

1 PROCESS FOR THE UPGRADING OF THE PRODUCTS
2 OF FISCHER-TROPSCH PROCESSES

3
4 FIELD OF THE INVENTION

5
6 The instant invention is directed to a means for hydroprocessing
7 Fischer-Tropsch products in which hydrocracking of distillate range
8 components is minimized.

9
10 BACKGROUND OF THE INVENTION

11
12 The majority of combustible liquid fuel used in the world today is derived from
13 crude oil. However, there are several limitations to using crude oil as a fuel
14 source. For example, crude oil is in limited supply; it includes aromatic
15 compounds believed to cause cancer and contains sulfur and nitrogen-
16 containing compounds that can adversely affect the environment.

17
18 Alternative sources for developing combustible liquid fuel are desirable. An
19 abundant source is natural gas. The conversion of natural gas to combustible
20 liquid fuel typically involves converting the natural gas, which is mostly
21 methane, to synthesis gas, or syngas, which is a mixture of carbon monoxide
22 and hydrogen. An advantage of using fuels prepared from syngas is that they
23 typically do not contain appreciable amounts of nitrogen and sulfur and
24 generally do not contain aromatic compounds. Accordingly, they have less
25 health and environmental impact than conventional petroleum-based fuels.
26 Fischer-Tropsch synthesis is a preferred means for converting syngas to
27 higher molecular weight hydrocarbon products.

28
29 Fischer-Tropsch synthesis is often performed under conditions which produce
30 a large quantity of C₂₀+ wax, which must be hydroprocessed to provide
31 distillate fuels. Often, the wax is hydrocracked to reduce the chain length, and

1 then hydrotreated to reduce oxygenates and olefins to paraffins. Although
2 some catalysts have been developed with selectivity for longer chain
3 hydrocarbons, the hydrocracking tends to reduce the chain length of all of the
4 hydrocarbons in the feed. When the feed includes hydrocarbons that are
5 already in a desired range, for example, the distillate fuel range,
6 hydrocracking of these hydrocarbons is undesirable.

7
8 It would be advantageous to provide a method for hydroprocessing
9 Fischer-Tropsch wax which minimizes the hydrocracking of hydrocarbons in
10 the distillate fuel range. The present invention provides such methods.

11
12 U.S. Pat. No. 6,583,186 discloses a means of hydroprocessing
13 Fischer-Tropsch products without overcracking distillate components. In this
14 scheme, however, all of the heavier, hydrocracked material is recombined
15 with lighter materials, such as Fischer-Tropsch condensate and subsequently
16 hydrotreated. There is no interstage separation step following hydrocracking,
17 as in the instant invention.

18
19 U.S. Pat. No. 6,224,747 discloses hydrocracking a VGO stream in a
20 hydrocracking reaction zone within an integrated hydroconversion process.
21 Effluent from the hydrocracking reaction zone is combined, without interstage
22 separation with a light aromatic-containing feed stream, and the blended
23 stream is hydrotreated in a hydrotreating reaction zone. The hydrocracked
24 effluent serves as a heat sink for the hydrotreating reaction zone. The
25 integrated reaction system provides a single hydrogen supply and
26 recirculation system for use in two reaction systems. This patent is not
27 directed to hydroprocessing of Fischer-Tropsch products, as is the instant
28 invention. Furthermore, there is no interstage separation between the
29 hydrocracking and hydrotreating stages.

SUMMARY OF THE INVENTION

The instant invention is directed to a means for hydroprocessing Fischer-Tropsch products in which hydrocracking of distillate range components is minimized. This results in reduction in capital investment, particularly for large scale plants, reduction in operating costs, and an increase in production of more valuable products.

According to a first aspect, there is provided an integrated hydroconversion process for the treatment of Fischer-Tropsch products including a first hydrocarbon stream comprising a wax and a second hydrocarbon stream comprising a condensate, the process having at least two stages, a hydrocracking stage and a hydrotreating stage, each stage possessing at least one reaction zone, wherein the process comprises the following steps:

- (a) combining a first hydrocarbon stream with a first hydrogen-rich gaseous stream to form a first feedstock;
- (b) passing the first feedstock of step (a) to a hydrocracking reaction zone, which is maintained at hydrocracking conditions, to form a hydrocracking zone effluent comprising normally liquid phase components and normally gaseous phase components;
- (c) passing the hydrocracking zone effluent of step (b) to a heat exchanger or series of exchangers, where it is cooled;
- (d) separating the components of the cooled effluent of step (c) into a vapor stream and a liquid stream;

