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(54) METHOD OF REFINING PETROLEUM

(76) Inventors: **Makoto Inomata**, Ibaraki-ken (JP);
Yasushi Fujimura, Ibaraki-ken (JP);
Tsuyoshi Okada, Kanagawa-ken (JP);
Kozo Imura, Kanagawa-ken (JP);
Hajime Sasaki, Kanagawa-ken (JP)

Correspondence Address:
Darby & Darby
805 Third Avenue
New York, NY 10022 (US)

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(57) ABSTRACT

The oil refining method according to the present invention comprises the fractional distillation process **1** for distilling and separating the feed oil into the distillate **M1** and the residue **M2**; the hydrorefining process **2** wherein at least a part of the distillate **M1** is refined by hydrogenation and desulfurized thereby to obtain the hydrorefined oil **M3**; the solvent deasphalting process **3** wherein the residue **M2** is deasphalted with a solvent thereby to obtain the deasphalted oil **M4** as an extract and asphaltene (pitch) **M5** as the residue; the hydrodemetalizating/desulfurizing process **4** wherein at least a part of the deasphalted oil **M4** is demetalized and desulfurized by hydrogenation thereby to obtain the HDMS refined oil **M6**; and the first mixing process **5** wherein a part of the HDMS refined oil **M6** and at least a part of the hydrorefined oil **M3** are mixed thereby to produce oil products.

FIG. 1

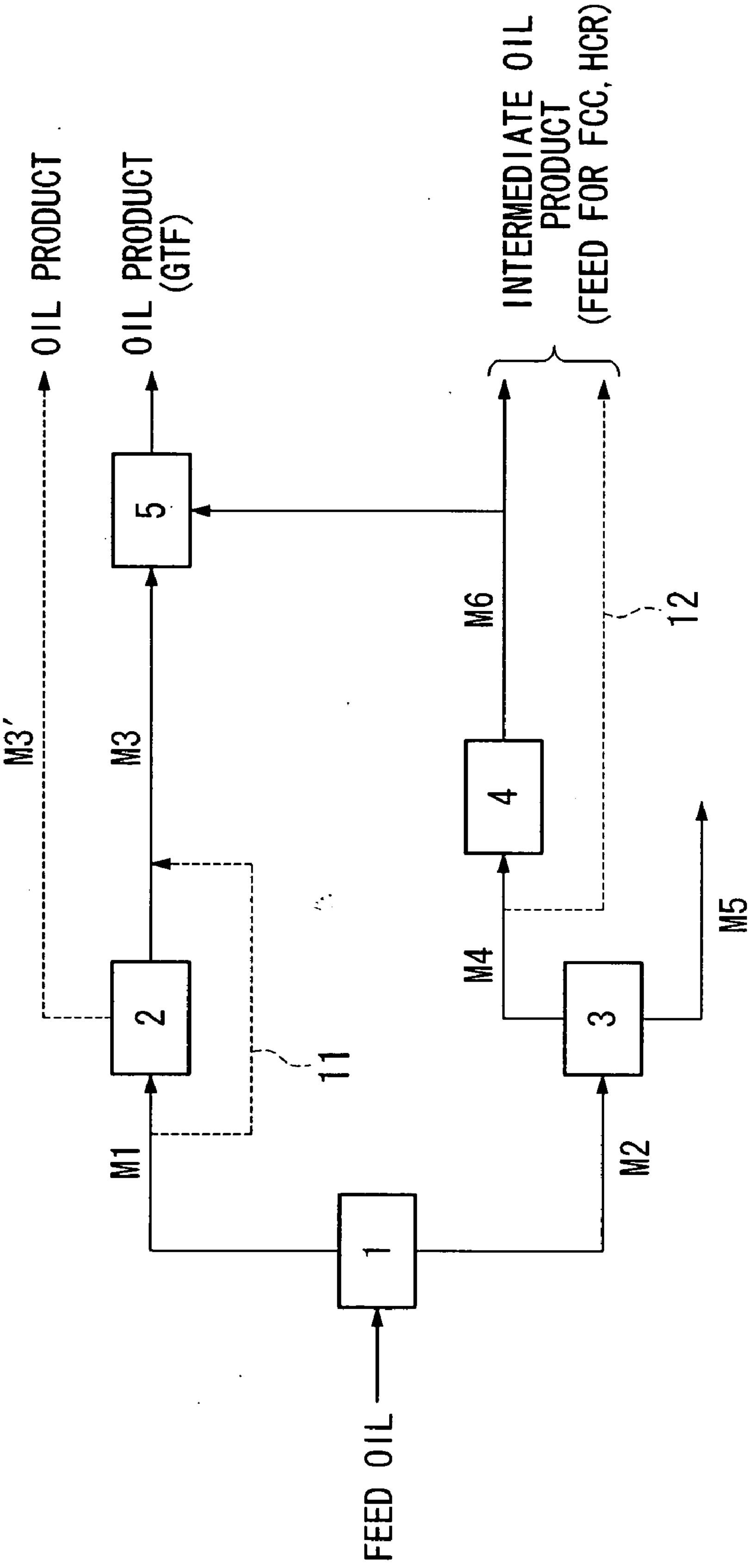

FEED OIL
1
M1
M2
2
3
11
M4
M5
M3'
M3
4
12
M6
5
OIL PRODUCT
OIL PRODUCT (GTF)
INTERMEDIATE OIL PRODUCT (FEED FOR FCC, HCR)

FIG. 2

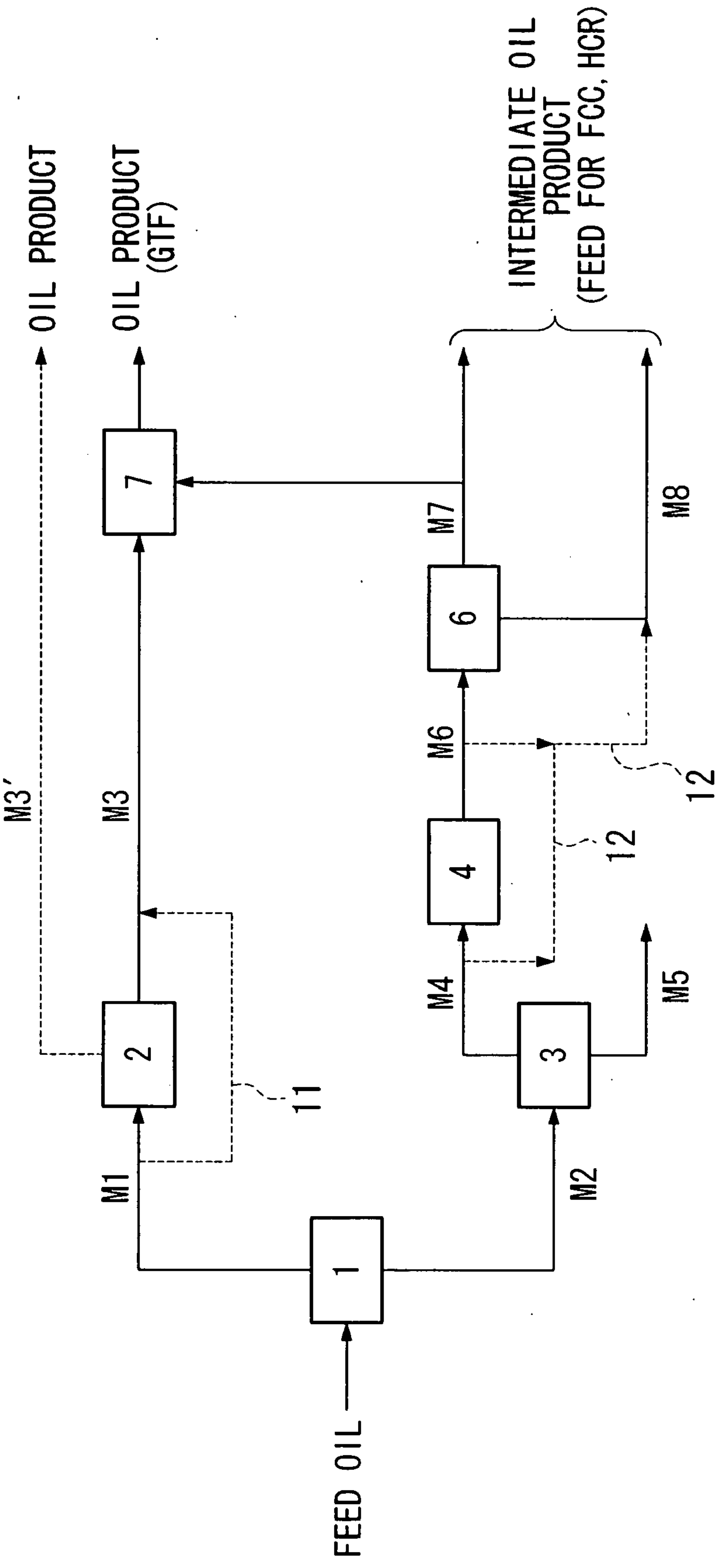

FEED OIL
1
M1
M2
2
3
11
M3′
M3
M4
M5
4
12
M6
12
6
M7
M8
7
OIL PRODUCT
OIL PRODUCT (GTF)
INTERMEDIATE OIL PRODUCT (FEED FOR FCC, HCR)

FIG. 3

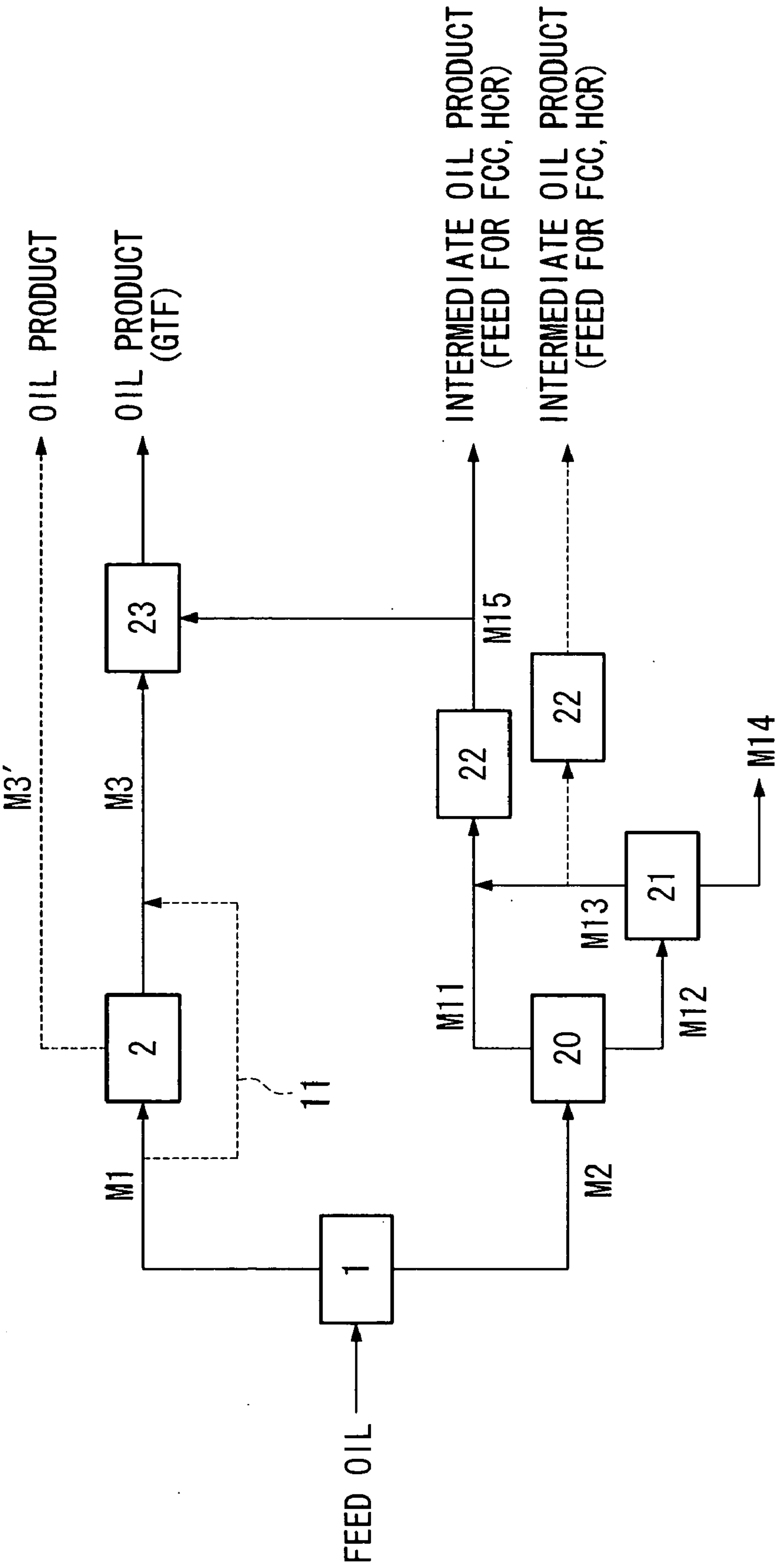

FEED OIL
1
M1
M2
11
2
20
M3
M3′
M11
M12
M13
21
M14
22
22
M15
23
OIL PRODUCT
OIL PRODUCT (GTF)
INTERMEDIATE OIL PRODUCT (FEED FOR FCC, HCR)
INTERMEDIATE OIL PRODUCT (FEED FOR FCC, HCR)

FIG. 4

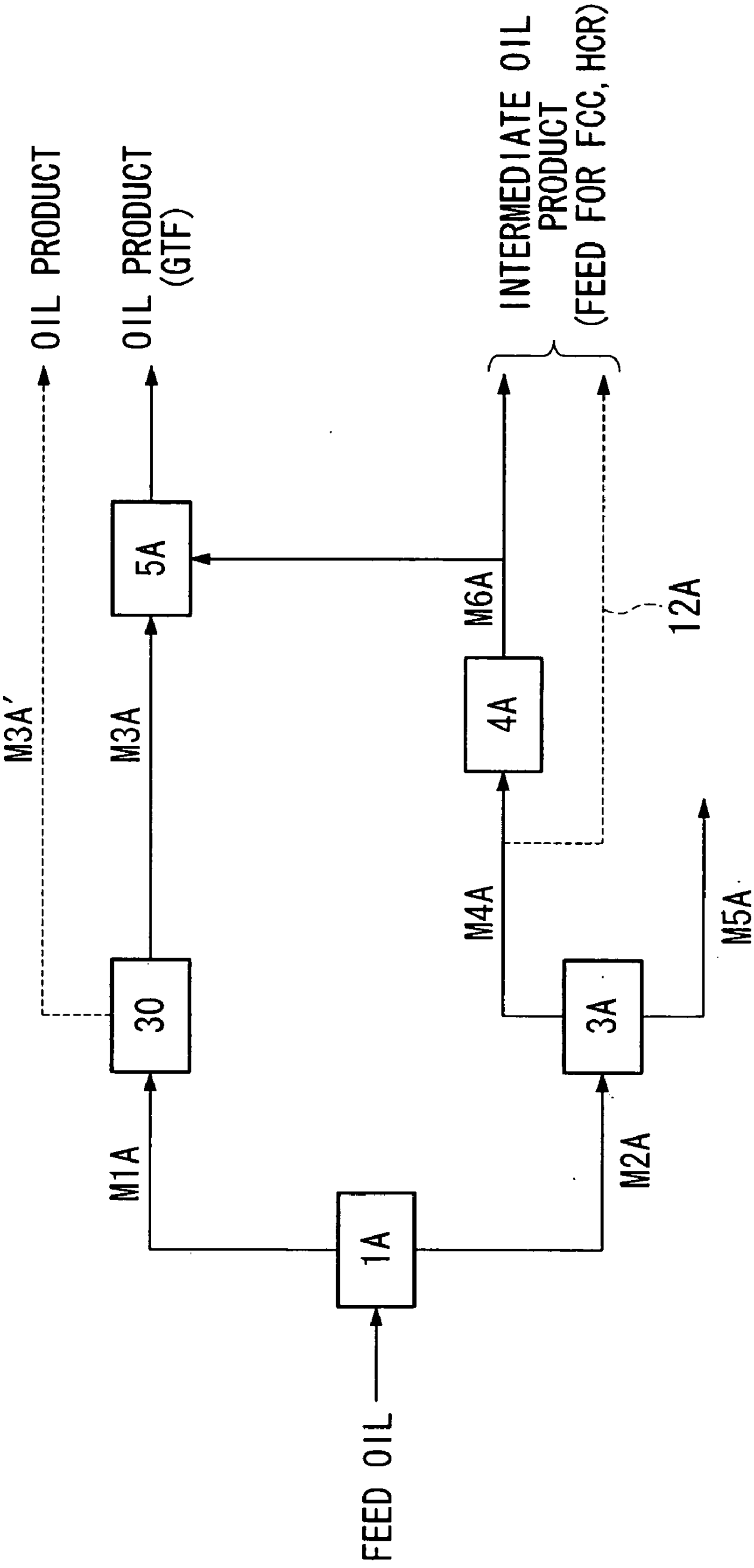

FEED OIL
1A
M1A
M2A
30
3A
M3A′
M3A
M4A
M5A
4A
5A
M6A
12A
OIL PRODUCT
OIL PRODUCT (GTF)
INTERMEDIATE OIL PRODUCT (FEED FOR FCC, HCR)

