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(54) **Title:** A DUAL RISER CATALYTIC CRACKING PROCESS FOR MAKING MIDDLE DISTILLATE AND LOWER OLEFINS

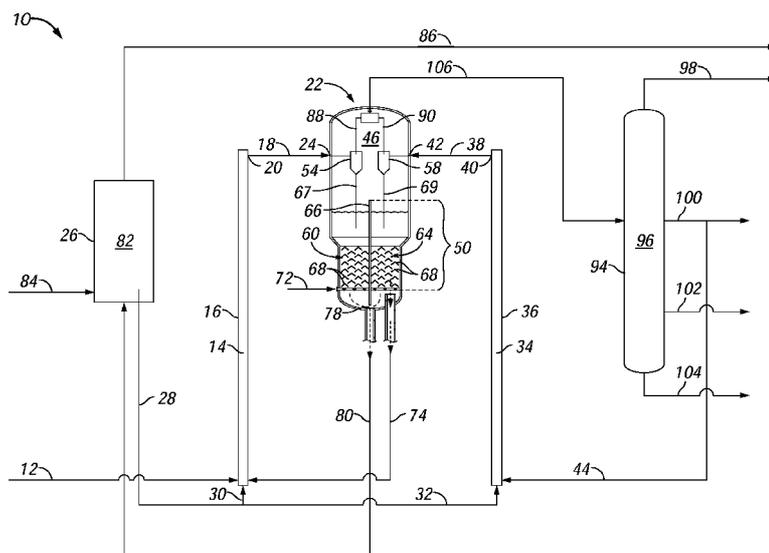


FIG. 7

(57) **Abstract:** A dual riser catalytic cracking process for preferentially making middle distillate and lower olefins. The system and process provide for the processing of multiple hydrocarbon feedstocks so as to selectively produce middle distillate boiling range product and lower olefins. The system and process uses two riser reactors, a single vessel for separating the cracked product and cracking catalyst received from both riser reactors, and a regenerator for regenerating coked or spent cracking catalyst.

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**A DUAL RISER CATALYTIC CRACKING PROCESS FOR MAKING MIDDLE DISTILLATE AND LOWER OLEFINS**

This invention relates to method and apparatus for the manufacture of a middle distillate product and lower olefins from a hydrocarbon feedstock by the use of a dual riser catalytic system and process.

The fluidized catalytic cracking (FCC) of heavy hydrocarbons to produce lower boiling hydrocarbon products, such as gasoline, has been around since the 1940's. Typically, an FCC unit or process system includes a single riser reactor, a catalyst separator and stripper, and a regenerator. An FCC feedstock is introduced into the riser reactor in which it is contacted with hot FCC catalyst from the regenerator. The mixture of FCC feedstock and FCC catalyst passes through the riser reactor and into the catalyst separator wherein the cracked product is separated from the FCC catalyst. The separated cracked product passes from the catalyst separator to a downstream separation system and the separated catalyst passes to the regenerator where the coke deposited on the FCC catalyst during the cracking reaction is burned off the catalyst to provide a regenerated catalyst. The resulting regenerated catalyst is used as the aforementioned hot FCC catalyst and is mixed with the FCC feedstock that is introduced into the riser reactor.

Many processes and systems are designed so as to provide for a high conversion of the FCC feedstock to yield products having boiling temperatures in the gasoline boiling range. But, some prior art processes provide for the preferential conversion of a hydrocarbon feedstock to a middle distillate product and lower olefins. One such process is disclosed in the US Patent Publication No. US 2006/0231461 of Mo et al. The process taught by Mo et al. includes the use of a riser reactor in combination with a dense bed reactor to process a gas oil feedstock and a gasoline feedstock in a way to preferentially make middle distillate and lower olefins. The disclosed process includes regenerating a spent cracking catalyst and using the resulting regenerated catalyst in the dense bed reactor. Used regenerated catalyst is passed from the dense bed reactor and introduced into the riser reactor wherein it is used in combination with regenerated catalyst in the fluidized catalytic cracking of the gas oil feedstock.

Other publications disclose the use of a combination of riser reactors or a combination of a dense fluid bed reactor with a riser reactor to provide for re cracking of a gasoline product from the cracking of gas oil. US Patent No. 3,928, 172 to Davis, Jr. et al. discloses a number of alternative fluid catalyst systems and processes that involve the re cracking of cracked gasoline over a zeolite-containing catalyst. It is asserted by Davis that the zeolite catalyst is able to effect a degree of octane improvement that was previously not possible with amorphous silica-alumina catalysts.

One process and system disclosed by Davis uses a dense bed reactor with a single riser reactor arranged in a catalyst flow sequence such that the dense bed is placed between the regenerator and riser. Davis further discloses a hydrocarbon upgrading process that includes a first cracking zone in which gas oil is cracked and a second cracking zone in which gasoline is cracked. The second cracking zone may include a dense bed. In another disclosure of Davis, gasoline is cracked within a dense bed reaction zone in which freshly regenerated catalyst is introduced. Catalyst from the dense bed reaction zone is then used for gas oil cracking in a riser cracking zone.

In the article published by the *Chinese Journal of Chemical Engineering*, 16(3) 394-400 (2008), entitled "Alternative Processing Technology for Converting Vegetable Oils and Animal Fats to Clean Fuels and Light Olefins," the authors Tian et al. disclose a catalytic cracking process that utilizes two risers which share a common disengager and regenerator. Fresh feedstock is introduced into the first stage riser, and a recycle stream of gasoline or heavy oil, or both, is introduced into the second stage riser. There is no disclosure, however, of the use of multiple catalyst separators or strippers nor is there any disclosure of the selective separation or stripping of catalyst taken from each of the two risers and the separate or selective recycle thereof.

One of the objects of this invention is to provide method and apparatus for the preferential conversion of a hydrocarbon feedstock to a middle distillate product and lower olefins.