- 1 (e) combining the vapor stream of step (d) with the second hydrocarbon
2 stream to form a second feedstock, the liquid stream of step (d) being
3 passed to lubricant production or to further processing for manufacture
4 of fuel and diesel products;
5
6 (f) passing the second feedstock of step (e) to a hydrotreating zone, which
7 is maintained at conditions sufficient for reducing the content of sulfur,
8 nitrogen, oxygenates and unsaturates present in the second
9 hydrocarbon stream, to form a hydrotreating zone effluent;
10
11 (g) separating the hydrotreating zone effluent of step (f) into a liquid stream
12 comprising products and a second hydrogen-rich gaseous stream;
13
14 (h) passing the liquid stream of step (g) to further processing, and passing
15 the hydrogen-rich gaseous stream of step (g) to further separation into a
16 light hydrogen-rich gaseous stream, and a stream comprising liquid
17 products; and
18
19 (i) recycling at least a portion of the hydrogen-rich gaseous stream of
20 step (h) to the hydrocracking zone and hydrotreating zones.
21

22 BRIEF DESCRIPTION OF THE FIGURES

23
24 Figure 1 illustrates the basic flow scheme of the preferred embodiment.
25

26 Figures 2 and 3 show variations of the basic flow scheme.
27

DETAILED DESCRIPTION OF THE INVENTION

Feeds

The products from Fischer-Tropsch reactions performed in slurry bed reactors generally include a light fraction (also known as a condensate fraction) and a heavy fraction (also known as a wax fraction). In the instant invention, the wax fraction comprises the feed to the hydrocracker and the condensate comprises a portion of the feed to the hydrotreater. The condensate includes hydrocarbons boiling below about 700°F (e.g., tail gases through middle distillates, with increasingly smaller amounts of material up to about C₃₀), preferably in the range C₅-650°F. The waxy reaction product includes hydrocarbons boiling above about 600°F (e.g., vacuum gas oil through heavy paraffins with increasingly smaller amounts of material down to about C₁₀).

When the gaseous reaction product (part of the condensate) from the Fischer-Tropsch synthesis step is being cooled and condensed and various fractions collected, the first liquid fractions collected tend to have higher average molecular weights than subsequent fractions.

The light and heavy fractions described above can optionally be combined with hydrocarbons from other streams, for example, streams from petroleum refining. The light fractions can be combined, for example, with similar fractions obtained from the fractional distillation of crude oil and/or liquids recovered from natural gas wells. The heavy fractions can be combined, for example, with waxy crude oils, crude oils and/or slack waxes from petroleum deoiling and dewaxing operations.

The light fraction typically includes a mixture of hydrocarbons, including mono-olefins and alcohols. The mono-olefins are typically present in an

amount of at least about 5.0 wt% of the fraction. The alcohols are usually present in an amount typically of at least about 0.5 wt% or more.

Conditions - Hydrocracking Stage

Reaction conditions in the hydrocracking reaction zone include a reaction temperature between about 250°C and about 500°C (482°F-932°F), pressures from about 3.5 MPa to about 24.2 MPa (500-3,500 psi), and a feed rate (vol oil/vol cat h) from about 0.1 to about 20 hr⁻¹. Hydrogen circulation rates are generally in the range from about 350 std liters H₂/kg oil to 1780 std liters H₂/kg oil (2,310-11,750 standard cubic feet per barrel). Preferred reaction temperatures range from about 340°C to about 455°C (644°F-851°F). Preferred total reaction pressures range from about 6.9 MPa to about 20.7 MPa (1,000-3,000 psi). With the preferred catalyst system, it has been found that preferred process conditions include contacting a hydrocarbon feedstock with hydrogen under hydrocracking conditions comprising a pressure of about 6.9 MPa to about 20.7 MPa (1,000-3000 psi), a gas to oil ratio between about 379-909 std liters H₂/kg oil (2,500-6,000 scf/bbl), a LHSV of between about 0.5-1.5 hr⁻¹, and a temperature in the range of 350°C to 427°C (662°F-800°F).

Conditions in the hydrocracking stage are sufficient to effect a boiling point conversion of at least 25%, preferably between 30% and 90%. Conversion involves breaking the relatively high boiling molecules of the feed into lower boiling components.