FIG. 5

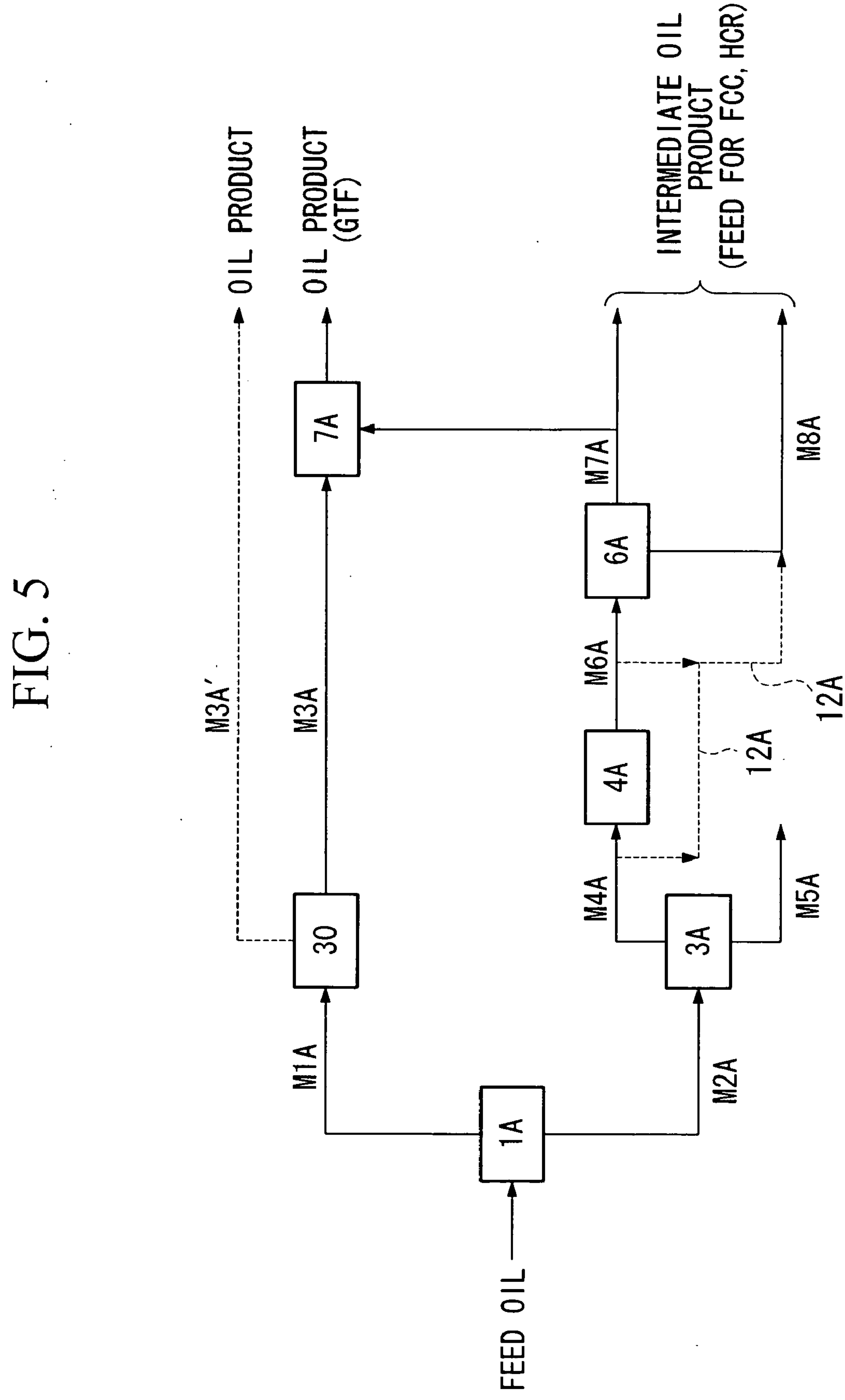

FEED OIL
1A
M1A
M2A
30
3A
M3A'
M3A
M4A
M5A
4A
M6A
6A
M7A
M8A
7A
12A
12A
OIL PRODUCT
OIL PRODUCT (GTF)
INTERMEDIATE OIL PRODUCT (FEED FOR FCC, HCR)

FIG. 6

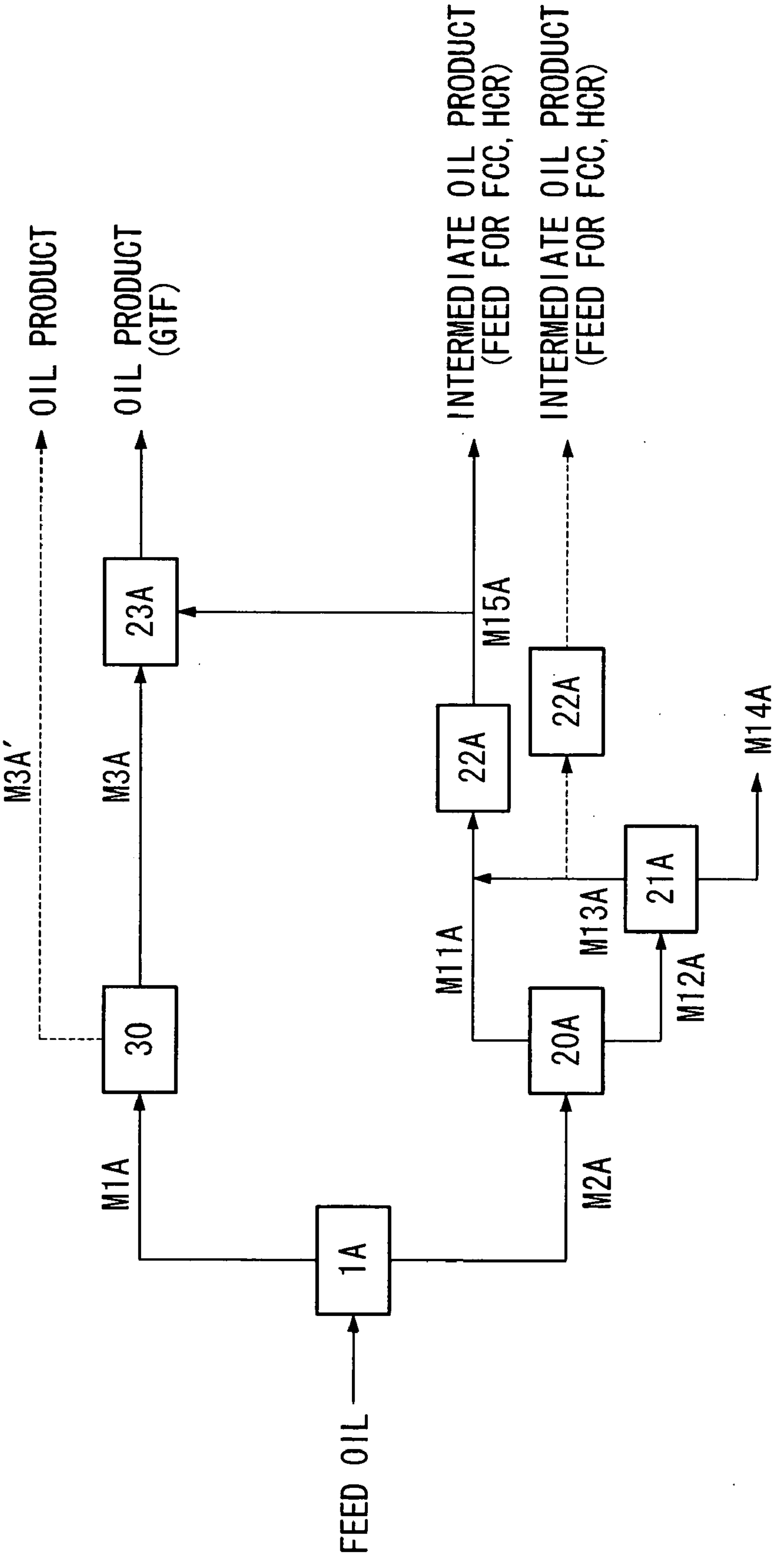

FEED OIL
1A
M1A
M2A
30
M3A′
M3A
23A
OIL PRODUCT
OIL PRODUCT (GTF)
20A
M11A
M12A
21A
M13A
M14A
22A
22A
M15A
INTERMEDIATE OIL PRODUCT (FEED FOR FCC, HCR)
INTERMEDIATE OIL PRODUCT (FEED FOR FCC, HCR)

FIG. 7

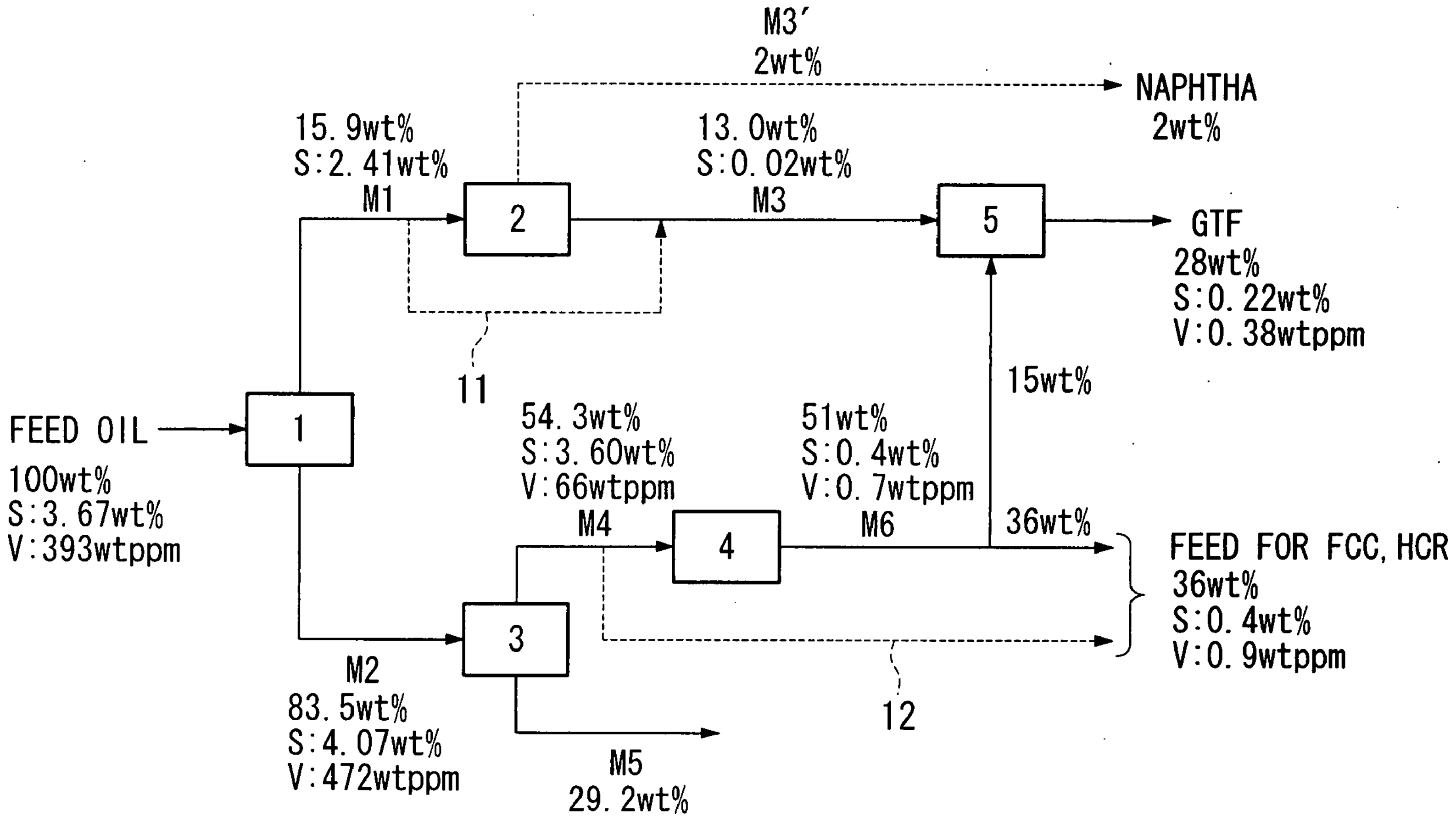

M3′
2wt%
NAPHTHA
2wt%
15. 9wt%
S:2. 41wt%
M1
2
13. 0wt%
S:0. 02wt%
M3
5
GTF
28wt%
S:0. 22wt%
V:0. 38wtppm
11
FEED OIL
100wt%
S:3. 67wt%
V:393wtppm
1
54. 3wt%
S:3. 60wt%
V:66wtppm
M4
4
51wt%
S:0. 4wt%
V:0. 7wtppm
M6
15wt%
36wt%
FEED FOR FCC, HCR
36wt%
S:0. 4wt%
V:0. 9wtppm
3
M2
83. 5wt%
S:4. 07wt%
V:472wtppm
M5
29. 2wt%
12

