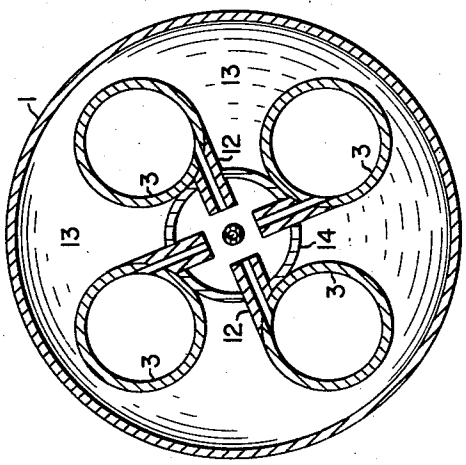
Nov. 4, 1958 M. L. DOWNING ET AL 2,859,168

FLUID COKING REACTOR

Filed May 26, 1955

FIGURE II



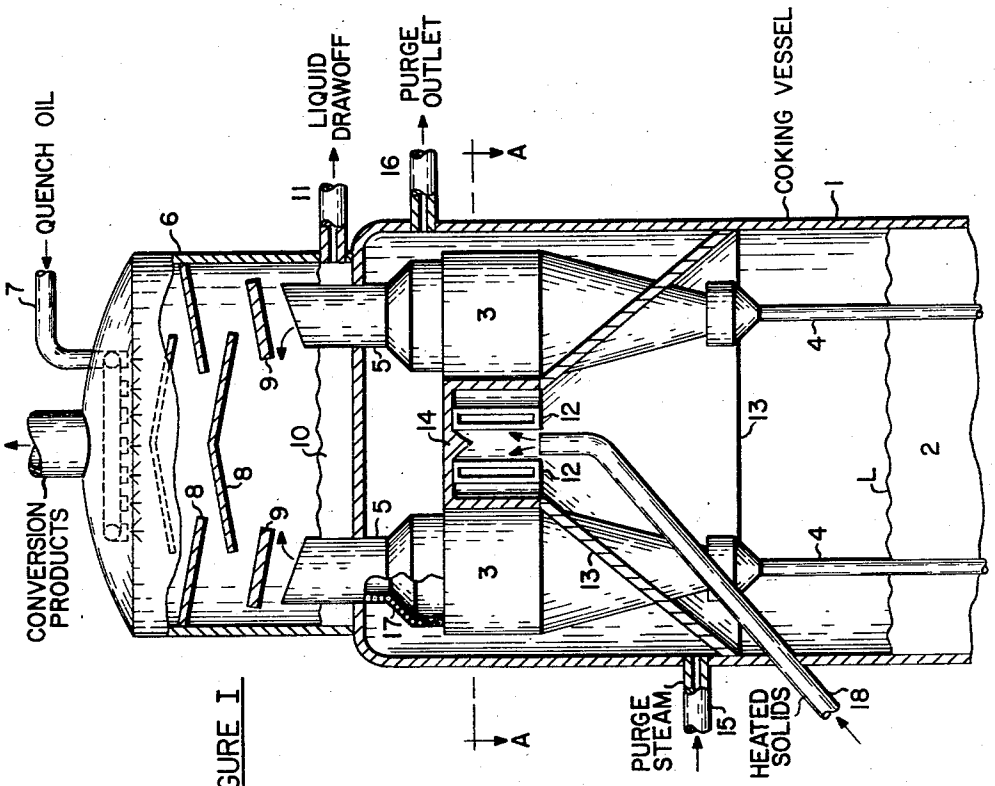


FIGURE I

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FLUID COKING REACTOR

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6 Claims. (Cl. 208—48)

The present invention is concerned with an improved fluidized solids reactor, and more particularly with an improved reactor for carrying out hydrocarbon oil fluid coking reactions. The invention proposes a method for reducing coke deposition in the upper portions of fluidized solids reactors and for reducing vapor phase cracking, particularly in reactors wherein heavy residual oils are processed.

In accordance with the present invention, a specially designed conical baffle is placed in the upper portion of a fluidized solids reactor to direct the flow of the conversion products and to seal off normally stagnant zones in the reactor in the area of the cyclone separators removing entrained solids from the conversion products recovered overhead. A purging medium such as steam is injected into the stagnant areas so isolated to assure that the vapors are denied access to the stagnant areas.