Catalysts - Hydrocracking Stage

The hydrocracking stage and the hydrotreating stage may each contain one or more catalysts. If more than one distinct catalyst is present in either of the stages, they may either be blended or be present as distinct layers. Layered

1 catalyst systems are taught, for example, in U.S. Patent No. 4,990,243, the
2 disclosure of which is incorporated herein by reference for all purposes.
3 Hydrocracking catalysts useful for the hydrocracking stage are well known. In
4 general, the hydrocracking catalyst comprises a cracking component and a
5 hydrogenation component on an oxide support material or binder. The
6 cracking component may include an amorphous cracking component and/or a
7 zeolite, such as a Y-type zeolite, an ultrastable Y type zeolite, or a
8 dealuminated zeolite. A suitable amorphous cracking component is
9 silica-alumina.

10
11 The hydrogenation component of the catalyst particles is selected from those
12 elements known to provide catalytic hydrogenation activity. At least one metal
13 component selected from the Group VIII (IUPAC Notation) elements and/or
14 from the Group VI (IUPAC Notation) elements are generally chosen. Group V
15 elements include chromium, molybdenum and tungsten. Group VIII elements
16 include iron, cobalt, nickel, ruthenium, rhodium, palladium, osmium, iridium
17 and platinum. The amount(s) of hydrogenation component(s) in the catalyst
18 suitably range from about 0.5% to about 10% by weight of Group VIII metal
19 component(s) and from about 5% to about 25% by weight of Group VI metal
20 component(s), calculated as metal oxide(s) per 100 parts by weight of total
21 catalyst, where the percentages by weight are based on the weight of the
22 catalyst before sulfiding. The hydrogenation components in the catalyst may
23 be in the oxidic and/or the sulphidic form. If a combination of at least a
24 Group VI and a Group VIII metal component is present as (mixed) oxides, it
25 will be subjected to a sulfiding treatment prior to proper use in hydrocracking.
26 Suitably, the catalyst comprises one or more components of nickel and/or
27 cobalt and one or more components of molybdenum and/or tungsten or one
28 or more components of platinum and/or palladium. Catalysts containing
29 nickel and molybdenum, nickel and tungsten, platinum and/or palladium are
30 particularly preferred.
31

1 The hydrocracking catalyst particles of this invention may be prepared by
2 blending, or co-mulling, active sources of hydrogenation metals with a binder.
3 Examples of suitable binders include silica, alumina, clays, zirconia, titania,
4 magnesia and silica-alumina. Preference is given to the use of alumina as
5 binder. Other components, such as phosphorous, may be added as desired
6 to tailor the catalyst particles for a desired application. The blended
7 components are then shaped, such as by extrusion, dried and calcined at
8 temperatures up to 649°C (1200°F) to produce the finished catalyst particles.
9 Alternatively, equally suitable methods of preparing the amorphous catalyst
10 particles include preparing oxide binder particles, such as by extrusion, drying
11 and calcining, followed by depositing the hydrogenation metals on the oxide
12 particles, using methods such as impregnation. The catalyst particles,
13 containing the hydrogenation metals, are then further dried and calcined prior
14 to use as a hydrocracking catalyst.

16 **Conditions - Hydrotreater Stage**

18 The hydrotreater is maintained at conditions sufficient to remove at least a
19 portion of the nitrogen, oxygen and unsaturated compounds from the second
20 hydrocarbon stream. The hydrotreater will operate at a lower temperature
21 than the hydrocracker, except for possible temperature gradients resulting
22 from exothermic heating within the reaction zones, optionally moderated by
23 the addition of relatively cooler streams into the one or more reaction zones.
24 Feed rate of the reactant liquid stream through the reaction zones will be in
25 the region of 0.1 to 20 hr⁻¹ liquid hourly space velocity. Hydrotreating
26 conditions typically used in the hydrotreater will include a reaction
27 temperature between about 150°C and about 500°C (302°F-932°F),
28 pressures from about 2.1 MPa to about 24.2 MPa (300-3,500 psig), and a
29 feed rate (vol oil/vol cat h) from about 0.1 to about 20 hr⁻¹. Hydrogen
30 circulation rates are generally in the range from about 350 std liters H₂/kg oil
31 to 1780 std liters H₂/kg oil (2,310-11,750 standard cubic feet per barrel).