FIG. 8

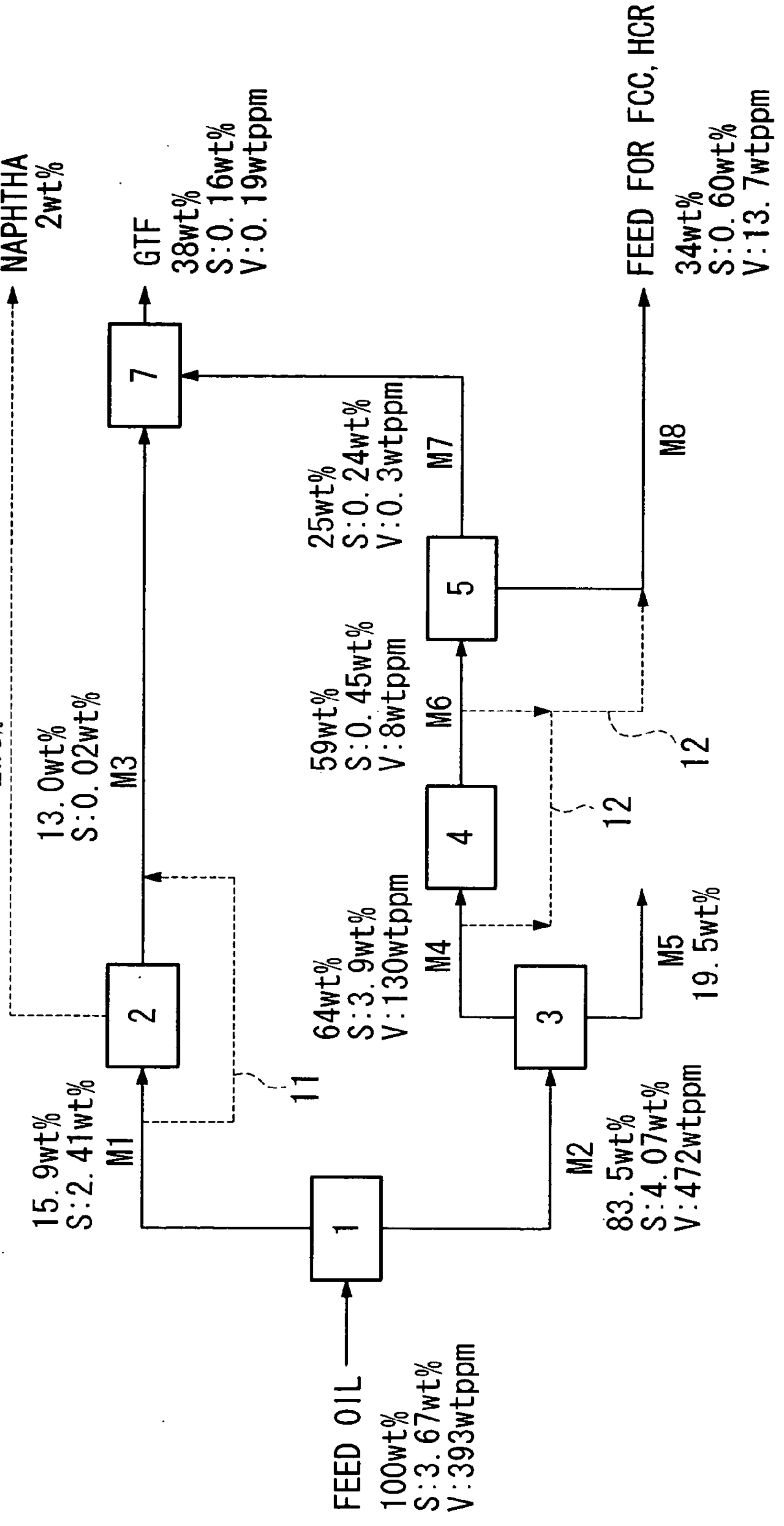

FEED OIL
100wt%
S:3.67wt%
V:393wtppm
1
15.9wt%
S:2.41wt%
M1
11
2
M3′
2wt%
13.0wt%
S:0.02wt%
M3
NAPHTHA
2wt%
7
GTF
38wt%
S:0.16wt%
V:0.19wtppm
M2
83.5wt%
S:4.07wt%
V:472wtppm
3
M5
19.5wt%
64wt%
S:3.9wt%
V:130wtppm
M4
4
12
59wt%
S:0.45wt%
V:8wtppm
M6
12
5
25wt%
S:0.24wt%
V:0.3wtppm
M7
M8
FEED FOR FCC, HCR
34wt%
S:0.60wt%
V:13.7wtppm

FIG. 9

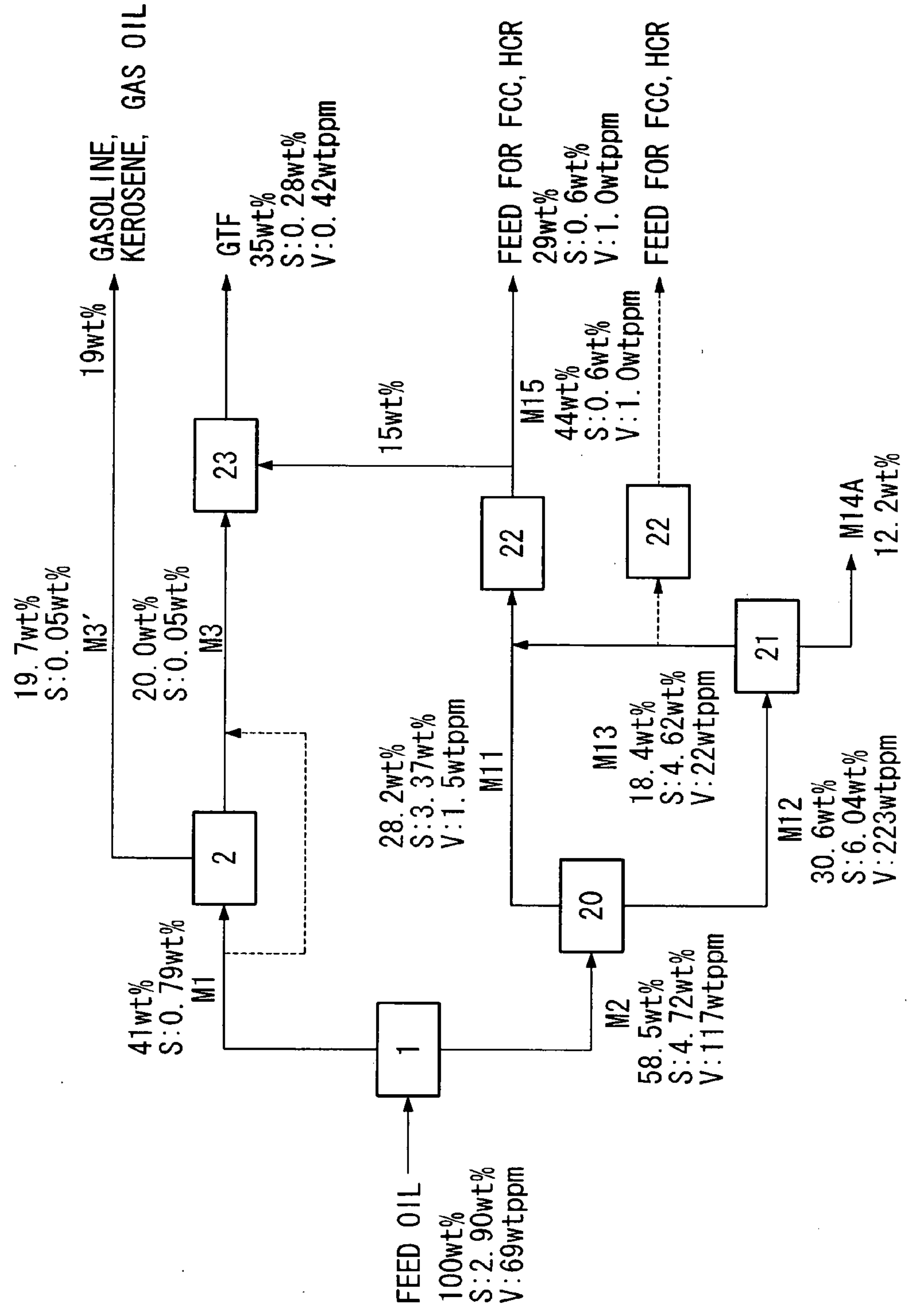

FEED OIL
100wt%
S:2.90wt%
V:69wtppm
1
41wt%
S:0.79wt%
M1
2
19wt%
GASOLINE, KEROSENE, GAS OIL
19.7wt%
S:0.05wt%
M3'
20.0wt%
S:0.05wt%
M3
23
GTF
35wt%
S:0.28wt%
V:0.42wtppm
15wt%
M2
58.5wt%
S:4.72wt%
V:117wtppm
20
28.2wt%
S:3.37wt%
V:1.5wtppm
M11
22
M15
44wt%
S:0.6wt%
V:1.0wtppm
FEED FOR FCC, HCR
29wt%
S:0.6wt%
V:1.0wtppm
M12
30.6wt%
S:6.04wt%
V:223wtppm
M13
18.4wt%
S:4.62wt%
V:22wtppm
21
M14A
12.2wt%
22
FEED FOR FCC, HCR

FIG. 10

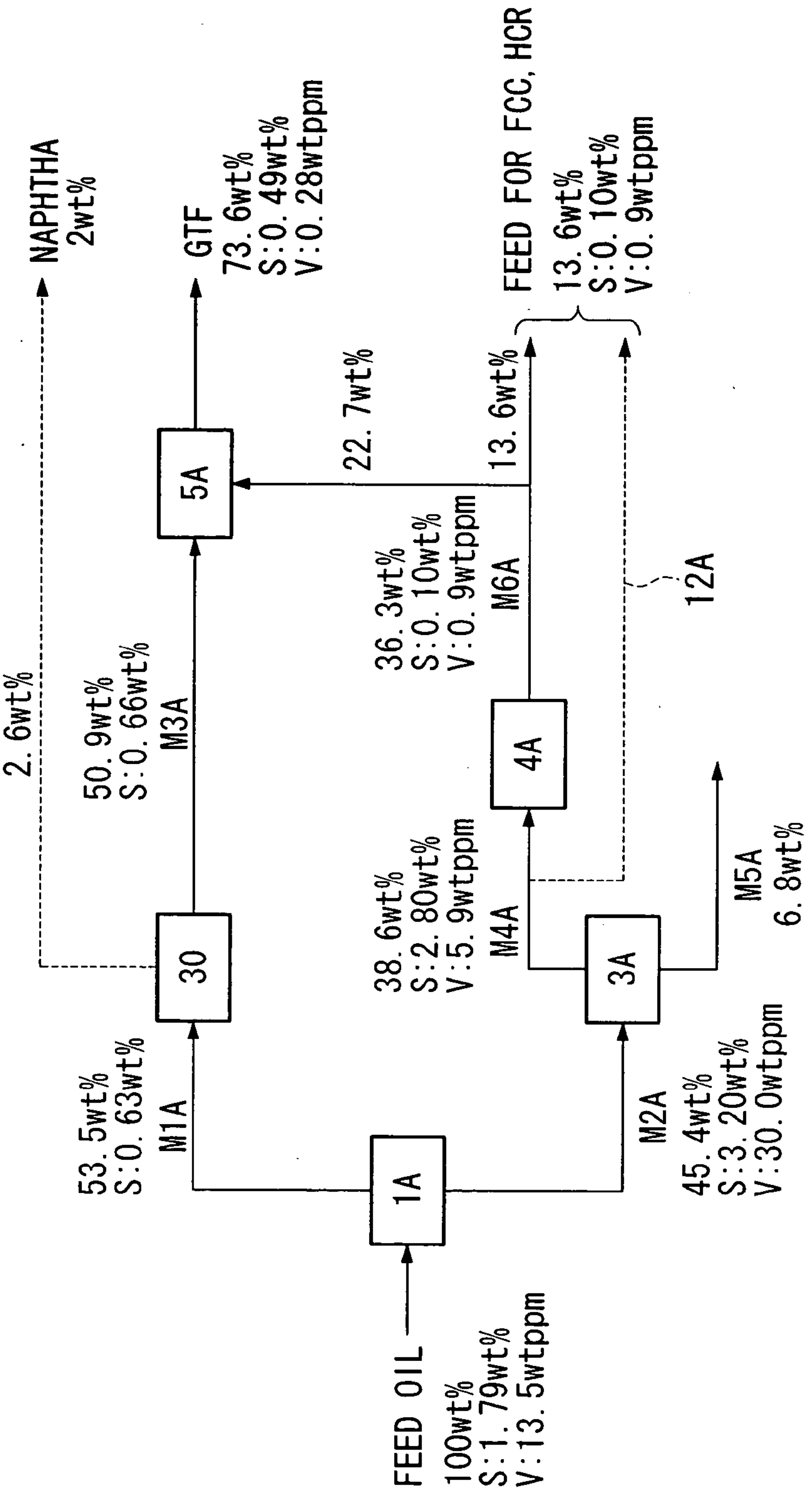

FEED OIL
100wt%
S:1. 79wt%
V:13. 5wtppm
1A
53. 5wt%
S:0. 63wt%
M1A
M2A
45. 4wt%
S:3. 20wt%
V:30. 0wtppm
30
3A
M3A′
2. 6wt%
50. 9wt%
S:0. 66wt%
M3A
38. 6wt%
S:2. 80wt%
V:5. 9wtppm
M4A
M5A
6. 8wt%
4A
36. 3wt%
S:0. 10wt%
V:0. 9wtppm
M6A
12A
5A
22. 7wt%
13. 6wt%
NAPHTHA
2wt%
GTF
73. 6wt%
S:0. 49wt%
V:0. 28wtppm
FEED FOR FCC, HCR
13. 6wt%
S:0. 10wt%
V:0. 9wtppm