Further, this invention comprises a method of maintaining a certain concentration of solids in the conversion products which aids in greatly reducing their coke depositing tendencies.

The present invention has applicability to many types of fluidized solids processes wherein hydrocarbons are converted. For example, it is applicable to catalytic cracking processes, coal gasification, hydroforming processes, and shale oil recovery operations. It is particularly applicable, however, to residual oil fluid coking processes, known in the art, wherein the conversion vapors have a ready tendency to deposit coke on the interior surfaces of the equipment. A fluid coking process is here used to illustrate and to give a setting for the present invention, but the invention is not to be so limited.

The prior art is familiar with a fluid coking process wherein a heavy hydrocarbon oil is pyrolytically upgraded by contact at a coking temperature with particulate solids maintained in a fluidized condition in a coking vessel. Upon contact with the solids, the oil undergoes pyrolysis evolving lighter hydrocarbons and depositing carbonaceous residue on the solid particles. The necessary heat for the pyrolysis is supplied by circulating a stream of the fluidized solids through an external heating zone, e. g., a combustion zone, and back to the coking vessel. This fluid coking process is more fully presented by co-pending application entitled, "Fluid Coking of Heavy Hydrocarbon and Apparatus Therefor," S. N. 375,088, filed August 19, 1953, by Pfeiffer et al.

Serious problems have been encountered in the development of this type of coking process. One problem in particular is the building up of coke deposits on the confines of the vapor space above the fluidized bed. These deposits can cause the pressure drop through the coker and overhead lines to increase to such an extent as to require the coker to be shut down periodically and cleaned out.

As the vapors leaving the coking bed are at or near their dew or condensation point, they will readily condense, particularly in areas of stagnation. This condensation is aided by endothermic polymerization and condensation reactions occurring in the vapor phase. It has been found that if this condensation of the coker vapors is on surfaces having a temperature of about 700° to 1000° F., severe coke deposition occurs.

In a fluid coking process the conversion products are removed overhead through cyclones located in the upper portion of the reactor. By the nature of the equipment, stagnant areas, i. e., areas having little or no vapor velocity, exist in the uppermost portion of the reactor around the cyclone separation system. The high temperature conversion products driven into these stagnant areas will remain resident there for a time sufficient to permit appreciable cooling and perhaps more cracking and condensation to occur. Thus vapors in areas of stagnation readily deposit coke on the surrounding equipment surfaces.

The present invention proposes a method for eliminating this problem of coking or coke deposition in the uppermost portions of a fluid coking reactor and for inhibiting the deposition of coke in the product cyclones and in the lines beyond the cyclones.

The invention will become clear as this description proceeds and the attached drawings, forming a part of this specification, are described in detail.

Figure I is a vertical sectional view of the upper portion of a fluid coking reactor modified in accordance with the teachings of this invention. Figure II is a sectional view of the reactor illustrated in Figure I taken along the indicated line A—A.

The present invention proposes an improved fluidized solids hydrocarbon conversion process wherein hydrocarbons are converted in a lower portion of a conversion zone by contact with high temperature fluidized solids and the vapors created thereby are upwardly removed and entrained solids are separated from the vapors in a cyclone separating zone located in the upper portion of the conversion zone. The improvement comprises maintaining a seal in the upper portion of the conversion zone to prevent access of vapors and solids to stagnant zones in the area of the cyclone separators and to increase the velocity of the vapors. The seal is designed to form an upwardly converging confined passageway for the vapors to the inlet of the cyclone separators. An inert gas is introduced as a purge into the stagnant zones to assure maintenance of the seal. The seal is formed by strategic placement of a conical baffle in the upper portion of the conversion zone.

The invention further comprises a method of maintaining the temperature of the vapors and of preventing deposition of coke in the lines leading from the cyclone. This method comprises introducing freshly heated solids in the upper portion of the confined passageway defined by the baffle.