Accordingly, provided is a dual riser cracking process for making middle distillate and lower olefins, wherein said process comprises: catalytically cracking a first hydrocarbon feedstock within a first riser reactor zone by contacting under first catalytic cracking

conditions within said first riser reactor zone said first hydrocarbon feedstock with a combination of a clean spent catalyst and a first portion of a regenerated cracking catalyst to yield a first riser reactor product comprising a first cracked product and a coked spent catalyst; catalytically cracking a second hydrocarbon feedstock within a second riser reactor zone by contacting under second catalytic cracking conditions within said second riser reactor zone said second hydrocarbon feedstock with a second portion of said regenerated cracking catalyst to yield a second riser reactor product comprising a second cracked product and said clean spent catalyst; passing said first riser reactor product to a single vessel separator/stripper providing means for separating said first riser reactor product into a separated first cracked product and a separated coked spent catalyst; passing said second riser reactor product to said single vessel separator/stripper providing means for separating said second riser reactor product into a separated second cracked product and a separated clean spent catalyst; using at least a portion of said separated clean spent catalyst as said clean spent catalyst of said combination; and passing said separated coked spent catalyst to a regenerator that defines a regeneration zone and provides means for regenerating said separated coked spent catalyst to yield said regenerated cracking catalyst.

FIG. 1 is a process flow schematic illustrating certain aspects of one embodiment of the inventive process.

FIG. 2 presents an enlarged schematic of one embodiment of the single vessel separator/stripper that is depicted in FIG. 1.

The invention is a process and apparatus that provide for the processing of hydrocarbon feedstocks to selectively or preferentially produce a middle distillate boiling range product and lower olefins. The inventive process uses two riser reactors, a single vessel for separating the cracked product and cracking catalyst received from both riser reactors, and a regenerator for regenerating coked or spent cracking catalyst. The two riser reactors, the single vessel separator/stripper, and the regenerator are operatively integrated to provide a process system for carrying out the process of the invention.

In the inventive process, a first hydrocarbon feedstock is introduced into the bottom of a first riser reactor zone that is defined by a first riser reactor. Hot cracking catalyst is also introduced into the first riser reactor zone wherein it is mixed and contacted with the first

hydrocarbon feedstock under suitable first catalytic cracking conditions to provide for the catalytic cracking of the first hydrocarbon feedstock. Additionally, a second hydrocarbon feedstock is introduced into the bottom of a second riser reactor zone that is defined by a second riser reactor. Regenerated catalyst is introduced into the second riser reactor zone wherein it is mixed and contacted with the second hydrocarbon feedstock under suitable second catalytic cracking conditions to provide for the catalytic cracking of the second hydrocarbon feedstock.

The fresh catalytic cracking catalyst used in the inventive process and circulated within the process system can be any suitable cracking catalyst known in the art to have cracking activity under the catalytic cracking conditions contemplated by the invention. Preferred catalytic cracking catalysts for use in the inventive process include fluidizable cracking catalysts comprised of a molecular sieve having cracking activity dispersed in a porous, inorganic refractory oxide matrix or binder.

The term "molecular sieve" as used herein refers to any material capable of separating atoms or molecules based on their respective dimensions. Molecular sieves suitable for use as a component of the cracking catalyst include pillared clays, delaminated clays, and crystalline aluminosilicates. Normally, it is preferred to use a cracking catalyst that contains a crystalline aluminosilicate. Examples of such aluminosilicates include Y zeolites, ultrastable Y zeolites, X zeolites, zeolite beta, zeolite L, offretite, mordenite, faujasite, and zeolite omega. The preferred crystalline aluminosilicates for use in the cracking catalyst are X and Y zeolites with Y zeolites being the most preferred.

U.S. Patent No. 3,130,007, the disclosure of which is hereby incorporated by reference in its entirety, describes Y-type zeolites having an overall silica-to-alumina mole ratio between about 3.0 and about 6.0, with a typical Y zeolite having an overall silica-to-alumina mole ratio of about 5.0. It is also known that Y-type zeolites can be produced, normally by dealumination, having an overall silica-to-alumina mole ratio above about 6.0. Thus, for purposes of this invention, a Y zeolite is one having the characteristic crystal structure of a Y zeolite, as indicated by the essential X-ray powder diffraction pattern of Y zeolite, and an overall silica-to-alumina mole ratio above 3.0, and includes Y-type zeolites having an overall silica-to-alumina mole ratio above about 6.0.

The stability and/or acidity of a zeolite used as a component of the cracking catalyst may be increased by exchanging the zeolite with hydrogen ions, ammonium ions, polyvalent metal cations, such as rare earth-containing cations, magnesium cations or calcium cations, or a combination of hydrogen ions, ammonium ions and polyvalent metal cations, thereby  
5 lowering the sodium content until it is less than about 0.8 weight percent, preferably less than about 0.5 weight percent and most preferably less than about 0.3 weight percent, calculated as  $\text{Na}_2\text{O}$ . Methods of carrying out the ion exchange are well known in the art.

The zeolite or other molecular sieve component of the cracking catalyst is combined with a porous, inorganic refractory oxide matrix or binder to form a finished catalyst prior to  
10 use. The refractory oxide component in the finished catalyst may be silica-alumina, silica, alumina, natural or synthetic clays, pillared or delaminated clays, mixtures of one or more of these components and the like. Preferably, the inorganic refractory oxide matrix will comprise a mixture of silica-alumina and a clay such as kaolin, hectorite, sepiolite and attapulgite.

A preferred finished catalyst will typically contain between about 5 weight percent to about 40 weight percent zeolite or other molecular sieve and greater than about 20 weight percent inorganic, refractory oxide. In general, the finished catalyst may contain between about 10 to about 35 weight percent zeolite or other molecular sieve, between about 10 to about 30 weight percent inorganic, refractory oxide, and between about 30 to about 70  
15 weight percent clay.

The crystalline aluminosilicate or other molecular sieve component of the cracking catalyst may be combined with the porous, inorganic refractory oxide component or a precursor thereof by any suitable technique known in the art including mixing, mulling, blending or homogenization. Examples of precursors that may be used include alumina,  
25 alumina sols, silica sols, zirconia, alumina hydrogels, polyoxycations of aluminum and zirconium, and peptized alumina.

In a preferred method of preparing the cracking catalyst, the zeolite is combined with an aluminosilicate gel or sol or other inorganic, refractory oxide component, and the resultant mixture is spray dried to produce finished catalyst particles normally ranging in  
30 diameter between about 40 and about 80 microns. If desired, however, the zeolite or other

molecular sieve may be milled or otherwise mixed with the refractory oxide component or precursor thereof, extruded and then ground into the desired particle size range. Normally, the finished catalyst will have an average bulk density between about 0.30 and about 0.90 gram per cubic centimeter and a pore volume between about 0.10 and about 0.90 cubic centimeter per gram.