FIG. 11

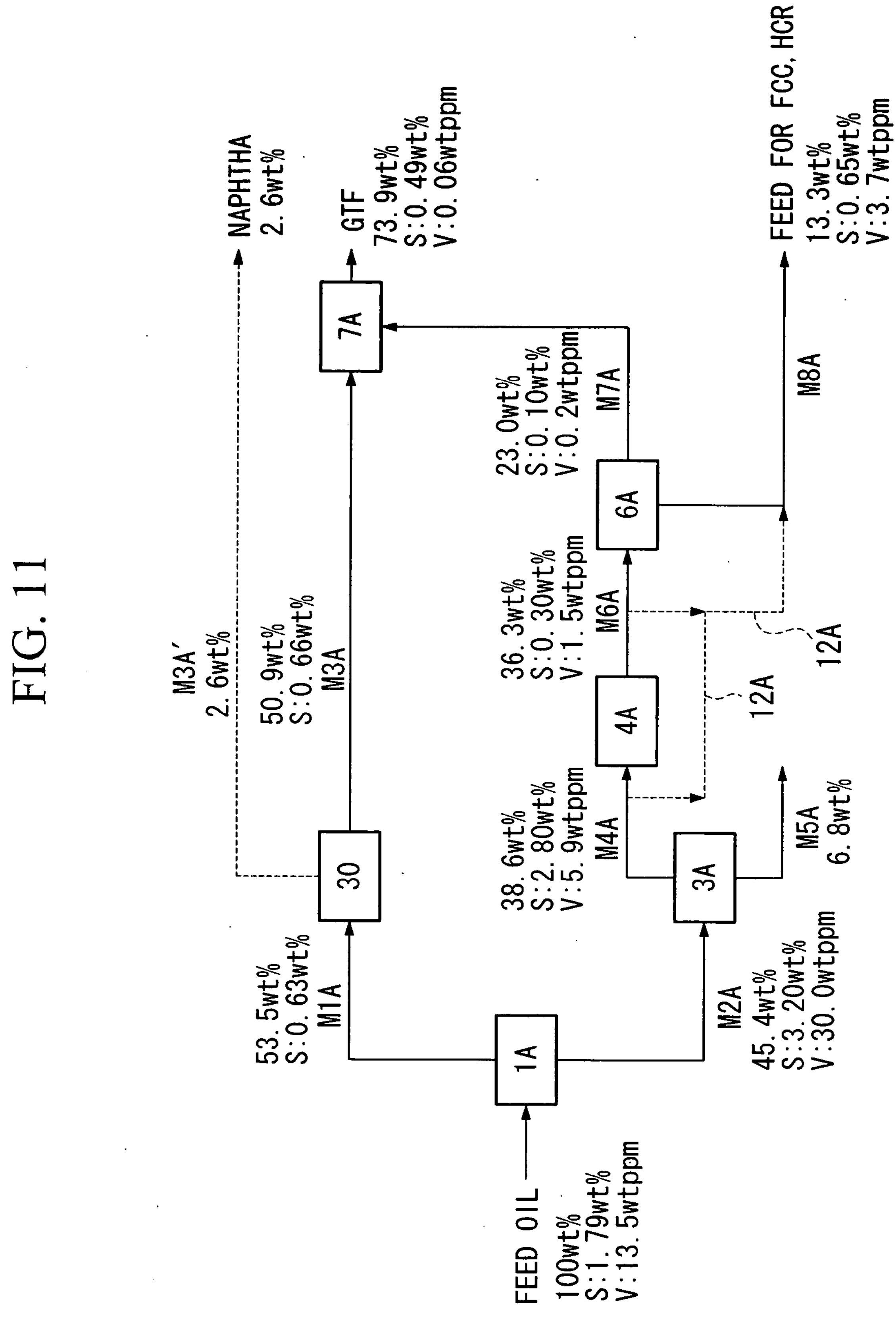
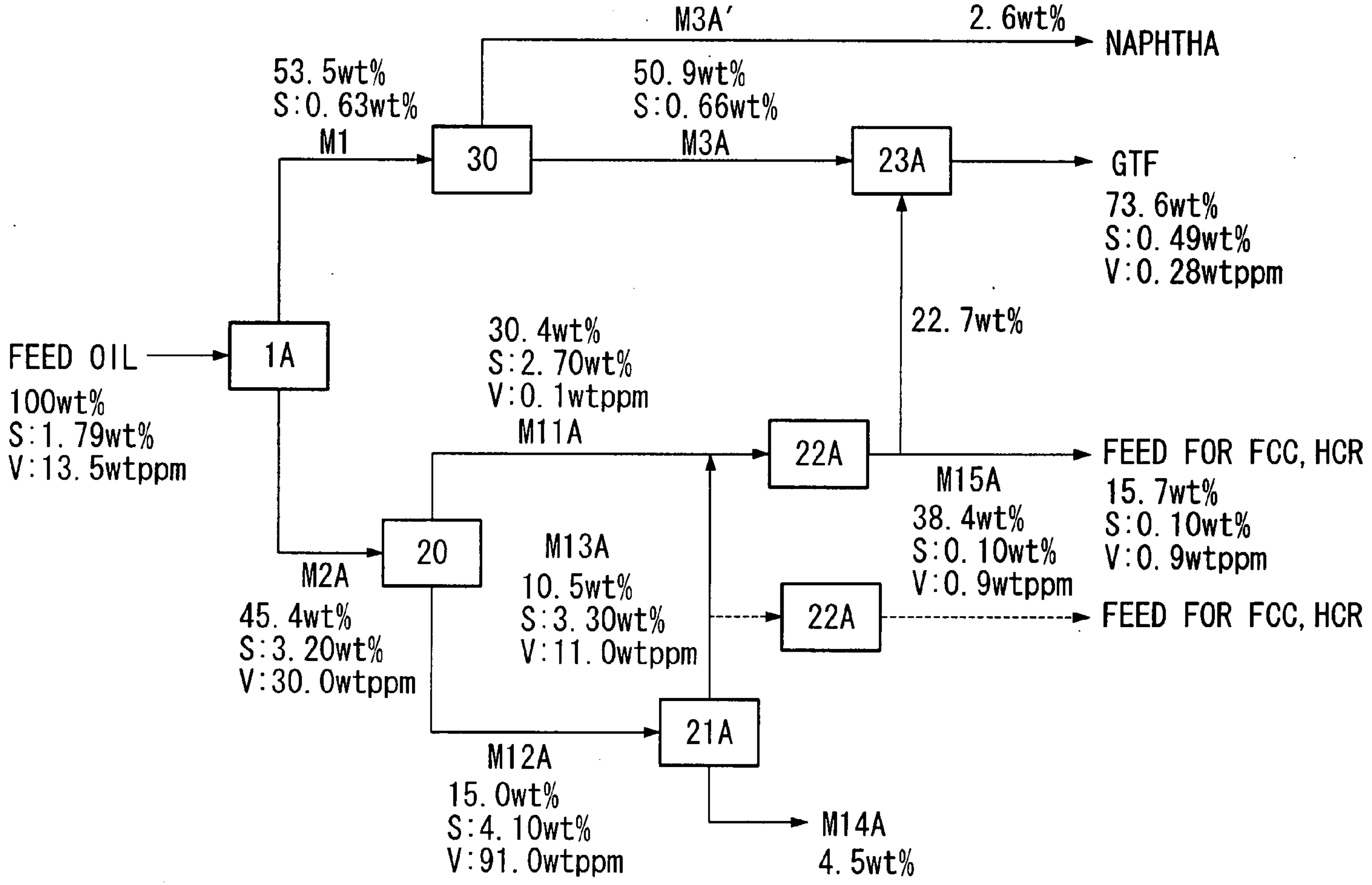

FEED OIL
100wt%
S:1.79wt%
V:13.5wtppm
1A
53.5wt%
S:0.63wt%
M1A
45.4wt%
S:3.20wt%
V:30.0wtppm
M2A
30
M3A′
2.6wt%
50.9wt%
S:0.66wt%
M3A
NAPHTHA
2.6wt%
3A
38.6wt%
S:2.80wt%
V:5.9wtppm
M4A
M5A
6.8wt%
4A
12A
36.3wt%
S:0.30wt%
V:1.5wtppm
M6A
12A
6A
23.0wt%
S:0.10wt%
V:0.2wtppm
M7A
7A
GTF
73.9wt%
S:0.49wt%
V:0.06wtppm
M8A
FEED FOR FCC, HCR
13.3wt%
S:0.65wt%
V:3.7wtppm

FIG. 12


FEED OIL
100wt%
S:1. 79wt%
V:13. 5wtppm
1A
53. 5wt%
S:0. 63wt%
M1
30
M3A′
2. 6wt%
NAPHTHA
50. 9wt%
S:0. 66wt%
M3A
23A
GTF
73. 6wt%
S:0. 49wt%
V:0. 28wtppm
22. 7wt%
M2A
45. 4wt%
S:3. 20wt%
V:30. 0wtppm
20
30. 4wt%
S:2. 70wt%
V:0. 1wtppm
M11A
22A
M15A
38. 4wt%
S:0. 10wt%
V:0. 9wtppm
FEED FOR FCC, HCR
15. 7wt%
S:0. 10wt%
V:0. 9wtppm
M13A
10. 5wt%
S:3. 30wt%
V:11. 0wtppm
22A
FEED FOR FCC, HCR
M12A
15. 0wt%
S:4. 10wt%
V:91. 0wtppm
21A
M14A
4. 5wt%

METHOD OF REFINING PETROLEUM

TECHNICAL FIELD

[**0001**] The present invention relates to an oil refining method for producing a plurality of oil products of high added value with a high efficiency, and more particularly, to an oil refining method for producing a plurality of oil products of high added value that have different specifications with a high efficiency from a heavy feed oil or a low sulfur oil.

BACKGROUND ART

[**0002**] Technologies of this type known in the prior art include the following technologies that are capable of efficiently producing oil products and intermediate products used for producing the same:

> [**0003**] (1) A technology for producing thermally cracked gasoline and gas oil by separating a feed oil into distillate and atmospheric residue through atmospheric distillation, distilling the atmospheric residue in a vacuum and processing the vacuum residue (VR) in a coker; and
>
> [**0004**] (2) A technology that applies solvent deasphalting (SDA) to the atmospheric residue and uses deasphalted oil (DAO) thus obtained as a feed for a fluid catalytic cracking (FCC) process, or applies vacuum distillation (VDU) to the atmospheric residue and uses vacuum gas oil (VGO) thus obtained as a feed for fluid catalytic cracking (FCC) process.

[**0005**] However, the technology (1) described above faces the problem that the market for coker bottom (coke) is pressured by over supply that hinders the construction of cokers which produce coke as a byproduct.

[**0006**] The technology (2) described above has such a problem as described below. Fuels for transportation such as gasoline and gas oil can be produced by separating deasphalted oil and vacuum gas oil from ultra heavy crude that is found in vast amount of reserves or atmospheric residue of which an over supply is expected in the future, and processing the deasphalted oil or vacuum gas oil by fluid catalytic cracking (FCC) or hydrocracking (HCR) process. But this scheme would cause supply-demand imbalance in the market of fuels for transportation and power generation, since a higher increase in the demand for electricity over the demand increase for gasoline and gas oil is expected world over.

[**0007**] Besides the technologies (1) and (2) described above, there is such a technology of producing gas turbine fuel (GTF) from ultra heavy crude that includes much vanadium (V) content or from atmospheric residue through solvent deasphalting process. However, this technology also has the problem that increasing the yield (extraction rate) of producing the deasphalted oil in the solvent deasphalting process leads to higher contamination of the deasphalted oil product by metals and/or residual carbon. This results in increased process load (higher pressure, low LHSV) when refining the deasphalted oil by demetalization and desulfurization, thus making this method economically disadvantageous. When the yield of deasphalted oil production is lowered to circumvent the problem described above, the yield of the gas turbine fuel produced decreases, leading to the new problem of increased production of asphaltene (pitch) that has lower added value.

[**0008**] An object of the present invention is to provide a method of refining oil for producing oil products (for example, gas turbine fuel) that includes a vanadium (V) content of 0.5 wt ppm or lower and intermediate oil products having metal content (V+Ni) of 30 wt ppm or lower that can be used as the feed for a fluid catalytic cracking (FCC) or a hydrocracking (HCR) process efficiently at the same time, whether a particularly heavy feed oil or a feed oil having a low sulfur content is used as the starting material.

DISCLOSURE OF THE INVENTION

[**0009**] A method for refining oil according to the first aspect of the present invention is a method for producing oil products including a plurality of intermediate oil products by refining a feed oil, comprising a fractional distillation process for separating the feed oil into distillate and a residue through distillation; a hydrorefining process wherein at least a part of the distillate obtained in the fractional distillation process is refined and desulfurized by hydrogenation in the presence of hydrogen and a catalyst thereby to obtain a hydrorefined oil; a solvent deasphalting process wherein the residue is deasphalted with a solvent thereby to obtain deasphalted oil as an extract and asphaltene (pitch) as the residue; a hydrodemetalizating/desulfurizing process wherein at least a part of the deasphalted oil is demetalized and desulfurized by hydrogenation in the presence of hydrogen and a catalyst thereby to obtain HDMS refined oil that has been demetalized and desulfurized; and a first mixing process wherein a part of the HDMS refined oil and at least a part of the hydrorefined oil are mixed in order to produce one of the oil products.

[**0010**] According to this refining method, since at least a part of the hydrorefined oil is mixed with a part of the HDMS refined oil in the first mixing process, it is possible to obtain an oil product that has a sufficiently low vanadium (V) content such as gas turbine fuel, and also to produce intermediate oil products having a relatively low metal content (V+Ni) that can be used as the feed for fluid catalytic cracking (FCC) or a hydrocracking (HCR) process from the remainder of the HDMS refined oil.

[**0011**] Since the intermediate oil product used as the feed for a fluid catalytic cracking or a hydrocracking process has more lenient tolerance for metal contents than gas turbine fuel or the like does, the yield of deasphalted oil produced in the solvent deasphalting process can be improved by producing the gas turbine fuel and the feed for a fluid catalytic cracking or a hydrocracking process at the same time, thereby suppressing the production of asphaltene (pitch) from the atmospheric residue.

[**0012**] A method for refining oil according to the second aspect of the present invention comprises a fractional distillation process for separating the feed oil into a distillate and a residue through distillation; a hydrorefining process wherein at least a part of the distillate obtained in the fractional distillation process is refined and desulfurized through hydrogenation in the presence of hydrogen and a catalyst thereby to obtain a hydrorefined oil; a solvent deasphalting process wherein the residue is deasphalted with a solvent thereby to obtain deasphalted oil as an extract and asphaltene (pitch) as the residue; a hydrodemetalizating/

desulfurizing process wherein at least a part of the deasphalted oil is demetalized and desulfurized through hydrogenation in the presence of hydrogen and a catalyst thereby to obtain HDMS refined oil that has been demetalized and desulfurized; a vacuum fractional distillation process wherein the HDMS refined oil is distilled in a vacuum and separated into vacuum gas oil and vacuum residue; and a second mixing process wherein at least a part of the vacuum gas oil and at least a part of the hydrorefined oil are mixed thereby to produce one of the oil products.

[0013] According to this refining method described above, since at least a part of the vacuum gas oil and at least a part of the hydrorefined oil are mixed in the second mixing process, oil products can be obtained that have a sufficiently low vanadium (V) content such as gas turbine fuel. It is also possible to obtain an intermediate oil product having a relatively low metal content (V+Ni) that can be used as the feed for a fluid catalytic cracking or a hydrocracking process from the remainder of vacuum gas oil or the vacuum residue obtained by vacuum distillation, and even from the HDMS refined oil.

[0014] Also because the HDMS refined oil is subjected to a vacuum fractional distillation process to be separated into vacuum gas oil and vacuum residue having low metal content and residual carbon content by making use of the range of boiling points of the distillation properties particularly in the vacuum fractional distillation process, relatively high concentrations of vanadium and metals can be allowed for the HDMS refined oil, thus improving the yield of deasphalted oil in the solvent deasphalting process, and therefore it is possible to suppress the production of asphaltene (pitch) from the atmospheric residue.

[0015] A method for refining oil according to the third aspect of the present invention comprises a fractional distillation process for separating the feed oil into distillate and a residue through distillation; a hydrorefining process wherein at least a part of the distillate obtained in the fractional distillation process is refined and desulfurized through hydrogenation in the presence of hydrogen and a catalyst thereby to obtain a hydrorefined oil; a vacuum fractional distillation process wherein the residue is distilled in a vacuum and separated into vacuum gas oil and vacuum residue; a solvent deasphalting process wherein the vacuum residue is deasphalted with a solvent thereby to obtain deasphalted oil as an extract and asphaltene (pitch) as the residue; a hydrodemetalizating/desulfurizing process wherein the vacuum gas oil and deasphalted oil are mixed and the mixture is subjected to hydrodemetalizating/desulfurizing process in the presence of hydrogen and a catalyst thereby to obtain HDMS refined oil that is demetalized and desulfurixed; and a third mixing process wherein a part of the HDMS refined oil and at least a part of the hydrorefined oil are mixed thereby to produce one of the oil products.

[0016] According to this refining method, since a part of the HDMS refined oil and at least a part of the hydrorefined oil are mixed in the third mixing process, the vanadium (V) content of the mixed oil thus obtained is decreased sufficiently and it is possible to obtain an oil product used as gas turbine fuel. It is also possible to obtain an intermediate oil product having a relatively low metal content (V+Ni) that can be used as the feed for a fluid catalytic cracking or a hydrocracking process even from the remainder of the HDMS refined oil obtained by processing the mixture of the vacuum gas oil and deasphalted oil in the hydrodemetalizating/desulfurizing process.

[0017] Since the intermediate oil product used as the feed for a fluid catalytic cracking or a hydrocracking process has a higher tolerable concentrations of metal contents than those of gas turbine fuel or the like, the yield of the deasphalted oil in the solvent deasphalting process can be improved by producing the gas turbine fuel and the feed for a fluid catalytic cracking or a hydrocracking process at the same time, thereby suppressing the production of asphaltene (pitch) from the atmospheric residue.

[0018] In case the present invention is applied to a heavy oil having an API gravity of 20 or lower, the amount of pitch produced can be made lower than in the prior art, in which a large quantity of pitch that has a low commodity value generated as a byproduct, and the yield of producing a plurality of oil products having a high added values is improved, thus resulting in a greatly improved productivity.

[0019] A method for refining oil according to the fourth aspect of the present invention is a method for producing oil products including a plurality of intermediate oil products by refining a feed oil that includes low sulfur content, and comprises a fractional distillation process for separating the feed oil into distillate and a residue through distillation; a solvent deasphalting process wherein the residue obtained in the fractional distillation process is deasphalted with a solvent thereby to obtain deasphalted oil as an extract and asphaltene (pitch) as the residue; a hydrodemetalizating/desulfurizing process wherein at least a part of the deasphalted oil is demetalized and desulfurized through hydrogenation in the presence of hydrogen and a catalyst thereby to obtain HDMS refined oil that has been demetalized and desulfurized; and a fourth mixing process wherein a part of the HDMS refined oil and at least a part of the distillate are mixed thereby to produce one of the oil products.