This invention is also concerned with an improved fluidized solids reactor. This reactor comprises a vertically elongated vessel, means for establishing and maintaining in the lower portion thereof a fluid bed of high temperature particulate solids, means for introducing a hydrocarbon reactant into the fluid bed, a plurality of cyclone separators positioned within the upper portion of the vessel, the inlets of the cyclone separators being centrally directed to the vessel, means for recovering reaction products from the cyclone separators, a conical upward extending imperforate baffle extending from the walls of the vessel above the fluid bed and encompassing the cyclone separators below the inlets, a top enclosed imperforate cylindrical baffle extending upwardly from the conical baffle terminating above and enclosing the inlets while permitting confined passageway of fluids and solids from the lower portion to the inlets, the conical

and cylindrical baffles forming with the cyclone separators and/or the reactor walls a restricted fluid passageway between the uppermost portion of the vessel and the lower portion of sufficient size only to provide for differences in expansion, and gas inlet means for introduction of an inert gas to the uppermost portion above the baffles whereby fluids and solids from the fluid bed are denied access to the uppermost portion.

It is preferred to further modify this improved fluidized solids reactor by adding thereto conduit means for introducing freshly reheated solids into the central portion of the reactor defined by the cylindrical baffle.

Referring specifically to the attached drawings, a vertically elongated fluid coking vessel **1** contains a dense fluid bed **2** of particulate coke maintained at a coking temperature in the range of 900° to 1600° F. in a manner well known by the art. The fluid bed is maintained as such by the injection of fluidizing gas, e. g., steam, at the base of the vessel and by the vaporous conversion products created therein. A heavy oil feed, e. g., a vacuum residuum, is injected into this bed and undergoes vaporization and pyrolysis. The fluid bed has a defined upper level "L" with a dilute or disperse phase thereabove. The conversion products pass through this disperse phase carrying some entrained solids to a plurality of cyclone separators **3**. For example, four cyclone separators may be used. Entrained solids are removed from the vapors and returned to the fluid bed via cyclone diplegs **4**. The vapors, now substantially free of solids, are then removed from the vessel via lines **5** and may be further processed as desired as by fractionation.

It is preferred to rapidly quench the conversion products to arrest further cracking reactions. As illustrated, this can be done by maintaining a superposed quench system on top of the coking vessel **1**. The quench system comprises a suitable housing **6** with means **7** for introducing and dispersing a quench liquid in the upper portion. The quench liquid may comprise suitably cool oils. For example, the heavier ends condensed from the conversion products can be cooled to a temperature of about 600° F. and injected via line **7** into the conversion products to quench the products to a temperature below about 750° F. Baffles **8** may be suitably disposed in quench vessel **6** to promote contacting of the liquid and gases. Other baffles **9** may be suitably placed in vertically spaced relation to the outlet conduits from the cyclones to prevent liquid from entering therein. The lower surfaces of baffles **9** may be suitably heated as with steam coils to prevent condensation of liquid with consequent coke deposition thereon. By this quench arrangement, heavy ends of the conversion products boiling above about 900° to 1100° F. will be condensed and will collect as a liquid **10** in the base of the quench vessel. This liquid is withdrawn via line **11**. A portion of it may be used as the above described quench oil and another portion or the remainder of it may be recycled to the fluid coking bed to be further converted therein.

Without the improvement of this invention, the coking vessel would be under the disadvantage of having coke deposits occur in the upper portion in the area of conduits **5**. The deposits can eventually become so severe as to block off the inlets **12** to the cyclones and large chunks may break off causing fluidization and solids circulation difficulties.

In accordance with the present invention, this upper coke formation is eliminated by the use of a suitably designed and placed frusto-conical imperforate baffle **13**. This baffle extends from the sides of the coking vessel above the fluid bed as shown to the inlets **12** of the cyclones and terminates in a relatively small diameter top enclosed imperforate cylindrical baffle **14** which suitably encloses the cyclone inlets and defines a restricted vapor passageway for the vapors from the fluid bed to the inlets of the cyclones. The top portion of the cylindrical baffle **14** is suitably designed to provide for smooth flow of the vapors to the cyclone inlets. The conical baffle may be tapered 20° to 75° from the vertical and may extend in some cases below the level of the fluid bed. The conical and cylindrical baffles form but one unit and have suitable openings to permit the cyclones to extend upwardly therethrough. The baffle unit is so designed as to have minimum clearance around the cyclones passing therethrough, sufficient to permit differences in expansion of the equipment. The baffle unit is made substantially gas tight with respect to the coking vessel wall.

