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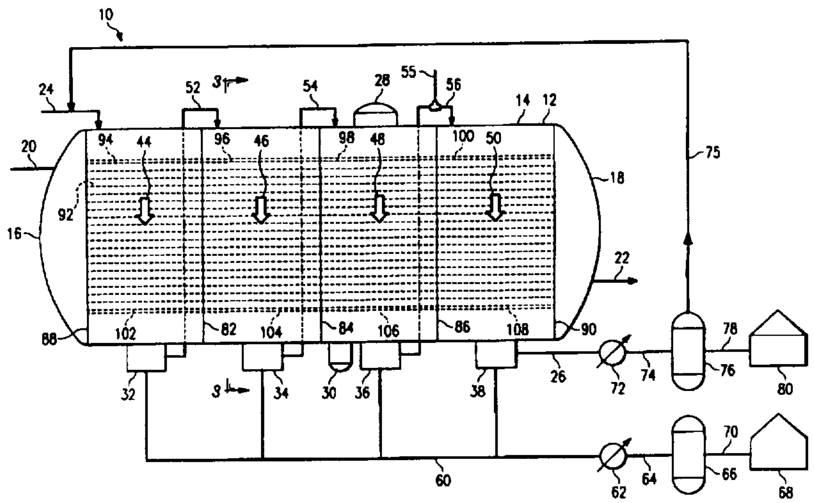

(57) Abstract

A fixed-bed, catalytic, cross-flow reactor (10, 210), has a cylindrical body (14, 214), a first hemispherical end cap (16, 216) attached to a first end of the cylindrical body (14, 214), a second hemispherical end cap (18, 218) attached to a second end of the cylindrical body (14, 214). A heat-exchange-fluid inlet (20, 220) is provided on the first hemispherical end cap (16, 216), and a heat-exchange-fluid outlet (22, 222) is provided on the second hemispherical end cap (18, 218). A first tube sheet (88, 288) and a second tube sheet (90, 290) are attached in first end cap (16, 216) and second end cap (90, 290), respectively. A plurality of heat-exchange tubes (92, 292) run between the tube sheets (18, 218; 90, 290). At least one baffle (82, 84, 86, 282, 284, 286) is provided within body (14, 214) for directing flow of a process fluid within reactor (10, 210). The body (14, 214) has a product inlet (24, 224) and a product outlet (26, 226) wherein the process fluid inlet, baffle, and process fluid outlet are operable to force a process fluid to flow substantially traverse to the plurality of heat exchange tubes (92, 292). A plurality of separators (32, 34, 36 and 38) may be provided on reactor (10) to remove condensate.

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FIXED-BED, CATALYTIC REACTOR AND METHOD FOR MANUFACTURING SAME

TECHNICAL FIELD OF THE INVENTION

The present invention relates to fixed-bed, catalytic reactors and more particularly to a fixed-bed, catalytic, crossflow reactor.

BACKGROUND OF THE INVENTION

Reactors are devices or process vessels in which chemical reactions take place during a chemical conversion type of process. Reactors may be catalyzed or non-catalyzed. A catalyzed reactor may include a fixed bed of catalysts within the reactor. Because a reaction involved in a reactor may be exothermic or endothermic, a heat exchanger must frequently be included as part of the reactor design to provide heat or to absorb heat. For example, if an exothermic reaction is occurring, heat will generally need to be removed from the reactor to maintain the desired operating temperature because heat is given off during the process. If an endothermic reaction is occurring, heat will generally need to be supplied to properly sustain the reaction.

While the reactor of the present invention may be used for any number of exothermic or endothermic reactions, one example presented below involves a Fischer-Tropsch reaction, and therefore, some background on that reaction is provided. The Fischer-Tropsch process involves an exothermic catalytic reaction. The Fischer-Tropsch process or reaction refers to the synthetic production of hydrocarbons by the catalytic reaction of carbon monoxide and hydrogen. Numerous catalysts have been used in carrying out the reaction, and at relatively low to medium pressure (near atmospheric to 600 psig) and temperatures in the range of from about 300° F. to 600° F., both saturated and unsaturated hydrocarbons can be produced. The synthesis reaction is very exothermic and temperature sensitive whereby temperature control is required to maintain a desired hydrocarbon product selectivity. The Fischer-Tropsch reaction can be characterized by the following general formula:

$$2H_2 + CO \xrightarrow{Catalyst} -CH_2^- + H_2O$$

Two basic methods have generally been employed for producing the synthesis gas ("syngas") utilized as feedstock in the Fischer-Tropsch reaction. The two methods are steam reforming, wherein one or more light hydrocarbons such as methane are reacted with steam over a catalyst to form carbon monoxide and hydrogen, and partial oxidation, wherein one or more light hydrocarbons are combusted sub-stoichiometrically to produce synthesis gas.

The basic steam reforming reaction of methane is represented by the following formula:

$$CH_4 + H_2O \xrightarrow{Catalyst} CO + 3H_2$$

The steam reforming reaction is endothermic and a catalyst containing nickel is often utilized. The hydrogen to carbon monoxide ratio of the synthesis gas produced by steam reforming of methane is approximately 3:1.

Partial oxidation is the non-catalytic, sub-stoichiometric combustion of light hydrocarbons such as methane to produce the synthesis gas. The basic reaction is represented as follows:

$$CH_4 + \tfrac{1}{2} O_2 \rightarrow CO + 2H_2$$

The partial oxidation reaction is typically carried out using high purity oxygen. High purity oxygen, however, can be quite expensive. The hydrogen to carbon monoxide ratio of synthesis gas produced by the partial oxidation of methane is approximately 2:1.

