gaseous phase material into the bed at a level above the level of catalyst withdrawal; regenerating the catalyst so withdrawn to effect reconditioning thereof and heating of the catalyst to a temperature within the range about 900 to 1200° F. and returning said catalyst to said bed as said second stream; withdrawing catalyst from the bottom of said bed and returning it to the upper end thereof as said first stream.

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