[0020] According to this refining method, since a part of the HDMS refined oil and at least a part of the hydrorefined oil are mixed in the fourth mixing process, it is possible to obtain an oil product such as gas turbine fuel that has a sufficiently low vanadium (V) content. It is also possible to obtain an intermediate oil product having low metal content (V+Ni) that can be used as the feed for a fluid catalytic cracking or a hydrocracking process from the remainder of the HDMS refined oil.

[0021] Since the intermediate oil product used as the feed for a fluid catalytic cracking or a hydrocracking process has a higher tolerable concentrations of metal contents than that of gas turbine fuel or the like, the yield of deasphalted oil produced in the solvent deasphalting process can be improved by producing the gas turbine fuel and the feed for a fluid catalytic cracking or a hydrocracking process at the same time, thereby suppressing the production of asphaltene (pitch) from the atmospheric residue.

[0022] A oil refining method according to the fifth aspect of the invention comprises a fractional distillation process for separating the feed oil into distillate and a residue through distillation; a solvent deasphalting process wherein the residue obtained in the fractional distillation process is deasphalted with a solvent thereby to obtain deasphalted oil as an extract and asphaltene (pitch) as the residue; a hydrodemetalizating/desulfurizing process wherein at least a part of the deasphalted oil is demetalized and desulfurized by hydrogenation in the presence of hydrogen and a catalyst thereby to obtain HDMS refined oil that has been demetalized and desulfurized; a vacuum fractional distillation process wherein the HDMS refined oil is distilled in a vacuum and separated into vacuum gas oil and vacuum residue; and a fifth mixing process wherein at least a part of the vacuum gas oil and at least a part of the distillate are mixed in order to produce one of the oil products.

[**0023**] According to this refining method, since at least a part of the vacuum gas oil and at least a part of the distillate are mixed in the fifth mixing process, it is possible to obtain an oil product that has a sufficiently low vanadium (V) content such as gas turbine fuel. It is also possible to produce an intermediate petroleum product, that has relatively low metal content (V+Ni) and can be used as the feed for a fluid catalytic cracking or a hydrocracking process, from the remainder of the vacuum gas oil or the vacuum residue obtained by vacuum distillation process, and even from the HDMS refined oil.

[**0024**] Also, the HDMS refined oil is subjected to vacuum distillation so as to separate into vacuum gas oil and vacuum residue having low metal content and residual carbon content by making use of the range of boiling points of the distillation properties particularly in the vacuum fractional distillation process, thus relatively high concentrations of vanadium and metals can be allowed for the HDMS refined oil, thereby improving the yield of deasphalted oil in the solvent deasphalting process, and therefore it is possible to suppress the production of asphaltene (pitch) from the atmospheric residue.

[**0025**] A oil refining method of the sixth aspect of the present invention comprises a fractional distillation process for separating the feed oil into distillate and a residue through distillation; a vacuum fractional distillation process wherein the residue obtained in the fractional distillation process is distilled in a vacuum and separated into vacuum gas oil and vacuum residue; a solvent deasphalting process wherein the vacuum residue is deasphalted with a solvent thereby to obtain deasphalted oil as an extract and asphaltene (pitch) as the residue; a hydrodemetalizating/desulfurizing process wherein the vacuum gas oil and the deasphalted oil are mixed and the mixture is demetalized and desulfurized by hydrogenation in the presence of hydrogen and a catalyst thereby to obtain HDMS refined oil that has been demetalized and desulfurized; and a sixth mixing process wherein a part of the HDMS refined oil and at least a part of the distillate are mixed thereby to produce one of the oil products.

[**0026**] According to this refining method, since a part of the HDMS refined oil and at least a part of the distillate are mixed in the sixth mixing process, the vanadium (V) content of the mixed oil becomes sufficiently low and it is possible to obtain an oil product that can be used as gas turbine fuel. It is also possible to produce an intermediate oil product having sufficiently low metal content (V+Ni) that can be used as the feed for a fluid catalytic cracking or a hydrocracking process even from the remainder of HDMS refined oil that is obtained by processing the mixture of vacuum gas oil and deasphalted oil in the hydrodemetalizating/desulfurizing process.

[**0027**] Since the intermediate oil product used as the feed for a fluid catalytic cracking or a hydrocracking process has a higher tolerable concentration of metal contents than that of gas turbine fuel or the like, the yield of deasphalted oil produced in the solvent deasphalting process can be improved by producing the gas turbine fuel and the feed for a fluid catalytic cracking or a hydrocracking process at the same time, thereby suppressing the production of asphaltene (pitch) from the vacuum residue.

[**0028**] When the method of one of fourth through sixth aspects of the invention is applied to a crude oil having low sulfur content of 2.0 wt % or lower, the amount of pitch produced can be made less than in the prior art where a large quantity of pitch that has low commodity value is produced, thus improving the yield of a plurality of oil products having a high added values, resulting in greatly improved productivity.

BRIEF DESCRIPTION OF THE DRAWINGS

[**0029**] **FIG. 1** through **FIG. 6** are process flow diagrams explaining the first through sixth embodiments of the oil refining method according to the present invention.

[**0030**] **FIG. 7** through **FIG. 12** are process flow diagrams explaining the oil refining methods of the first through sixth experimental examples.

BEST MODE FOR CARRYING OUT THE INVENTION

[**0031**] Now preferred embodiments of the oil refining method according to the present invention will be described below with reference to the accompanying drawings. It should be understood, however, that the present invention is not limited to the embodiments described below and, for example, any combination of components of these embodiments is deemed to fall within the scope of the present invention.

[**0032**] **FIG. 1** is a process flow diagram explaining an embodiment of the oil refining method according to the present invention, wherein a heavy crude oil is used as feed oil from which gas turbine fuel (GTF) and a feed for fluid catalytic cracking (FCC) process or a feed for hydrocracking (HCR) process are produced at the same time.

[**0033**] There is no limitation to the feed oil to be processed, and any hydrocarbon oil ranging from crude oil to heavy oil can be used. The description that follows will deal with cases where the present invention is applied to heavy crude oil such as Orinoco tar, particularly to heavy oils having an API gravity not higher than 20 while achieving a remarkable effect of improving the yield of producing a plurality of oil products having a high added values.

[**0034**] API gravity is an index for classifying crude oils by the physical properties thereof, and is calculated from the specific gravity by the following formula, where S is the specific gravity at 60 degrees Fahrenheit.

$$\mathrm{API}=(141.5/S)-131.5$$

[**0035**] According to the method of this example where the heavy crude oil described above is used as the feed oil, the feed oil is first subjected to fractional distillation process **1** to separate into a distillate M1 consisting of low-boiling point oil and a residue M2 of high boiling point by distilling similarly to the prior art. While a topper, which is a commonly used atmospheric distillation apparatus, is preferably used as the fractional distillation apparatus of this example, there is no limitation to the apparatus as long as it is means for fractional distillation. Distillates may be either collectively recovered without classifying, or recovered individually after classifying by the boiling point. In case distillates are recovered in a plurality of classes and some class of the distillate satisfies the specification requirements for petroleum, the hydrorefining process **2** that would follow may be omitted or bypassed as indicated by arrow **11**.

[**0036**] Then at least a part of the distillate M1 obtained in the fractional distillation process **1** is introduced into the hydrorefining process (HT process) **2** to be refined and desulfurized by hydrogenation in the presence of hydrogen and a catalyst, thereby producing hydrorefined oils M3, M3'.

[**0037**] In the hydrorefining process of the distillate M1, hydrogen gas is mixed with the distillate M1 and the mixture is introduced into a reactor filled with a CoMo catalyst or a NiMo catalyst where sulfur and nitrogen contents included in the distillate M1 are removed by hydrogenation in the presence of hydrogen under a high pressure, followed by the separation of hydrogen gas in a high-pressure separator thereby to obtain the hydrorefined oils M3, M3'.

[**0038**] Apart from the hydrorefining process **2**, the residue M2 obtained in the fractional distillation process **1** is introduced into the solvent deasphalting process (SDA process) **3** to be deasphalted with a solvent, thereby to obtain deasphalted oil (DAO) M4 as an extract and asphaltene (pitch) M5.

[**0039**] In the solvent deasphalting process, the residue M2 is put into contact with the solvent in counterflow in a solvent extraction tower and is separated into deasphalted oil and asphaltene (pitch) that includes metals and residual carbon in high concentrations. The deasphalted oil is recovered together with the solvent through the top of the tower, and the solvent is separated from the recovered material in super-critical state. Asphaltene (pitch) is recovered together with the solvent through the bottom of the tower, and the solvent in the recovered material is removed by evaporation.

[**0040**] It is known that, in solvent deasphalting process in general, the extraction ratio of deasphalted oil from the feed oil varies among components included in the deasphalted oil such as sulfur, vanadium, nitrogen and residual carbon. According to the present invention, in case the residue obtained by fractional distillation of heavy oil is used as the feed oil, the extraction ratio for the vanadium content included in the deasphalted oil to the vanadium content included in the feed oil is preferably controlled to within 20% when the atmosphere distilled residue is used as the feed oil, or within 15% when the vacuum distilled residue is used as the feed oil. There is not a specific lower limit to the extraction ratio in either case, and the extraction ratio may be in a range appropriately selected in accordance to the type of feed oil and the vanadium content. In case the residue obtained by fractional distillation of low-sulfur feed oil including a sulfur content of 2.0 wt % or lower is used as the feed oil, the vanadium content included in the deasphalted oil is preferably controlled to within 25 wt ppm when atmosphere distilled residue is used as the feed oil, or within 70 wt ppm when vacuum distilled residue is used as the feed oil.

[**0041**] According to the present invention, refined oil can be produced efficiently with the extraction ratio in the solvent deasphalting process being maximized, without placing a significant load on the hydrodemetalizating/desulfurizing process that follows the solvent deasphalting process, in either of the cases described above.

[**0042**] In case the refining process that follows the solvent deasphalting process **3** includes only the hydrodemetalizating/desulfurizing process **4**, it is preferable to control the extraction rate of the solvent deasphalting process **3** so that the extraction ratio for the vanadium content included in the deasphalted oil M4 to the vanadium (V) content included in the residue M2 used as the feed oil is 20% or lower.

[**0043**] At least a part of the deasphalted oil M4 obtained in the solvent deasphalting process **3** is introduced into the hydrodemetalizating/desulfurizing process (HDMS process) **4**, wherein the deasphalted oil is demetalized and desulfurized by hydrogenation in the presence of hydrogen and a catalyst thereby to obtain HDMS refined oil that has been demetalized and desulfurized. The hydrodemetalizating/desulfurizing process is basically the same as the hydrorefining process **2** described previously, and the description thereof will be omitted.

[**0044**] The demetalizing and desulfurizing conditions for the HDMS refined oil M6 obtained in the hydrodemetalizating/desulfurizing process are preferably selected so as to achieve the vanadium (V) content of 2 wt ppm or lower, preferably 1 wt ppm or lower, and a sulfur content of 0.5 wt % or lower, preferably 0.3 wt % or lower.

[**0045**] Then a part of the HDMS refined oil M6 obtained in the hydrodemetalizating/desulfurizing process **4** and at least part of the hydrorefined oil M3 obtained in the hydrorefining process **2** are mixed in the first mixing process **5** thereby to obtain a petroleum product.

[**0046**] In order to produce gas turbine fuel (GTF) as the oil product obtained in the first mixing process **5**, mixing condition is set so as to achieve the vanadium (V) content of 0.5 wt ppm or lower. In this case, when the vanadium content of the HDMS refined oil M6 is assumed to be 1 wt ppm, for example, rate of the HDMS refined oil M6 to the hydrorefined oil M3 is set to 1:1 or less (that is, a smaller proportion of the HDMS refined oil M6) in volume proportion for mixing, with the vanadium content in the hydrorefined oil M3 being set to 0 wt ppm.

[**0047**] Of the HDMS refined oil M6 obtained in the hydrodemetalizating/desulfurizing process **4**, the remainder that is not subjected to the first mixing process **5** is used as an intermediate oil product to be used as the feed for the fluid catalytic cracking (FCC) process or the hydrocracking (HCR) process. Of the hydrorefined oil M3, the remainder that is not subjected to the first mixing process **5** may be used as oil product M3' such as naphtha, gasoline, kerosene, or gas oil.

[**0048**] According to the oil refining method described above, since a part of the HDMS refined oil M6 and at least a part of the hydrorefined oil M3 are mixed, it is possible to obtain an oil product that has a sufficiently low vanadium (V) content, such as gas turbine fuel. It is also possible to produce an intermediate oil product having relatively low metal content (V+Ni) that can be used as the feed for fluid catalytic cracking (FCC) or hydrocracking (HCR) process, from the remainder of HDMS refined oil M6 and therefore a plurality of oil products having a high added values can be produced efficiently at the same time.

[**0049**] Since the intermediate oil product used as the feed for fluid catalytic cracking (FCC) or hydrocracking (HCR) process has a higher tolerable concentrations of metal contents than that of gas turbine fuel (GTF) or the like, the yield of deasphalted oil M4 produced in the solvent deasphalting process **3** can be improved without accompanying a load of hydrodemetalizating/desulfurizing process, thereby suppressing the production of asphaltene (pitch) M5 from the residue M2.

[**0050**] Now referring to the process flow diagram of **FIG. 1**, in case the deasphalted oil M4 obtained in the solvent deasphalting process **3** includes relatively low concentrations of metals and sulfur, and is mixed with a part of the HDMS refined oil that includes further lower concentrations of metals and sulfur so that the requirements for the feed stock properties for fluid catalyst cracking (FCC) or hydrocracking (HCR) process are satisfied, a part thereof may be sent through the bypass shown by reference numeral **12** in **FIG. 1** to be mixed with a part of the HDMS refined oil M6, instead of being subjected to the hydrodemetalizating/desulfurizing process **4**, thereby to produce intermediate oil products used as the feed for fluid catalytic cracking (FCC) process or the feed for hydrocracking (HCR) process.

[**0051**] [Second Embodiment]

[**0052**] **FIG. 2** is a process flow diagram explaining the second embodiment of the oil refining method according to the present invention, wherein gas turbine fuel (GTF) and feed for fluid catalytic cracking (FCC) process or feed for hydrocracking (HCR) process are produced at the same time from a feed oil, similarly to the first embodiment shown in **FIG. 1**.

[**0053**] The second embodiment is different from the first embodiment shown in **FIG. 1** mainly in that a vacuum fractional distillation process **6** is provided to follow the hydrodemetalizating/desulfurizing process **4**, so as to process the HDMS refined oil M6 that has been obtained in a vacuum distillation and separate it into vacuum gas oil M7 and vacuum residue M8 through a vacuum distillation process. In other words, with the oil refining method shown in **FIG. 2**, the HDMS refined oil M6 obtained similarly to the example shown in **FIG. 1** is distilled in a vacuum in the vacuum fractional distillation process **6**.

[**0054**] In the vacuum fractional distillation process, the HDMS refined oil M6 is introduced into a vacuum distillation tower where the HDMS refined oil M6 is distilled and separated into a low-boiling point component and a high-boiling point component, while the vacuum gas oil M7 having low boiling point is obtained from the top of the tower and the vacuum residue M8 having a high boiling point is obtained from the bottom of the tower.

[**0055**] Since the vacuum fractional distillation process described above is applied, extraction ratio for the vanadium content included in the deasphalted oil M4 to the vanadium (V) content included in the residue M2 used as the feed oil is 30% or lower. This makes it possible to improve the yield of the oil products without applying a large load of a hydrodemetalizating/desulfurizing process.