In some situations these approaches may be combined. A combination of partial oxidation and steam reforming, known as autothermal reforming, wherein air is used as a source of oxygen for the partial oxidation reaction has also been used for producing synthesis gas heretofore. For example, U.S. Patent Nos. 2,552,308 and 2,686,195 disclose low pressure hydrocarbon synthesis processes wherein autothermal reforming with air is utilized to produce synthesis gas for the Fischer-Tropsch reaction. Autothermal reforming is a simple combination of partial oxidation and steam reforming where the exothermic heat of the partial oxidation supplies the necessary heat for the endothermic steam reforming reaction. The autothermal reforming process can be carried out in a relatively inexpensive refractory lined carbon steel vessel whereby low cost is typically involved.

The autothermal process results in a lower hydrogen to carbon monoxide ratio in the synthesis gas than does steam reforming alone. That is, as stated above, the steam reforming reaction with methane results in a ratio of about 3:1 while the partial oxidation of methane results in a ratio of about 2:1. The optimum ratio for the hydrocarbon synthesis reaction carried out at low or medium pressure over a cobalt catalyst is 2:1. When the feed to the autothermal reforming process is a mixture of light hydrocarbons such as a natural gas stream, some form of additional control is required to maintain the ratio of hydrogen to carbon monoxide in the synthesis gas at the optimum ratio of about 2:1.

Once the syngas is produced, it is treated and delivered to a synthesis reactor, where heavier hydrocarbons are formed. The synthesis reaction is typically very exothermic and temperature sensitive. Attention must, therefore, be given to the reactor design.

A traditional reactor design, which is presently used, includes a vertical reactor having tubes containing catalysts into which the syngas may be introduced. The syngas passes over or through the catalyst in the tubes and then exits the reactor. A fluid for removing or adding heat, such as boiling water, flows around the tubes. Some of these reactors have 10,000 or more tubes and might be 30 or 40 feet long. Frequently it is difficult to load the tubes of a vertical reactor design. Also, this design has another shortcoming by being difficult to add additional reactant or other substances at an intermediate point in the vertical reactor vessel. Additionally, in reactor vessels with this design, it is generally difficult to vary the flow rate and to establish discrete flow zones within the vertical reactor. This type of design has a further disadvantage of being relatively difficult to build and to operate.

SUMMARY OF THE INVENTION

Therefore, a need has arisen for a reactor that addresses the shortcomings of prior reactors. According to an aspect of the present invention a fixed-bed, catalytic, crossflow reactor is provided that includes a cylindrical body having a process fluid inlet for receiving a process fluid and a process fluid outlet for removing the process fluid, a first hemispherical end cap attached to a first end of the cylindrical body having a heat-exchange-fluid inlet, a second hemispherical end cap attached to a second end of the cylindrical body and having a heat-exchange-fluid outlet, a first tube sheet coupled within the first hemispherical end cap, a second tube sheet coupled to the second hemispherical end cap, a plurality of heat-exchange tubes coupled to and running between the first tube sheet and the second tube sheet such that a heat-exchange fluid introduced into the heat-exchange-fluid inlet may flow into and through the plurality of heat-exchange tubes into the second hemispherical end cap and be removed through the heat-exchange-fluid outlet, at least one baffle attached within the cylindrical body for directing flow of the process fluid therein, and wherein the process fluid inlet, baffle, and process fluid outlet are operable to force a process fluid to flow substantially transverse to the plurality of heat exchange tubes.

According to another aspect of the present invention, the reactor may further include a plurality of separators for removing condensates or other liquid fluids from the reactor, the plurality of separators coupled to the cylindrical body, and at least one separator of the plurality of separators associated with the process fluid outlet. According to another aspect of the invention the reactor may include a plurality of separators and at least one conduit for transporting the process fluid exiting one of the plurality of separators to an opposite side of the cylindrical body where it is reintroduced into the body.

A technical advantage of the present invention is that the reactor may be easier to load catalyst than previously known designs. Another technical advantage of the present invention is that additional substances may be readily introduced into the reactor at points in between the feedstock fluid inlet and process fluid outlet. Another technical advantage of the present invention is that the crossflow of the process fluid relative to heat-exchange fluid provides more efficient heat transfer allowing lower fluid flow rates. Another technical advantage of the present invention is that the geometry within the reactor may be readily varied to provide multiple flow zones with the same or different fluid flow rates in each flow zone. Another technical advantage of the present invention may be that it is relatively easier to manufacture than most prior art reactors.

Another aspect of the present invention includes providing a reactor having a generally cylindrical body with a longitudinal axis extending substantially horizontal and one or more separators or boots extending from a lower portion of the cylindrical body to receive condensate or other liquids from the reactor. For some applications the separators may be maintained at a different temperature as compared to the temperature of the cylindrical body. By maintaining the separators at a different temperature, one or more substances may be added to the separators to initiate a reaction which is different from the reaction carried out within the cylindrical body. For example the separators may be maintained at a suitable temperature such that hydrogen can be introduced into the separator to initiate cracking of the hydrocarbon condensate and/or liquids contained therein.

A further aspect of the present invention includes providing a primary reactor having a generally cylindrical body with a longitudinal axis extending substantially horizontally therethrough. One or more separators or boots extending from a lower portion of the cylindrical body to receive condensate or other liquids from the primary reactor. One or more secondary reactors communicating with an upper portion of the cylindrical body to provide a chamber for a secondary vapor phase reaction such as oligomerization of reactants flowing from one fluid flow zone or pathway to the next fluid flow zone or pathway.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention and advantages thereof, reference is now made to the following description taken in conjunction with the accompanying drawings in which like reference numbers indicate like features, and wherein:

FIGURE 1 is a schematic diagram of a reactor according to one aspect of the present invention;

FIGURE 2 is a longitudinal cross-section of the reactor of FIGURE 1;

FIGURE 3 is a radial cross-section of the reactor of FIGURES 1 and 2 taken along line 3-3;

FIGURE 4 is a schematic diagram of a second embodiment of the present invention; and

FIGURE 5 is a schematic diagram of a third embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The preferred embodiments of the present invention and its advantages are best understood by referring to FIGURES 1-5, like numerals being used for like and corresponding parts of the various drawings.

