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(54) Improved fluid catalytic cracking process and apparatus.

(57) A fluidized bed catalytic cracking process and apparatus are disclosed. Hydrocarbon feed and catalyst are introduced into a vertical riser reactor (1). Catalyst and cracked hydrocarbons exit a downstream end (5) of the riser reactor. Catalyst is deflected down to a primary stripper (17). Entrained catalyst, which was not deflected, is separated from the cracked hydrocarbons in a cyclone separator (21) and discharged via a dipleg. Stripped catalyst from the primary stripper (17) passes to a secondary stripper (23) and then to a first stage regenerator (33), which partially regenerates the catalyst, and a second stage regenerator (29) which completes the regeneration. The resulting hot regenerated catalyst is recycled to the secondary stripper to aid in stripping and to the riser (1) to crack the hydrocarbon feed. A mixing tray (31) between the primary and secondary strippers may be used to mix catalyst from the primary stripper, and the cyclone dipleg with hot regenerated catalyst prior to passage of the mixture into the secondary stripper (23).

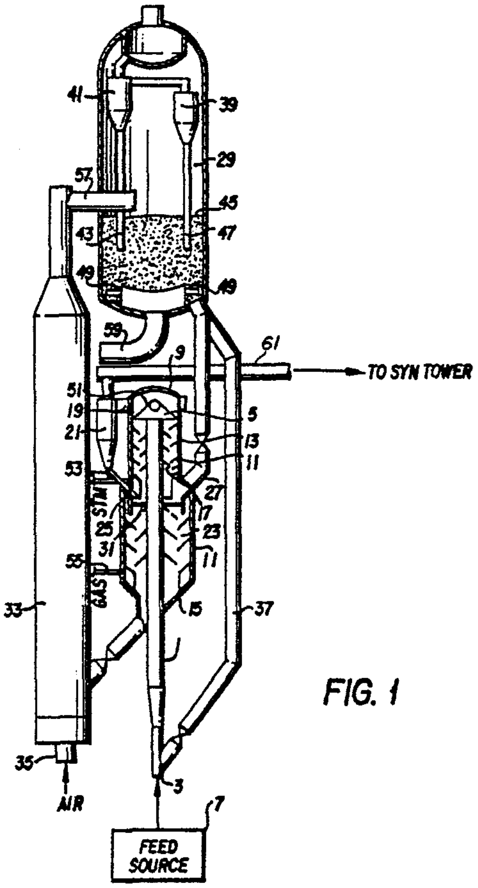

FIG. 1

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Rank Xerox

IMPROVED FLUID CATALYTIC CRACKING PROCESS AND APPARATUS

This invention relates to methods and apparatus for fluid catalytic cracking, FCC, of hydrocarbons with subsequent regeneration of catalyst particles.

Hot catalyst contacts oil in a riser reactor. The oil is catalytically cracked, thereby deactivating the catalyst with coke. Deactivated catalyst is stripped, and then regenerated by burning coke from catalyst with air.

Large amounts of catalyst are suspended in gas materials in the riser. It is necessary to separate rapidly the suspension into a spent catalyst phase and a gas phase after catalytic cracking in the riser.

Various attempts have been made to improve suspension separation techniques to decrease losses in the catalyst phase or the gas phase resulting from overcracking.

Multistage stripping is disclosed in U. S. Patent No. 4,043,899 to Anderson et al. A catalyst riser terminating in a cylindrical vessel and a riser comprising baffles is disclosed by U.S. Patent No. 4,206,174 to Heffley et al and risers attached to conduits are disclosed by U. S. Patent No. 4,219,407 to Haddad et al.

Along with the development of process modifications and catalysts, which could accommodate heavier, dirtier feeds, there has been a growing concern about the amount of sulfur contained in the feed that ended up as SO_X in the regenerator flue gas. Higher sulfur levels in the feed, combined with a more complete regeneration of the catalyst in the fluid catalytic cracking regenerator, tended to increase the amount of SO_X contained in the regenerator flue gas. Some attempts have been made to minimize the amount of SO_X discharged to the atmosphere through the flue gas by providing agents to react with the SO_Xin the flue gas. These agents pass along with the regenerated catalyst back to the fluid catalytic cracking reactor, where the reducing atmosphere releases the sulfur compounds as H_2S. Suitable agents for this purpose have been described in U. S. Patent Nos. 4,071,436 and 3,834,031. Use of a cerium oxide agent is shown in U. S. Patent No. 4,001,375.

Unfortunately, the conditions in most fluid catalytic cracking regenerators are not the best for SO_X adsorption. The high temperatures encountered in modern fluid catalytic cracking regenerators (up to 871°C [1600°F]) tend to discourage SO_Xadsorption. One approach to overcome the problem of SO_X in flue gas is to pass catalyst from a fluid catalytic cracking reactor to a long residence time steam stripper. After the long residence time steam stripping, the catalyst passes to the regenerator, as disclosed by U. S. Patent No. 4,481,103 to Krambeck et al. However, it preferably steam strips spent catalyst at 500° to 550°C (932° to 1022°F), which is not sufficient to remove some undesirable sulfur- or hydrogen- containing components. Furthermore, catalyst passing from a fluid catalytic cracking stripper to a fluid catalytic cracking regenerator contains hydrogen-containing components, such as coke, adhering thereto. This causes hydrothermal degradation when the hydrogen reacts with oxygen in the regenerator to form water.

U. S. Patent No. 4,336,160 to Dean et al attempts to reduce hydrothermal degradation by staged regeneration. However, this process has the disadvantage that the flue gas from both stages of regeneration contains SO_X, which is difficult to clean.

It would be desirable to separate hydrogen from catalyst to eliminate hydrothermal degradation. It would be further advantageous to remove sulfur-containing compounds prior to regeneration to prevent SO_X from passing into the regenerator flue gas.

Accordingly, the present invention provides a process for fluid catalytic cracking (FCC) of a hydrocarbon feed, by passing a mixture of catalyst and feed up through a conventional FCC riser and discharging from the riser a mixture of coked catalyst and cracked product, separating coked catalyst from cracked product, stripping coked catalyst to remove strippable hydrocarbons and regenerating the stripped catalyst by burning coke from catalyst, characterized by heating the coked catalyst by combining with a hot regenerated catalyst from the FCC regenerator and stripping the heated coked catalyst by contact with a stripping gas before regeneration of the hot stripped catalyst in the FCC regenerator.

In another embodiment, the present invention provides an apparatus for fluid catalytic cracking of oil by adding oil and catalyst to an upstream end of a riser reactor, and discharging spent catalyst and cracked product at a downstream end, separating catalyst from product, and the spent catalyst is stripped and then regenerated, characterized by a two stage regenerator including a vertical, dilute phase first stage regenerator, receiving stripped catalyst and discharging partially regenerated catalyst into a second stage dense bed regenerator.

Fig. 1 illustrates a fluid catalytic cracking reactor-regenerator system according to the present invention;

Fig. 2 illustrates a hot stripping vessel below the regenerator of the present invention;

Fig. 3 illustrates the system of Fig. 2 further, including a means for mixing hot stripped catalyst and regenerated catalyst;

Fig. 4 illustrates a fluidized hot stripping vessel of the present invention;

Fig. 5 illustrates a riser hot stripper of the present invention;

Fig. 6 illustrates a stripping vessel, seal pot and hot stripper located in a reactor vessel of the present invention; and

Fig. 7 illustrates details of the stripping vessel and seal pot of Fig. 6.

Fig. 1 shows a riser reactor of a vertical elongated tube 1 having an upstream end 3 wherein hydrocarbon feed from line 7 and hot regenerated catalyst from line 37 are introduced and a downstream end 5 where a mixture of spent catalyst and cracked hydrocarbons exit. The riser is preferably a short contact time riser reactor 0.1 to 10 seconds, preferably 0.2 to 5 seconds gas residence time, having a multiple point feed injection nozzle and an acceleration zone. At downstream end 5 the gas catalyst mixture exiting conduit 1 is deflected downwardly by, e.g., deflector 51, to separate a major portion of the catalyst from the cracked hydrocarbons. Although a deflector 51 is shown, a cyclone may also be used. The riser reactor terminates within elongated enclosed vessel 11, which has a substantially continuous sidewall 13 attached to bottom member 15 and top member 9 which can function with deflector 51 to deflect catalyst in the gas catalyst mixture exiting riser conduit 1 to separate a portion of the catalyst from the cracked hydrocarbons. One or more perpendicular conduits 19 provide an exit from vessel 11 for the mixture of hydrocarbon product and entrained catalyst. Stripping medium from the stripping regions 17 and 23 also exits vessel 11 via conduits 19. Deflection can also be accomplished by means of an inertial separator or other equivalent means.

