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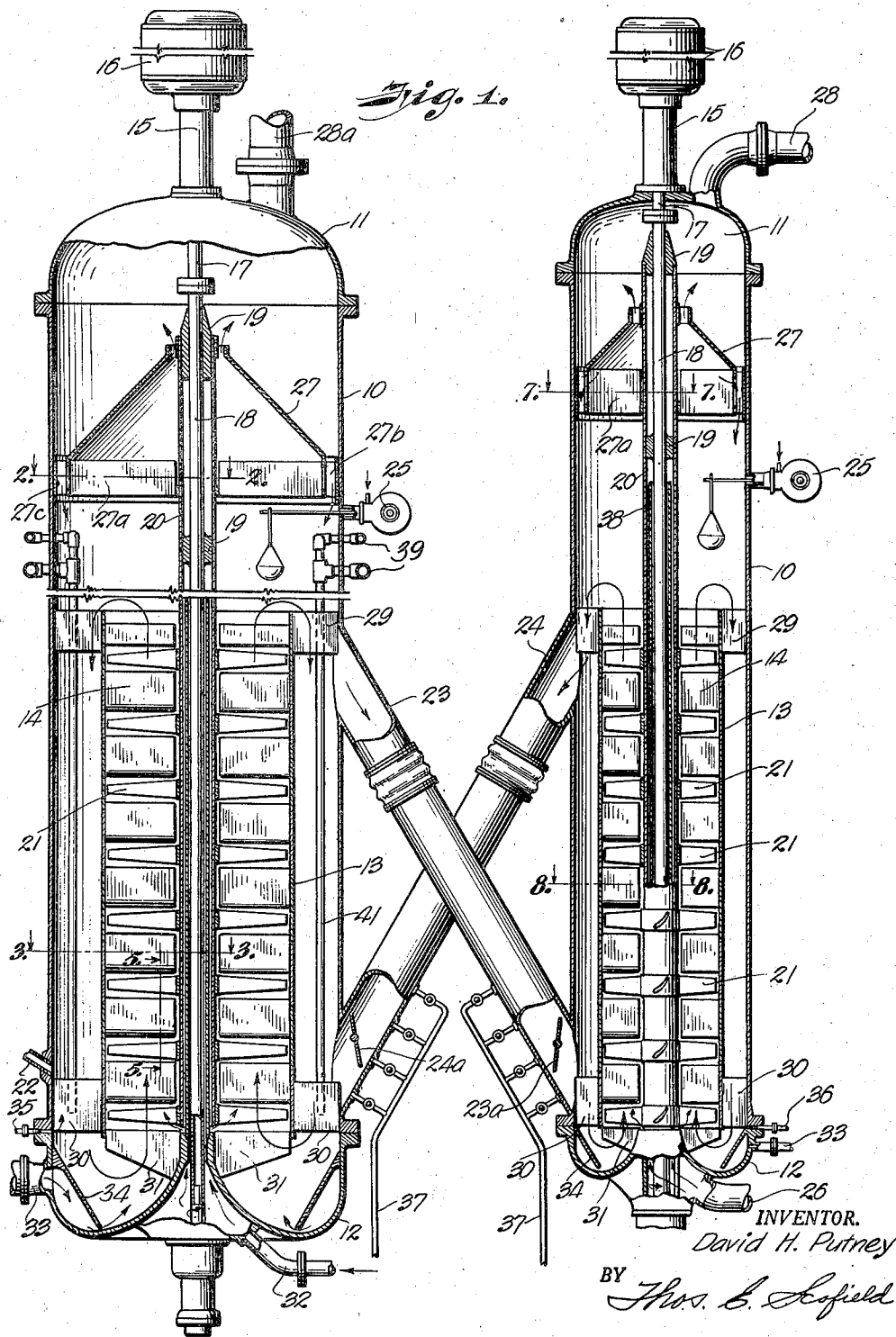
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2,453,592

