

METHOD AND APPARATUS FOR MAKING A MIDDLE DISTILLATE PRODUCT AND LOWER OLEFINS FROM A HYDROCARBON FEEDSTOCK

The invention relates to method and apparatus for the manufacture of a middle distillate product and lower olefins from a hydrocarbon feedstock.

The fluidized catalytic cracking (FCC) of heavy hydrocarbons to produce lower boiling hydrocarbon products such as gasoline is well known in the art. FCC processes have been around since the 1940's. Typically, an FCC unit or process includes a riser reactor, a catalyst separator and stripper, and a regenerator. A FCC feedstock is introduced into the riser reactor wherein it is contacted with hot FCC catalyst from the regenerator. The mixture of the 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 FCC processes and systems are designed so as to provide for a high conversion of the FCC feedstock to products having boiling temperatures in the gasoline boiling range. There are situations, however, when it is desirable to provide for the high conversion of the FCC feedstock to middle distillate boiling range products, as opposed to gasoline boiling range products, and to lower olefins.

It is, thus, an object of this invention to provide method and apparatus for the preferential conversion of a hydrocarbon feedstock to a middle distillate product and lower olefins.

Accordingly, a process is provided for making middle distillate and lower olefins by catalytically cracking a gas oil feedstock within a riser reactor zone by contacting under suitable catalytic cracking conditions within the riser reactor zone the gas oil feedstock with a middle distillate selective cracking catalyst that comprises amorphous silica alumina and a zeolite to yield a cracked gas oil product and a spent cracking catalyst. The spent cracking catalyst is regenerated

to yield a regenerated cracking catalyst. The gasoline feedstock is contacted within a dense bed reactor zone and under suitable high severity cracking conditions with the regenerated cracking catalyst to yield a cracked gasoline product and a used regenerated cracking catalyst. The used regenerated cracking catalyst is used as the middle distillate selective catalyst.

According to another invention, provided is an apparatus that comprises riser reactor means for contacting a gas oil feedstock with a catalytic cracking catalyst under catalytic cracking conditions to yield a riser reactor product comprising a cracked gas oil product and a spent cracking catalyst; separator means for separating the riser reactor product into the cracked gas oil product and the spent cracking catalyst; regenerator means for regenerating the spent cracking catalyst to yield a regenerated catalyst; dense bed reactor means for contacting a gasoline feedstock with the regenerated catalyst under high severity conditions to yield a cracked gasoline product and a used regenerated catalyst; and means for providing for the use of the used regenerated catalyst as the catalytic cracking catalyst.

FIG. 1 is a process flow schematic representing certain aspects of the inventive process.

The invention is a process and apparatus that provides for the processing of a heavy hydrocarbon feedstock to selectively produce middle distillate boiling range products and lower olefins. It has been discovered that the use of a dense phase reactor, or fixed fluidized bed reactor, between the catalyst regenerator and riser reactor of a conventional FCC process or unit can provide for an improved middle distillate yield and for enhanced selectivity toward the production of lower olefins. The inventive process utilizes the dense phase reactor to provide for the cracking of a gasoline feedstock that preferably boils in the gasoline temperature range to yield lower olefins and for the conditioning of the catalyst so that when it is used in the cracking of the FCC feedstock in the riser reactor the reactor conditions are more suitable for the production of a middle distillate product.

In the inventive process, a gas oil feedstock is introduced into the bottom of a riser reactor where it is mixed with hot cracking catalyst such as a regenerated cracking catalyst or a used regenerated cracking catalyst or a combination of both catalysts. The starting catalytic cracking catalyst used in the inventive process and

regenerated to ultimately become the regenerated cracking catalyst can be any suitable cracking catalyst known in the art to have cracking activity at the elevated temperatures 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 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 Na₂O. 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 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 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, 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 alumino-silicate gel or sol or other inorganic, refractory oxide component, and the resultant mixture is spray dried to produce finished catalyst particles normally ranging in 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.

In the case of the use in the inventive process of a riser reactor that is vertically arranged, lift gas or lift steam may also be introduced into the bottom of the riser reactor along with the gas oil feedstock and the hot cracking catalyst. The regenerated cracking catalyst that is yielded from the catalyst regenerator has a

higher temperature than the used regenerated cracking catalyst that is yielded from the dense phase reactor. Also, the used regenerated cracking catalyst has deposited thereon as a result of its use in the dense phase reactor a certain amount of coke. As will be discussed more fully elsewhere herein, a particular catalyst or combination of catalysts may be used to help control the conditions within the riser reactor to provide for certain desired cracking conditions required to provide a desired product or mix of products.