Referring to FIGURE 1, one embodiment of the present invention is presented. Reactor 10 may be generally described as a fixed-bed, cross-flow, gas-phase or two phase catalytic reactor that is suitable for conducting most exothermic or endothermic chemical reactions typically carried out using a fixed-bed catalyst. Examples of reactions that may occur in reactor 10 may include a Fischer-Tropsch reaction, synthesis gas reaction producing methanol and ammonia, and the like. Reactor 10 has a housing 12 that includes a main cylindrical body 14, and a first hemispherical end 16 and a second hemispherical end 18, which are attached to body 14. Reactor 10 has a heat-exchange-fluid inlet 20 and a heat-exchange-fluid outlet 22. The fluid flow path between inlet 20 and outlet 22 will be explained in more detail in connection with FIGURE 2. Reactor 10 has a process inlet 24 and a process outlet 26.

Various reactants or feedstocks may be introduced into reactor 10 through inlet 24. The feedstock may contain one or more substances depending upon the intended use of reactor 10. For one application the feedstock will preferably include synthesis gas suitable for use in a Fischer-Tropsch reaction. Process fluid which originates as feedstock at inlet 24 travels through reactor 10 and contains varying levels of feedstock, desired product, unreacted synthesis gas, water, and inert compounds depending upon the location of the process fluid within reactor 10. Near inlet 24, the process fluid will consist almost entirely of feedstock and near outlet 26 the process gas is greatly depleted of reactants. As the process fluid flows through reactor 10 one or more additional substances or reactants may be added at selected locations in accordance with teachings of the present invention.

Reactor 10 may have a first manway 28 and a second manway 30 for allowing access to the internal portion of reactor 10 for the purposes of loading catalysts and removing spent catalysts from reactor 10. Reactor 10 may also have a plurality of separators or boots such as separators 32, 34, 36, and 38. Separators 32, 34, 36, 38 may be attached to reactor 10 when reactor 10 is to be used for reactions involving the production of condensate such as in a Fischer-Tropsch reaction. The number of separators 32, 34, 36 and 38 included with reactor 10 depends on the number of pathways or zones desired through reactor 10 as will be described further below.

Reactor 10 is preferably mounted horizontally as shown in FIGURE 1; that is, with the longitudinal axis of housing 12 extending generally perpendicular to the direction of gravitational forces. As such, reactor 10 has a top side 40 and a bottom side 42. The flow is generally vertical in each pathway or zone. A plurality of pathways or zones for the process fluid are defined within reactor 10. For purposes of illustration only, the reactor 10 is shown with four pathways: first flow pathway 44, second flow pathway 46, third flow pathway 48, and fourth flow pathway 50, which will be described below in connection with FIGURE 2.

Referring to FIGURE 1 and 2, a feedstock having one or more reactants enters inlet 24. Through reactions within reactor 10 and further processing by a heat exchanger 72 and a separator 76, the feedstock is converted from feedstock into desired liquid hydrocarbon products exiting through a conduit 78. The process fluid, which originates as feedstock, first travels through the first pathway 44 until reaching first separator 32. Upon reaching first separator 32, the process fluid is returned to topside 40 of reactor 10 through process fluid return conduit 52. Conduit 52 delivers the process fluid to second pathway 46, and after flowing through pathway 46, the process fluid arrives at second separator 34. Second separator 34 returns the process fluid to the topside 40 through second process fluid return conduit 54 on topside 40 at reactor 10. The process fluid then flows through third pathway 48 until reaching third separator 36. Third separator 36 delivers the process fluid to third process fluid return conduit 56 for delivery to topside 40 of reactor 10 and into fourth pathway 50. Process fluid return conduits 52, 54, and 56 are shown on an external surface of reactor 10, but they may be included internally in some embodiments.

The process fluid is passed through a fourth pathway 50 until reaching fourth separator 38. The product is delivered by fourth separator 38 to outlet 26. At each of the separators 32, 34, 36, and 38, condensate, e.g. wax, is removed and delivered to conduit 60. Conduit 60 delivers the condensate to heat exchanger 62, which may remove heat, and then on through conduit 64 to separator 66. Condensate exiting separator 66 is then delivered to storage 68 through conduit 70. As explained further below, other embodiments to the present invention do not include separators 32, 34, 36, and 38 because no condensation is produced by the process carried out in the reactor 10; for example, if a low-alfa catalyst is used in a Fischer-Tropsch process, there should be little or no condensation and, therefore, no need for separators 32, 34, 36 and 38.

The process fluid exiting outlet 26 is delivered to heat exchanger 72, which may remove heat, and then on through conduit 74 to a separator 76. The desired liquid hydrocarbon products exit separator 76 and are introduced through conduit 78 to storage 80. Separator 76 may return tail gas, which consists of unreacted feedstock, though conduit 75 to inlet 24 for possible reintroduction into first flow pathway 44 for further reaction or to other locations within the process for energy recovery.

Referring to FIGURE 2, a longitudinal cross-section of reactor 10 is shown with representations shown of the first flow pathway 44, second flow pathway 46, third flow pathway 48, and fourth flow pathway 50. In this instance, the first flow pathway 44 is defined by first tube sheet 88 and first baffling 82. The second flow pathway 46 is defined by first baffling 82 and second baffling 84. Similarly, the third pathway is defined by second baffling 84 and third baffling 86. Finally, in this example, the fourth pathway 50 is defined by third baffling 86 and second tube sheet 90. An important aspect of the present invention is that placement of bafflings 82, 84 and 86 allow for control of the geometry of the flow path from inlet 24 through outlet 26. The ability to vary the geometry allows for varying flow rates to be constructed through reactor 10. For example, it may be desirable to have a wider first zone 44 because the product entering inlet 24 is more voluminous than the product delivered by product-return conduit 56 into zone 50. In the preferred embodiment, baffling 82, 84, and 86 is secured in place at the time of manufacturing of reactor 10. Baffling 82, 84, and 86 may be, for example, welded to body 14.