Vessel 11 includes a stripping zone with a primary stripping region 17 and a secondary stripping region 23. Primary stripping region 17 is formed in an upper portion of vessel 11 and receives the downwardly deflected catalyst. A stripping medium is introduced into primary stripper 17 via line 53 to contact the downwardly deflected catalyst to separate entrained hydrocarbons from the catalyst.

The stripped hydrocarbon ascends with the stripping medium to exit vessel 11 through conduits 19 to external closed cyclone system 21 and then via line 61 to conventional product recovery and fractionators (not shown).

Secondary stripping region 23 is formed in a lower portion of vessel 11 and receives stripped catalyst from primary stripper 17, stripped catalyst from one or more diplegs 25 associated with cyclone system 21 and hot regenerated catalyst along conduit 27 which is connected to a bottom portion of second stage regenerator 29.

The secondary region 23 is a hot stripping zone because the recycle of hot regenerated catalyst directly to the region 23 allows the catalyst within region 23 to be at a temperature greater than that at which it is discharged from the riser 1. Preferably the catalyst in region 23 is at a temperature between 56°C (100°F) above that at which it exits the riser 1 and 871°C (1600°F). Most preferably the catalyst in the region 23 is at a temperature between 83°C (150°F) above that at which it exits the riser 1 and 871°C (1600°F).

Mixing means, in a form of mixing tray 31, is disposed between primary stripper 17 and secondary stripper 23 for mixing stripped catalyst from stripper 17, cyclone diplegs 25 and hot regenerated catalyst from second stage regenerator 29, prior to passage of this mixed catalyst into secondary stripper 23. A stripping medium is introduced into secondary stripper 23 via line 55 to separate additional entrained hydrocarbon from the catalyst. This latter stripping medium can be light hydrocarbon gas, inert gas or steam. Hot regenerated catalyst from second stage regenerator 29 is recycled to mixing tray 31 and then into secondary stripping region 23, to provide more complete removal of hydrocarbons from the spent catalyst.

First stage regenerator 33, which is preferably a fast fluidized bed regenerator, receives stripped catalyst leaving secondary stripper 23 to burn off additionally entrained coke deposits by contact with a rapidly ascending stream of air at, e.g., 4 to 20 ft/sec, which is provided via air inlet 35. First stage regenerator 33 passes regenerated catalyst output into second stage regenerator 29 via conduit 57. Second stage regenerator 29 includes a first conduit 27 for recycling hot regenerated catalyst onto mixing tray 31, and then to secondary stripper 23, and a second conduit 37 for recirculating hot regenerated catalyst into upstream end 3 of riser conversion zone conduit 1 where it is mixed with hydrocarbon feed from feed source 7. Air distributor header 49 distributes air from conduit 59 to a bottom region of catalyst bed 45 in second stage regenerator 29.

Second stage regenerator 29 can include a cyclone system having a primary cyclone 39 and a secondary cyclone 41. The secondary cyclone includes dipleg 43 for fines removal from catalyst bed 45 of second stage regenerator 29.

The apparatus and process of the first embodiment of the present invention are particularly adapted for conversion of a thermofor catalytic cracking (TCC) system to fluid catalytic cracking operation. This is beneficial in that numerous thermofor catalytic cracking units are presently idle, with restarting in a thermofor catalytic cracking mode of operation being uneconomical. However, in many instances, conversion to fluid catalytic cracking operation by the method and apparatus of the present invention would be very economical.

Fig. 2 illustrates a second embodiment of a fluid catalytic cracking system of the present invention. In Fig. 2, a hydrocarbon feed passes from a hydrocarbon feed source (feeder) 7 to the lower end of a riser conversion zone 104 which is a vertically elongate tubular conduit. Regenerated catalyst from a standpipe 202, having a control valve 204, is combined with the hydrocarbon feed in the riser 104, such that a hydrocarbon-catalyst mixture rises in an ascending dispersed stream until it is discharged at a riser discharge temperature into a reactor vessel 102, and passes through a riser effluent conduit 106 into a first reactor cyclone 108. The riser discharge temperature, defined as the temperature at which the mixture is discharged from the riser 104 to conduit 106, may be any suitable temperature but preferably ranges from 482° to 593°C (900° to 1100°F), and most preferably 538° to 566°C (1000° to 1050°F). Riser effluent conduit 106 is attached at one end to the riser 104 and at its other end to the cyclone 108.

The first reactor cyclone 108 separates a portion of catalyst from the catalyst-hydrocarbon mixture and passes this catalyst down a first reactor cyclone dipleg 112 to a preliminary stripping zone 130 located therebelow. The remaining gas and catalyst pass from the first reactor cyclone 108 through a gas effluent conduit 110. The conduit 110 is provided with a connector 111 to allow for thermal expansion. The catalyst passes through the conduit 110, into a second reactor cyclone 114 as part of a closed cyclone system. The second cyclone 114 separates the stream to form a catalyst stream, which passes through a second reactor cyclone dipleg 118 to the preliminary stripping zone 130 located therebelow.

A second cyclone overhead stream, which contains the remaining gas and catalyst, passes through a second cyclone gaseous effluent conduit 116 to a reactor overhead port 120. Gases from the atmosphere of the reactor vessel 102 may pass through a reactor overhead conduit 122 into the reactor overhead port 120. The gases which exit the reactor 102 through the second cyclone gaseous effluent conduit 116 and the reactor overhead conduit 122 are combined and exit through the reactor overhead port 120 as reactor overhead stream 124. It will be apparent to those skilled in the art that although only one series connection of cyclones 108, 114 is shown in the embodiment, more than one series connection and/or more or less than two consecutive cyclones in series connection could be employed.

The mixture of catalyst and hydrocarbons passes through the first reactor cyclone oerhead conduit 110 to the second reactor cyclone 114 as part of a closed cyclone system without entering the reactor vessel 102 atmosphere. However, the connector 111 may provide an annular port to admit stripping gas from the reactor vessel 102 into the conduit 110 to aid in separating catalyst from hydrocarbons adhering thereto. The closed cyclone system and annular port is described more fully in U. S. Patent No. 4,502,947 to Haddad et al.

The separated catalyst from cyclones 108, 114 pass through respective diplegs 112, 118 and are discharged therefrom after a suitable pressure is generated within the diplegs by the buildup of the catalyst. The catalyst falls from the diplegs into a bed of catalyst 131 located in the stripping zone 130. The first dipleg 112 and second dipleg 118 are sealed by being extended into the catalyst bed 131. However, diplegs 112, 118 could instead be sealed by trickle valves (not shown).

The separated catalyst is passed to a preliminary stripping zone 130 where it is contacted with stripping gas. The stripping gas is introduced into the lower portion of the stripping zone 130 by one or more conduits 134 attached to a stripping gas header 136. The preliminary stripping zone 130 strips portions of coke, sulfur and hydrogen from the separated catalyst at conventional stripping conditions, such as temperature, pressure, gas residence time and solids residence time as known in the art.

The stripping zone 130 may also be provided with trays (baffles) 132. The trays 132 may be disc- and doughnut-shaped and may be perforated or unperforated.

The preliminary stripped catalyst passed from the zone 130 through a reactor effluent conduit 138 and combines with hot regenerated catalyst. The conduit 138 is provided with a valve 139. The regenerated catalyst has a temperature between 56°C (100°F) above that of catalyst 142 in a hot stripping zone 143 and 871°C (1600°F) to heat the preliminarily stripped catalyst. The regenerated catalyst passes from the regenerator 180 to the reactor effluent conduit 138 through a transfer line 206 attached at one end to the regenerator vessel 80 and at another end to the reactor effluent conduit 138. The transfer line 206 is provided with a slide valve 208.