The mixture of gas oil feedstock and hot cracking catalyst, and, optionally, lift gas or steam, passes through the riser reactor wherein cracking takes place.

The riser reactor defines a catalytic cracking zone and provides means for providing a contacting time to allow the cracking reactions to occur. The average residence time of the hydrocarbons in the riser reactor generally can be in the range of upwardly to about 5 to 10 seconds, but usually is in the range of from 0.1 to 5 seconds. The weight ratio of catalyst to 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 riser reactor generally can be in the range of from about 400 °C (752 °F) to about 600 °C (1112 °F). More typically, the riser reactor temperature can be in the range of from 450 °C (842 °F) to 550 °C (1022 °F).

The riser reactor temperatures of the inventive process will tend to be lower than those of typical conventional fluidized catalytic cracking processes; because, the inventive process is to provide for a high yield of middle distillates as opposed to the production of gasoline as is often sought with conventional fluidized catalytic cracking processes.

The mixture of hydrocarbons and catalyst from the riser reactor pass as a riser reactor product comprising cracked gas oil product and spent cracking catalyst to a stripper system that provides means for separating hydrocarbons from catalyst and defines a stripper separation zone wherein the cracked gas oil product is separated from the spent cracking catalyst. The stripper system can be any system or means known to those skilled in the art for separating FCC catalyst from a hydrocarbon product. In a typical stripper operation, the riser reactor product, which is a mixture of cracked gas oil product and spent cracking catalyst passes to the stripper system that includes cyclones for separating the spent

cracking catalyst from the vaporous cracked gas oil product. The separated spent cracking catalyst enters the stripper vessel from the cyclones where it is contacted with steam to further remove cracked gas oil product from the spent cracking catalyst. The coke content on the separated spent cracking catalyst is, 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. Typically, the coke content on the separated spent cracking catalyst is in the range of from or about 0.5 wt. % to or about 1.5 wt. %.

The separated spent cracking catalyst is then passed to a catalyst regenerator that provides means for regenerating the separated spent cracking catalyst and defines a regeneration zone into which the separated spent cracking catalyst is introduced and wherein carbon that is deposited on the separated spent cracking catalyst is burned in order to remove the carbon to provide a regenerated cracking catalyst having a reduced carbon content. The catalyst regenerator typically is a vertical cylindrical vessel that defines the regeneration zone and wherein the spent cracking catalyst is maintained as a fluidized bed by the upward passage of an oxygen-containing regeneration gas, such as air.

The 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). The residence time of the separated spent cracking 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 spent cracking catalyst and, generally, is less than 0.5 wt. %. The coke content 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 thus preferably be in the range of from 0.01 wt. % to 0.1 wt. %.

The regenerated cracking catalyst from the catalyst regenerator is passed to the dense phase reactor, or fixed fluidized bed reactor, that provides means for

contacting a gasoline feedstock with the regenerated cracking catalyst and which defines a dense phase reaction zone wherein the gasoline feedstock is contacted with the regenerated cracking catalyst under suitable high severity cracking conditions.

5 The dense phase reactor can be a vessel that defines the dense phase reaction zone. Contained within the vessel is regenerated cracking catalyst that is fluidized by the introduction of the gasoline feedstock and, optionally, steam. The dense phase reaction zone is operated under such reaction conditions as to provide for a cracked gasoline product and, preferably, to provide for a high
10 cracking yield of lower olefins. The high severity cracking conditions can include a temperature within the dense phase reaction zone that is in the range from about 482 °C (900 °F) to about 871 °C (1600 °F), but, preferably, the temperature is in the range of from 510 °C (950 °F) to 871 °C (1600 °F), and, most preferably, from 538 °C (1000 °F) to 732 °C (1350 °F). The pressure within the dense phase
15 reaction zone can be 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).

 While, as previously mentioned, the introduction of steam along with the gasoline feedstock into the dense phase reaction zone is optional, a preferred aspect of the invention, however, is for both steam and gasoline feedstock to be
20 introduced into the dense phase reaction zone and to be contacted with the regenerated cracking catalyst contained therein. The use of the steam is particularly desirable; because, it can provide in the cracking of the gasoline feedstock for an improved selectivity toward lower olefin yield. Thus, when steam is used, the weight ratio of steam to gasoline feedstock introduced into the dense
25 phase reaction zone can be in the range of upwardly to or about 15:1, but, preferably, the range is from 0.1:1 to 10:1. More preferably, the weight ratio of steam to gasoline feedstock is in the range of from 0.2:1 to 9:1, and, most preferably, from 0.5:1 to 8:1.