Another important aspect of the present invention is that the multiple pathways allow for flexibility in introducing additional catalysts or substances at points in between inlet 24 and outlet 26. For example, it may be desirable in some situations to add hydrogen or olefins or other substances to one particular flow path to control the reactions. The additional substances may be introduced into a flow path by a simple T-fitting on one of the product-return conduits 52, 54, or 56; for example, conduit 56 is shown with a T-fitting 55 for introducing a substance such as hydrocarbon or another reactant after flow path 48 and before flow path 50.

In between first tube sheet 88 and second tube sheet 90 are a plurality of heat-exchange tubes generally referenced by numeral 92. The tubes are shown substantially perpendicular to the flow paths 44, 46, 48 and 50. The heat-exchange tubes 92 carry a heat-exchange fluid for removing or providing heat to the product flowing between inlet 24 and outlet 26. The heat-exchange fluid is delivered to inlet 20 and is distributed into tubes 92 by tube sheet 88. The heat-exchange fluid exits tubes 92 at second tube sheet 90 and then exits reactor 10 through outlet 22. This cross-flow, tube-and-shell arrangement provides effective and efficient heat transfer between the process product and the heat-exchange fluid passing through the plurality of heat exchange tubes 92. This embodiment shows a single pass arrangement of the plurality of tubes 92, but in other embodiments a multiple pass arrangement could be utilized.

First, second, third, and fourth distribution baffles or manifolds 94, 96, 98 and 100, respectively, are provided to evenly distribute the product into the flow paths 44, 46, 48, and 50, respectively. In other embodiments, this may be a single integral distributor. A first, second, third and fourth catalyst bed 102, 104, 106, and 108 are used to hold catalyst 110 (FIGURE 3). In some embodiments, the catalyst bed is formed as a single integral bed.

Referring now to FIGURE 3, a radial cross-section taken along line 3-3 of FIGURE 2 is shown. The cross flow of path 46 through the plurality of heat-exchange tubes 92 is reflected in this cross-sectional view. A portion of catalyst 110 which is loaded onto catalyst bed 104 is shown in the lower right-hand corner of FIGURE 3. For the embodiment shown, internal sidewalls 120 and 122 are attached to the first tube sheet 88 and second tube sheet 90 and run the longitudinal length of body 14. Internal sidewalls 120 and 122 help to provide a more consistent and even flow through paths 44, 46, 48 and 50. The space between internal sidewalls 120 and 122 and the inner surface of body 14 may be filled with an insulating material. In other embodiments, sidewalls 120 and 121 may be removed such that pipes may be extended to the inner surface of body 14 or if the catalyst is not sensitive to flow rate, the catalyst may fill the entire zone.

To load catalyst 110 into reactor 10, catalyst pellets may be introduced from topside 40 onto the plurality of heat-exchange tubes 92. The catalyst pellets 110 will interact with the plurality of heat-exchange tubes 92 until they arrive on catalyst bed 104 and are built up back towards the top of the tubes 92. This arrangement allows for the catalyst 110 to be quickly and easily loaded into reactor 10 without damage to catalyst 110 from free falling great distances. A person may enter manway 28 to help distribute catalyst 110 onto the plurality of tubes 92. Manway 30 allows access to a lower portion of reactor 10 to assist with removal of spent catalyst 110.

Referring to FIGURE 4, an alternative embodiment is shown. Reactor 210 is analogous in most respects with the embodiment shown in FIGURES 1-3. In this embodiment, however, flow pathways 244, 246, 248 and 250 alternate direction without requiring a product-return conduit. This arrangement may be appropriate where the process occurring in reactor 210 does not produce condensate or produces only an insubstantial amount of liquids. To redirect the flow path between first flow path 244 and second flow path 246, baffling 282 does not run the full width of reactor 10 but stops short to provide a flow path, and additional baffle 283 is added to direct the flow as indicated by flow path 246. The reorienting of path 246 over to third path 248 is accomplished using baffling 284 with an opening 285 and with an additional baffling 287. Similarly, the reorientation of flow path 248 over to flow path 250 is accomplished using baffling 286 to form opening 287 and with the use of an additional baffling 289. In this embodiment, the plurality of heat-exchange tubes 292 run between first tube sheet 288 and second flow sheet 290.

Referring to FIGURE 5, another alternative embodiment is shown. Reactor 310 is analogous in most respects with the embodiment shown in FIGURES 1-3. In this embodiment, however, heat sources 433, 435, 437, and 439 are added to separators 332, 334, 336, and 338 to maintain them at a different temperature than the flow paths 344, 346, 348, and 350. By maintaining the separators at a different temperature than the flow paths, one or more substances may be added to the separators to initiate a reaction which is different from the reaction carried out within the cylindrical body. For example the separators may be maintained at a suitable temperature such that hydrogen can be introduced into the separator to initiate cracking of the hydrocarbon condensate, e.g. wax, contained therein.

The addition of heat to the separators allows for the combination of hydrocracking and Fischer-Tropsch reactions within the same reactor. Generally hydrocracking and Fischer-Tropsch reactions are not combined because Fischer-Tropsch reactions occur at a temperature substantially lower than that of hydrocracking. However, the use of separators 332, 334, 336, and 348 in conjunction with heat sources 444, 446, 448 and 450 allows for elevated temperatures in the separators while maintaining lower temperatures in flow paths 444, 446, 448, and 450. In addition, the separators eliminate water generated in the Fischer-Tropsch reactions, the presence of which would generally prevent hydrocracking. The addition of hydrocracking of the hydrocarbon condensate reduces the amount of heavy hydrocarbons in line 60 and increases the amount of lighter, liquid hydrocarbons. Such liquid hydrocarbons are separated in separator 366 and delivered through conduit 371 to storage 369 for storage. In adding hydrogen to the separators 332, 334, 336, and 338, the rate of hydrogen addition should be controlled to prevent liquid carryover back into the previous flow path, such as flow path 344 for separator 332.