1 Preferred reaction temperatures range from about 200°C to about 427°C
2 (392°F-800°F). Preferred total reaction pressures range from about 6.9 MPa
3 to about 20.7 MPa (1,000-3,000 psi).

4

5 The hydrotreating stage contains hydrotreating catalyst, maintained at
6 hydrotreating conditions. Catalysts known for hydrotreating are useful for the
7 hydrotreater. Such hydrotreating catalysts are suitable for hydroconversion of
8 feedstocks containing sulfur, nitrogen, oxygenates and/or unsaturated
9 molecules. Such catalysts generally contain at least one metal component
10 selected from Group VIII (IUPAC Notation) and/or at least one metal
11 component selected from the Group VI (IUPAC notation) elements. Group VI
12 elements include chromium, molybdenum and tungsten. Group VIII elements
13 include iron, cobalt and nickel. While the noble metals, especially palladium
14 and/or platinum, may be included, alone or in combination with other
15 elements, in the hydrotreating catalyst, use of the noble metals as
16 hydrogenation components is not preferred. The amount(s) of hydrogenation
17 component(s) in the catalyst suitably range from about 0.5% to about 10% by
18 weight of Group VIII metal component(s) and from about 5% to about 25% by
19 weight of Group VI metal component(s), calculated as metal oxide(s) per
20 100 parts by weight of total catalyst, where the percentages by weight are
21 based on the weight of the catalyst before sulfiding. The hydrogenation
22 components in the catalyst may be in the oxidic and/or the sulfidic form. If a
23 combination of at least a Group VI and a Group VIII metal component is
24 present as (mixed) oxides, it will be subjected to a sulfiding treatment prior to
25 proper use in hydrotreating. Suitably, the catalyst comprises one or more
26 components of nickel and/or cobalt and one or more components of
27 molybdenum and/or tungsten. Catalysts containing cobalt and molybdenum
28 are particularly preferred.

29

30 The hydrotreating catalyst particles of this invention are suitably prepared by
31 blending, or co-mulling, active sources of hydrogenation metals with a binder.

1 Examples of suitable binders include silica, alumina, clays, zirconia, titania,
2 magnesia and silica-alumina. Preference is given to the use of alumina as
3 binder. Other components, such as phosphorous, may be added as desired
4 to tailor the catalyst particles for a desired application. The blended
5 components are then shaped, such as by extrusion, dried and calcined at
6 temperatures up to 649°C (1200°F) to produce the finished catalyst particles.
7 Alternatively, equally suitable methods of preparing the amorphous catalyst
8 particles include preparing oxide binder particles, such as by extrusion, drying
9 and calcining, followed by depositing the hydrogenation metals on the oxide
10 particles, using methods such as impregnation. The catalyst particles,
11 containing the hydrogenation metals, are then further dried and calcined prior
12 to use as a hydrotreating catalyst.

13
14 The subject process is especially useful in the production of middle distillate
15 fractions boiling in the range of about 121°C-371°C (250°F-700°F) as
16 determined by the appropriate ASTM test procedure. By a middle distillate
17 fraction having a boiling range of about 121°C-371°C (250°F-700°F) is meant
18 that at least 75 vol%, preferably 85 vol%, of the components of the middle
19 distillate have a normal boiling point of greater than about 121°C (250°F) and
20 furthermore that at least about 75 vol%, preferably 85 vol%, of the
21 components of the middle distillate have a normal boiling point of less than
22 371°C (700°F). The term "middle distillate" is intended to include the diesel,
23 jet fuel and kerosene boiling range fractions. The kerosene or jet fuel boiling
24 point range is intended to refer to a temperature range of about 138°C-274°C
25 (280°F-525°F), and the term "diesel boiling range" is intended to refer to
26 hydrocarbon boiling points of about 121°C-371°C (250°F-700°F). Gasoline or
27 naphtha is normally the C₅ to 204°C (400°F) endpoint fraction of available
28 hydrocarbons. The boiling point ranges of the various product fractions
29 recovered in any particular plant will vary with such factors as the
30 characteristics of the hydrocarbon source, plant local markets, product prices,

1 etc. Reference is made to ASTM standards D 975 and D 3699 83 for further
2 details on kerosene and diesel fuel properties.

3

4 Reference is now made to Figure 1, which discloses preferred embodiments
5 of the invention. Not included in the figures are various pieces of auxiliary
6 equipment such as heat exchangers, condensers, pumps and compressors,
7 which are not essential to the invention.