The first hydrocarbon feedstock may be any suitable hydrocarbon feedstock that is chargeable to a fluidized catalytic cracking unit or that will result in providing a particularly desired product mix. In one preferred embodiment of the inventive process, the first hydrocarbon feedstock is a gas oil. In general terms, hydrocarbon mixtures boiling in the range of from 345 °C (653°F) to 760 °C (1400 °F) can suitably be used as the first hydrocarbon feedstock of the invention. Examples of the types of refinery feed streams that can make suitable gas oil feedstocks include vacuum gas oils, coker gas oil, straight-run residues, thermally cracked oils and other hydrocarbon streams.

The catalytic cracking conditions can be defined by such parameters as the average residence time of the hydrocarbons in a particular riser reactor, the catalyst-to-oil ratio, and the riser reactor temperature.

The first catalytic cracking conditions at which the first riser reactor zone is operated can include an average residence time of the hydrocarbons in the first riser reactor zone that is generally in the range of upwardly to about 5 to 10 seconds, but, usually, it is in the range of from 0.1 to 5 seconds.

The weight ratio of catalyst (i.e., the first portion of regenerated cracking catalyst, as defined below, and the at least a portion of the separated clean spent catalyst, as defined below) to first hydrocarbon feedstock (catalyst/oil ratio) introduced into the first reactor zone generally can be in the range of from about 2 to about 100 and even as high as 150. More typically, the catalyst-to-oil ratio can be in the range of from 5 to 100.

The temperature in the first riser reactor zone generally can be in the range of from about 400 °C (752 °F) to about 600 °C (1112 °F). More typically, the first riser reactor temperature can be in the range of from 450 °C (842 °F) to 550 °C (1022 °F).

The second hydrocarbon feedstock charged to the FCC unit or process system may be any suitable hydrocarbon feedstock that is chargeable to a fluidized catalytic cracking unit or

that will result in providing the desired product mix. In one preferred embodiment of the inventive process, the second hydrocarbon feedstock is a naphtha or gasoline feedstock having a boiling temperature in the gasoline or naphtha boiling temperature range.

Generally, the gasoline feedstock comprises hydrocarbons boiling in the temperature range of from about 32 °C (90 °F) to about 204 °C (400 °F). Examples of refinery streams that may be used as the gasoline feedstock of the inventive process include straight run gasoline, naphtha, catalytically cracked gasoline, and coker naphtha.

The second catalytic cracking conditions at which the second riser reactor zone is operated can include an average residence time of the hydrocarbons in the second riser reactor zone generally in the range upwardly to about 20 seconds, but usually the average residence time is in the range of from 0.1 to 10 seconds.

The weight ratio of catalyst (i.e., second portion of regenerated cracking catalyst, as defined herein) to second hydrocarbon feed (catalyst/oil ratio) generally can be in the range of from about 2 to about 100 and even as high as 150. More typically, the catalyst-to-oil ratio can be in the range of from 5 to 100.

The temperature in the second riser reactor zone generally can be in the range of from about 482°C (900 °F) to about 871 °C (1600 °F). More typically, the second riser reactor zone generally can be in the range of from 538°C (1000 °F) to 732 °C (1350 °F).

The hot cracking catalyst that is introduced into the first riser reactor zone along with the first hydrocarbon feedstock includes regenerated cracking catalyst taken from the regenerator and a so-called clean spent catalyst. Thus, a combination of the clean spent catalyst and at least a portion of the regenerated cracking catalyst is contacted with the first hydrocarbon feedstock within the first riser reactor zone.

The clean spent catalyst is referred to herein as being "clean" because it is derived from the product of the second riser reactor zone that is defined by a second riser reactor. The second riser reactor zone of the process is operated under suitable second catalytic cracking conditions that are more severe than the reaction conditions under which the first riser reactor zone is operated. The second hydrocarbon feedstock charged to the second riser reactor zone is, preferably, a lighter feedstock than the first hydrocarbon feedstock charged to the first riser reactor zone, thus, resulting in less coke yield.

Due to the cracking of a lighter feedstock, the used cracking catalyst yielded from the product of the second riser reactor zone has a lower concentration of coke than the spent or coked spent catalyst yielded from the product of the first riser reactor zone. Therefore, the used cracking catalyst from the second riser reactor product is referred to herein as being "clean" for the purpose of distinguishing it from the spent or coked spent catalyst yielded from the first riser reactor product.

Yielded from the first riser reactor zone is a first riser reactor product that comprises a first cracked product and a coked spent catalyst. The first riser reactor product is passed to the single vessel separator/stripper, which provides means for separating the first riser reactor product into a separated first cracked product and a separated coked spent catalyst.

The separated coked spent catalyst has a coke content, generally, in the range of from about 0.5 to about 5 weight percent (wt. %), based on the total weight of the catalyst and the carbon. More typically, the coke content on the separated coked spent catalyst is in the range of from or about 0.5 wt. % to or about 1.5 wt. %.

A second riser reactor product is yielded from the second riser reactor zone and comprises a second cracked product and a clean spent catalyst. This second riser reactor product is also passed to the single vessel separator/stripper, which additionally provides means for separating the second riser reactor product into a separated second cracked product and a separated clean spent catalyst.

The separated clean spent catalyst has a coke content that typically is lower than the coke content of the separated coked spent catalyst. Generally, the coke content of the separated clean spent catalyst is in the range of from about 0.1 to about 1 weight percent (wt. %), based on the total weight of the catalyst and the carbon. More typically, the coke content on the separated clean spent catalyst is in the range of from or about 0.1 wt. % to or about 0.6 wt. %.

The use or application of a single vessel apparatus for receiving both the first riser reactor product from the first riser reactor zone and the second riser reactor product from the second riser reactor zone is an important feature of the inventive process and apparatus. Not only does the use of the single vessel apparatus help in providing for the unique process flows of and product yields from the inventive dual riser catalytic cracking process, but its

use can also be particularly beneficial in situations when an existing fluidized catalytic cracking unit having a single riser reactor associated with a single separator/stripper is revamped to include two riser reactors. In this situation, significant revamp cost savings are achievable by using the existing single separator/stripper vessel or apparatus and modifying it to provide both means for separating the first riser reactor product into a separated first cracked product and a separated coked spent catalyst and means for separating the second riser reactor product into a separated second cracked product and a separated clean spent catalyst.