The additional hydrogen may be added, for example, through conduit 325, which receives hydrogen from the feedstock. A portion of the hydrogen in the feedstock may be separated from the feedstock by hydrogen membrane 327. This hydrogen may also be added to the various flow paths (not explicitly shown), such as through T-fitting 55 in FIGURE 2. As discussed above, the addition of reactants into the various flow paths is useful in controlling the quantity, quality and volume of desired liquid hydrocarbon products at conduit 378 and conduit 370.

The embodiment of the present invention as previously described with respect to FIGURE 5 may be generally described as a secondary liquid phase reaction occurring at the bottom of cylindrical body 314. In a similar manner, a secondary vapor phase reaction may occur at the top of cylindrical body 314. For this embodiment, one or more secondary reaction chambers (not shown) similar to separators 332, 334, 336 and 338 may be mounted on the upper portion of cylindrical body 314. Depending upon the desired secondary reaction, an appropriate catalyst (not expressly shown) may be disposed within each secondary reaction chamber. Also, appropriate heating or cooling may be provided for each secondary reaction chamber depending upon the desired vapor phase reaction. For example, a secondary reaction chamber may be provided in conduit 352 to allow oligomerization of any olefins contained within the process fluid as it travels between flow paths or zones 344 and 346. Adding one or more secondary reaction chambers as part of cylindrical body 314 to carry out an oligomerization process because the resulting polymers would be generally unaffected as they travel through the remainder of cylindrical body 314 and would result in an increased in the desired liquid hydrocarbon product at conduit 378.

Although the present invention and its advantages have been described in detail, it should be understood that various changes, substitutions and alterations can be made therein without departing from the spirit and scope of the invention as defined by the appended claims.

WHAT IS CLAIMED IS:

1. A fixed-bed, catalytic, crossflow reactor comprising:

a generally cylindrical body having a fluid inlet for receiving a feedstock and a fluid outlet for removing a process fluid;

a first end cap attached to a first end of the cylindrical body having a heat-exchange-fluid inlet;

a second end cap attached to a second end of the cylindrical body and having a heat-exchange-fluid outlet;

a first tube sheet coupled within the first end cap;

a second tube sheet coupled to the second end cap;

a plurality of heat-exchange tubes coupled to and running between the first tube sheet and the second tube sheet such that a heat-exchange fluid introduced into the heat-exchange-fluid inlet may flow into and through the plurality of heat-exchange tubes into the second end cap and be removed through the heat-exchange-fluid outlet;

at least one baffle attached within the cylindrical body for directing flow of the process fluid therein; and

wherein the fluid inlet, baffle, and fluid outlet are operable to force the process fluid to flow substantially transverse to the plurality of heat exchange tubes.

2. The reactor of Claim 1 further comprising a plurality of separators for removing liquid fluids from the reactor, the plurality of separators coupled to the cylindrical body, and at least one separator of the plurality of separators associated with the fluid outlet.

3. The reactor of Claim 2 further comprising:

at least one conduit for transporting the fluid exiting one of the plurality of separators to an opposite side of the cylindrical body where it is reintroduced into the body.

4. The reactor of Claim 2 and further comprising:

at least one heating element for adding heat to one of the separators; and

at least one conduit for transporting reactants to a separator.

5. The reactor of Claim 2 and further comprising at least one conduit for returning a portion of the fluid to the process fluid inlet.

6. The reactor of Claim 1 further comprising:

at least two fluid flow zones formed in the cylindrical body by one of the baffles;

a conduit for directing process fluid flow from the bottom of one of the fluid flow zones to the top of the other fluid flow zone; and

a secondary reaction chamber formed in the conduit to allow a vapor phase reaction to occur as the process fluid flow from one fluid flow zone to the other fluid flow zone.

7. The reactor of Claim 6 further comprising a catalyst disposed within the secondary reaction vessel to cause an oligomerization reaction to occur with a portion of the process fluid.

8. A method of manufacturing a fixed-bed, catalytic, crossflow reactor comprising the steps of:

forming a generally cylindrical body having a fluid inlet for receiving a feedstock and a fluid outlet for removing a process fluid;

attaching a first end cap to a first end of the cylindrical body having a heat-exchange-fluid inlet;

attaching a second end cap to a second end of the cylindrical body and having a heat-exchange-fluid outlet;

coupling a first tube sheet within the first end cap;

coupling a second tube sheet to the second end cap;

placing a plurality of heat-exchange tubes between the first tube sheet and the second tube sheet such that a heat-exchange fluid introduced into the heat-exchange-fluid inlet may flow into and through the plurality of heat-exchange tubes into the second end cap and be removed through the heat-exchange-fluid outlet;

attaching at least one baffle within the cylindrical body for directing flow of the process fluid therein so that the fluid inlet, baffle, and fluid outlet are operable to force the process fluid to flow substantially transverse to the plurality of heat exchange tubes.

9. The method of Claim 8 further comprising the step of attaching a plurality of separators for removing liquid fluids from the reactor to the cylindrical body.

10. The method of Claim 9 wherein the step of attaching a plurality of separators comprises attaching at least one separator that is associated with the fluid outlet.

11. The method of Claim 9 further comprising the step of:

attaching at least one conduit for transporting the fluid exiting one of the plurality of separators to an opposite side of the cylindrical body where it is reintroduced into the body.

12. The method of Claim 9 further comprising the step of:

attaching at least one heating element for adding heat to one of the separators; and

attaching at least one conduit for transporting reactants to a separator.

13. The method of Claim 12 further comprising the step of: attaching at least one conduit for returning a portion of the fluid to the process fluid inlet.

14. The method of Claim 8 further comprising the step of:

forming at least two fluid flow zones in the cylindrical body by one of the baffles;

attaching a conduit for directing process fluid flow from the bottom of one of the fluid flow zones to the top of the other fluid flow zone; and

forming a secondary reaction chamber in the conduit to allow a vapor phase reaction to occur as the process fluid flow from one fluid flow zone to the other fluid flow zone.