8

9 **Description of the Preferred Embodiment**

10

11 In Figure 1, two downflow reactor vessels, 5 and 15, are depicted. The first
12 stage reaction, hydrocracking, occurs in vessel 5. The second stage,
13 hydrotreating, occurs in vessel 15. Each vessel contains at least one reaction
14 zone. Vessel 5 is depicted as having three catalyst beds, while vessel 15 is
15 depicted as possessing a single catalyst bed. The first reaction vessel 5 is for
16 cracking a first hydrocarbon stream 1, which is comprised primarily of
17 preheated Fischer-Tropsch wax and recycle hydrocarbon from fractionation.
18 The hydrocarbon feed is partially converted into products in the reactor. The
19 reactor effluent 14 comprises light vaporized hydrocarbons, distillate oils,
20 heavy unconverted hydrocarbon, and excess hydrogen not consumed in the
21 reaction. The effluent stream 14 is slightly cooled by heat exchange
22 (Exchanger 20) before it is sent, as stream 17, to a hot high pressure
23 separator (HHPS) 55. The second reaction vessel 15, a hydrotreater
24 removes nitrogen-containing, oxygen-containing and unsaturated molecules
25 from a second hydrocarbon stream 34. Stream 34 contains vapor from the
26 HHPS, which is combined with preheated condensate from line 2.

27

28 In the integrated process of this invention, a first hydrocarbon stream 1 is
29 combined with a hydrogen-rich gaseous stream 4 to form a first feedstock 12
30 which is passed to first reaction vessel 5. Hydrogen-rich gaseous stream 4
31 contains greater than 50% hydrogen, the remainder being varying amounts of

light gases, including hydrocarbon gases. The hydrogen-rich gaseous stream 4 shown in the drawing is a blend of make-up hydrogen 3 and recycle hydrogen 26. While the use of a recycle hydrogen stream is generally preferred for economic reasons, it is not required. First feedstock 1 may be heated in one or more exchangers or in one or more heaters (this is not depicted in Figure 1) before being combined with hydrogen-rich stream 4 to create stream 12. Stream 12 is then introduced to first reaction vessel 5, where the first stage, in which hydrocracking preferably occurs, is located. The second stage is located in vessel 15, where hydrotreating preferably occurs.

The effluent from the first stage, stream 14 is cooled in heat exchanger 20. Stream 14 emerges from exchanger 20 as stream 17 and passes to the HHPS 55. The liquid stream 36 emerges from the HHPS 55 and proceeds to further processing. A stream (not shown) may be taken from stream 36 and passed to a lubricant base oil plant. The lubricant plant (not shown) comprises a catalytic dewaxing unit followed by a hydrofinishing unit. Waxy material not converted in the dewaxer may be recycled to stream 1 for further processing, while dewaxed effluent is hydrofinished. The hydrofinished material is subsequently subjected to atmospheric distillation. Heavier streams may then be vacuumed distilled to produce light and heavy base hydrocarbon stocks.

The gaseous stream 34 emerges from the HHPS 55, and joins with stream 2, which comprises Fischer-Tropsch condensate, before entering vessel 15 for hydrotreating. Vessel 15 effluent is stream 18.

The second reaction zone, found in vessel 15, contains at least one bed of catalyst, such as hydrotreating catalyst, which is maintained at conditions sufficient for converting at least a portion of the nitrogen, oxygen and at least a portion of the unsaturated compounds in the second feedstock.

Stream 18, the second stage effluent (vessel 15), contains thermal energy which may be recovered by heat exchange with other process streams, such as in heat exchanger 10. The hydrotreater effluent stream 18 may also be cooled with air coolers (not shown). If necessary, wash water may be injected upstream of the air coolers to prevent the deposition of salts in the air cooler tubes. Second stage effluent 18 emerges from exchanger 10 as stream 19 and is passed to cold high pressure separator CHPS 35. The liquid effluent of the CHPS 35, stream 42, passes to fractionation. Gaseous overhead stream 26, comprising primarily hydrogen and some other light gases, passes to the compressor 40, where it is recompressed and passed as recycle to one or more of the reaction vessels and as a quench stream for cooling the reaction zones. Such uses of hydrogen are well known in the art.