Combining the separated catalyst with the regenerated catalyst heats the separated catalyst to promote subsequent hot stripping in the hot stripping zone 143 defined by a hot stripping vessel 140. The hot stripping occurs at a temperature between 56°C (100°F) above the riser exit temperature and 816°C (1500°F). Preferably, the catalyst in the hot stripping zone 143 has a temperature from 83°C (150°F) above the riser exit temperature to 760°C (1400°F). Most preferably, the hot catalyst stripping zone 143 has a temperature between 593° and 760°C (1100° and 1400°F).

The catalyst 142 in the hot stripping zone 143 is contacted at high temperature, discussed above, with a stripping gas, such as steam, flowing countercurrently to the direction of flow of the catalyst. The stripping gas is introduced into the lower portion of the hot stripping zone 143 by one or more conduits 146 each attached to a stripping gas injection point 148. The catalyst residence time in the hot stripping zone 143 ranges from 2.5 to 7 minutes. The vapor residence time in the hot stripping zone 143 ranges from 0.5 to 30 seconds, and preferably 0.5 to 5 seconds. The hot stripping zone 143 removes coke, sulfur and hydrogen from the separated catalyst which has been combined with the regenerated catalyst. The sulfur is removed as hydrogen sulfide and mercaptans. The hydrogen is removed as molecular hydrogen, hydrocarbons, and hydrogen sulfide. Preferably, the hot stripping zone 143 is maintained at desired conditions sufficient to reduce coke load to the regenerator by about 50% and strip away 70-80% of the hydrogen as molecular hydrogen, light hydrocarbons and other hydrogen-containing compounds. The hot stripping zone 143 is also preferably maintained at conditions sufficient to remove 45 to 55% of the sulfur as hydrogen sulfide and mercaptans, as well as a portion of nitrogen as ammonia and cyanides. The stripped hydrogen-, coke, sulfur- and nitrogen-containing compounds pass from the hot stripping vessel through a gaseous effluent conduit 150 as a stream 149.

The hot stripping zone 143 may also be provided with trays (baffles) 144. The trays 144 may be disc- and doughnut-shaped and may be perforated or unperforated.

The hot stripping vessel 140 is located directly underneath the regenerator vessel 180. In the embodiment shown in Fig. 2, the hot stripping vessel 140 is attached to the regenerator vessel 180. The atmosphere of vessel 140 is separated from that of vessel 180 by a hot stripping vessel top wall 141. Locating vessel 140 below the vessel 180 results in an economical, long catalyst residence time hot stripper. It is cheaper to stack a long residence time hot stripper in this fashion than to build a separate vessel. It would also be more desirable to build a hot stripper under the regenerator than under the reactor vessel 102 for ease of catalyst circulation. The hot stripped catalyst passes from the hot stripping vessel 140 through an effluent conduit 152 and into a regenerator riser 160. Conduit 152 is attached to the hot stripping vessel 140 and riser 160 and provided with a slide valve 154.

In the regenerator riser 160, lift air from a conduit 166 and the hot stripped catalyst combine and pass upwardly as a dilute phase to the regenerator vessel 180. In the riser 160, combustible materials such as coke which adheres to the cooled catalyst are burned off the catalyst by contact with the air. The dilute phase passes upwardly through the riser 160, through a radial arm 184 attached to the riser 160, and then passes downwardly to a relatively dense bed of catalyst 182 located within the regenerator vessel 180.

The major portion of catalyst passes downwardly through the radial arms 184, while the gases and remaining catalyst pass into the atmosphere of the regenerator vessel 180. The gases and remaining catalyst then pass through an inlet conduit 189 into the first regenerator cyclone 186. The first cyclone 186 separates a portion of catalyst and passes it through a first dipleg 190, while remaining catalyst and gases pass through an overhead conduit 188 into a second regenerator cyclone 192. The second cyclone 192 separates a portion of catalyst and passes the separated portion through a second dipleg 196, with the remaining gas and catalyst passing through a second overhead conduit 194 into a regenerator vessel plenum chamber 198. A flue gas stream 201 exits from the regenerator plenum chamber 198 through a regenerator flue gas conduit 200.

The regenerated catalyst settles to form the bed 182, which is dense compared to the dilute catalyst passing through the riser 160. The regenerated catalyst bed 182 is at a substantially higher temperature than the stripped catalyst from the hot stripping zone 143, due to the coke burning which occurs in the riser 160 and regenerator 180. The catalyst in bed 182 is at least 56°C (100°F) hotter than the temperature of the catalyst 142 in the hot stripping zone 143, preferably at least 83°C (150°F) hotter than the temperature of the catalyst 142 in the hot stripping zone 143. The regenerator temperature is, at most, 871°C (1600°F) to prevent deactivating the catalyst.

Air also passes through an air transfer line 170, to an air header 174 located in the regenerator 180. This provides for additional regeneration in the regenerator 180. The regenerated catalyst then passes from the relatively dense bed 182 through the conduit 206 to conduit 138 to combine with and heat the catalyst from the preliminary stripping zone 130.

Fig. 3 shows a third embodiment of the present invention. This third embodiment is an optional modification of the second embodiment of Fig. 2. In the embodiment shown on Fig. 3, if the temperature of the hot stripped catalyst from the conduit 152 is less than 593°C (1100°F), the hot stripped catalyst passes through the conduit 152 into a lift pot (preheat chamber) 155. A portion of hot regenerated catalyst passes through a conduit 156, provided with a control valve 158, into the lift pot 155. These catalyst streams form a catalyst bed 153. The air from a conduit 168 passes through a nozzle 162, fluidizes the catalyst in the bed 153, and subsequently transports the catalyst continuously as a dilute phase through the regenerator riser 160.

Any conventional fluid catalytic cracking catalyst can be used in the present invention. Use of zeolite catalysts in an amorphous base is preferred. Many suitable catalysts are discussed in U. S. Patent No. 3,926,778 to Owen et al. The catalyst should not contain any agents designed to absorb or react with SO_X in the fluid catalytic cracking regenerator.

In the fourth embodiment of the present invention, shown by Fig. 4, the countercurrent hot stripping zone 143, shown in Figs. 2 and 3, is replaced by a fluidized bed hot stripping zone 243 contained within a hot stripping vessel 240. The hot stripping vessel 240 contains a fluidized, dense phase catalyst bed 242. A stream of spent catalyst 236 containing catalyst from the preliminary stripping zone 130 of Fig. 2 or separated catalyst taken directly from a fluid catalytic cracking reactor vessel without preliminary stripping, passes through a hot stripper inlet conduit 238 into the hot stripping vessel 240. The spent catalyst 236 is fluidized and stripped by contact with stripping gas provided by a stripping gas conduit 246 through injection points 248. Hot regenerated catalyst passes from the regenerator vessel 180 through a catalyst conduit 306, provided with a slide valve 308, into the hot stripping vessel 240 to mix with the spent catalyst.

In the hot stripping vessel 240 hydrogen-, sulfur-, and nitrogen-containing compounds are separated from the spent catalyst 236 and are discharged from the hot stripping vessel 240 as a gaseous effluent stream 249 through a gaseous effluent conduit 250. The stripped catalyst is discharged from the stripping vessel 240 by passing into a catalyst effluent conduit 252 where it combines with lift air provided by a conduit 266 and passes upwardly in dilute phase through a regenerator riser 260. The dilute phase catalyst then discharges from the regenerator riser 260 through radial arms 184 and is regenerated in the regenerator vessel 180 as described above for the embodiments shown by Figs. 2 and 3. A regenerated catalyst stream 304 is discharged from the regenerator vessel 180 through the catalyst conduit 202 and passes to the riser conversion zone 104 (shown on Fig. 2).

The fluidized hot stripping zone 243 operates under the same ranges of temperature and gas residence time as the countercurrent stripping zone 143 shown in Figs. 2 and 3.

A fifth embodiment of the present invention, as shown by Fig. 5, employs the reactor vessel as shown by Figs. 2 and 3. However catalyst passes from the preliminary stripping zone 130 through a preliminary stripper effluent conduit 310 into a hot stripping zone 317 comprising a hot stripping riser 316. In riser 316 the preliminarily stripped catalyst from zone 130 combines with a regenerated catalyst stream 314 which passes through a conduit 312 from a fluid catalytic cracking regenerator (not shown) into the hot striping riser 316. The fluid catalytic cracking regenerator operates at the temperature conditions outlined for the fluid catalytic cracking regenerator 180 of Figs. 2 and 3. These temperature conditions include a fluid catalytic cracking temperature between 56°C (100°F) above the temperature of catalyst in the hot stripping riser 158° and 871°C (316° and 1600°F), preferably a temperature between 83°C (150°F) above the temperature of catalyst in the hot stripping riser 158° and 871°C (316° and 1600°F).