CONTACTING APPARATUS FOR CATALYTIC PROCESSES

Filed Dec. 8, 1944

2 Sheets-Sheet 1



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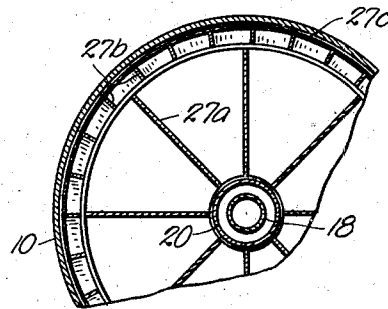
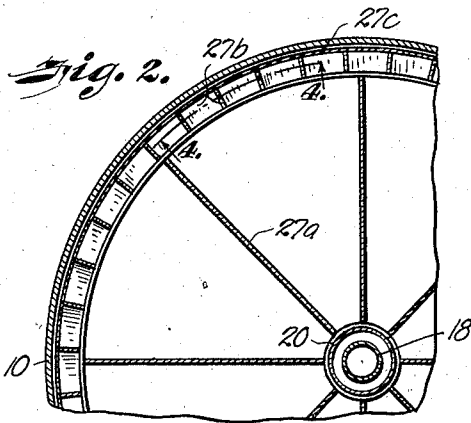


Fig. 7.

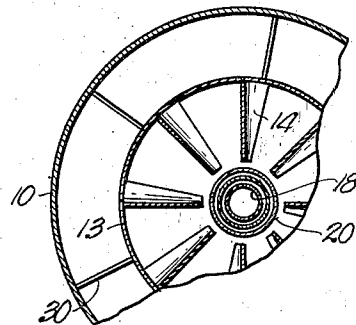
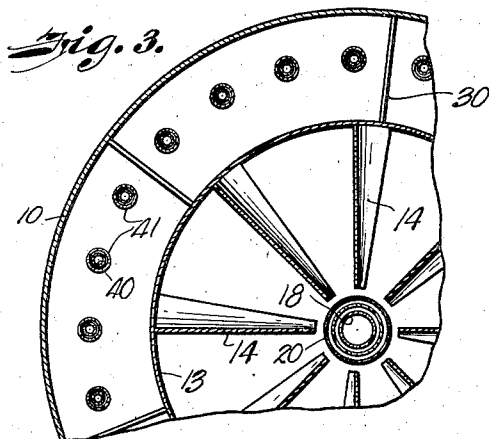


Fig. 8.

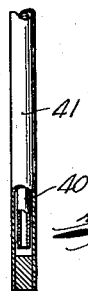
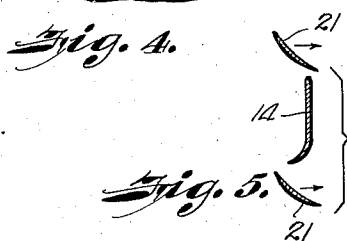
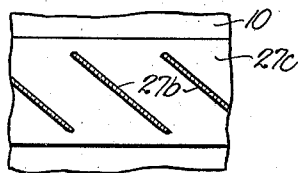


Fig. 6.

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CONTACTING APPARATUS FOR CATALYTIC PROCESSES

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2 Claims. (Cl. 23—288)

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This invention relates to improvements in contacting apparatus and refers more particularly to the construction of contactors for intimately mixing a finely divided solid catalyst with fluid reactants.

While the apparatus is adapted for use in any type of process wherein fluids are contacted with a solid catalyst, it has particular application to processes commonly designated as fluid catalyst cracking processes for the conversion of petroleum hydrocarbons to produce motor fuel and the invention will be described with regard to this application.

This application is a continuation-in-part of Serial No. 558,251, filed October 11, 1944, now abandoned.

In the copending application, Serial No. 558,251, there is disclosed a contacting apparatus of a similar nature. The construction there shown is identical with that contemplated here except that there was omitted from the prior application the stationary vanes within the circulating tubes of the reactor and regenerator and straightening vanes in the passageway between the down-flowing and up-flowing columns in the bottom of the vessels. While the construction shown in the prior application provides an effective means of contacting the catalyst and reactants, experimental tests have proved that increased efficiency and better results are accomplished where the straightening vanes are used. The primary purpose of these stationary vanes is to limit and, to a great extent, prevent the effects of centrifugal force originating in the rotating impellers from taking precedent and seriously interrupting the straight line or lineal flow of the materials in the circulating rings which are set up and maintained in the respective vessels.