Stream 26 may pass through an absorber (not shown) which includes means for contacting the stream with an alkaline aqueous solution, for removing contaminants such as hydrogen sulfide and ammonia which may be generated in the reaction zones. The hydrogen-rich gaseous stream 26 is preferably recovered from the absorber at a temperature in the range of 38°C-149°C (100°F-300°F) or 38°C-93°C (100°F-200°F).

Stream 26 then flows into the recycle gas compressor suction. The recycle compressor delivers the recycle gas to vessel 5, as stream 4. Part of the recycle compressor discharge gas, now stream 4, is routed to the hydrocracker reactor, vessel 5, as quench to control the reactor temperature. The remaining recycle gas that is not used as quench is combined with make-up hydrogen to become the hydrocracker reactor feed gas. The hydrocracker reactor feed gas is heated by process streams before combining with the Fischer-Tropsch wax and recycle hydrocarbon stream 1.

Figure 2 illustrates the base invention of Figure 1 as adapted for fuels production. The hydrotreating reactor 15 is modified, in the fuels case, to

1 employ at least two beds, rather than one. Hydrogen, in line 27, is used as an
2 inter-bed quench.

3
4 Line 19, the cooled effluent of hydrotreater 15, passes to the hot high
5 pressure separator 25, where it is separated into a gaseous stream 21 and a
6 heavier stream 22. The gaseous stream 21 passes to the cold high pressure
7 separator 35, where processing continues as described in the discussion of
8 Figure 1, with overhead stream 26 passing to compressor 40 and liquid
9 effluent 42 being further processed.

10
11 Stream 22, the liquid effluent of hot high pressure separator 25, is combined
12 with stream 36, shown in Figure 1.

13
14 Stream 36 enters hot low pressure separator 65, where it is separated into
15 overhead stream 44 and liquid effluent 37. Stream 44 combines with stream
16 42 and proceeds to cold low pressure separator 70. Fuel gas is removed
17 overhead while liquid effluent 43 is passed to fractionator 50.

18
19 Stream 37 also passes to fractionator 50, where it is separated into overhead
20 gasoline stream 28, naphtha stream 29, kerosene fraction 31 and diesel
21 stream 32. Bottoms stream 33 is recycled to the hydrocracker 5. A preferred
22 distillate product has a boiling point range within the temperature range
23 121-371°C (250°F-700°F). A gasoline or naphtha fraction having a boiling
24 point within the temperature range C₅-204°C(C₅-400°F) is also desirable.

25
26 Figure 3 illustrates the base invention of Figure 1 as adapted for lubricant
27 production. The hydrotreating reactor 15 is modified, in the lubricant case, to
28 employ at least two beds, rather than one. Hydrogen, in line 27, is used as an
29 inter-bed quench.

1 Stream 18, the effluent of hydrotreater 15, is cooled in heat exchanger 10 and
2 passed, as stream 19 to cold high pressure separator 35, as depicted in
3 Figure 1. Overhead stream 26 passes to compressor 40, as depicted in
4 Figure 1 and liquid effluent 42 is further processed as depicted in Figure 2.
5 Stream 44 combines with stream 42 and proceeds to cold low pressure
6 separator 70. Fuel gas is removed overhead while liquid effluent 43 is passed
7 to fractionator (not shown).
8
9 Stream 36, liquid effluent from the hot high pressure separator 55 is
10 separated into gaseous stream 44 and liquid stream 37, as depicted in
11 Figure 2, the fuels case. Unlike Figure 2, however, line 37 proceeds to
12 lubricants processing (details not shown, but including dewaxing procedures)
13 rather than passing to fractionator.

1 WHAT IS CLAIMED IS:

- 2
- 3 1. An integrated hydroconversion process for the treatment of
- 4 Fischer-Tropsch products including a first hydrocarbon stream
- 5 comprising a wax and a second hydrocarbon stream comprising a
- 6 condensate, the process having at least two stages, a hydrocracking
- 7 stage and a hydrotreating stage, each stage possessing at least one
- 8 reaction zone, wherein the process comprises the following steps:
- 9
- 10 (a) combining a first hydrocarbon stream with a first hydrogen-rich
- 11 gaseous stream to form a first feedstock;
- 12
- 13 (b) passing the first feedstock of step (a) to a hydrocracking reaction
- 14 zone, which is maintained at hydrocracking conditions, to form a
- 15 hydrocracking zone effluent comprising normally liquid phase
- 16 components and normally gaseous phase components;
- 17
- 18 (c) passing the hydrocracking zone effluent of step (b) to a heat
- 19 exchanger or series of exchangers, where it is cooled;
- 20
- 21 (d) separating the components of the cooled effluent of step (c) into a
- 22 vapor stream and a liquid stream;
- 23
- 24 (e) combining the vapor stream of step (d) with the second
- 25 hydrocarbon stream to form a second feedstock, the liquid stream
- 26 of step (d) being passed to lubricant production or to further
- 27 processing for manufacture of fuel and diesel products;
- 28
- 29 (f) passing the second feedstock of step (e) to a hydrotreating zone,
- 30 which is maintained at conditions sufficient for reducing the content