15. The method of Claim 9 further comprising the step of: disposing a catalyst within the secondary reaction vessel to cause an oligomerization reaction to occur with a portion of the process fluid.

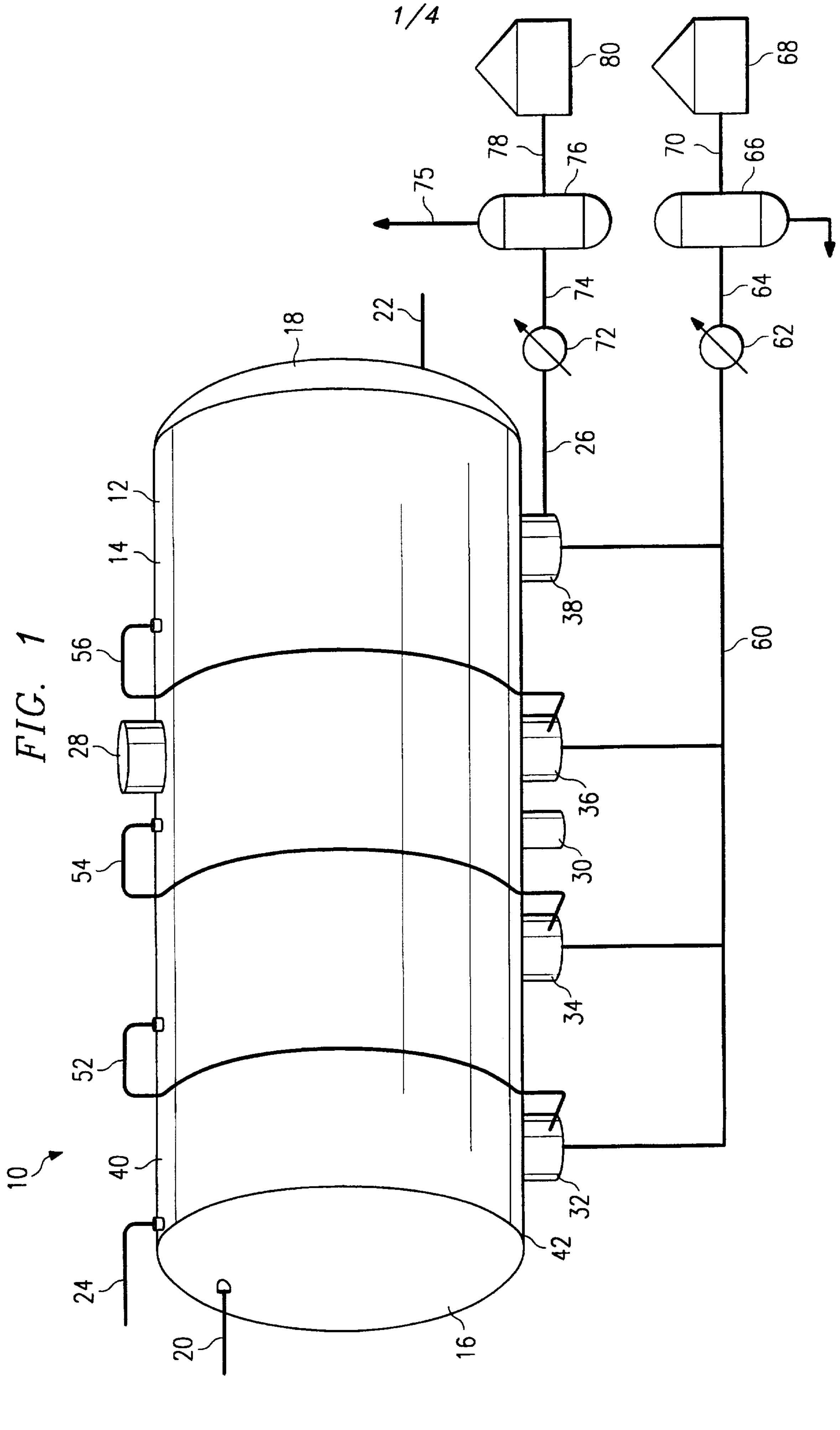
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FIG. 1