As an alternative, the baffle **13** may be integral with the cyclones with a minimum space being provided between baffle **13** and the reactor wall, the space being only sufficient for thermal expansion. The space may be closed with an expansion joint.

To assure that the vapors arising from the fluid coking bed do not enter into the sealed off uppermost portion of the coking reactor **1**, a purge gas such as steam is admitted to this area via line **15** under pressure sufficient to permit some to escape through the openings formed by the baffle unit and the cyclones or vessel walls. To permit good circulation of the purged gas throughout the sealed off area, a portion of the purged gas may be continuously removed from the vessel by line **16**.

The purge gas injected into the sealed off area may be superheated so as to heat the cyclones and the baffle unit. In this way, the surfaces of the cyclones and of the baffle unit coming in contact with the conversion products are maintained above the condensation temperature of the products. By this means coke deposition on the surfaces may be greatly inhibited. As a further aid, or separately therefrom, certain of the surfaces may be heated as by electrical elements or by steam coils **17** as shown in conduit **5**.

The design of the baffle unit is particularly efficacious in preventing deposition of coke in the area of the cyclone inlets. The vapors emerging from the fluid bed are forced to assume a higher velocity which insures continued entrainment of the solids in the vapors once the vapors reach the area of the baffle. These entrained solids help to uphold the temperature of the vapors and to scrub any incipient coke deposits formed on the confining walls. The amount of initial entrainment in the vapors leaving the bed may be readily controlled as by varying the particle size or particle size distribution of the fluidized solids and/or by varying the level "L" of the fluid bed and/or by varying the superficial velocity of the gases passing through the bed.

Besides the desirability of securing a certain entrainment of solids to the cyclone inlets, it has been found that to inject freshly reheated solids into the vapors near the cyclone inlets is particularly efficacious. These reheated solids are at a temperature of 100° to 300° F. above the coking temperature and not only serve to scour incipient coke deposits and to provide surfaces for condensation of the vapors, but also advantageously give some degree of superheat to the vapors whereby the vapors are raised substantially above incipient condensation temperatures. Accordingly, reheated solids can be introduced into the vapors in a central portion of the reactor near the inlets of the cyclones by line **18**. According to this invention, the baffle unit is particularly designed so that only one conduit (**18**) is needed to supply heated solids to the plurality of cyclone inlets (**12**). The restricted passageway formed by the baffle unit causes the ascending vapors to have a velocity sufficient to carry these added solids.

Because the vapor velocity is increased by the baffle unit, an added advantage is obtained. The increased velocity of the vapors minimizes vapor residence time before quenching so that after-cracking or gas phase cracking of the vapors is substantially reduced. Vapor residence time before quenching is maintained below 7 seconds by the design of this invention. It is known that vapor phase cracking will, in many cases, account for

a substantial loss of valuable products and will cause poor product distributions to be obtained from the coking process.

Example

A cone bottom fluid coking reactor, the upper portion of which is depicted in Figure I, is 18 ft. in diameter and contains a fluid bed of coke 74 ft. high. 275 tons of coke are maintained in the vessel at a coking temperature of 950° F. The coke has a true particle density of 100 lbs./cu. ft., a fluidized density of 41 lbs./cu. ft., and a particle size such that 90 wt. percent of it is within the range of 100 to 300 microns, with 200 microns being the median particle size. 10 wt. percent steam on fresh feed is introduced into the vessel to serve as fluidizing gas. The superficial velocity of the vapors is 3.6 ft./sec. as they emerge from the fluid bed. 0.12 lb. of coke/lb. of fresh feed at a temperature of 1125° F. is continuously introduced into the reactor to maintain the coking temperature and a slightly greater amount is withdrawn to be reheated.

21,300 bbl./day of a heavy oil are injected into the reactor. The heavy oil comprises 20 vol. percent of a recycle fraction boiling above 1015° F. and a vacuum residuum having an API gravity of 4°, a Conradson carbon of 24 wt. percent, a hydrogen to carbon atomic ratio of 1.4, and an initial boiling point of 850° F. 27 wt. percent of the fresh feed is converted to coke and deposited on the solids. 73 vol. percent of the fresh feed is converted to products boiling below 1015° F.