In other words, the salient object of the invention is to provide an apparatus for preventing the rotation or spinning of the flowing mixture of catalyst and reactants in the cycles established in the reactor and regenerator.

Another object of the invention is to provide a design wherein the straightening vanes are pitched on the side adjacent to the impeller discharge to approximately the same angle as the discharge from the rotating impellers beneath, thereby functioning to straighten the angularity of the discharged material leaving the impeller and changing its direction back to strictly straight-line flow parallel to the impeller shaft and preventing rotation of the flowing mass.

A further object of the straightening vanes is to limit the action of centrifugal force which

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would throw the heavier catalyst to the outside and the lighter vapor to the inside resulting in separation of the catalyst from the vapor.

Another object is to provide straightening vanes which have their upper portions vertical thus preventing any tendency of the mixture to vortex or prerotate before entering the impellers above them.

The straightening vanes in the passageways between the down-flowing and up-flowing columns provide straight surfaces parallel with the flow of the material and prevent prerotation or vortexing of the mixture of catalyst and reactants entering the up-flowing column and flowing stream in which the impellers are located. Other and further objects will appear from the following description.

In the accompanying drawings which form a part of the instant specification and are to be read in conjunction therewith and in which like reference numerals are used to indicate like parts in the various views,

Fig. 1 is a sectional elevational view of a reactor and regenerator designed for the cracking of hydrocarbons in the presence of a solid pulverulent catalyst,

Fig. 2 is a view taken along the line 2—2 in Fig. 1 in the direction of the arrows,

Fig. 3 is a view taken along the line 3—3 in Fig. 1 in the direction of the arrows,

Fig. 4 is a view taken along the line 4—4 in Fig. 2 in the direction of the arrows,

Fig. 5 is a view taken along the line 5—5 in Fig. 1 in the direction of the arrows,

Fig. 6 is an enlarged detail of the lower end of the heat exchange tubes employed in the regenerator for removing heat,

Fig. 7 is a view taken along the line 7—7 in Fig. 1 in the direction of the arrows, and

Fig. 8 is a view taken along the line 8—8 in Fig. 1 in the direction of the arrows.

Referring to the drawings the smaller vessel shown in Fig. 1 is the reactor, and the larger vessel the regenerator. The construction and design of the two vessels is substantially identical so that a brief explanation of one will suffice for both. The design includes an upright cylindrical vessel having an open-ended circulating tube positioned centrally of the vessel and extending to a level about one-half its height. The circulating tube has a common axis with the vessel. Extending the length of the vessel and centrally thereof is a shaft rotated either from above or below by a suitable prime mover and mounted on the shaft and within the circulating tube is a

plurality of impellers which produce a cyclic flow of catalyst in an up-flowing column within the circulating tube and a down-flowing column in the annular space between the circulating tube and the shell of the vessel. Catalyst is transferred from the upper portion of the down-flowing column of the respective vessels to the lower portion of the down-flowing column of the other vessel. Reactants are introduced into the bottom of the up-flowing column of each vessel and, after separation from the catalyst in the upper part of the vessel, are removed from the top. Thus, it is seen that there is established within both the reactor and regenerator flowing streams of catalyst in the form of cyclic rings, each ring having an up-flowing column and a down-flowing column. The flow of the catalyst in the rings is initiated and maintained by mechanical devices, such as rotating impellers, producing positive circulation and intimate mixture of the reactants and catalyst flowing through the vessels.