One typical separator/stripper apparatus of a fluidized catalytic cracking unit includes a vessel that defines a separation zone and a stripping zone. Within the separation zone there may be one or more cyclones that define one or more cyclone separation zones. The cyclones may be operated in series flow or in parallel flow and they provide means for receiving a riser reactor effluent and for separating spent catalyst and catalytically cracked vaporous hydrocarbons of the riser reactor effluent. The separated vaporous hydrocarbon product exits the cyclones and the separator/stripper apparatus to pass downstream for further processing such as with a main fractionator of the fluidized catalytic cracking unit. The separated spent catalyst passes from the cyclones through diplegs into the stripping zone or section of the separator/stripper apparatus. The separated spent catalyst is stripped of hydrocarbons within the stripping zone, typically, by the use of stripping steam that is introduced into the stripping section of the separator/stripper apparatus. Stripped catalyst is removed from the stripping section of the separator/stripper apparatus by way of a catalyst standpipe conduit.

The inventive process and apparatus or system, as noted above, provides for receiving both the first riser reactor product and the second riser reactor product into a single vessel separator/stripper. Within a separation zone defined by the single vessel separator/stripper are first separation means and second separation means. First separation means provides for separating the first riser reactor product into a separated first cracked product and a separated coked spent catalyst. Second separation means provides for separating the second riser reactor product into a separated second cracked product and a separated clean spent catalyst.

Any suitable means known in the art may be used as either first separation means or second separation means, but, typically, and preferably, such means include cyclone separators that utilize centrifugal flow and gravity to provide for the separation of hydrocarbon gases and catalyst particles. Many of the various types or designs of suitable cyclone separators and their uses are known to those skilled in the art.

The separated first cracked product and separated second cracked product yielded from the two separation means pass from the single vessel separator/stripper to the downstream where they may further be processed. It is preferred for the separated first cracked product and the separated second cracked product to pass either separately or in combination to one or more fractionators, but, typically, a combined stream is passed to a main fractionator. The main fractionator defines a fractionation zone and provides means for separating the separated first cracked product or the separated second cracked product, or a combination of both, into one or more product streams including a naphtha product stream. Other product streams may include a lower olefins stream, a cracked gasoline stream, and a cracked gas oil stream.

The single vessel separator/stripper further defines a stripping zone that includes a first stripping zone and a second stripping zone that are generally contained within the bottom section of the single vessel separator/stripper. Each of the stripping zones is provided for by segregation means for defining the two stripping zones. Segregation means may be any apparatus or equipment or device that provides for a division of the bottom section of the single vessel separator/stripper into compartments that define the first stripping zone and second stripping zone. Example of such segregation means may include a wall made of any suitable material including, a metal or ceramic material, plates of metal or other suitable material, and partitions of metal or other suitable material.

In the operation of the single vessel separator/stripper, the separated coked spent catalyst falls from first separation means into the first stripping zone wherein it is stripped of hydrocarbons, and the separated clean spent catalyst falls from second separation means into the second stripping zone wherein it is stripped of hydrocarbons. Any suitable stripping fluid may be used to strip the hydrocarbons from the separated coked spent catalyst or the separated clean spent catalyst, or both, but, the preferred stripping fluid is steam, which

may, in general, be introduced into the bottom of each of the stripping zones or sections of the single vessel separator/stripper. The stripped hydrocarbons will pass to downstream along with the separated first cracked product and separated second cracked product for further processing.

5           The single vessel separator/stripper further may be equipped with a clean catalyst withdrawal conduit and a catalyst standpipe conduit. The clean catalyst withdrawal conduit provides means for withdrawing of at least a portion of the separated clean spent catalyst from the second stripping zone and passing the at least a portion of the separated clean spent catalyst for introduction thereof into the first riser reactor zone of the first riser  
10 reactor wherein it is contacted with the first hydrocarbon feedstock.

          The remaining portion of the separated clean spent catalyst (i.e., that portion of the separated clean spent catalyst not removed from the second stripping zone by way of clean catalyst withdrawal conduit) will pass with the separated coked spent catalyst from the stripping zone of the single vessel separator/stripper to the regenerator by way of the  
15 catalyst standpipe conduit. The clean catalyst withdrawal conduit, thus, provides for fluid communication between the second stripping zone and the first riser reactor zone. This fluid communication allows for withdrawing the at least a portion of the separated clean spent catalyst from the second stripping zone and introducing it into the first riser reactor zone.

          In the stripping zone of the single vessel separator/stripper, the separated coked  
20 spent catalyst passes through the first stripping zone to the bottom of the single vessel separator/stripper and the remaining portion of the separated clean spent catalyst that is not removed from the second stripping zone by way of the clean catalyst withdrawal conduit is removed from the bottom of the stripping zone by way of the catalyst standpipe conduit.

          As noted above, the separated coked spent catalyst and the remaining portion of the  
25 separated clean spent catalyst pass by way of the catalyst standpipe conduit to the regenerator, and, thus, the catalyst standpipe provides fluid communication between the stripping zone, including the first stripping zone and the second stripping zone, of the single vessel separator/stripper and the regeneration zone of the regenerator. This fluid communication allows for withdrawing the separated coked spent catalyst from the  
30 stripping zone or the first stripping zone, or both, and introducing it into the regenerator

zone of the regenerator, and the fluid communication allows for withdrawing the remaining portion of the separated clean spent catalyst, which has not been removed from the second stripping zone by way of the clean catalyst withdrawal conduit, from the stripping zone or the second stripping zone, or both, and introducing it into the regenerator zone of the  
5 regenerator.

The separated coked spent catalyst and the remaining portion of the separated clean spent catalyst may each be separately removed from the stripping zones of the single vessel separator/stripper to be separately introduced into the regenerator zone, or a combination or mixture of the two flows may be removed from the stripping zones and introduced into  
10 the regenerator zone.

A preferred embodiment of the inventive process or apparatus provides for a combined flow of the separated coked spent catalyst and the remaining portion of the separated clean spent catalyst that together are removed from the bottom section of the stripping zone of the single vessel separator/stripper and passed to the regeneration zone of  
15 the regenerator wherein they are regenerated to yield a regenerated cracking catalyst.

The regenerator of the process or system provides means for regenerating the separated coked spent catalyst and the remaining portion of the separated clean spent catalyst to yield the regenerated cracking catalyst. The regenerator defines a regeneration zone into which the separated coked spent catalyst and the remaining portion of the  
20 separated clean spent catalyst are introduced and wherein deposited carbon is burned to provide the regenerated cracking catalyst having a reduced carbon content. The regenerator, typically, is a vertical vessel of any suitable configuration that defines the regeneration zone and wherein the separated coked spent catalyst and the remaining portion of the separated clean spent catalyst is maintained as a fluidized bed by the upward passage of an oxygen-  
25 containing regeneration gas, such as air.