The combined catalyst passes in dilute phase through the riser 316 for a gas residence time 0.5 to 30 seconds and preferably 0.5 to 5 seconds. The combined catalyst is hot stripped in the riser 316 and is discharged from the riser 316 into a gas disengaging vessel 320. In vessel 320 the gas continues upwardly and exits through an overhead conduit 322 as an overhead stream 324 while the solids drop downwardly to form a relatively dense bed of catalyst 326 in a lower portion of the vessel 320. The catalyst from the dense bed 326 then exits from the vessel 320 as a hot stripped catalyst stream 328 which passes through conduit 330 to a fluid catalytic cracking regenerator (not shown).

Figs. 6 and 7 disclose a sixth embodiment of the present invention in which preliminary stripping and catalyst separation occur in a reactor vessel 342. In this embodiment, a hydrocarbon-catalyst mixture passes through a riser conversion zone 340, at suitable catalytic cracking temperature conditions as described for riser 104 discussed above. The mixture of catalyst and cracked hydrocarbons is deflected by a frusto conical deflector 390, as shown by Fig. 7, attached to a conical deflector 392 and thus deflected through a conduit 344 into a cyclone portion 345 of a short contact time stripper 347. The cyclone 345 is a centrifugal separator. The short contact time stripper 347 includes a preliminary stripping vessel 349 which defines a preliminary stripping zone located adjacent a barrel 346 of the cyclone separator 345. This construction is such that extensions of the exit barrel walls 346 make up the walls of the preliminary stripping vessel 349. The preliminary stripping vessel 349 operates at preliminary stripping conditions as discussed in regard to the previous embodiments.

Fig. 7 illustrates the details of the short contact time stripper 347. The hydrocarbon catalyst mixture ascends vertically through the riser conversion zone 340, and enters the cyclone 345 located in the upper portion of the short contact time stripper 347 and descends towards a lower portion thereof. Baffles 402 and 404 serve to direct the descending separated catalyst particles toward perforated conical diffusers 332 and 334. Steam is provided by inlets 398 and 400 and travels through only a portion of the flowing separated catalyst particles. The portion referred to is that catalyst located between the steam injection point and the intake of the baffles 402 and 404 which are inverted funnels. The steam does not flow through the catalyst particles above its associated funnel intake, therefore it does not place the hydrocarbon entrained therewith in further contact with catalyst. Although all catalyst is contacted with steam, a given amount of steam does not contact all catalyst contained thereabove in the stripping vessel 347.

The separated catalyst passes from the cyclone 345 to the baffle 404 through a conduit 394. The catalyst from the second conical diffuser 334 passes through a conduit 396 to a bed of catalyst 410 located therebelow. The catalyst in bed 410 is discharged from the short contact time stripping vessel 347 into an exit conduit 414 which is inserted into a seal pot 348. The catalyst exits the seal pot 348 by overflowing through an annulus between conduit 414 and the seal pot 348 as well as through drain holes 412 provided at the bottom of the seal pot 348. The drain holes 412 allow 10-90% of the catalyst to flow therethrough. The seal pot provides a catalyst seal as opposed to extending the conduit 414 into a catalyst bed 362, shown on Fig. 6, located therebelow or providing the conduit 414 with a trickle valve.

As further seen on Fig. 6, the overhead from the short contact time stripper 347 passes through an overhead conduit 350 into a second cyclone 354 which separates a second portion of catalyst from the short contact time stripper overhead and passes the separated portion of catalyst through a dipleg 358 to catalyst bed 362 therebelow. The overhead conduit 350 may be provided with a connector 352 which may have an annulus as described above in relation to connector 24 of Figs. 2 and 3.

Catalyst from the seal pot 348 passes to the catalyst bed 362 located in a hot stripping zone 363 defined by the lower portion 360 of the reactor vessel 342.

In the hot stripping zone 363 the preliminarily stripped catalyst from the seal pot 348 combines with hot regenerated catalyst from conduit 382. The conduit 382 is provided with a slide valve 384. The regenerated catalyst is provided by passing a regenerated catalyst air mixture upwardly through a riser 372 which discharges the regenerated catalyst air mixture into a disengaging vessel 374. Gasiformed material continues upwardly and exits vessel 374 through an overhead conduit 378 as an overhead stream 376. Solids separated from the regenerated catalyst air mixture drop through the vessel 374 to form a dense catalyst bed 380. The regenerated catalyst from bed 380 passes through the conduit 382 into the reactor vessel 342, at the temperature conditions outlined for regenerated catalyst in the previous embodiments. The regenerated catalyst in the previous embodiments. The regenerated catalyst from the conduit 382 provides heat to the hot stripping zone 363.

The combined catalyst within the lower portion 360 of the reactor vessel 342 passes countercurrently to stripping gas provided by a stripping gas conduit 366 which feeds a stripping gas header 368. The hot stripping zone 363 may be provided with baffles (trays) 364 which are disc- and doughnut-shaped and may be perforated or unperforated. The hot stripped catalyst is discharged from the hot stripping zone 363 through a conduit 370 and passes to a fluid catalytic cracking regenerator (not shown).

Operating the stripping zone as a high temperature (hot) stripper has the advantage that it separates hydrogen, as molecular hydrogen as well as hydrocarbons, from catalyst. Hydrogen removal eliminates hydrothermal degradation, which typically occurs when hydrogen reacts with oxygen in a fluid catalytic cracking regenerator to form water. The hot stripper also removes sulfur from coked catalyst as hydrogen sulfide and mercaptans, which are easy to scrub. By removing sulfur from coked catalyst in the hot stripper, the hot stripper prevents formation of SO_X in the regenerator. It is more difficult to remove SO_X from regenerator flue gas than to remove hydrogen sulfide and mercaptans from a hot stripper effluent. The hot stripper enhances removal of hydrocarbons from spent catalyst, and thus prevents burning of valuable hydrocarbons in the regenerator. Furthermore, the hot stripper quickly separates hydrocarbons from catalyst to avoid overcracking.

Preferably the hot stripper is maintained at desired conditions sufficient to reduce coke load to the regenerator by about 50% and strip away 70-80% of the hydrogen as molecular hydrogen, light hydrocarbons and other hydrogen-containing compounds. The hot stripper is also maintained at conditions sufficient to remove 45 to 55% of the sulfur as hydrogen sulfide and mercaptans, as well as a portion of nitrogen as ammonia and cyanides.

The hot stripper controls the amounts of carbon removed from the catalyst in the stripper. Accordingly, the hot stripper controls the amount of carbon (and hydrogen, sulfur) remaining on the catalyst to the regenerator. This residual carbon level controls the temperature rise between the reactor stripper and the regenerator. The hot stripper also controls the hydrogen content of the spent catalyst sent to the regenerator as a function of residual carbon. Thus, the hot stripper controls the temperature and amount of hydrothermal deactivation of catalyst in the regenerator. This concept may be practiced in a multistage, multi-temperature stripper or a single stage stripper.

The degree of regeneration desired is set by the CO/CO_2 ratio desired, the amount of carbon burn-off desired, the catalyst recirculation rate from the regenerator to the hot stripper, and the degree of desulfurization/denitrification/decarbonization desired in the hot stripper.

Employing a hot stripper, to remove carbon on the catalyst, rather than a regeneration stage reduces air pollution, and allows all of the carbon made in the reaction to be burned to CO_2, if desired. In contrast, the process of U. S. Patent No. 4,336,160 to Dean et al (also known as the TOTAL process) employs two flue gas streams, and only one of these flue gas streams is combustible to CO_2.

Claims

1. A process for fluid catalytic cracking (FCC) of a hydrocarbon feed by passing a mixture of hot regenerated catalyst and feed up through a conventional FCC riser reactor 104 and discharging from the riser a mixture of coked catalyst and cracked product, separating coked catalyst from cracked product, stripping coked catalyst to remove strippable hydrocarbons and regenerating the stripped catalyst in a regenerator 180 by burning coke from catalyst, to form hot regenerated catalyst characterized by heating the coked catalyst by combining it with hot regenerated catalyst and stripping the heated coked catalyst by contact with a stripping gas in a hot stripping zone 143 and then regenerating the hot stripped catalyst in the FCC regenerator 180.