Referring to Fig. 1 the shells of both the reactor and regenerator are designated by the numeral 10. Each has a head 11 and a bottom 12. Within the vessels are open-ended circulating tubes 13 to which are attached stationary radial straightening vanes 14. Mounted on the top of the vessels on pedestals 15 are prime movers 16 which are shown in the drawings as electric motors. Through shafts 17 the motors drive the vertical propeller shafts 18 which extend longitudinally of the vessels and have suitable upper and lower bearings which are cooled in order that they are operated within the proper temperature range. Outside the shaft and rigidly connected thereto by annular supports 19 are sleeves 20 upon which are mounted the impeller blades 21. These impeller blades are positioned within the annular tubes and are pitched and rotated, as shown in Fig. 5, to move the solid material within the circulating tubes upwardly. Pulverized catalyst is supplied to the regenerator from any convenient source not shown through pipe 22 and the motors 16 are started to rotate the impellers 21. The circulating stream or ring of catalyst is established in the regenerator flowing upwardly through the circulating tube and downwardly through the annular space outside the tube. Catalyst overflowing the top of the circulating tube in the regenerator passes through transfer pipe 23 to the reactor where it is picked up by the impellers and a similar cyclic ring established in this vessel. In a like manner a portion of the catalyst overflowing the top of the circulating tube in the reactor is returned through transfer pipe 24 to the bottom of the regenerator. The levels of the catalysts in the vessels is determined by a level float arrangement shown diagrammatically at 25. When sufficient catalyst has been admitted to the vessels to provide an adequate amount of catalyst for the two cyclic rings and the temperature of the vessels raised to proper operating conditions reactants in vapor form are introduced into the bottom of the reactor through pipe 26. In the reactor the catalyst and reactants are intimately mixed as they pass upwardly through the up-flowing column of the catalyst ring. In this column the impellers agitate the catalyst and disperse the reactants through the catalyst. Vanes 14 positioned between the impeller blades prevent rotation of the up-flowing column and keep the flow of catalyst in a relatively straight line. At the top of the circulating tube 13 the flow of the catalyst is reversed separating the solid particles from the reactants which rise into the vapor space in the upper part

of the reactor. Inevitably there is entrained a portion of reactants which are circulated back with the catalyst into the down-flowing column of the ring. Positioned in the vapor space of both vessels is a catalyst separator in the form of an inverted funnel 27 which is attached to and rotates with the sleeve 20. In the bell-shaped lower portion of the catalyst separators are radial vanes 27a which contact the solid particles entrained with the vapors and by centrifugal force project them outwardly through apertures in the periphery of the separator into a down-flowing stream created at the outer edge of the separator by down-pumping vanes 27b between the periphery of the separator and a ring 27c which surrounds the separator and rotates with it. After separation of the entrained catalyst the vapors rise through the top of the separator and are discharged from the reactor through pipe 28. The cracked product passing off from the top of the reactor is directed to conventional fractionation and recovery equipment not shown.

Returning to the travel of the catalyst, after overflowing the top of the circulating tube it flows into the annular space between the circulating tube and shell in a down-flowing column. A portion of the catalyst overflowing the top of the circulating tube passes into the transfer pipe 24 and is directed to the regenerator. The rest of the catalyst in the down-flowing column after passing the straightening circulation tube supports 29 and 30 positioned in the annular space has its direction reversed in the bottom of the shell. Recycled catalyst returned through the down-flowing column and catalyst transferred from the regenerator through pipe 23 is drawn into the bottom of the circulating tube by the rotation of the impellers and is again mixed with the reactants in the up-flowing column. In the bottom heads and beneath the lower impellers are stationary straightening vanes 31. These vanes 31 extend radially from the central support of the rotating shaft and are positioned in the throat or lower end of the circulating tube. The effect of these straightening vanes 31 and 30 is to eliminate in so far as is possible rotating tendencies of the catalyst mass and to cause the mass to move through the circulating tube and annular space surrounding the tube in a straight line flow.

Catalyst in the regenerator is circulated in the same manner as is the catalyst in the reactor. Air is added to the bottom of the regenerator through pipe 32 to furnish a combustion supporting gas. Air is introduced to the regenerator and gas oil vapor to the reactor through pipes 33 behind baffles 34 to prevent accumulation of catalyst in stagnant portions of the lower heads of the vessels and to facilitate circulation. Air is introduced through pipe 35 in the regenerator to supply a combustion supporting gas to the annular space surrounding the circulation tube and steam is introduced at a similar location through pipe 36 in the reactor to strip or aerate the down-flowing column of entrained reactants. Steam is introduced to transfer ducts 23 and 24 through pipes 37 to strip the catalyst passing through the ducts of entrained vapors or combustible gases. Dampers 23a and 24a in the ducts 23 and 24 respectively control the amount of catalyst permitted to pass through the ducts to the respective vessels.