[**0056**] The demetalizing and desulfurizing conditions for the HDMS refined oil M6 obtained by hydrodemetalizating/desulfurizing process of the deasphalted oil M4 are selected so as to control the vanadium (V) content of the HDMS refined oil M6 to 20 wt ppm or lower, preferably 10 wt ppm or lower, and the sulfur content is desirably controlled to 0.5 wt % or lower, preferably 0.3 wt % or lower.

[**0057**] Moreover, it is desirable to set the vanadium content of the vacuum gas oil obtained by vacuum distillation of the HDMS refined oil M6 to 1 wt ppm or lower.

[**0058**] Following the process described above, at least a part of the vacuum gas oil M7 obtained in the vacuum fractional distillation process **6** and at least a part of the hydrorefined oil M3 obtained in the hydrorefining process **2** are mixed in the second mixing process **7** thereby to obtain one of the oil products.

[**0059**] In order to produce gas turbine fuel (GTF) as the oil product obtained in the second mixing process **7**, the mixing condition is set so as to achieve the vanadium (V) content of 0.5 wt ppm or lower similarly to the example shown in **FIG. 1**. In this case, the mix proportion is properly adjusted according to the vanadium content of the vacuum gas oil M7 similarly to the previous example. When vanadium (V) content of the vacuum gas oil M7 is 0.5 wt ppm or lower, this may be used as gas turbine fuel (GTF) without adding the hydrorefined oil M3 thereto.

[**0060**] The remainder of the vacuum gas oil M7, the vacuum residue M8 obtained by vacuum distillation, and remainder of the HDMS refined oil M6 that is not fed to the vacuum fractional distillation process **6** are used individually or in an appropriate combination thereof thereby to provide an intermediate oil product used as the feed for fluid catalytic cracking (FCC) process or the feed for hydrocracking (HCR) process.

[**0061**] With the oil refining method described above, since the HDMS refined oil M6 is subjected to vacuum distillation and is separated into the vacuum gas oil M7 and the vacuum residue M8 that include no significant metal content or residual carbon content, by making use of the range of boiling points of the distillation properties in the vacuum fractional distillation process **6**, relatively high concentrations of vanadium, metals and residual carbon can be allowed for the HDMS refined oil M6 itself, thus improving the yield of deasphalted oil M4 in the solvent deasphalting process **3**, and therefore it is possible to suppress the production of asphaltene (pitch) M5 from the residue M2.

[**0062**] With regard to the deasphalted oil M4 obtained in the solvent deasphalting process **3**, too, in case the vanadium (V) content of M4 is sufficiently low, a part of the M4 may be introduced into the bypass **12** to be mixed with a part of the vacuum residue M8 sent from the vacuum fractional distillation process **6**, instead of being subjected to the hydrodemetalizating/desulfurizing process **4**, thereby to produce intermediate oil products used as the feed for fluid catalytic cracking (FCC) or hydrocracking (HCR) process. The HDMS refined oil M6 obtained in the hydrodemetalizating/desulfurizing process **4** may also be introduced into the bypass **12** to be mixed with the vacuum residue M8 sent from the vacuum fractional distillation process **6** thereby to produce intermediate oil products used as the feed for fluid catalytic cracking (FCC) or hydrocracking (HCR) process.

[**0063**] [Third Embodiment]

[**0064**] **FIG. 3** is a process flow diagram explaining the third embodiment of the present invention, wherein gas turbine fuel (GTF) and feed for fluid catalytic cracking (FCC) or hydrocracking (HCR) process are produced at the same time from a feed oil, similarly to the example shown in **FIG. 1**.

[**0065**] The third embodiment is different from the first embodiment shown in **FIG. 1** mainly in that fractional distillation process **1** is followed by a vacuum fractional distillation process **20** wherein the residue M2 is separated into vacuum gas oil M11 and vacuum residue M12 by vacuum distillation, a solvent deasphalting process **21** wherein the vacuum residue M12 is separated into deasphalted oil M13 and asphaltene (pitch) M14 by solvent deasphalting, and a hydrodemetalizating/desulfurizing process **22** wherein a mixture of the deasphalted oil M13 and the vacuum gas oil M11 is subjected to hydrodemetalizating/desulfurizing process thereby to produce HDMS refined oil M15 .

[**0066**] With the oil refining method shown in **FIG. 3**, the residue M2 obtained similarly to the example shown in **FIG. 1** is distilled in a vacuum in the vacuum fractional distillation process **20**.

[**0067**] In the vacuum fractional distillation process, the residue M2 is introduced into a vacuum distillation tower where the residue M2 is distilled and separated into a low-boiling point component and a high-boiling point component, while the vacuum gas oil M11 having the lower boiling point is obtained from the top of the tower and the vacuum residue M12 having the higher boiling point is obtained from the bottom of the tower.

[**0068**] Following the vacuum fractional distillation process **20**, the vacuum residue M12 thus obtained is subjected to the solvent deasphalting process **21** and is separated into deasphalted oil M13 and asphaltene (pitch) M14 . Although the solvent deasphalting process is similar to those in the examples shown in **FIG. 1** and **FIG. 2**, the desirable upper limit of the extraction ratio of vanadium for the deasphalted oil M13 obtained from the vacuum residue by solvent deasphalting process becomes lower in correspondence to the concentrations of metals, residual carbon and sulfur that are higher than those of the residue M2, and therefore the extraction ratio is preferably controlled to 15%.

[**0069**] Then the deasphalted oil M13 and the vacuum gas oil M11 thus obtained are mixed and the mixture is subjected to the hydrodemetalizating/desulfurizing process, thereby to obtain the HDMS refined oil M15 . The demetalizing and desulfurizing conditions for the HDMS refined oil M15 thus obtained are preferably selected so as to achieve the vanadium (V) content of 2 wt ppm or lower, preferably 1 wt ppm or lower, and a sulfur content of 0.5 wt ppm or lower, preferably 0.3 wt ppm or lower.

[**0070**] Then a part of the HDMS refined oil M15 obtained in the hydrodemetalizating/desulfurizing process **22** and at least a part of the hydrorefined oil M3 obtained in the hydrorefining process **2** are mixed in the third mixing process **23**, thereby to obtain gas turbine fuel (GTF) as one of the oil products that has vanadium (V) content of 0.5 wt ppm or lower.

[**0071**] Of the HDMS refined oil M15 obtained in the hydrodemetalizating/desulfurizing process **22**, the remainder that is not subjected to the third mixing process **23** may be used as an intermediate oil product to be fed to fluid catalytic cracking (FCC) or hydrocracking (HCR) process.

[**0072**] In case the deasphalted oil M13 and the vacuum gas oil M11 include significantly different concentrations of metals, residual carbon and sulfur and require reaction conditions, particularly partial pressure of hydrogen, that are significantly different from each other, the M13 and the M11 may be, instead of being mixed, subjected to hydrodemetalizating/desulfurizing process in separate reactors each under optimum conditions, and then mixed or at least part of the vacuum gas oil M11 that has been subjected to hydrodemetalizating/desulfurizing process and at least a part of the hydrorefined oil M3 may be mixed thereby to obtain gas turbine fuel (GTF) that has vanadium (V) content of 0.5 wt ppm or lower.

[**0073**] According to the oil refining method described above, since a part of the HDMS refined oil M15 and at least a part of the hydrorefined oil M3 are mixed in the third mixing process **23**, vanadium (V) content of the mixture oil thus obtained becomes sufficiently low, and it is possible to obtain gas turbine fuel as one of the petroleum product. It is also possible to obtain an intermediate oil product having sufficiently low metal content (V+Ni) that can be used as the feed for a fluid catalytic cracking or a hydrocracking process, even from the remainder of HDMS refined oil M15 obtained from a mixture of the vacuum gas oil M7 and the deasphalted oil M13 by hydrodemetalizating/desulfurizing process, and therefore a plurality of oil products having a high added value can be produced at the same time.

[**0074**] Since the intermediate oil product used as the feed for fluid catalytic cracking (FCC) or hydrocracking (HCR) process has a higher tolerable concentrations of metal contents than that of gas turbine fuel (GTF) or the like, the yield of deasphalted oil M13 in the solvent deasphalting process **21** can be improved by producing the gas turbine fuel and the feed for a fluid catalytic cracking or a hydrocracking process at the same time, thereby suppressing the production of asphaltene (pitch) M14 from the vacuum residue M12 .

[**0075**] Now fourth through sixth embodiments that can be preferably applied when low-sulfur crude is used as the feed oil will be described below. The low-sulfur crude in this specification refers to crude oil such as Arabian Light, Iranian Light, Iranian Heavy, Marban, and other crude oil that includes sulfur content in a concentration similar to or lower than those of the former species, specifically crude oils including a sulfur content of 2.0 wt % or lower.

[**0076**] The hydrorefining process (HT process) **2** of the first embodiment that deals with heavy crude oil is omitted in the following embodiments because low-sulfur crude is used. In other respects, basically the same processes as those of the first embodiment are carried out. In the description that follows, processes identical to those of the first embodiment will be indicated by adding a letter A to the end of the reference numeral used in the first embodiment.

[**0077**] [Fourth Embodiment]

[**0078**] **FIG. 4** is a process flow diagram showing the fourth embodiment of the present invention. In the fourth embodiment, the low-sulfur crude mentioned above is used as the feed oil which is subjected to a fractional distillation process **1**A and is distilled similarly to the prior art so as to be separated into a distillate M1A consisting of low-boiling point oil and a residue M2A having a higher boiling point. An apparatus similar to that of the first embodiment may be used.

[**0079**] The distillate M1A obtained in the fractional distillation process **1**A is separated into distillates M3 A, M3 A' by a flasher **30**.

[**0080**] The residue M2A obtained in the fractional distillation process **1**A is deasphalted with a solvent in a solvent deasphalting process (SDA process) **3**A, thereby to obtain deasphalted oil (DAO) M4A as an extract and asphaltene (pitch) M5A.

[**0081**] In the solvent deasphalting process, first the residue **2**A is put into contact with the solvent in counterflow in a solvent extraction tower and is separated into deasphalted oil and asphaltene (pitch) that includes metal and residual carbon in high concentrations. The deasphalted oil is recovered together with the solvent through the top of the tower, and the solvent is separated from the recovered material in super-critical state. Asphaltene (pitch) is recovered together with the solvent through the bottom of the tower, and the solvent in the recovered material is removed by evaporation.

[**0082**] In case the refining process that follows the solvent deasphalting process **3**A includes only the hydrodemetalizating/desulfurizing process **4**A, it is preferable to control the extraction ratio of the solvent deasphalting process so that vanadium (V) content in the deasphalted oil M4A becomes 25 wt ppm or lower.

[**0083**] At least a part of the deasphalted oil M4A obtained in the solvent deasphalting process **3**A is introduced into the hydrodemetalizating/desulfurizing process (HDMS process) **4**A, so that the part of the deasphalted oil is demetalized and desulfurized by hydrogenation in the presence of hydrogen and a catalyst thereby to obtain the HDMS refined oil M6A that has been demetalized and desulfurized. Since the hydrodemetalizating/desulfurizing process is basically the same as the hydrorefining process that deals with heavy crude oil described previously, and the description thereof will be omitted.

[**0084**] Hydrodemetalizing and desulfurizing conditions are preferably selected so as to obtain the HDMS refined oil M6A having vanadium (V) content of 2 wt ppm or lower, preferably 1 wt ppm or lower, and a sulfur content of 0.5 wt % or lower, preferably 0.3 wt % or lower.

[**0085**] A part of the HDMS refined oil M6A obtained in the hydrodemetalizating/desulfurizing process **4**A and at least a part of the distillate M3 A are mixed in the fourth mixing process **5**A thereby to obtain a petroleum product.

[**0086**] In order to produce gas turbine fuel (GTF) as the oil product obtained in the fourth mixing process **5**A, the mix proportion is set so as to achieve a vanadium (V) content of 0.5 wt ppm or lower in the petroleum product. In case the vanadium content of the HDMS refined oil M6A is 1 wt ppm and the vanadium content of the distillate M3 A is 0 wt ppm, for example, rate of the HDMS refined oil M6A to the distillate M3 A is set to 1:1 or less (that is, the smaller proportion of the HDMS refined oil M6A) in volume proportion for mixing.

[**0087**] Of the HDMS refined oil M6A obtained in the hydrodemetalizating/desulfurizing process **4**A, the remainder thereof that is not subjected to the fourth mixing process **5**A is used as an intermediate oil product to be fed to the fluid catalytic cracking (FCC) or hydrocracking (HCR) process. Of the hydrorefined oil M3, the remainder thereof that is not subjected to the first mixing process **5**A may be used as an oil product M3 A' such as naphtha, gasoline, kerosene or gas oil.

[**0088**] According to the oil refining method described above, since a part of the HDMS refined oil M6A and at least a part of the hydrorefined oil M3 A are mixed, it is possible to obtain an oil product that has a sufficiently low vanadium (V) content such as gas turbine fuel. It is also possible to produce an intermediate oil product having a relatively low metal content (V+Ni) that can be used as the feed for fluid catalytic cracking (FCC) or hydrocracking (HCR) process from the remainder of the HDMS refined oil M6A, and efficiently produce a plurality of oil products having high added values.

[**0089**] Since the intermediate oil product used as the feed for fluid catalytic cracking (FCC) or hydrocracking (HCR) process has a higher tolerable concentrations of metal contents than that of gas turbine fuel (GTF) or the like, the yield of deasphalted oil M4A produced in the solvent deasphalting process **3**A can be improved without accompanying load of hydrodemetalizating/desulfurizing process, thereby suppressing the production of asphaltene (pitch) M5A from the residue M2A.

[**0090**] Now referring to the process flow diagram of **FIG. 4**, in case the deasphalted oil M4A obtained in the solvent deasphalting process **3**A includes relatively low concentrations of metals and sulfur, and is mixed with a part of the HDMS refined oil that includes further lower concentrations of metals and sulfur so as to satisfy the requirements for the feed stock properties for fluid catalytic cracking (FCC) or hydrocracking (HCR) process, a part thereof may be sent through the bypass shown by reference numeral **12**A in **FIG. 4** thereby to be mixed with a part of the HDMS refined oil M6A, instead of being subjected to the hydrodemetalizating/desulfurizing process **4**A, thereby to produce an intermediate oil product used as the feed for the fluid catalytic cracking (FCC) process or the feed for the hydrocracking (HCR) process.

[**0091**] [Fifth Embodiment]

[**0092**] **FIG. 5** is a process flow diagram explaining the fifth embodiment of the oil refining method according to the present invention, in which gas turbine fuel (GTF) and feed for fluid catalytic cracking (FCC) process or feed for hydrocracking (HCR) process are produced at the same time from a feed oil, similarly to the embodiment shown in **FIG. 4**.

[**0093**] This embodiment is different from the embodiment shown in **FIG. 4** mainly in that vacuum fractional distillation process **6**A is provided to follow the hydrodemetalizating/desulfurizing process **4**A, so as to process the HDMS refined oil M6A in a vacuum distillation and separate it into vacuum gas oil M7A and vacuum residue M8A.

[**0094**] In other words, with the oil refining method shown in **FIG. 5**, the HDMS refined oil M6A obtained similarly to the example shown in **FIG. 4** is distilled in a vacuum in the vacuum fractional distillation process **6**A.

[**0095**] In the vacuum fractional distillation process, the HDMS refined oil M6A is introduced into a vacuum distillation tower where the HDMS refined oil M6A is distilled and separated into a low-boiling point component and a high-boiling point component, while the vacuum gas oil M7A having the lower boiling point is obtained from the top of the tower and the vacuum residue M8A having the higher boiling point is obtained from the bottom of the tower.

[**0096**] Since the vacuum fractional distillation process described above is carried out, extraction ratio of the deasphalted oil M4A obtained in the solvent deasphalting process can be controlled so that desirable upper limit of the vanadium (V) content is set to, for example, 50 wt ppm. Thus the extraction ratio can be made higher and the yield of recovering the oil products can be improved.