2. The process of Claim 1 further characterized in that the residence time of the stripping gas with heated, coked catalyst is 0.5 to 30 seconds.

3. The process of Claim 2 further characterized in that the coked catalyst is heated to 540°C to 760°C and the residence time of the stripping gas in the hot stripping zone 143 is 0.5 to 5 seconds.

4. The process of any preceding Claim wherein the coked catalyst contains sulfur compounds and stripping of heated coked catalyst removes 45 to 55% of the sulfur compounds and 70 to 80% of hydrogen from the hydrocarbons in the coked catalyst.

5. The process of any preceding Claim wherein the coked catalyst contacts a conventional stripping gas stream in a conventional stripping zone 130, prior to mixing with hot regenerated catalyst.

6. The process of Claim 5, wherein a mixing tray downstream of the conventional stripping zone is used to mix catalyst from the preliminary stripping zone with hot regenerated catalyst.

7. An apparatus for fluid catalytic cracking of oil by adding oil and catalyst to an upstream end (3) of a riser reactor (1), and discharging spent catalyst and cracked product at a downstream end (5), separating catalyst from product, and the spent catalyst is stripped and then regenerated, characterized by a two stage regenerator including a vertical, dilute phase first stage regenerator (33), receiving stripped catalyst and discharging partially regenerated catalyst into a second stage dense bed regenerator (29).

8. An apparatus for fluid catalytic cracking of oil by adding oil and catalyst to an upstream end (3) of a riser reactor and discharging spent catalyst and cracked product at a downstream end (5), separating catalyst from product, stripping spent catalyst, and regenerating the stripped catalyst, characterized by a two stage stripper including a conventional primary stripper (17) with a stripping gas inlet (53) for stripping medium to contact the spent catalyst and strip hydrocarbons from spent catalyst, and a secondary stripper (23) for receiving catalyst from the primary stripper and regenerated catalyst, the secondary stripper including a stripping gas inlet (55) for a stripping medium to contact the catalyst and strip hydrocarbons from catalyst.

9. The apparatus of Claim 7 or Claim 8, further characterized in that the first stage regenerator has a length to diameter ratio in excess of 2.

10. An apparatus for fluid catalytic cracking of oil by adding oil and catalyst to an upstream end (3) of a riser reactor (1) and discharging spent catalyst and cracked product at a downstream end (5) separating spent catalyst from cracked product, stripping spent catalyst, and regenerating stripped catalyst characterized by

a) a stripper at the downstream end (5) for deflecting catalyst in the mixture downwardly to separate a portion of the catalyst from the cracked hydrocarbons;

b) a stripper receiving the downwardly deflected catalyst, including a primary stripper (17) with a stripping gas inlet (53) for stripping medium to contact the downwardly deflected catalyst and strip hydrocarbons from catalyst, and a secondary stripper (23) for receiving catalyst from the primary stripper and regenerated catalyst, the secondary stripper including a stripping gas inlet (55) for a stripping medium to contact the catalyst and strip hydrocarbons from catalyst;

c) a catalyst regenerator (29), which discharges hot regenerated catalyst into the secondary stripper (23) and upstream end (3) of the riser reactor; and

d) a cyclone separator (21) connected to at least one external conduit providing an exit adjacent the downstream end of the riser reactor for separating entrained catalyst from hydrocarbon product and stripping medium introduced into the primary and secondary strippers, the cyclone (21) having a vapor exhaust (61) for hydrocarbon product and stripping medium and a catalyst outlet to a cyclone dipleg (25) discharging into the secondary stripper (23), whereby the secondary stripper receives stripped catalyst from the primary stripper (17), catalyst from the cyclone dipleg (25) and hot regenerated catalyst,

11. An apparatus for fluid catalytic cracking of oil by adding oil and catalyst to an upstream end (3) of a riser reactor (1), and discharging spent catalyst and cracked product at a downstream end (5) separating spent catalyst from cracked product, stripping spent catalyst and regenerating stripped catalyst characterized by

a) a catalyst separator at the downstream end (5) for deflecting catalyst in the mixture downwardly to separate a portion of the catalyst from the cracked hydrocarbons;

b) a stripper receiving the downwardly deflected catalyst, including a primary stripper (17) with a stripping gas inlet (53) for stripping medium to contact the downwardly deflected catalyst and strip hydrocarbons from catalyst, and a secondary stripper (23) for receiving catalyst from the primary stripper and regenerated catalyst, the secondary stripper including a stripping gas inlet (55) for a stripping medium to contact the catalyst and strip hydrocarbons from catalyst;

c) a regenerator including a first stage regenerator (33), receiving stripped catalyst from the secondary stripper (23) and discharging partially regenerated catalyst into a second stage regenerator (29), which discharges hot regenerated catalyst into the secondary stripper (23) and upstream end (3) of the riser reactor; and

d) a cyclone separator (21) connected to at least one external conduit providing an exit adjacent the downstream end of the riser reactor for separating entrained catalyst from hydrocarbon product and stripping medium introduced into the primary and secondary strippers, the cyclone (21) having a vapor exhaust (61) for hydrocarbon product and stripping medium and a catalyst outlet to a cyclone dipleg (25) discharging into the secondary stripper (23), whereby the secondary stripper receives stripped catalyst from the primary stripper (17), catalyst from the cyclone dipleg (25) and hot regenerated catalyst.

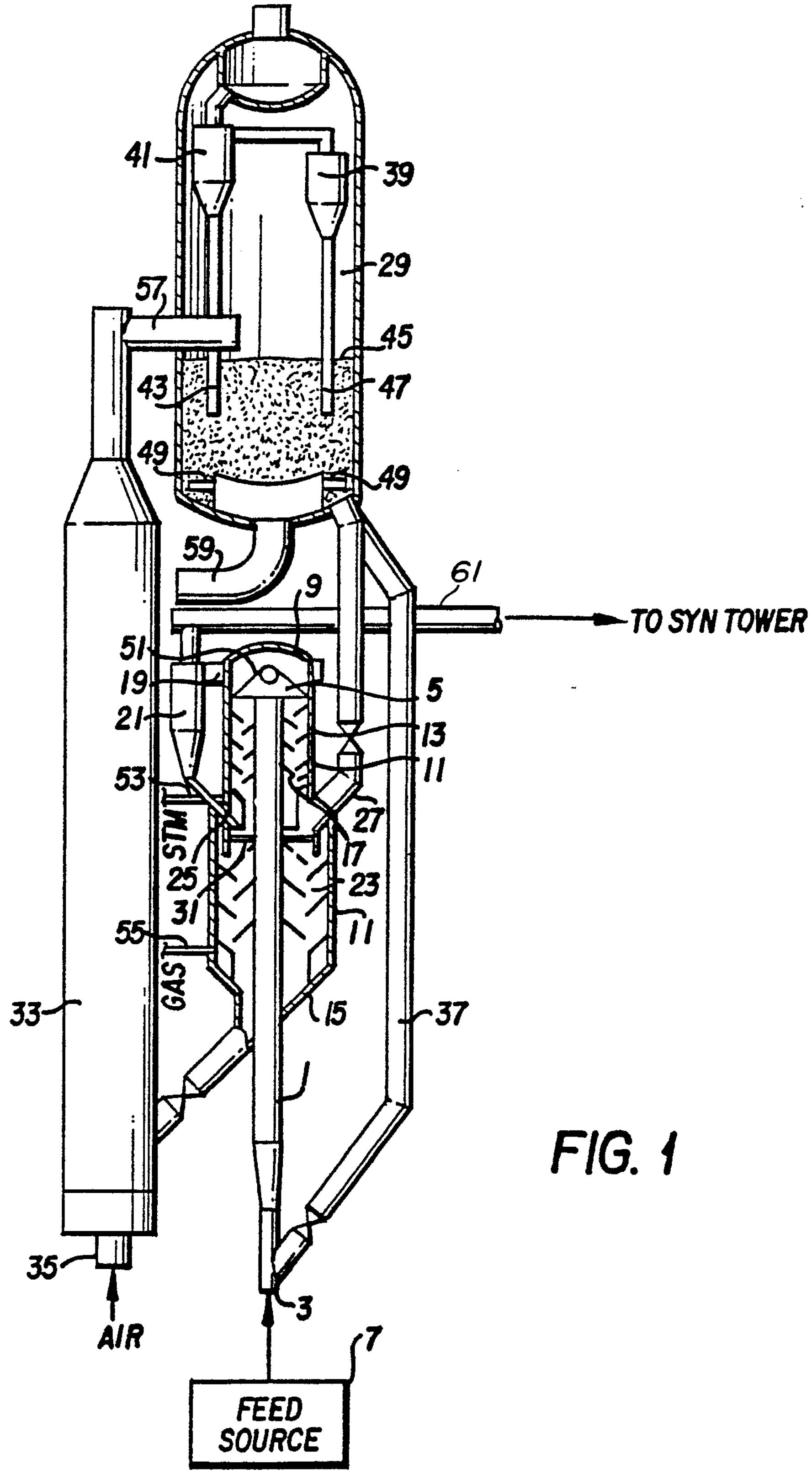
12. The apparatus of any of Claims 8 to 11, further characterized by a mixing tray (31) between the primary and the secondary stripper for mixing stripped catalyst with hot regenerated catalyst.