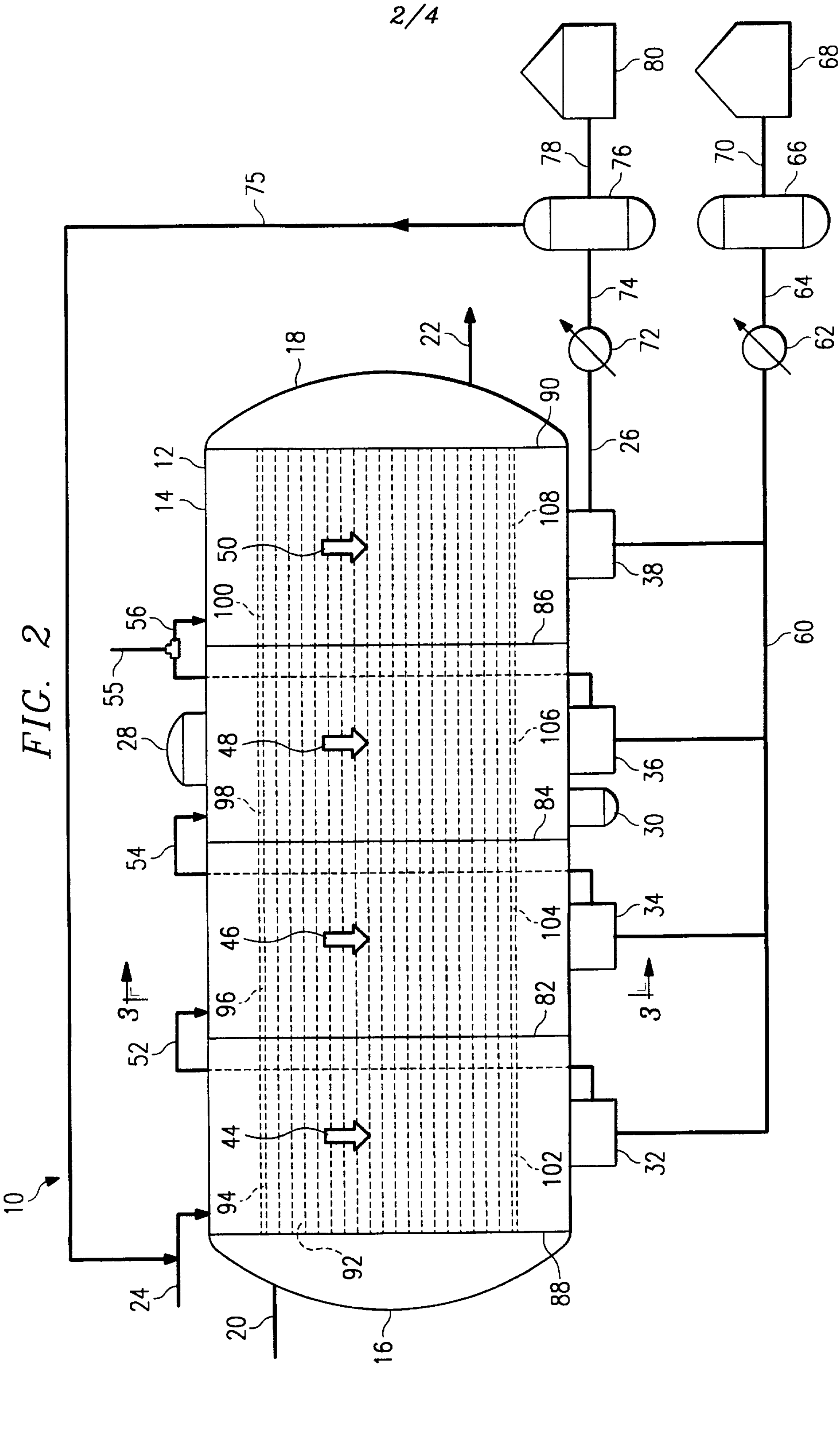
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FIG. 2

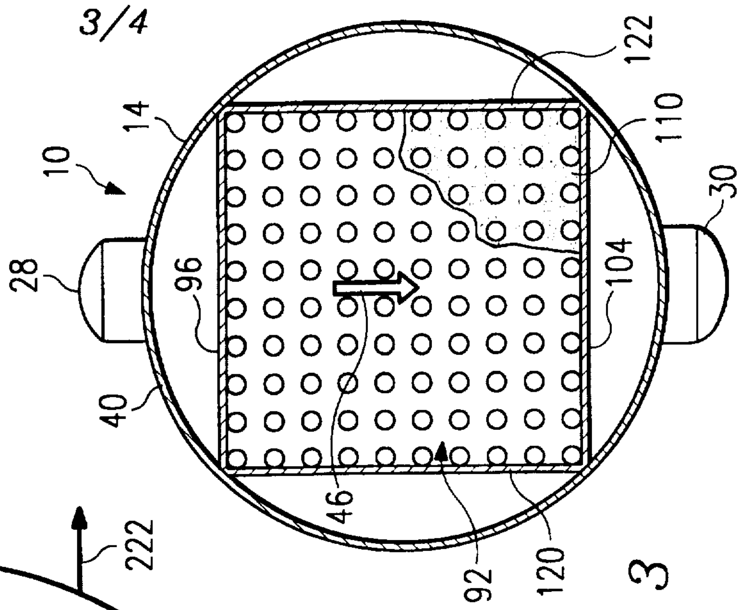
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FIG. 3

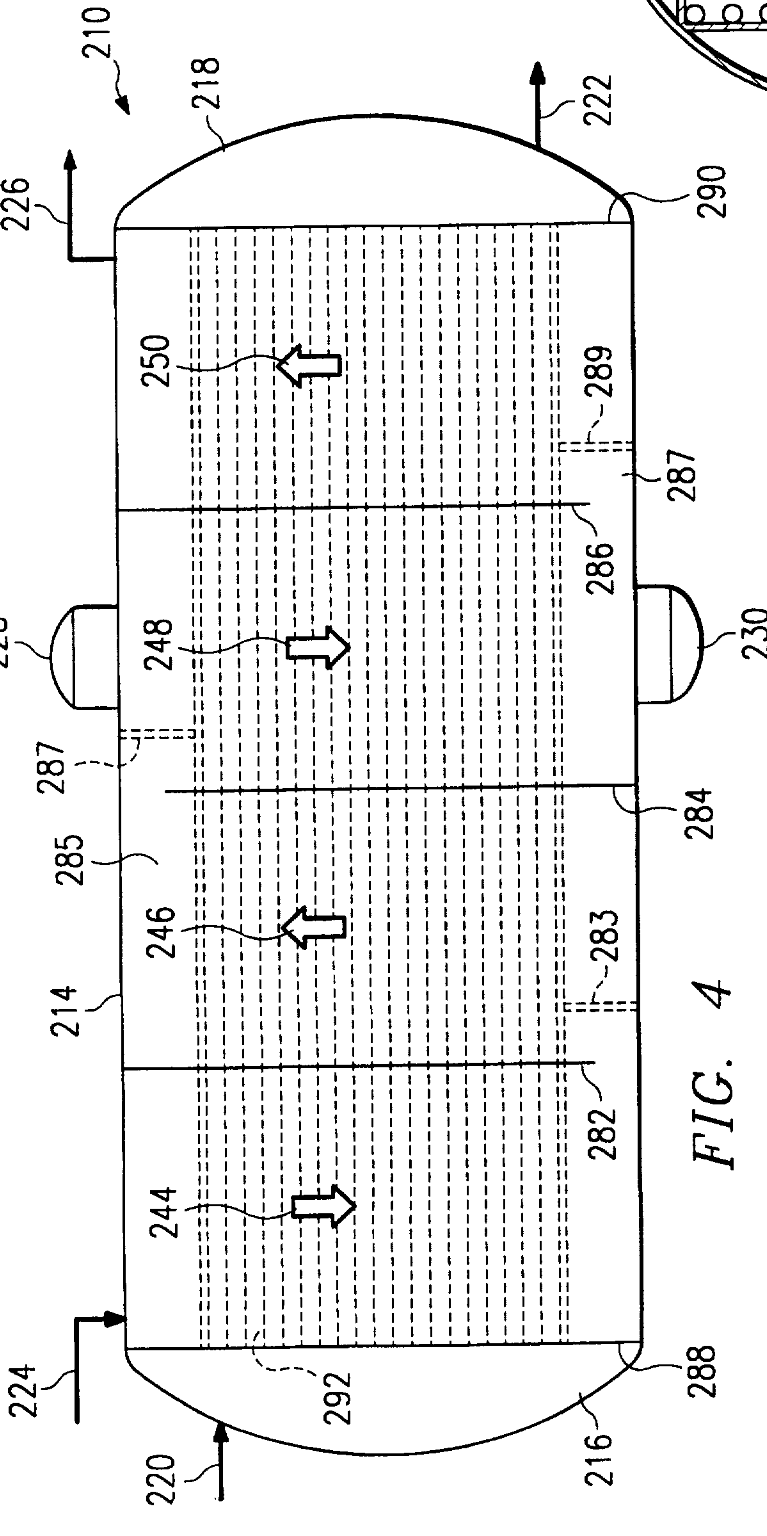
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FIG. 4