1 of sulfur, nitrogen, oxygenates and unsaturates present in the
2 second hydrocarbon stream, to form a hydrotreating zone effluent;

3

4 (g) separating the hydrotreating zone effluent of step (f) into a liquid
5 stream comprising products and a second hydrogen-rich gaseous
6 stream;

7

8 (h) passing the liquid stream of step (g) to further processing, and
9 passing the hydrogen-rich gaseous stream of step (g) to further
10 separation into a light hydrogen-rich gaseous stream, and a
11 stream comprising liquid products; and

12

13 (i) recycling at least a portion of the hydrogen-rich gaseous stream of
14 step (h) to the hydrocracking zone and hydrotreating zones.

15 2. The process of claim 1, wherein the liquid stream comprising products of
16 step (h) is passed to further separation into a liquid products stream as
17 well as light gaseous components which are sent to fuel gas.

18

19 3. The process of claim 1, wherein the liquid products stream of claim 2 is
20 sent to fractionation and separated into product streams comprising gas
21 or naphtha stream which are removed overhead, one or more middle
22 distillate streams, and a bottoms stream suitable for further processing.

23

24 4. The process according to claim 1, wherein further processing for
25 manufacture of fuel and diesel products of the liquid stream of step (d)
26 further comprises:

27

28 (a) combining the liquid stream of claim 1, step (d), with the liquid
29 fraction of claim 1, step (g), to form a single stream;

30

(b) separating the single stream of step 4(a) into a light stream and a heavy stream, the heavy stream being sent to fractionation;

(c) combining the light stream of step 4(b) with the products stream of claim 1, step (h), to form a single stream; and

(d) separating the single stream of step 4(c) into a light gaseous stream and a liquid products stream, the light gaseous stream proceeding to fuel gas and the liquid products stream proceeding to fractionation.

5. The process according to claim 1, wherein the hydrocracking zone of step 1(b) is maintained at conditions sufficient to effect a boiling range conversion of the first hydrocarbon stream of at least about 25%.

6. The process according to claim 5, wherein the hydrocracking zone of step 1(b) is maintained at conditions sufficient to effect a boiling range conversion of the first hydrocarbon stream of between 30% and 90%.

7. The process according to claim 1, wherein the waxy first hydrocarbon stream of claim 1 has a normal boiling point greater than about 600°F.

8. The process according to claim 1, wherein the second hydrocarbon stream of claim 1 has a normal boiling point below 700°F.

9. The process according to claim 8, wherein the second hydrocarbon stream boils in the range C₅-650°F.

10. The process according to claim 1, wherein the reaction zone of step 1(b) stage is maintained at hydrocracking reaction conditions, including a reaction temperature in the range from about 340°C to about 455°C

- 1 (644°F-851°F), a reaction pressure in the range of about 3.5-24.2 MPa
2 (500-3500 pounds per square inch), a feed rate (vol oil/vol cat h) from
3 about 0.1 to about 10 hr⁻¹ and a hydrogen circulation rate ranging from
4 about 350 std liters H₂/kg oil to 1780 std liters H₂/kg oil (2,310-11,750
5 standard cubic feet per barrel).
6
- 7 11. The process according to claim 1, wherein the reaction zone of step 1(g)
8 is maintained at hydrotreating reaction conditions, including a reaction
9 temperature in the range of from about 150°C to about 500°C
10 (302°F-932°F), a reaction pressure in the range of from about 2.1 MPa
11 to 24.2 MPa (300-3,500 psi), a feed rate (vol oil/vol cat hr⁻¹) from about
12 0.1 to about 20 hr⁻¹, and a hydrogen circulation rate in the range from
13 about 350 std liters H₂/kg oil to 1780 std liters H₂/kg oil (2,310-11,750
14 standard cubic feet per barrel).