Four cyclone separators are used in the upper portion of the reactor with the center line of the inlets 22 ft. above the level of the fluid bed. Each cyclone is designed to handle 13,200 cubic feet per minute (C. F. M.) of vapors (at reactor conditions) at an initial solids loading of 0.12 lb./c. f., and to discharge the vapors with a solids content below 0.005 lb./c. f. The vapors enter the cyclones at a velocity of 60 ft./sec., a pressure of 6 p. s. i. g., and a temperature of 950° F. The pressure drop through the cyclones is 1 p. s. i.

430 lbs. of solids/bbl. of fresh feed is entrained from the fluid bed and in addition 170 lbs. of the heated solids introduced into the reactor per bbl. of fresh feed are injected into the vapors at a central portion of the reactor 2 ft. below the center line cyclone inlets.

The conical baffle has a taper of 45° from the vertical and terminates in a cylindrical baffle 4.5 ft. in diameter. Above the baffle there exists a stagnant area of about 2000 c. f. 100,000 c. f. of steam per hour is admitted to this stagnant area as a purge gas.

The vapors emerging from the cyclones are met with 1.3 vols. of quench oil/vol. of fresh feed, having a temperature of 600° F. which is sufficient to cool the vapors below 750° F. and to condense from the vapors material boiling above 1015° F.

Having described the invention, what is sought to be protected by Letters Patent is succinctly set forth in the following claims.

What is claimed is:

1. An improved fluidized solids reactor comprising a vertically elongated vessel adapted to contain a fluid solids bed in its lower portion, a plurality of cyclone separators positioned within the upper portion of said vessel, the inlets of said cyclone separators being centrally directed to said vessel, means for recovering reaction products from said cyclone separators, a frusto-conical upwardly extending imperforate baffle extending from the walls of said vessel and encompassing said cyclone separators below said inlets, a top enclosed imperforate cyclindrical baffle extending upwardly from said frusto-conical baffle terminating above and enclosing said inlets while permitting confined passageway of fluids and solids from said lower portion to said inlets, and gas inlet means for introduction of an inert gas to said upper portion above said baffles whereby fluids and solids from said fluid bed are denied access to said upper portion of the vessel above said baffles.

2. The reactor of claim 1 comprising conduit means for introducing freshly reheated solids into the central portion of the reactor defined by said cylindrical baffle.

3. In a fluidized solids hydrocarbon conversion process wherein hydrocarbons are converted in a lower portion of a conversion zone by contact with high temperature fluidized solids, vapors therefrom are upwardly removed and entrained solids are separated from said vapors in a cyclone separating zone in the upper portion of said conversion zone, the improvement which comprises maintaining a seal in the upper portion of said conversion zone to prevent access of vapors and solids to stagnant zones in the area of said cyclone separating zone and to reduce vapor residence time, said seal forming an upwardly converging confined passage for said vapors to the inlet of said cyclone separating zone, and introducing an inert gas as a purge into said stagnant zones.

4. The improvement of claim 3 comprising in addition thereto introducing freshly heated solids in the upper portion of said confined passage.

5. In the process of operating a reactor for conducting hydrocarbon conversion reactions utilizing fluidized solids wherein said reactor comprises a lower reaction zone with a stagnant zone thereabove, a cyclone separator at least partially in said stagnant zone and extending into said reaction zone, and an upward converging imperforate baffle forming in conjunction with said separator a restricted fluid passage between said stagnant zone and said reaction zone, and wherein vaporous hydrocarbon conversion products from said reaction zone are withdrawn overhead through said cyclone separator, the improvement comprising introducing freshly heated solids into said conversion products near the point of entry into said cyclone separator so as to uphold hydrocarbon vapor temperature and scour deposited coke, and introducing an inert gas into said stagnant zone under sufficient pressure to seal said stagnant zone from passage of said conversion products into said stagnant zone through said restricted fluid passage.

6. The improvement of claim 3 wherein said inert gas is heated steam, whereby said cyclone separating zone is maintained above the condensation temperature of conversion vapors by means of the heat supplied by said steam.

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