[**0097**] The demetalizing and desulfurizing conditions for the HDMS refined oil M6A obtained from the deasphalted oil M4A through the hydrodemetalizating/desulfurizing process are preferably selected so as to achieve the vanadium (V) content of 20 wt ppm or lower, preferably 10 wt ppm or lower, while the sulfur content is desirably set to 0.5 wt % or lower, preferably 0.3 wt % or lower.

[**0098**] Moreover, it is desirable to set the vanadium content of the vacuum gas oil obtained by vacuum distillation of the HDMS refined oil M6A to 1 wt ppm or lower.

[**0099**] Following the process described above, at least a part of the vacuum gas oil M7A obtained in the vacuum fractional distillation process **6**A and the distillate M3 A are mixed in the fifth mixing process **7**A thereby to obtain one of the oil products.

[**0100**] In order to produce gas turbine fuel (GTF) as the oil product obtained in the fifth mixing process **7**A, vanadium (V) content is controlled to 0.5 wt ppm or lower similarly to the example shown in **FIG. 4**. In that case, the mix proportion is adjusted according to the vanadium content of the vacuum gas oil M7A similarly to the previous example. When vanadium (V) content of the vacuum gas oil M7A is 0.5 wt ppm or lower, this may be used as gas turbine fuel (GTF) without adding the distillate M3 A.

[**0101**] The remainder of the vacuum gas oil M7A, the vacuum residue M8A obtained by vacuum distillation and remainder of the HDMS refined oil M6A that is not fed to the vacuum fractional distillation process **6**A are used individually or in an appropriate combination thereof as an intermediate oil product to be used as the feed for fluid catalytic cracking (FCC) process or the feed for hydrocracking (HCR) process.

[**0102**] With the oil refining method described above, since the HDMS refined oil M6A is subjected to vacuum distillation in the vacuum fractional distillation process **6**A so as to separate into the vacuum gas oil M7A and the vacuum residue M8A that include no significant metal content and residual carbon content by making use of the range of boiling points of the distillation properties, relatively high concentrations of vanadium, metals and residual carbon can be allowed for the HDMS refined oil M6A itself, thus improving the yield of deasphalted oil M4A in the solvent deasphalting process **3**A, and therefore it is possible to suppress the production of asphaltene (pitch) M5A from the residue M2A.

[**0103**] With regard to the deasphalted oil M4A obtained in the solvent deasphalting process **3**A, too, in case the vanadium (V) content of M4 is sufficiently low, a part of the M4 may be introduced into the bypass **12**A to be mixed with the vacuum residue M8A sent from the vacuum fractional distillation process **6**A, instead of being subjected to the hydrodemetalizating/desulfurizing process **4**A, thereby to produce intermediate oil products used as the feed for fluid catalytic cracking (FCC) or hydrocracking (HCR) process. The HDMS refined oil M6A obtained in the hydrodemetalizating/desulfurizing process **4**A may also be introduced into the bypass **12**A to be mixed with the vacuum residue M8A sent from the vacuum fractional distillation process **6**A thereby to produce intermediate oil products used as the feed for fluid catalytic cracking (FCC) or hydrocracking (HCR) process.

[**0104**] [Sixth Embodiment]

[**0105**] **FIG. 6** is a process flow diagram explaining the sixth embodiment of the oil refining method according to the present invention, for a case of producing gas turbine fuel (GTF) and feed for fluid catalytic cracking (FCC) process or feed for hydrocracking (HCR) process at the same time from a feed oil, similarly to the embodiment shown in **FIG. 4**.

[**0106**] This embodiment is different from the embodiment shown in **FIG. 4** mainly in that the fractional distillation process **1**A is followed by a vacuum fractional distillation process **20**A wherein the residue M2A is separated into vacuum gas oil M11 A and vacuum residue M12 A by vacuum distillation, a solvent deasphalting process **21**A wherein the vacuum residue M12 A is separated into deasphalted oil M13 A and asphaltene (pitch) M14 A by solvent deasphalting, and a hydrodemetalizating/desulfurizing process **22**A wherein a mixture of the deasphalted oil M13 A and the vacuum gas oil M11 A is subjected to hydrodemetalizating/desulfurizing process thereby to produce HDMS refined oil M15 A.

[**0107**] With the oil refining method shown in **FIG. 6**, the residue M2A obtained similarly to the example shown in **FIG. 4** is distilled in a vacuum in the vacuum fractional distillation process **20**A.

[**0108**] In the vacuum fractional distillation process, the residue M2A is introduced into a vacuum distillation tower where the M2A is distilled and separated into a low-boiling point component and a high-boiling point component, while the vacuum gas oil M11 A having the lower boiling point is obtained from the top of the tower and the vacuum residue M12 A having the higher boiling point is obtained from the bottom of the tower.

[**0109**] The vacuum fractional distillation process **20**A is followed by the solvent deasphalting process **21**A where the vacuum residue M12 A obtained in the former process is separated into deasphalted oil M13 A and asphaltene (pitch) M14 A. While the vacuum fractional distillation process is similar to the cases shown in **FIG. 4** and **FIG. 5**, the extraction ratio of the deasphalted oil M13 A obtained in the solvent deasphalting process of the vacuum residue is controlled so that the desirable upper limit of the vanadium (V) content rises to, for example, 70 wt ppm in correspondence to the concentrations of metals, residual carbon, and sulfur in M13 A that are higher than those of the residue M2A.

[**0110**] Then the deasphalted oil M13 A and the vacuum gas oil M11 A thus obtained are mixed and the mixture is subjected to the hydrodemetalizating/desulfurizing process, thereby to obtain the HDMS refined oil M15 A. The demetalizing and desulfurizing conditions for the HDMS refined oil M1SA thus obtained are preferably selected so as to achieve the vanadium (V) content of 2 wt ppm or lower, preferably 1 wt ppm or lower, and a sulfur content of 0.5 wt % or lower, preferably 0.3 wt % or lower.

[0111] Then a part of the HDMS refined oil M15 A obtained in the hydrodemetalizating/desulfurizing process **22**A and the distillate M3 A are mixed in the sixth mixing process **23**A thereby to obtain gas turbine fuel (GTF) as one of the oil product that has vanadium (V) content of 0.5 wt ppm or lower.

[0112] The remainder of the HDMS refined oil M15 obtained in the hydrodemetalizating/desulfurizing process **22**A that is not fed to the sixth mixing process **23**A may be used as an intermediate oil product to be used as the feed for the fluid catalytic cracking (FCC) process or the feed for the hydrocracking (HCR) process.

[0113] In case the deasphalted oil M13 A and the vacuum gas oil M11 A have significantly different concentrations of metals, residual carbon and sulfur and require reaction conditions, particularly partial pressure of hydrogen, which are significantly different from each other, the M13 A and M11 A may be, instead of being mixed, subjected to hydrodemetalizating/desulfurizing process in separate reactors each under optimum conditions, and then mixed with each other, or at least part of the vacuum gas oil M11 A that has been subjected to the hydrodemetalizating/desulfurizing process and at least a part of the distillate M3 A are mixed thereby to obtain gas turbine fuel (GTF) that has vanadium (V) content of 0.5 wt ppm or lower.

[0114] According to the oil refining method described above, since a part of the HDMS refined oil M15 A and at least a part of the distillate M3 A are mixed in the sixth mixing process **23**A, the vanadium (V) content of the mixed oil becomes sufficiently low and it is possible to obtain gas turbine fuel as one of the petroleum products. It is also possible to produce intermediate oil products of low metal content (V+Ni) used as the feed for a fluid catalytic cracking or a hydrocracking process even from the remainder of the HDMS refined oil M15 A obtained from a mixture of the vacuum gas oil M7A and the deasphalted oil M13 A by hydrodemetalizating/desulfurizing process. Thus a plurality of intermediate oil products having a high added value can be produced efficiently.

[0115] Since the intermediate oil product used as the feed for fluid catalytic cracking (FCC) or hydrocracking (HCR) process has more lenient tolerance for metal contents than gas turbine fuel or the like, the yield of deasphalted oil M13 A in the solvent deasphalting process **21**A can be improved by producing the gas turbine fuel (GTF) and feed for the fluid catalytic cracking (FCC) process or feed for the hydrocracking (HCR) process at the same time, thereby suppressing the production of asphaltene (pitch) M14 A from the vacuum residue M12 A.

EXPERIMENT EXAMPLES

[0116] Now the present invention will be described below more specifically by way of experimental examples.

Experimental Example 1

[0117] A plurality of oil products including gas turbine fuel and intermediate oil products to be used as the feed for a fluid catalytic cracking or a hydrocracking process were produced as shown in **FIG. 7** by the oil refining method shown in **FIG. 1**.

[0118] An ultra heavy crude (Orinoco oil) having an API gravity of 8.5, a sulfur content of 3.67 wt % and a vanadium content of 393 wt ppm was used as feed oil that was first distilled under atmospheric pressure (fractional distillation process **1**) in a topper thereby to obtain distillate M1 and residue M2. The yield of the distillate M1 was 15.9 wt % of the feed oil and the sulfur content was 2.41 wt %. The yield of the residue M2 was 83.5 wt % of the feed oil, while the sulfur content was 4.07 wt % and the vanadium content was 472 wt ppm.

[0119] Then the distillate M1 thus obtained was desulfurized in hydrorefining process **2** in the presence of hydrogen and catalyst, thereby to obtain hydrorefined oils M3, M3 '. M3 ' was used as a petroleum product, naphtha, without applying further processing. The yield of the hydrorefined oil M3 was 13.0 wt % of the feed oil and the sulfur content was 0.02 wt %. The yield of naphtha M3 ' was 2 wt % of the feed oil.

[0120] Apart from the hydrorefining process, the residue M2 was subjected to the solvent deasphalting process **3** in a solvent extraction tower using isobutane as the solvent, thereby to obtain deasphalted oil M4 with 65% extraction ratio and asphaltene (pitch) M5 as the residue. The ratio of the solvent to the residue M2 (solvent/M2) in the solvent deasphalting process was set to 8. The yield of the deasphalted oil M4 was 54.3 wt % of the feed oil, while the sulfur content was 3.60 wt %, the vanadium content was 66 wt ppm, and the extraction ratio was 14%. The yield of the asphaltene (pitch) M5 was 29.2 wt % of the feed oil.

[0121] The deasphalted oil M4 thus obtained was introduced into a reactor filled with a hydrodemetalizing catalyst and a hydrodesulfurizing catalyst in a ratio of 3:7 in volume proportion, thereby to obtain the HDMS refined oil M6 through hydrodemetalizing/desulfurizing process **4** in the presence of hydrogen and the catalysts. The process conditions were set to partial pressure of hydrogen of 100 atm, and the H_2 to oil ratio of 800 Nl/l. The LHSV was 0.7/hr and the reaction temperature was 370° C. The yield of the HDMS refined oil M6 was 51 wt % of the feed oil, the sulfur content was 0.4 wt %, and the vanadium content was 0.7 wt ppm.

[0122] Then 15 wt % (in terms of yield from the fed oil) of the HDMS refined oil M6 thus obtained was mixed with the hydrorefined oil M3 (first mixing process **5**) thereby to produce a gas turbine fuel (GTF) with a yield of 28 wt % of the feed oil, a sulfur content of 0.22 wt %, and a vanadium content of 0.38 wt ppm. The remainder, namely 36 wt % (in terms of yield from the fed oil) of the HDMS refined oil M6 was used as a feed stock for the fluid catalyst cracking (FCC) process or a feed stock for the hydrocracking (HCR) process without applying further processing.

Experimental Example 2

[0123] A plurality of oil products including gas turbine fuel and intermediate oil products to be used as the feed for a fluid catalytic cracking or a hydrocracking process were produced as shown in **FIG. 8** by the oil refining method shown in **FIG. 2**.

[**0124**] The ultra heavy crude (Orinoco oil) having an API gravity of 8.5, a sulfur content of 3.67 wt % and a vanadium content of 393 wt ppm was used as feed oil that was first distilled under atmospheric pressure (fractional distillation process **1**) in a topper thereby to obtain distillate M1 and residue M2. The yield of the distillate M1 was 15.9 wt % of the feed oil and the sulfur content was 2.41 wt %. The yield of the residue M2 was 83.5 wt % of the feed oil, while the sulfur content was 4.07 wt % and the vanadium content was 472 wt ppm.

[**0125**] Then the distillate M1 thus obtained was desulfurized in hydrorefining process **2** in the presence of hydrogen and catalyst, thereby to obtain hydrorefined oils M3, M3 '. M3 ' was used as a petroleum product, naphtha, without applying further processing. The yield of the hydrorefined oil M3 was 13.0 wt % of the feed oil and the sulfur content was 0.02 wt %. The yield of naphtha M3 ' was 2 wt % of the feed oil.

[**0126**] Apart from the hydrorefining process, the residue M2 was subjected to the solvent deasphalting process **3** in a solvent extraction tower using pentane as the solvent, thereby to obtain deasphalted oil M4 with a 76.6% extraction ratio and asphaltene (pitch) M5 as the residue. The ratio of the solvent to the residue M2 (solvent/M2) in the solvent deasphalting process was set to 8. The yield of the deasphalted oil M4 was 64 wt % of the feed oil, the sulfur content was 3.9 wt %, the vanadium content was 130 wt ppm and the extraction ratio was 27.5%. The yield of the asphaltene (pitch) M5 was 19.5 wt % of the feed oil.

[**0127**] The deasphalted oil M4 thus obtained was introduced into a reactor filled with a hydrodemetalizing catalyst and a hydrodesulfurizing catalyst in a ratio of 5:5 in volume proportion, thereby to obtain the HDMS refined oil M6 through hydrodemetalizating/desulfurizing process **4** in the presence of hydrogen and the catalysts. The process conditions were set to partial pressure of hydrogen of 100 atm, H_2 to oil ratio of 800 Nl/l. The LHSV was 0.5/hr and reaction temperature was 370° C. The yield of the HDMS refined oil M6 was 59 wt % of the feed oil, the sulfur content was 0.45 wt %, and the vanadium content was 8 wt ppm.

[**0128**] Then the HDMS refined oil M6 thus obtained was distilled in a vacuum (vacuum fractional distillation process **6**) thereby to obtain a vacuum gas oil (VGO) M7 and the vacuum residue M8. The yield of the vacuum gas oil M7 was 25 wt % of the feed oil, the sulfur content was 0.24 wt %, and the vanadium content was 0.3 wt ppm.

[**0129**] All of the vacuum gas oil M7 was mixed with the hydrorefined oil M3 (second mixing process **7**) thereby to produce gas turbine fuel (GTF) with a yield of 38 wt % of the feed oil, a sulfur content of 0.16 wt %, and a vanadium content of 0.19 wt ppm. The vacuum residue M8 obtained in the vacuum fractional distillation process was used as a feed stock for the fluid catalyst cracking (FCC) process or a feed stock for the hydrocracking (HCR) process without applying further processing. The feed stock for the fluid catalyst cracking (FCC) process or the feed stock for the hydrocracking (HCR) process may also be obtained by mixing a part of the deasphalted oil M4 or a part of the HDMS refined oil M6 with the vacuum residue M8. The feed stock for the fluid catalyst cracking (FCC) process or the feed stock for the hydrocracking (HCR) process that is obtained in this way showed yield of 34 wt % of the feed oil, a sulfur content of 0.60 wt %, and a vanadium content of 13.7 wt ppm.

Experimental Example 3

[**0130**] A plurality of oil products including gas turbine fuel and intermediate oil products to be used as the feed for a fluid catalytic cracking or a hydrocracking process were produced as shown in **FIG. 9** by the oil refining method shown in **FIG. 3**.