 Used regenerated cracking catalyst is removed from the dense phase
30 reaction zone and utilized as hot cracking catalyst mixed with the gas oil feedstock that is introduced into the riser reactor. One beneficial aspect of the inventive process, in addition to its high yield of lower olefins, is that it provides for the partial deactivation of the regenerated catalyst prior to its use as hot cracking catalyst in

the riser reactor. What is meant by partial deactivation is that the used regenerated cracking catalyst will contain a slightly higher concentration of carbon than the concentration of carbon that is on the regenerated cracking catalyst. This partial deactivation of the regenerated cracking catalyst helps provides for a preferred product yield when the gas oil feedstock is cracked within the riser reactor zone. The coke concentration on the used regenerated cracking catalyst is greater than the coke concentration on the regenerated cracking catalyst, but it is less than that of the separated spent cracking catalyst. Thus, the coke content of the used regenerated catalyst can be greater than 0.1 wt. % and even greater than 0.5 wt. %. Preferably, the coke content of the used regenerated catalyst is in the range of from about 0.1 wt. % to about 1 wt. %, and, most preferably, from 0.1 wt. % to 0.6 wt. %.

Another benefit provided by the use of the dense phase reaction zone is associated with the used regenerated cracking catalyst having a temperature that is lower than the temperature of the regenerated cracking catalyst. This lower temperature of the used regenerated cracking catalyst in combination with the partial deactivation, as discussed above, provides further benefits in a preferential product yield from the cracking of the gas oil feedstock.

To assist in providing for the control of the process conditions within the riser reactor of the inventive process and to provide for a desired product mix, the regenerated cracking catalyst can be divided into at least a portion that is passed to the dense phase reaction zone and a remaining portion of the regenerated cracking catalyst that is mixed with the gas oil feedstock to be introduced into the riser reactor. The at least a portion of the regenerated cracking catalyst introduced into the dense phase reaction zone can be in the range of upwardly to 100 percent (%) of the regenerated cracking catalyst yielded from the catalyst regenerator depending upon the requirements of the process and the desired product yields. Specifically, however, the at least a portion of regenerated cracking catalyst will represent from about 10 % to 100 % of the separated regenerated catalyst withdrawn from the catalyst regenerator. Also, the at least a portion of regenerated cracking catalyst can be from about 50 % to about 90% of the separated regenerated catalyst that is withdrawn from the catalyst regenerator.

Another method by which the process conditions within the riser reactor are controlled and a desired product mix is provided is through the addition of a ZSM-5 additive to the dense phase reaction zone. The ZSM-5 additive is a molecular sieve additive selected from the family of medium pore size crystalline aluminosilicates or zeolites.

Molecular sieves that can be used as the ZSM-5 additive of the present invention include medium pore zeolites as described in "Atlas of Zeolite Structure Types," eds. W. H. Meier and D. H. Olson, Butterworth-Heinemann, Third Edition, 1992, which is hereby incorporated by reference. The medium pore size zeolites generally have a pore size from about 0.5 nm, to about 0.7 nm and include, for example, MFI, MFS, MEL, MTW, EUO, MTT, HEU, FER, and TON structure type zeolites (IUPAC Commission of Zeolite Nomenclature). Non-limiting examples of such medium pore size zeolites, include ZSM-5, ZSM-12, ZSM-22, ZSM-23, ZSM-34, ZSM-35, ZSM-38, ZSM-48, ZSM-50, silicalite, and silicalite 2. The most preferred is ZSM-5, which is described in U.S. Patent Nos. 3,702,886 and 3,770,614. ZSM-11 is described in U.S. Patent No. 3,709,979; ZSM-12 in U.S. Patent No. 3,832,449; ZSM-21 and ZSM-38 in U.S. Patent No. 3,948,758; ZSM-23 in U.S. Patent No. 4,076,842; and ZSM-35 in U.S. Patent No. 4,016,245. All of the above patents are incorporated herein by reference. Other suitable molecular sieves include the silicoaluminophosphates (SAPO), such as SAPO-4 and SAPO-11 which is described in U.S. Patent No. 4,440,871; chromosilicates; gallium silicates, iron silicates; aluminum phosphates (ALPO), such as ALPO-11 described in U.S. Patent No. 4,310,440; titanium aluminosilicates (TASO), such as TASO-45 described in EP-A No. 229,295; boron silicates, described in U.S. Patent No. 4,254,297; titanium aluminophosphates (TAPO), such as TAPO-11 described in U.S. Patent No. 4,500,651; and iron aluminosilicates.

The ZSM-5 additive may be held together with a catalytically inactive inorganic oxide matrix component, in accordance with conventional methods.