The regeneration temperature within the regeneration zone is, in general, maintained in the range of from about 621 °C (1150 °F) to 760 °C (1400 °F), and more typically, in the range of from 677 °C (1250 °F) to 715 °C (1320 °F).

The pressure within the regeneration zone typically is in the range of from about atmospheric to about 345 kPa (50 psig), and, preferably, from about 34 to 345 kPa (5 to 50 psig).

5 The residence time of the separated coked spent catalyst and the remaining portion of the separated clean spent catalyst within the regeneration zone is in the range of from about 1 to about 6 minutes, and, typically, from or about 2 to or about 4 minutes.

The coke content on the regenerated cracking catalyst is less than the coke content on the separated coked spent catalyst and remaining portion of the separated clean spent catalyst that are introduced into the regeneration zone of the regenerator. The coke content  
10 of the regenerated cracking catalyst will, thus, generally be in the range of from or about 0.01 wt. % to or about 0.5 wt. %. It is preferred for the coke concentration on the regenerated cracking catalyst to be less than 0.1 wt. % and, it will preferably be in the range of from 0.01 wt. % to 0.1 wt. %.

The regenerated cracking catalyst yielded from the regenerator may be used as a hot  
15 cracking catalyst that is introduced into the first riser reactor zone and the second riser reactor zone for contacting with the respective hydrocarbon feedstocks. Therefore, a first portion of the regenerated cracking catalyst is introduced into the first riser reactor zone wherein it is contacted with the first hydrocarbon feedstock, and a second portion of the regenerated cracking catalyst is introduced into the second riser reactor zone wherein it is  
20 contacted with the second hydrocarbon feedstock.

Now referring to FIG. 1 which presents a process flow schematic representing certain embodiments of the inventive process 10. In process 10, a first hydrocarbon feedstock, which preferably is a gas oil feedstock, is passed by way of conduit 12 and introduced into the first riser reactor zone 14 that is defined by first riser reactor 16. First riser reactor 16 is  
25 an elongated conduit that extends vertically.

The first hydrocarbon feedstock is introduced into first riser reactor zone 14 at or near the bottom of first riser reactor 16, wherein it is mixed or contacted with hot catalyst. The mixture of first hydrocarbon feedstock and hot catalyst passes through first riser reactor zone 14, which is operated under suitable first catalytic cracking conditions so as to provide a  
30 first riser reactor product. The first riser reactor product, which comprises a first cracked

product and a coked spent catalyst, is yielded from first riser reactor zone 14 and passes by way of conduit 18 from outlet 20 of first riser reactor 16 to be introduced into single vessel separator/stripper 22 through inlet 24.

The sources of hot catalyst introduced into first riser reactor zone 14 include regenerated cracking catalyst taken from regenerator 26 and clean spent catalyst taken from single vessel separator/stripper 22. The regenerated cracking catalyst passes from regenerator 26 by way of conduit 28 and a first portion of the regenerated cracking catalyst is introduced into first riser reactor zone 14 by way of conduit 30.

A second portion of the regenerated cracking catalyst passes by way of conduit 32 and is introduced into second riser reactor zone 34 that is defined by second riser reactor 36. A second hydrocarbon feedstock, which preferably is a naphtha or gasoline feedstock, but it also may include a distillate such as kerosene or diesel, or even a light or heavy gas oil, is introduced by way of conduit 44 into second riser reactor zone 34 at or near the bottom of the second riser reactor 36, wherein it is mixed or contacted with the second portion of the regenerated cracking catalyst.

The mixture of second hydrocarbon feedstock and second portion of regenerated cracking catalyst passes through second riser reactor zone 34, which is operated under suitable second catalytic cracking conditions so as to provide a second riser reactor product. The second riser reactor product, which comprises a second cracked product and clean spent catalyst, is yielded from riser reactor zone 34 and passes by way of conduit 38 from outlet 40 of second riser reactor 36 to be introduced into single vessel separator/stripper 22 through inlet 42. The clean spent catalyst is derived from the product of second riser reactor zone 34

Single vessel separator/stripper 22 provides means for receiving both the first riser reactor product by way of conduit 18 and through inlet 24 and the second riser reactor product by way of conduit 38 and through inlet 42. Single vessel separator/stripper 22 includes and defines separation zone 46 and stripping zone 50. Included within separation zone 46 are one or more first cyclones 54, which provide first separation means for separating the first riser reactor product into a separated first cracked product and a separated coked spent catalyst, and one or more second cyclones 58, which provide second

separation means for separating the second riser reactor product into a separated second cracked product and a separated clean spent catalyst.

5 Stripping zone 50 of single vessel separator/stripper 22 is divided into at least first stripping zone 60 and second stripping zone 64 by partition wall 66. Partition wall 66 extends vertically through stripping zone 50 and provides means for the division of the bottom section of single vessel separator/stripper 22 into two individual compartments that define first stripping zone 60 and second stripping zone 64. First cyclones 54 discharge the separated coked spent catalyst into first stripping zone 60 through first cyclone bottom discharge conduit 55. Second cyclones 58 discharge the separated clean spent catalyst into 10 second stripping zone 64 through second cyclone bottom discharge conduit 59. Provided within each of the stripping zones are baffles or trays 68 that provide for enhanced contact between the falling catalyst and a stripping fluid, such as steam, that is introduced into the stripping zone by way of conduit 72 for the stripping zone 50, so as to assist in the stripping of the hydrocarbons from the falling catalyst.

15 Clean catalyst withdrawal conduit 74 extends into second stripping zone 64 and provides for the withdrawal of at least a portion of the separated clean spent catalyst from second stripping zone 64 and passing the at least a portion of the separated clean spent catalyst by way of clean catalyst withdrawal conduit 74 to first riser reactor zone 14. Clean catalyst withdrawal conduit 74, thus, provides for catalyst transfer means between second 20 stripping zone 64 and first riser reactor zone 14, wherein the at least a portion of the separated clean spent catalyst and the first portion of the regenerated cracking catalyst are both used in combination within first riser reactor zone 14 and are contacted with the first hydrocarbon feedstock under the suitable first catalytic cracking conditions of first riser reactor zone 14.