13. The apparatus of any of Claims 10 to 12, further characterized in that the first stage regenerator has a length to diameter ratio in excess of 2.

14. The apparatus of any of Claims 10 to 13, further characterized in that a primary cyclone (39) and a secondary cyclone (41), in the second stage regenerator (29) separate regenerated catalyst from flue gas and the secondary cyclone (41) has a dipleg for fines removal from the apparatus.

15. The apparatus of any of Claims 7 to 14 further characterized in that the riser reactor (1) terminates within an elongated enclosed vessel (11) having a substantially continuous sidewall attached to a bottom member (15) and a top member (9), the deflector (51) is within the top member (9) of the vessel, an upper portion of the vessel includes the primary stripper (17) and a lower portion of the vessel

includes the secondary stripper (23), and a mixing tray (31) is disposed at a bottom region of the primary stripper.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FEED SOURCE

FIG. 1

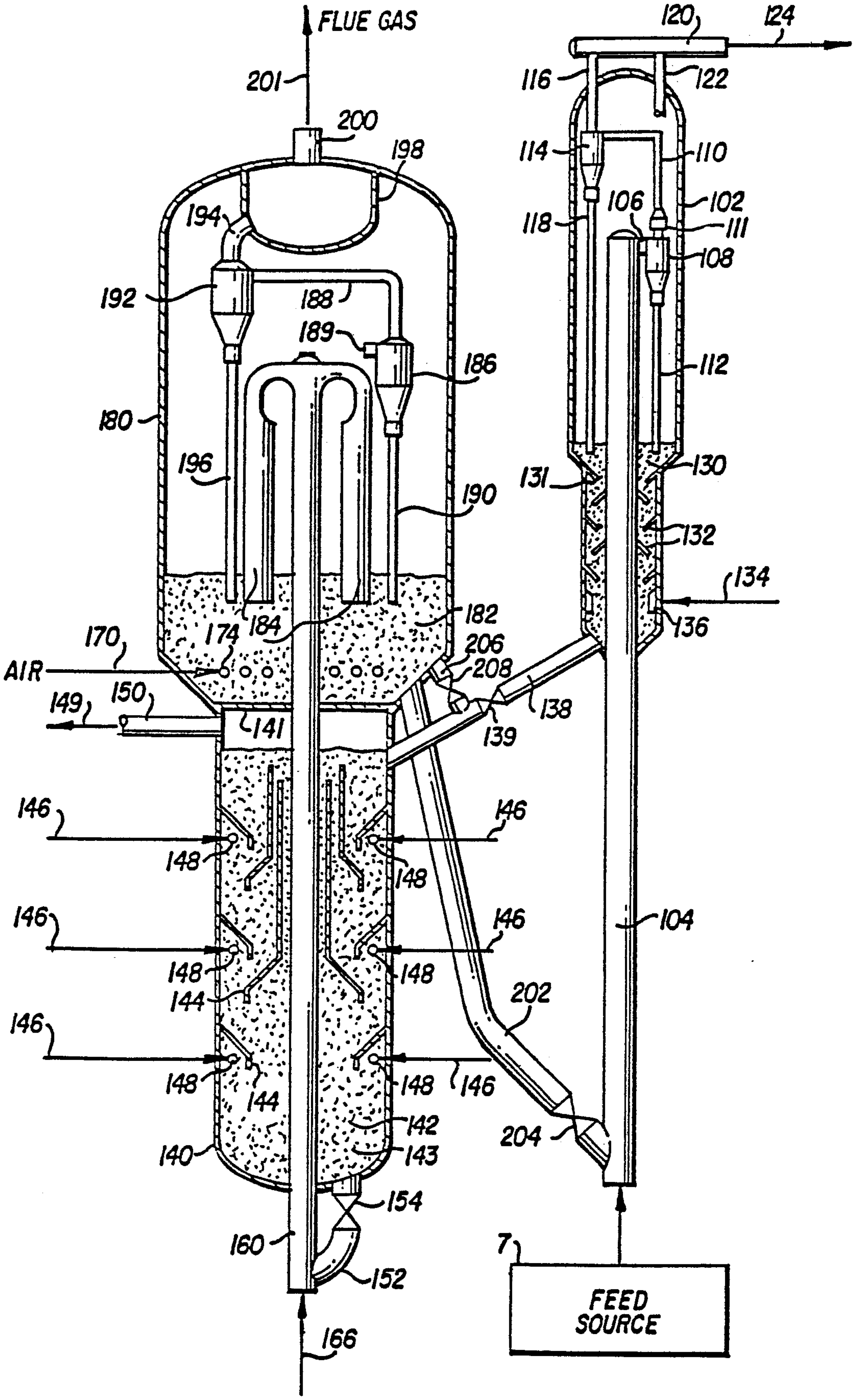
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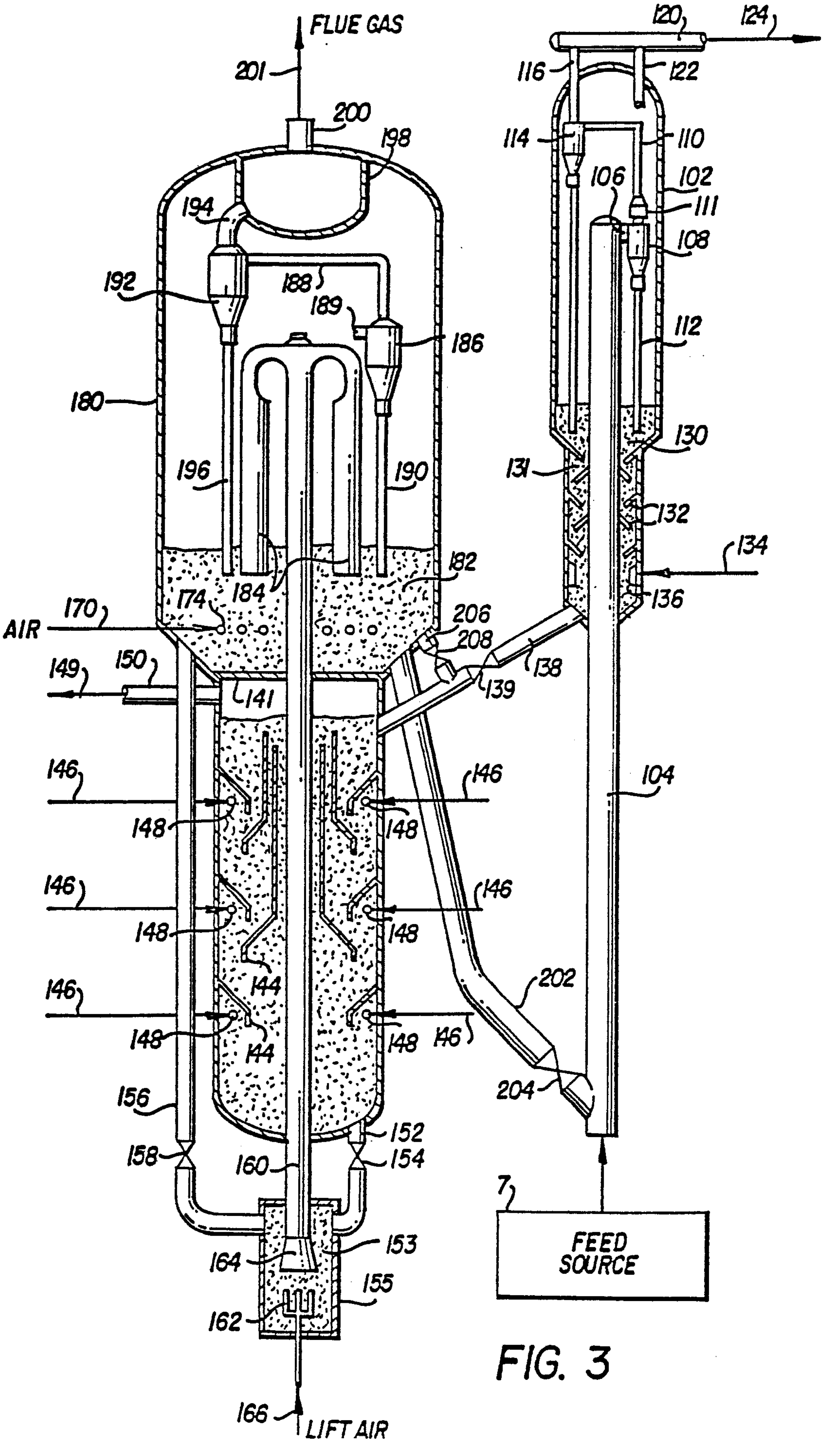
FIG. 2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LIFT AIR
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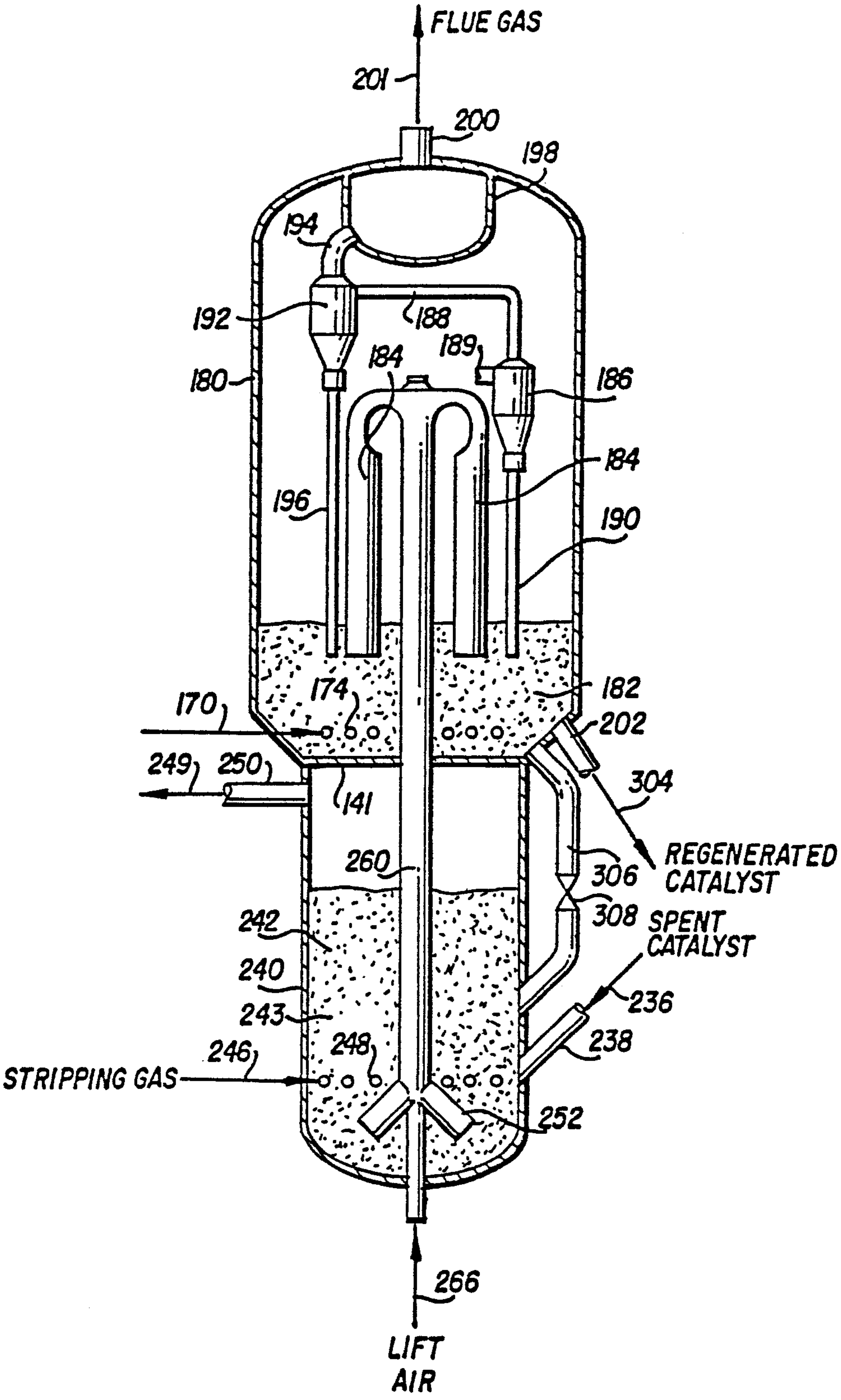
FIG. 3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REGENERATED CATALYST
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SPENT CATALYST
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STRIPPING GAS
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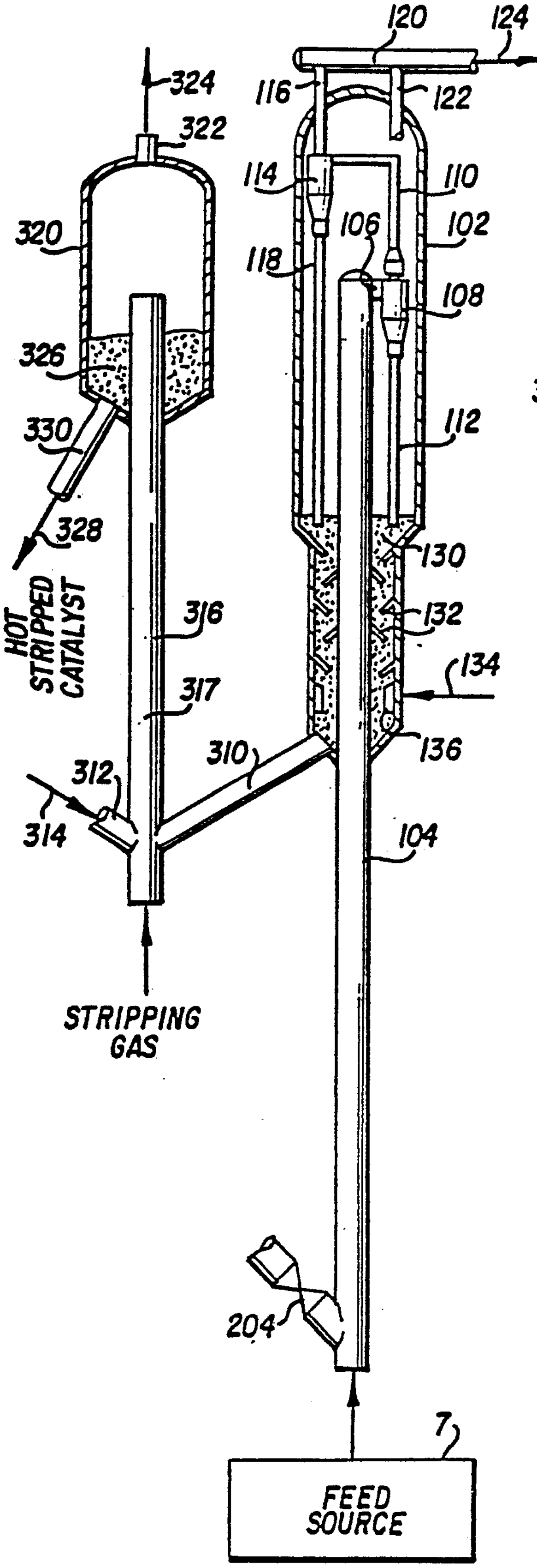
LIFT AIR