U. S. 4,368,114 describes in detail the class of zeolites that can be suitable ZSM-5 additives in the inventive process, and such patent is incorporated herein by reference.

The combination of one or more of the above described process variables and operating conditions allows for the control of the conversion of the gas oil

feedstock. Generally, it is desired for the gas oil feedstock conversion to be in the range of from 30 to 90 weight percent, and, preferably, from 40 to 85 weight percent. What is meant by gas oil feedstock conversion is the weight amount of hydrocarbons contained in the gas oil feedstock that has a boiling temperature greater than 221 °C (430 °F) that is converted in the riser reactor to hydrocarbons having a boiling temperature less than 221 °C (430 °F) divided by the weight amount of hydrocarbons contained in the gas oil feedstock having a boiling temperature greater than 221 °C (430 °F). As earlier noted, the inventive process may be operated so as to provide for the preferential or selective yielding of middle distillate boiling range products and lower olefins.

The gas oil feedstock charged to the process of the invention may be any hydrocarbon feedstock that may be or is typically charged to a fluidized catalytic cracking unit. In general terms, hydrocarbon mixtures boiling in the range of from 345 °C (650 °F) to 760 °C (1400 °F) can make suitable feedstocks for the inventive process. Examples of the types of refinery feedstreams 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 gasoline feedstock charged to the dense phase reaction zone may be any suitable hydrocarbon feedstock having a boiling temperature that is in the gasoline 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.

Now referring to FIG. 1 that presents a process flow schematic representative of one aspect of the inventive process 10. In the inventive process 10, a gas oil feedstock passes through conduit 12 and is introduced into the bottom of riser reactor 14. Riser reactor 14 defines a riser reactor zone, or cracking reaction zone, wherein the gas oil feedstock is mixed with a catalytic cracking catalyst. The catalytic cracking catalyst can be a used regenerated cracking catalyst or a regenerated cracking catalyst, or a combination of both catalysts.

The used regenerated cracking catalyst is a regenerated cracking catalyst that has been used in dense bed reactor 16 in the high severity cracking of a gasoline feedstock. The used regenerated cracking catalyst passes from dense bed reactor 16 and is introduced into riser reactor 14 by way of conduit 18.

5 Regenerated cracking catalyst may also be mixed with the gas oil feedstock. The regenerated cracking catalyst passes from regenerator 20 through conduit 22 and is introduced by way of conduit 24 into riser reactor 14 wherein it is mixed with the gas oil feedstock.

10 By passing through riser reactor 14 that is operated under catalytic cracking conditions the mixture of gas oil feedstock and hot catalytic cracking catalyst forms a riser reactor product that comprises a mixture of a cracked gas oil product and a spent cracking catalyst. The riser reactor product passes from riser reactor 14 and is introduced into stripper system or separator/stripper 26.

15 The separator/stripper 26 can be any conventional system that defines a separation zone or stripping zone, or both, and provides means for separating the cracked gas oil product and spent cracking catalyst. The separated cracked gas oil product passes from separator/stripper 26 by way of conduit 28 to separation system 30. The separation system 30 can be any system known to those skilled in the art for recovering and separating the cracked gas oil product into the various
20 FCC products, such as, for example, cracked gas, cracked gasoline, cracked gas oils and cycle oil. The separation system 36 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 products that make up the cracked gas oil product.

25 The separation system 30, thus, defines a separation zone and provides means for separating the cracked gas oil product into cracked products. The cracked gas, cracked gasoline and cracked gas oils respectively pass from separation system 30 through conduits 32, 34, and 36. The cycle oil passes from separation system 30 through conduit 38 and is introduced into riser reactor 14.

30 The separated spent cracking catalyst passes from separator/stripper 26 through conduit 40 and is introduced into regenerator 20. Regenerator 20 defines a regeneration zone and provides means for contacting the spent cracking catalyst with an oxygen-containing gas, such as air, under carbon burning conditions to

remove carbon from the spent cracking catalyst. The oxygen-containing gas is introduced into regenerator 20 through conduit 42 and the combustion gases pass from regenerator 20 by way of conduit 44.

The regenerated cracking catalyst passes from regenerator 20 through
5 conduit 22. As an optional feature of the inventive process, the stream of
regenerated cracking catalyst passing through conduit 22 may be divided into two
streams with at least a portion of the regenerated catalyst passing from
regenerator 20 through conduit 22 passing through conduit 46 to the dense bed
reactor 16 and with the remaining portion of the regenerated catalyst passing from
10 regenerator 20 passing through conduit 24 to riser reactor 14.