25 Partition wall 66 which divides and defines first stripping zone 60 and second stripping zone 64 may extend to the inside bottom of single vessel separator/stripper 22 to below the opening of clean catalyst withdrawal conduit 74, thereby isolate the first and the second stripping zones. Partition wall 66 also may extend only approximately to and terminate at a location above the inside bottom of single vessel separator/stripper 22 in 30 order to provide opening passageway 78 between first stripping zone 60 and second

stripping zone 64 so as to thereby allow for fluid or catalyst flow between the zones. Any other suitable means (not shown) may be used to provide for the fluid or catalyst flow between first stripping zone 60 and second stripping zone 64, such as, for example, openings within or defined by partition wall 66 or conduits through partition wall 66 or any other means for providing fluid or catalyst flow communication between first stripping zone 60 and second stripping zone 64 similar in the way provided by opening passageway 78.

Catalyst standpipe conduit 80 extends into the bottom section of single vessel separator/stripper 22 and provides for the removal or withdrawal of the separated coked spent catalyst from first stripping zone 60, and passing the separated coked spent catalyst by way of catalyst standpipe conduit 80 to regenerator 26 for introduction thereof into regeneration zone 82 defined by regenerator 26. Catalyst standpipe conduit 80 further provides for removal or withdrawal from second stripping zone 64 of the remaining portion of the separated clean spent catalyst that has not be removed from second stripping zone 64 by way of clean catalyst withdrawal conduit 74 and passing it to regenerator 26 for introduction thereof into regenerator zone 82.

Regenerator 26 defines regeneration zone 82 and provides means for contacting the separated coked spent catalyst or the remaining portion of the separated clean spent catalyst, or both, with an oxygen-containing gas, such as air, under carbon burning conditions to remove carbon therefrom. The oxygen-containing gas is introduced into regeneration zone 82 through conduit 84 and the combustion gases pass from regeneration zone 82 by way of conduit 86 to downstream for further handling or processing.

The separated first cracked product passes from first cyclone 54 by way of conduit 88 and the separated second cracked product passes from second cyclone 58 by way of conduit 90. Separated first cracked product or separated second cracked product, or a combination of the two streams, may be passed to main fractionation column or system 94. Main fractionation column or system 94 can be any separation system know to those skilled in the art for recovering and separating cracked product streams into various FCC products, such as, for example, cracked gas, cracked gasoline, cracked gas oils and cycle oil that respectively pass from main fractionation column 94 through conduits.

System 94 may include such systems as absorbers and strippers, fractionators, compressors and separators or any combination of known systems for providing recovery and separation of the cracked products that may make up the separated first cracked product or the separated second cracked product, or both. In a preferred embodiment of the process, a combination of the separated first cracked product and the separated second cracked product pass by way of conduit 106 to main fractionation column 94 which provides means for their separation into one or more product streams, as indicated above, including the cracked gasoline or a naphtha product stream.

In one embodiment of the inventive process, at least a portion of the cracked gasoline or naphtha product stream passing from system 94 by way of conduit 100 is recycled and utilized as the second hydrocarbon feedstock introduced into second riser reactor zone 34 by way of conduit 44.

Presented in FIG. 2 is an enlarged schematic of the single vessel separator/stripper that is depicted in FIG. 1 as one embodiment of this feature of the inventive process or system. Single vessel separator/stripper 22 defines a separation zone 46 that is generally contained within the upper section of single vessel separator/stripper 22 and a stripping zone 50 that is generally contained within the bottom section of the single vessel separator/stripper 22. The stripping zone 50 is divided into first stripping zone 60 and second stripping zone 64 by partition wall 66. Partition wall 66 provides segregation means for defining first stripping zone 60 and second stripping zone 64.

Housed within separation zone 46 are one or more first cyclones 54 and one or more second cyclones 58. The first riser reactor product is introduced into first cyclones 54 through conduit 18 and inlet 24, and the second riser reactor product is introduced into second cyclones 58 through conduit 38 and inlet 42. First cyclones 54 provide means for separating the first riser reactor product into a separated first cracked product and a separated coked spent catalyst. The separated coked spent catalyst falls through one or more diplegs 110 of first cyclones 54 into first stripping zone 60 of stripping zone 50. The catalyst bed within stripping zone 50 has a level 112.

Second cyclones 58 provide means for separating the second riser reactor product into a separated second cracked product and a separated clean spent catalyst. The separated

clean spent catalyst falls through one or more diplegs 114 of second cyclones 58 into second stripping zone 64 of stripping zone 50.

Trays or baffles 68 are utilized within first stripping zone 60 and second stripping zone 64, respectively, to provide for enhanced contact between the falling catalyst from each of first cyclones 54 and second cyclones 58 and the stripping fluid introduced into the stripping zones. The stripping fluid is introduced into the stripping zones by way of conduit 72 and distribution ring 118, which provides means for distributing a stripping fluid, such as steam, into either first stripping zone 60 or second stripping zone 64, or both stripping zones (stripping zone 50).

Clean catalyst withdrawal conduit 74 extends into second stripping zone 64 and provides means for withdrawing of at least a portion of the separated clean spent catalyst from second stripping zone 64 through inlet 120. The at least a portion of the separated clean spent catalyst passes through clean catalyst withdrawal conduit 74 in the direction indicated by arrow 122 to first riser reactor zone 14 (not shown in FIG. 2).

Partition wall 66 provides for opening passageway 78 that is near to the bottom of single vessel separator/stripper 22. The opening passageway 78 may be provided by any suitable manner, such as, for example, merely extending partition wall 66 approximately, but not completely, to the inside bottom of single vessel separator/stripper 22 so as to provide an opening that allows for fluid flow communication between first stripping zone 60 and second stripping zone 64. Any other structure may be used to provide for fluid flow communication between first stripping zone 60 and second stripping zone 64 by way of opening passageway 78.

Catalyst standpipe conduit 80 extends into the bottom section of stripping zone 50 and provides for the withdrawal of the separated coked spent catalyst and the remaining portion of the separated clean spent catalyst through inlet 124 of catalyst standpipe conduit 80. The separated coked spent catalyst and remaining portion of the separated clean spent catalyst passes through catalyst standpipe conduit 80 in the direction indicated by arrow 126 to be introduced into regeneration zone 82 (not shown in FIG. 2).

The separated first cracked product passes through conduit 88 and separated second cracked product passes through conduit 90 to be collected through withdrawal nozzle means

130 for collecting and withdrawing the separated cracked products from single vessel separator/stripper 22. These cracked products pass to downstream through conduit 106 to be introduced into main fractionation column 94 (not shown in FIG.2).