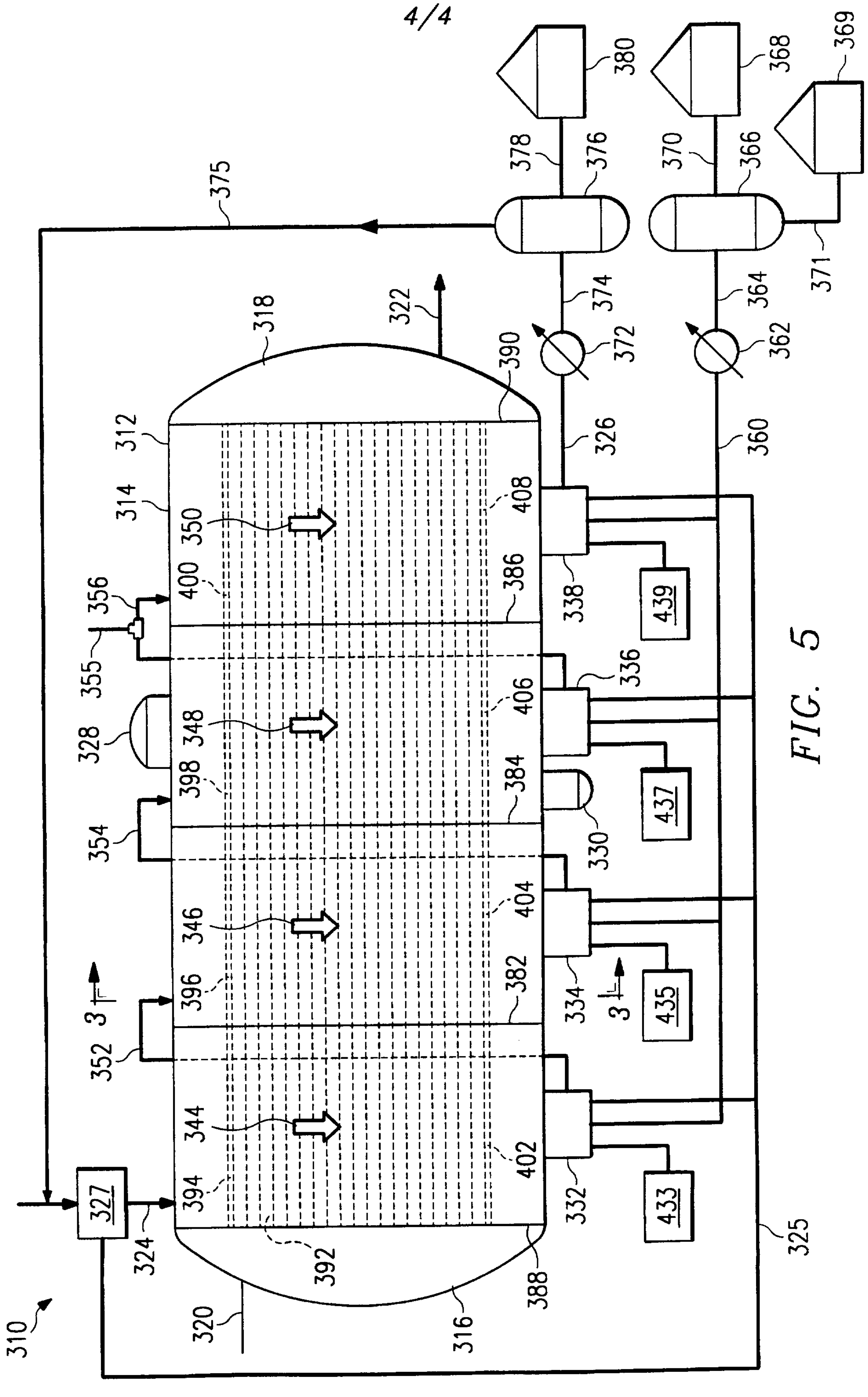
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FIG. 5

INTERNATIONAL SEARCH REPORT

Inte ,nal Application No
PCT/US 97/10732

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B01J8/02 B01J8/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 B01J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
14 October 1997	24. 10. 97

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A		7,8,14, 15
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INTERNATIONAL SEARCH REPORT

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Interr   nal Application No

PCT/US 97/10732

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