The dense bed reactor 16 defines a dense bed fluidization zone and
provides means for contacting a gasoline feedstock with the regenerated cracking
catalyst contained within the dense bed reactor 16. The dense bed fluidization
zone is operated under high severity cracking conditions so as to preferentially
15 crack the gasoline feedstock to lower olefin compounds, such as ethylene,
propylene, and butylenes, and to yield a cracked gasoline product. The cracked
gasoline product passes from dense bed reactor 16 through conduit 48.

The used regenerated cracking catalyst passes from dense bed reactor 16
through conduit 18 and is introduced into riser reactor 14. The gasoline feedstock
20 is introduced into the dense bed reactor 16 through conduit 50 and steam is
introduced into the dense bed reactor 16 by way of conduit 52. The gasoline
feedstock and steam are introduced into the dense bed reactor 16 so as to provide
for a fluidized bed of the regenerated catalyst. A ZSM-5 additive may be added to
the regenerated catalyst of the dense phase reactor 16 or introduced into the
25 dense bed reactor 16 through conduit 54.

Reasonable variations, modifications and adaptations can be made within
the scope of the described disclosure and the appended claims without departing
from the scope of the invention.

C L A I M S

1. A process for making middle distillate and lower olefins, said process comprises:
- 5 catalytically cracking a gas oil feedstock within a riser reactor zone by contacting under suitable catalytic cracking conditions within said riser reactor zone said gas oil feedstock with a middle distillate selective cracking catalyst that comprises amorphous silica alumina and a zeolite to yield a riser reactor product comprising a cracked gas oil product and a spent cracking catalyst;
- 10 regenerating said spent cracking catalyst to yield a regenerated cracking catalyst; contacting within a dense bed reactor zone and under suitable high severity cracking conditions a gasoline feedstock with said regenerated cracking catalyst to yield a cracked gasoline product and a used regenerated cracking catalyst; and using said used regenerated cracking catalyst as said middle distillate selective
- 15 catalyst.
2. A process as recited in claim 1, further comprising: separating said riser reactor product into said cracked gas oil product and said spent cracking catalyst.
3. A process as recited in claim 1 or 2, further comprising:
- 20 adding to said regenerated cracking catalyst a ZSM-5 additive.
4. A process as recited in claim 1, 2 or 3, further comprising: introducing steam into said dense bed reactor zone.
5. A process as recited in claim 1, 2, 3, or 4, wherein said suitable catalytic cracking conditions are such as to provide for a conversion of said gas oil
- 25 feedstock in the range of from 40 to 85 weight percent of the total gas oil feedstock.
6. A process as recited in claim 1, 2, 3, 4, or 5, wherein said used regenerated cracking catalyst includes a small concentration of carbon.

7. A process, comprising:

contacting a gas oil feedstock within a riser reactor zone under suitable catalytic cracking conditions with a cracking catalyst and yielding a riser reactor product comprising a cracked gas oil product and a spent cracking catalyst;

5 separating said riser reactor product into said cracked gas oil product and said spent cracking catalyst;

regenerating said spent cracking catalyst to yield a regenerated cracking catalyst;

splitting said regenerated cracking catalyst into at least a portion of said regenerated cracking catalyst and a remaining portion of said regenerated

10 cracking catalyst;

passing said at least a portion of said spent cracking catalyst to a dense bed reactor zone wherein said at least a portion of said spent cracking catalyst is contacted under suitable high severity cracking conditions with a gasoline feedstock to yield a cracked gasoline product and a used regenerated cracking

15 catalyst; and

using said remaining portion of said regenerated cracking catalyst and said used regenerated cracking catalyst as said cracking catalyst.

8. A process as recited in claim 7, further comprising:

mixing with said at least a portion of said spent cracking catalyst a ZSM-5 additive.

20 9. A process as recited in claim 7 or 8, further comprising:

introducing steam into said dense bed reactor zone.

10. A process as recited in claim 7, 8 or 9, further comprising:

separating a slurry product from said cracked gas oil product.

11. A process as recited in claim 7, 8, 9 or 10, further comprising:

25 introducing said slurry product to said riser reactor zone.

12. An apparatus, comprising:

riser reactor means for contacting a gas oil feedstock with a catalytic cracking catalyst under catalytic cracking conditions to yield a riser reactor product comprising a cracked gas oil product and a spent cracking catalyst;

5 separator means for separating said riser reactor product into said cracked gas oil product and said spent cracking catalyst;

regenerator means for regenerating said spent cracking catalyst to yield a regenerated catalyst;

dense bed reactor means for contacting a gasoline feedstock with said

10 regenerated catalyst under high severity conditions to yield a cracked gasoline product and a used regenerated catalyst; and

means for providing for the use of said used regenerated catalyst as said catalytic cracking catalyst.