FIG. 4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HOT STRIPPED CATALYST
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STRIPPING GAS
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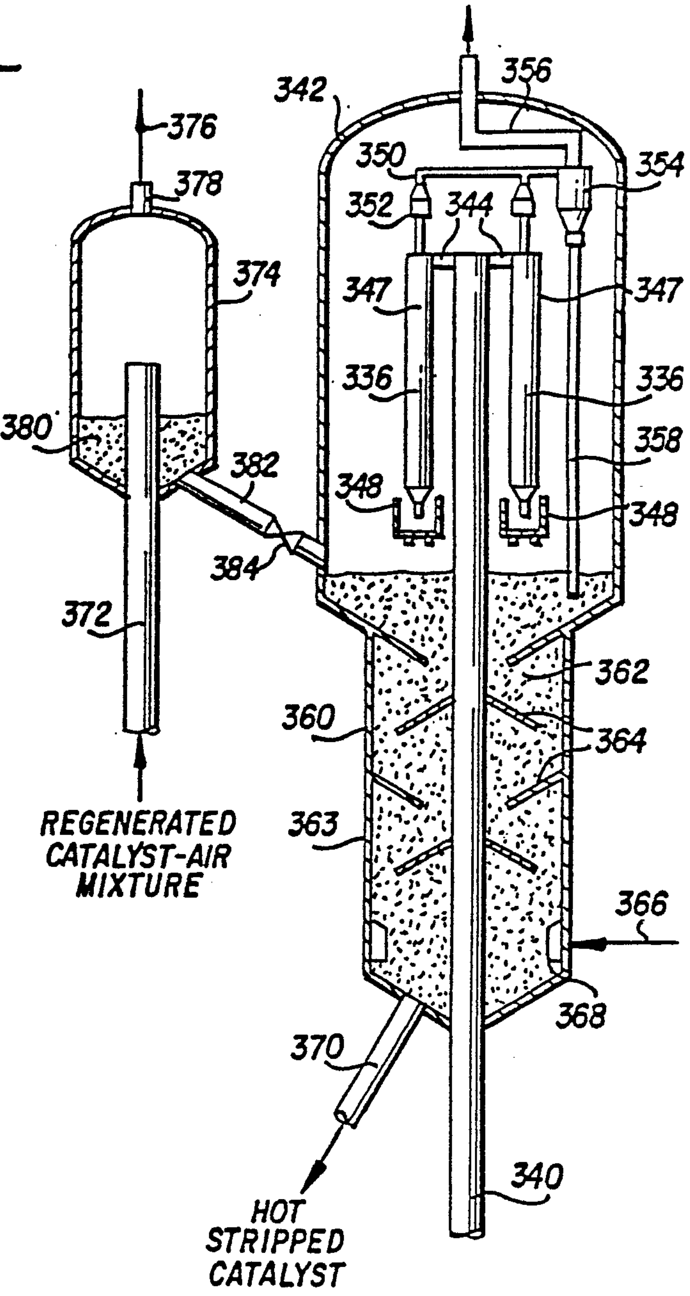
FIG. 5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REGENERATED CATALYST-AIR MIXTURE
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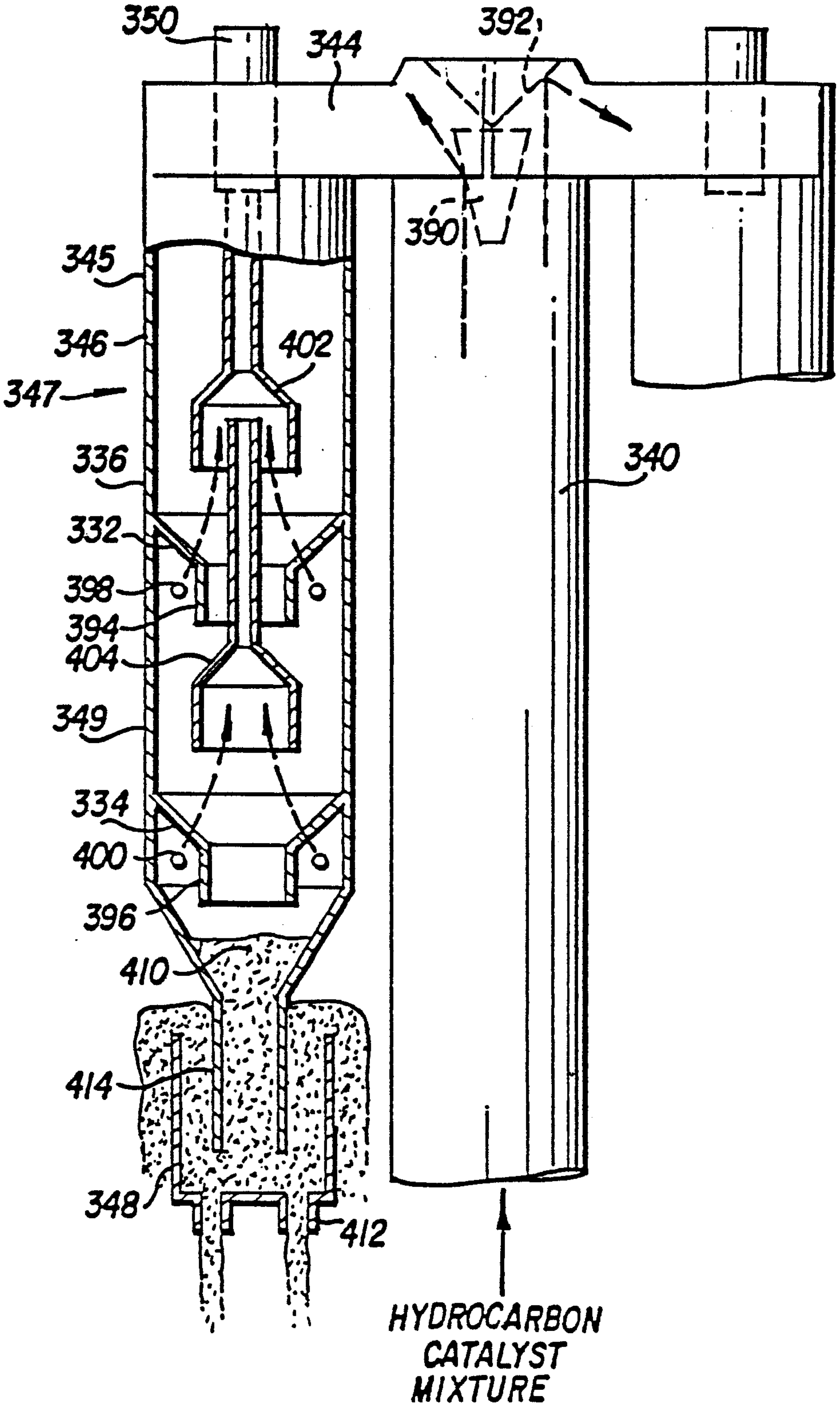
HOT STRIPPED CATALYST

FIG. 6

FIG. 7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HYDROCARBON
CATALYST
MIXTURE

European Patent Office

EUROPEAN SEARCH REPORT

Application number

EP 85 30 9354

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
X	US-A-3 821 103 (OWEN et al.) * Figures 1,2; claims 1,4-10; column 4, lines 53-62 * ---	1,4-15	C 10 G 11/18
X	US-A-4 424 116 (HETTINGER) * Figure 2; claims 1-29 * ---	1-3,5,6	
X	US-A-4 435 281 (VASALOS) * Figure 1; claims 1,3-5,11-13,15-20; column 8, lines 33-44 * ---	1,3,4	
X	US-A-4 419 221 (CASTAGNOS et al.) * Figure; claims 1-6 * ---	1,3,4,7	
			TECHNICAL FIELDS SEARCHED (Int. Cl.4)
X	US-A-3 008 896 (LAWSON et al.) * Figure; claims 1-4; column 3, line 63 - column 4, line 25 * ---	1,3	C 10 G
X	US-A-2 526 881 (KUNREUTHER et al.) * Figure 1 * ---	1	
X	US-A-2 944 963 (WILSON) * Figure 1; claims 1-3; column 3, line 66 - column 4, line 9 * -----	1	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	27-03-1986	MICHIELS P.

CATEGORY OF CITED DOCUMENTS

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& : member of the same patent family, corresponding document