Between the shafts 18 and the rotating sleeves 20 is a stationary barrier tube 38 which extends well above the level of the catalyst in the vessels and prevents catalyst particles working up into the sleeve 20 from below and accumulating

around the shaft. The vapor supplied to the reactor through pipe 26 and air supplied to the regenerator through pipe 32 passes into the annular space between the shafts and barrier tubes producing an upward flow of gaseous material through these inner ducts and a downward flow through the outer ducts between the barrier tube and sleeve 20. Thus, there is a discharge of gaseous material from the lower end of the tubes 20 which prevents the admission of catalyst.

To reduce the temperature of the catalyst in the regenerator a coolant is supplied through pipes 39 to the bayonet-type heat exchange tubes 41 arranged at intervals in the annular passageway. The coolant flows downwardly through the inner tubes 40, as shown in Fig. 6, and upwardly through outer tubes 41 to be discharged through outlet pipes 42. Any satisfactory coolant such as water, oil or other liquid may be circulated through the heat exchangers and thus lower the temperature of the catalyst circulating in the regenerator. This cooling system is necessary to prevent excessive heating of the catalyst.

Circulation of the catalyst in the regenerator is similar to that in the reactor. At the top of the circulating tube the combustion gases separate from the solid particles and entrained particles are removed by contact with the vanes 27a of the rotating separator 27. After the solid particles are removed the combustion gases pass out through the openings in the top of the separator and are discharged through flue gas pipe 28a which serves as a discharge for the combustion gases as the pipe 28 did for the cracked products removed from the reactor. Upon discharge from the regenerator the gases are passed to conventional waste heat recovery systems and either recycled or directed to a stack.

As previously indicated, the invention has been described as applied to a fluid catalyst process for cracking hydrocarbon oils. This application was selected as a pilot plant for this purpose is about to be constructed. Other applications are as feasible and will produce as good results, the feature of novelty residing in the mechanical features of the apparatus rather than the particular application to which the invention is used. In other words, wherever it is desirable and advantageous to intimately combine reactants with a finely divided solid catalyst the establishment of a circulating ring of catalyst and producing the flow through the ring by mechanical impellers is the first essential. Secondly, the avoidance or elimination of the rotative tendency in the catalyst mass by positioning straightening vanes in the line of flow of catalyst completes the concept.

It will be seen that the object of the invention has been accomplished. There has been pro-

vided a cyclic ring of finely divided solid catalyst comprising an up-flowing column and a down-flowing column. The flow in the ring is produced by mechanical impellers in the up-flowing column where the reactants are intimately mixed with the pulverulent catalyst. Straightening vanes in the up-flowing column on both sides of the impellers substantially eliminate rotative tendencies in the catalyst mass producing an even, uniform, straight line flow throughout the ring.

From the foregoing it will be seen that the invention is well adapted to attain all of the ends and objects hereinabove set forth together with other advantages which are obvious and which are inherent to the structure. It will be understood that certain features and subcombinations are of utility and may be employed without reference to other features and subcombinations. This is contemplated by and within the scope of the claims.

Having thus described my invention, I claim:

1. In an apparatus for intimately mixing a solid pulverulent catalyst with fluid reactants wherein the catalyst is circulated in a cyclic ring during mixing, the combination with a vertical vessel having inlet and outlet ports for the catalyst and reactants, an open-ended circulating tube within the vessel, a power-driven shaft extending axially of the tube, a plurality of impellers within the tube rotated by the shaft and adapted to create a cyclic circulation of the catalyst reactant mixture upwardly through the tube and downwardly in the annular space surrounding the tube, radial stationary straightening vanes within the circulating tube located both on the suction and discharge sides of the impellers, said straightening vanes having a length substantially that of the impellers and having a curved lower portion, said curved lower portion lying outside the plane in which the noncurved portion of the straightening vane lies.

2. An apparatus as in claim 1 with stationary straightening vanes in the annular space surrounding the circulating tube, said vanes being of relatively short length and located in the upper and lower portions of the annular space.

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The following references are of record in the file of this patent:

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