CLAIMS

1. A dual riser catalytic cracking process for making middle distillate and lower olefins, wherein said process comprises:

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catalytically cracking a first hydrocarbon feedstock within a first riser reactor zone by contacting under first catalytic cracking conditions within said first riser reactor zone said first hydrocarbon feedstock with a combination of a clean spent catalyst and a first portion of a regenerated cracking catalyst to yield a first riser reactor product comprising a first  
10 cracked product and a coked spent catalyst;

15

catalytically cracking a second hydrocarbon feedstock within a second riser reactor zone by contacting under second catalytic cracking conditions within said second riser reactor zone said second hydrocarbon feedstock with a second portion of said regenerated cracking  
15 catalyst to yield a second riser reactor product comprising a second cracked product and said clean spent catalyst;

20

passing said first riser reactor product to a single vessel separator/stripper providing means for separating said first riser reactor product into a separated first cracked product and a  
20 separated coked spent catalyst;

25

passing said second riser reactor product to said single vessel separator/stripper providing means for separating said second riser reactor product into a separated second cracked  
product and a separated clean spent catalyst;

using at least a portion of said separated clean spent catalyst as said clean spent catalyst of said combination; and

passing said separated coked spent catalyst and the remaining of said separated clean spent catalyst to a regenerator that defines a regeneration zone and provides means for regenerating said separated coked spent catalyst to yield said regenerated cracking catalyst.

5 2. A process as recited in claim 1, which further comprises: passing said separated first cracked product and said separated second cracked product to a fractionator defining a fractionation zone and providing fractionation means for separating either said separated first cracked product or said separated second cracked product, or both, into one or more product streams including a naphtha product stream.

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3. A process as recited in claim 2, which further comprises: using at least a portion of said naphtha product stream as at least a portion of said second hydrocarbon feedstock.

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4. A process as recited in claim 3, wherein said single vessel separator/stripper defines a separation zone that includes first separation means for separating said first riser reactor product into said separated first cracked product and said separated coked spent catalyst and second separation means for separating said second riser reactor product into said separated second cracked product and said separated clean spent catalyst, and wherein said single vessel separator/stripper further defines a stripping zone that includes a first stripping zone and a second stripping zone provided by segregation means for defining said first stripping zone and said second stripping zone contained within said single vessel separator/stripper, and wherein within said first stripping zone said separated coked spent catalyst is stripped of hydrocarbons, and wherein within said second stripping zone said separated clean spent catalyst is stripped of hydrocarbons.

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5. A process as recited in claim 4, wherein said single vessel separator/stripper further includes a clean catalyst withdrawal conduit and a catalyst standpipe conduit, wherein said clean catalyst withdrawal conduit provides fluid communication between said second stripping zone and said first riser reactor zone to thereby allow for withdrawing said at least a portion of said separated clean spent catalyst from said second stripping zone and

introducing said separated clean spent catalyst into said first riser reactor zone, and wherein said catalyst standpipe conduit provides fluid communication between said stripping zone and said regeneration zone to allow withdrawing said remaining portion of said separated clean spent catalyst and said separated coked spent catalyst and introducing said remaining portion of said separated clean spent catalyst and said separated coked spent catalyst into said regenerator zone.

6. A process as recited in claim 5, wherein said single vessel separator/stripper further includes a product withdrawal conduit in fluid communication between said separation zone and said fractionation zone and providing product withdrawal means for withdrawing said separated first cracked product or said separated second cracked product, or both, from said separation zone and introducing said separated first cracked product or said separated second cracked product, or both, into said fractionation zone.

7. A process as recited in claim 1, which further comprises: passing a remaining portion of said separated clean spent catalyst to said regenerator that provides means for regenerating said remaining portion of said separated clean spent catalyst to yield said regenerated cracking catalyst.

20

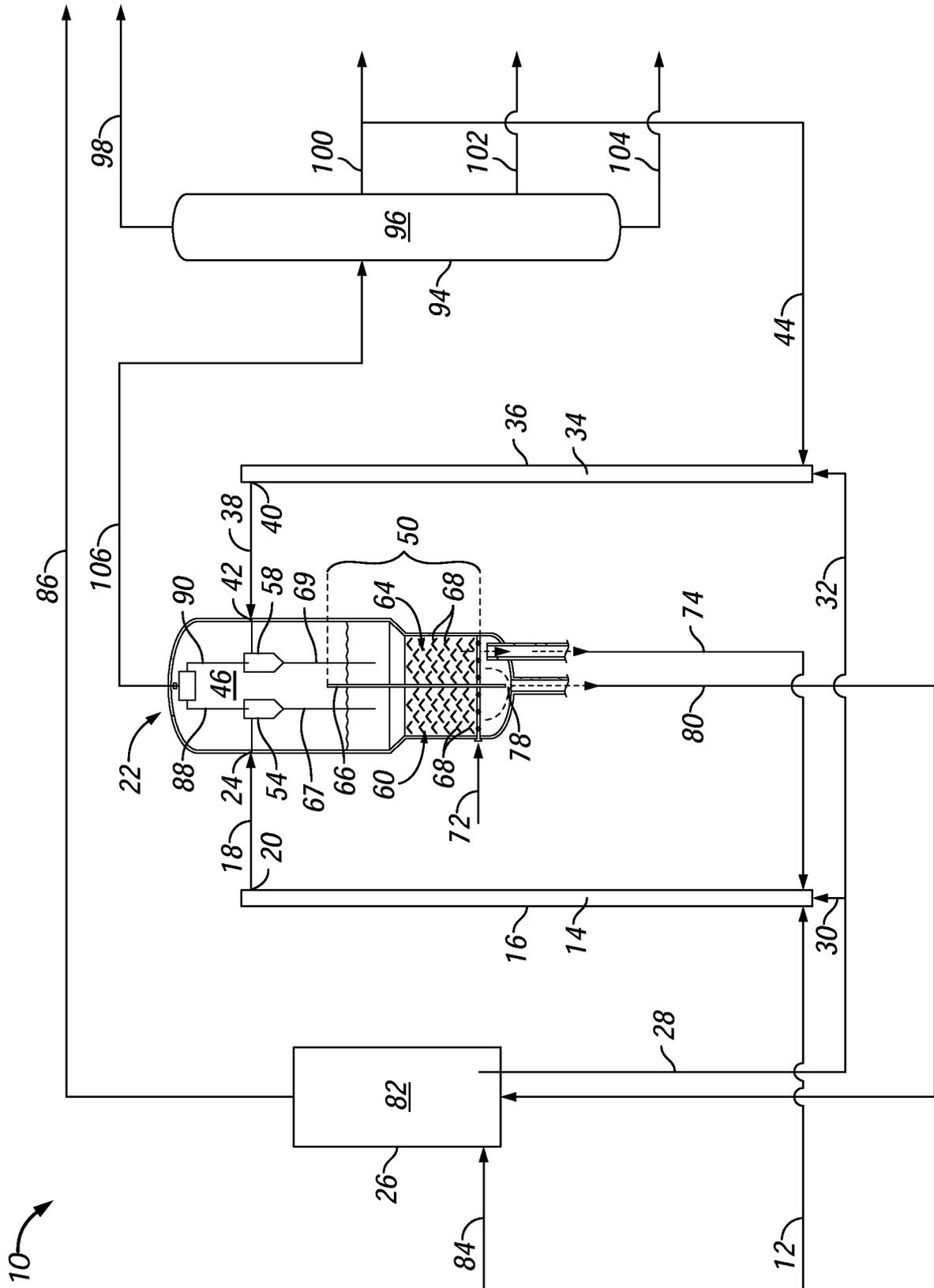


FIG. 1

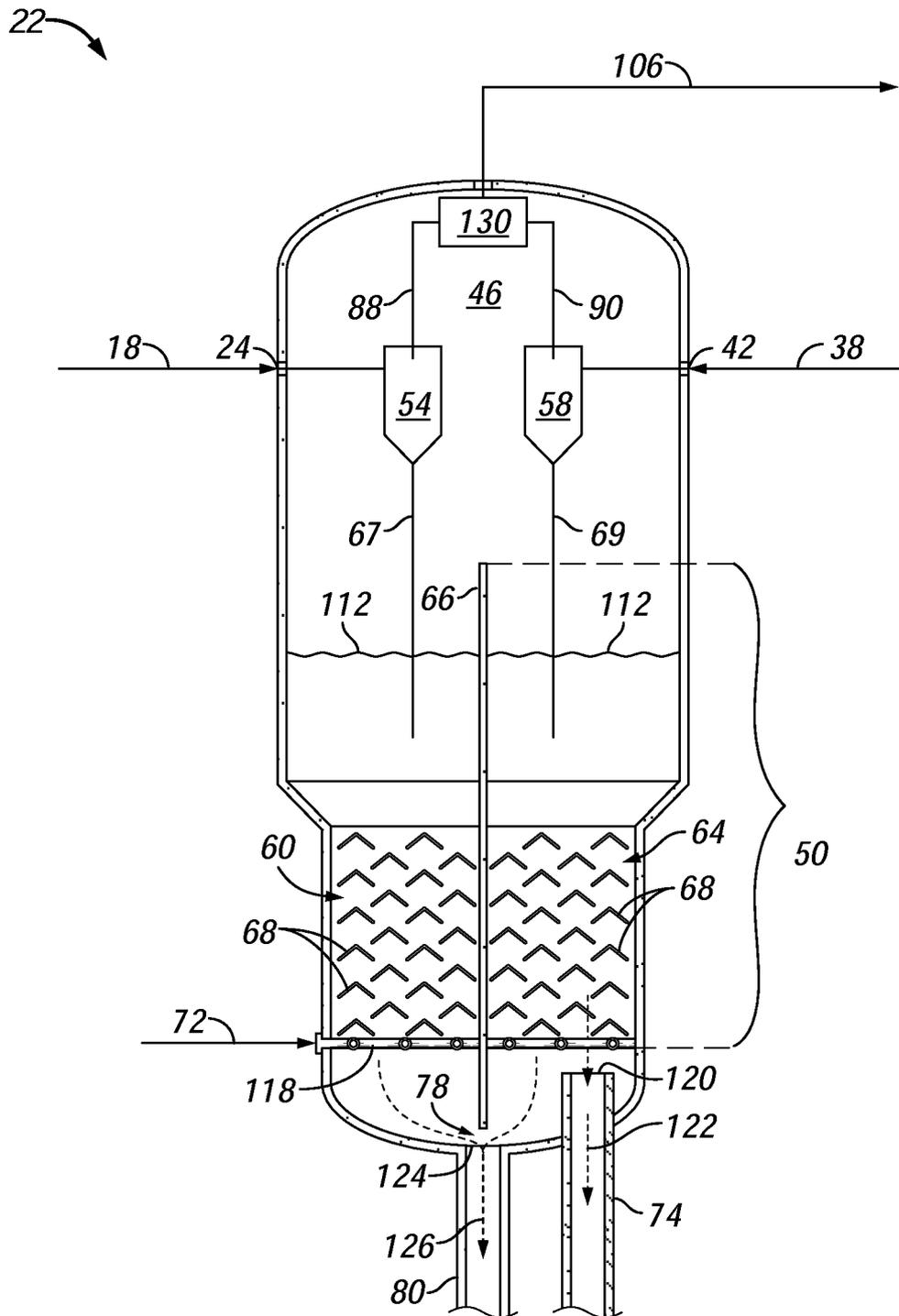


FIG. 2

**INTERNATIONAL SEARCH REPORT**

International application No  
PCT/US2012/044495

A. CLASSIFICATION OF SUBJECT MATTER  
**INV. CIOGII/18**  
 ADD.  
 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)  
**CIOG 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 practicable, search terms used)  
**EPO-Internal , WPI Data**

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3 849 291 A (OWEN H) 19 November 1974 (1974-11-19) the whole document -----	1-6
X	US 3 974 062 A (OWEN HARTLEY ET AL) 10 August 1976 (1976-08-10) the whole document -----	1-7
X	US 3 894 933 A (OWEN HARTLEY ET AL) 15 July 1975 (1975-07-15) the whole document -----	1,2
X	US 6 287 522 B1 (LOMAS DAVID A [US]) 11 September 2001 (2001-09-11) the whole document -----	1-3

Further documents are listed in the continuation of Box C.  See patent family annex.

\* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E" earlier application or patent but published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search <b>17 September 2012</b>	Date of mailing of the international search report <b>27/09/2012</b>
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Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer <b>Marchand, Kari n</b>
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# INTERNATIONAL SEARCH REPORT

Information on patent family members

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