[**0131**] An ultra heavy crude (Arabian heavy) having an API gravity of 28, a sulfur content of 2.9 wt % and a vanadium content of 69 wt ppm was used as feed oil that was first distilled under atmospheric pressure (fractional distillation process **1**) in a topper thereby to obtain distillate M1 and residue M2. The yield of the distillate M1 was 41 wt % of the feed oil and the sulfur content was 0.79 wt %. The yield of the residue M2 was 58.5 wt % of the feed oil, while the sulfur content was 4.72 wt % and the vanadium content was 117 wt ppm.

[**0132**] Then the residue M2 thus obtained was subjected to vacuum fractional distillation process **20** thereby to obtain a vacuum gas oil M11 and vacuum residue M12 . The yield of the vacuum gas oil M11 was 28.2 wt % of the feed oil, the sulfur content was 3.37 wt %, and the vanadium content was 1.5 wt ppm. The yield of the vacuum residue M12 was 30.6 wt % of the feed oil, the vanadium content was 223 wt ppm, (V+Ni) content was 294 wt ppm, residual carbon content was 24.4% and the sulfur content was 6.04 wt %.

[**0133**] Fractions of LPG, naphtha, kerosene, and gas oil obtained from the distillate M1 were refined separately by hydrogenation (hydrorefining process **2**) thereby to obtain corresponding hydrorefined oils (light fractions) M3, M3 '. The yield of the hydrorefined oil M3 was 20.3 wt % of the feed oil and the sulfur content was 0.05 wt %. The yield of the gasoline, kerosene, and gas oil from the hydrorefined oil M3 ' was 6.0 wt % and 13.7 wt %, respectively, of the feed oil.

[**0134**] Apart from the hydrorefining process, the vacuum residue M12 was subjected to the solvent deasphalting process **21** in a solvent extraction tower using isobutane as the solvent, thereby to obtain deasphalted oil M13 with a 60% extraction ratio and asphaltene (pitch) M14 as the residue. The ratio of the solvent to the vacuum residue M12 (solvent/M12) in the solvent deasphalting process was set to 8. The yield of the deasphalted oil M13 was 18.4 wt % of the feed oil, the sulfur content was 4.62 wt %, the vanadium content was 22 wt ppm and the extraction ratio was 19%. The yield of the asphaltene (pitch) M14 was 12.2 wt % of the feed oil.

[**0135**] A mixture of the deasphalted oil M13 and the vacuum gas oil M11 was introduced into a reactor filled with a hydrodemetalizing catalyst and a hydrodesulfurizing catalyst in a ratio of 1:9 in volume proportion, thereby to obtain the HDMS refined oil M15 through hydrodemetalizating/desulfurizing process **4** in the presence of hydrogen and the catalysts. The process conditions were set to partial pressure of hydrogen of 90 atm, the H_2 to oil ratio of 800 Nl/l. The LHSV was 0.7/hr and reaction temperature was 370° C. The yield of the HDMS refined oil M15 was 44 wt % of the feed oil, the sulfur content was 0.6 wt %, and the vanadium content was 1.0 wt ppm.

[**0136**] Then 15 wt % (in proportion to the fed oil) of the HDMS refined oil M15 thus obtained was mixed with the hydrorefined oil M3 thereby to produce gas turbine fuel that included sulfur content of 0.28 wt %, and a vanadium content of 0.42 wt ppm with a yield of 45 wt % of the feed oil. The remainder, specifically, 29 wt % of the HDMS refined oil was used as a feed stock for the fluid catalyst cracking (FCC) process or hydrocracking (HCR) process.

[**0137**] Now experimental examples that used low-sulfur content crude oil will be described below.

Experimental Example 4

[**0138**] A plurality of oil products including gas turbine fuel and intermediate oil products to be used as the feed for a fluid catalytic cracking or a hydrocracking process were produced as shown in **FIG. 10** by the oil refining method shown in **FIG. 4**.

[**0139**] A low-sulfur content crude oil (Arabian light) having a sulfur content of 1.79 wt % and a vanadium content of 13.5 wt ppm was used as feed oil that was first distilled under atmospheric pressure (fractional distillation process **1**A) in a topper thereby to obtain distillate M1A and residue M2A. The yield of the distillate M1A was 53.5 wt % of the feed oil and the sulfur content was 0.63 wt %. The yield of the residue M2A was 45.4 wt % of the feed oil, while the sulfur content was 3.20 wt % and the vanadium content was 30.0 wt ppm.

[**0140**] The distillate M1A thus obtained was separated in a flasher **30** thereby to obtain distillates M3 A, M3 A'. M3 ' was used as a petroleum product, naphtha, without applying further processing. The yield of the distillate M3 A was 50.9 wt % of the feed oil and the sulfur content was 0.66 wt %. The yield of naphtha M3 ' was 2.6 wt % of the feed oil.

[**0141**] The residue M2A was subjected to the solvent deasphalting process **3**A in a solvent extraction tower using isobutane as the solvent, thereby to obtain deasphalted oil M4A with 65% extraction ratio and asphaltene (pitch) M5A as the residue. The ratio of the solvent to the residue M2A (solvent/M2A) in the solvent deasphalting process was set to 8. The yield of the deasphalted oil M4A was 38.6 wt % of the feed oil, the sulfur content was 2.80 wt %, and the vanadium content was 5.9 wt ppm. The yield of the asphaltene (pitch) M5A was 6.8 wt % of the feed oil.

[**0142**] The deasphalted oil M4A thus obtained was introduced into a reactor filled with a hydrodemetalizing catalyst and a hydrodesulfurizing catalyst in a ratio of 1:9 in volume proportion, thereby to obtain the HDMS refined oil M6A through hydrodemetalizating/desulfurizing process **4**A in the presence of hydrogen and the catalysts. The process conditions were set to partial pressure of hydrogen of 100 atm, H_2 to oil ratio of 800 Nl/l. The LHSV was 0.5/hr and the reaction temperature was 370° C. The yield of the HDMS refined oil M6A was 36.3 wt % of the feed oil, the sulfur content was 0.10 wt %, and the vanadium content was 0.9 wt ppm.

[**0143**] Then 22.7 wt % (in terms of yield from the fed oil) of the HDMS refined oil M6A thus obtained was mixed with the distillate M3 A (fourth mixing process **5**A) thereby to produce gas turbine fuel (GTF) that included a sulfur content of 0.49 wt %, and a vanadium content of 0.28 wt ppm with a yield of 73.6 wt % of the feed oil. The remainder of the HDMS refined oil M6A, namely 13.6 wt % (in terms of yield from the fed oil) thereof was used as a feed stock for the fluid catalyst cracking (FCC) process or a feed stock for the hydrocracking (HCR) process without applying further processing.

Experimental Example 5

[**0144**] A plurality of oil products including gas turbine fuel and intermediate oil products to be used as the feed for a fluid catalytic cracking or a hydrocracking process were produced as shown in **FIG. 11** by the oil refining method shown in **FIG. 5**.

[**0145**] The low-sulfur content crude oil (Arabian light), the same oil as that used in the fourth experimental example, having a sulfur content of 1.79 wt % and a vanadium content of 13.5 wt ppm was used as the feed oil that was first distilled under atmospheric pressure (fractional distillation process **1**A) in a topper thereby to obtain distillate M1A and residue M2A. The yield of the distillate M1A was 53.5 wt % of the feed oil and the sulfur content was 0.63 wt %. The yield of the residue M2A was 45.4 wt % of the feed oil, while the sulfur content was 3.20 wt % and the vanadium content was 30.0 wt ppm.

[**0146**] The distillate M1A thus obtained was separated in the flasher **30** thereby to obtain distillates M3 A, M3 A'. The distillate M3 A was used as a petroleum product, naphtha, without applying further processing. The yield of the distillate M3 A was 50.9 wt % of the feed oil and the sulfur content was 0.66 wt %. The yield of naphtha M3 A' was 2.6 wt % of the feed oil.

[**0147**] Apart from the hydrorefining process, the residue M2A was subjected to the solvent deasphalting process **3**A in a solvent extraction tower using pentane as the solvent, thereby to obtain deasphalted oil M4A with 65% extraction ratio and asphaltene (pitch) M5A as the residue. The ratio of the solvent to the residue M2A (solvent/M2) in the solvent deasphalting process was set to 8. The yield of the deasphalted oil M4A thus obtained was 38.6 wt % of the feed oil, the sulfur content was 2.80 wt %, and the vanadium content was 5.9 wt ppm. The yield of the asphaltene (pitch) M5A was 6.8 wt % of the feed oil.

[**0148**] The deasphalted oil M4A was introduced into a reactor filled with a hydrodemetalizing catalyst and a hydrodesulfurizing catalyst in a ratio of 1:9 in volume proportion, thereby to obtain the HDMS refined oil M6A through hydrodemetalizating/desulfurizing process **4**A in the presence of hydrogen and the catalysts. The process conditions were set to partial pressure of hydrogen of 100 atm, H_2 to oil ratio of 800 Nl/l. The LHSV was 0.7/hr and the reaction temperature was 360° C. The yield of the HDMS refined oil M6A was 36.3 wt % of the feed oil, the sulfur content was 0.30 wt %, and the vanadium content was 1.5 wt ppm.

[**0149**] Then the HDMS refined oil M6A thus obtained was distilled in a vacuum (vacuum fractional distillation process **6**A) thereby to obtain a vacuum gas oil (VGO) M7A and the vacuum residue M8A. The yield of the vacuum gas oil M7A thus obtained was 23.0 wt % of the feed oil, the sulfur content was 0.10 wt %, and the vanadium content was 0.2 wt ppm.

[0150] All of the vacuum gas oil M7A was mixed with the distillate M3 A (fifth mixing process **7A**) thereby to produce gas turbine fuel (GTF) that included a sulfur content of 0.49 wt % and a vanadium content of 0.06 wt ppm, with a yield of 73.9 wt % of the feed oil. The vacuum residue M8A obtained in the vacuum fractional distillation process was used as a feed stock for the fluid catalyst cracking (FCC) process or a feed stock for the hydrocracking (HCR) process without applying further processing. The feed stock for the fluid catalyst cracking (FCC) process or the feed stock for the hydrocracking (HCR) process may also be obtained by mixing a part of the deasphalted oil M4A or a part of the HDMS refined oil M6A with the vacuum residue M8A. The feed stock for the fluid catalyst cracking (FCC) process or the feed stock for the hydrocracking (HCR) process obtained in this way showed yield of 13.3 wt % of the feed oil, a sulfur content of 0.65 wt %, and a vanadium content of 3.7 wt ppm.

Experimental Example 6

[0151] A plurality of oil products including gas turbine fuel and intermediate oil products used as the feed for a fluid catalytic cracking or a hydrocracking process were produced as shown in **FIG. 12** by the oil refining method shown in **FIG. 6**.

[0152] The low-sulfur content crude oil (Arabian light), the same oil as that used in the fourth experimental example, having a sulfur content of 1.79 wt % and a vanadium content of 13.5 wt ppm was used as feed oil that was first distilled under atmospheric pressure (fractional distillation process **1A**) in a topper thereby to obtain distillate M1A and residue M2A. The yield of the distillate M1A was 53.5 wt % of the feed oil and the sulfur content was 0.63 wt %. The yield of the residue M2A was 45.4 wt % of the feed oil, while the sulfur content was 3.20 wt % and the vanadium content was 30.0 wt ppm.

[0153] The residue M2A thus obtained was distilled in a vacuum (vacuum fractional distillation process **20A**) thereby to obtain a vacuum gas oil M11 A and vacuum residue M12 A. The yield of the vacuum gas oil M11 A was 30.4 wt % of the feed oil, while the sulfur content was 2.70 wt % and the vanadium content was 0.1 wt ppm. The yield of the vacuum residue M12 A was 15.0 wt % of the feed oil, while the vanadium content was 91.0 wt ppm and the sulfur content was 4.10 wt %.

[0154] The distillate M1A was separated in the flasher **30** thereby to obtain distillates M3 A, M3 A'. The distillate M3 A' was used as one of the petroleum product, naphtha, without applying further processing. The yield of the distillate M3 A was 50.9 wt % of the feed oil and the sulfur content was 0.66 wt %. The yield of naphtha M3 A' was 2.6 wt % of the feed oil.

[0155] Apart from the hydrorefining process, the vacuum residue M12 A was subjected to the solvent deasphalting process **21A** in a solvent extraction tower using isobutane as the solvent, thereby to obtain deasphalted oil M13 A with a 60% extraction ratio and asphaltene (pitch) M14 A as the residue. The ratio of the solvent to the vacuum residue M12 A (solvent/M12 A) in the solvent deasphalting process was set to 8. The yield of the deasphalted oil M13 A was 10.5 wt % of the feed oil, the sulfur content was 3.30 wt %, and the vanadium content was 11.0 wt ppm. The yield of the asphaltene (pitch) M14 A was 4.5 wt % of the feed oil.

[0156] A mixture of the deasphalted oil M13 A and the vacuum gas oil M11 A was introduced into a reactor filled with a hydrodemetalizing catalyst and a hydrodesulfurizing catalyst in a ratio of 1:9 in volume proportion, thereby to obtain the HDMS refined oil M15 A through hydrodemetalizating/desulfurizing process **22A** in the presence of hydrogen and the catalysts. The process conditions were set to partial pressure of hydrogen of 100 atm, H_2 to oil ratio of 800 Nl/l. The LHSV was 0.5/hr and the reaction temperature was 375° C. The yield of the HDMS refined oil M15 A was 38.4 wt % of the feed oil, while the sulfur content was 0.10 wt %, and the vanadium content was 0.9 wt ppm.

[0157] Then 22.7 wt % (in proportion to the fed oil) of the HDMS refined oil M15 A thus obtained was mixed with the distillate M3 A thereby to produce gas turbine fuel that included a sulfur content of 0.49 wt % and a vanadium content of 0.28 wt ppm, with a yield of 73.6 wt % of the feed oil. The remainder of the HDMS refined oil, namely 15.7 wt % thereof was used as a feed stock for the fluid catalyst cracking (FCC) process or hydrocracking (HCR) process without applying further processing.

Industrial Applicability

[0158] The oil refining method according to the present invention makes it possible to produce, for example, oil product (gas turbine fuel) having vanadium (V) content of 0.5 wt ppm or lower, and intermediate oil products having metal (V+Ni) content of 30 wt ppm or lower that is suitable as the feed stock to be used in the fluid catalyst cracking (FCC) process or in the hydrocracking (HCR) process, from a heavy feed oil such as Orinoco tar or a feed oil having low sulfur content.

1. An oil refining method for producing oil products including a plurality of intermediate oil products by refining a feed oil, comprising:

a fractional distillation process wherein the feed oil is distilled and separated into a distillate and a residue;

a hydrorefining process wherein at least a part of the distillate obtained in the fractional distillation process is refined and desulfurized by hydrogenation in the presence of hydrogen and catalyst thereby to obtain a hydrorefined oil;

a solvent deasphalting process wherein the residue is deasphalted with a solvent thereby to obtain a deasphalted oil as an extract and asphaltene (pitch) as the residue;

a hydrodemetalizating/desulfurizing process wherein at least a part of the deasphalted oil is demetalized and desulfurized by hydrogenation in the presence of hydrogen and a catalyst thereby to obtain an HDMS refined oil that has been demetalized and desulfurized; and

a first mixing process wherein a part of the HDMS refined oil and at least a part of the hydrorefined oil are mixed thereby to obtain one of the oil products.

2. An oil refining method according to claim 1, wherein the oil product obtained in the first mixing process is gas turbine fuel, while extraction ratio of vanadium content included in the deasphalted oil to the vanadium content included in the residue as the feed oil is controlled to become 20% or lower in the solvent deasphalting process, and demetalizing and desulfurizing conditions for producing the HDMS refined oil from the deasphalted oil in the hydrodemetalizating/desulfurizing process are selected so as to achieve the a vanadium content of 2 wt ppm or lower and a sulfur content of 0.5 wt % or lower included in the HDMS refined oil.

3. An oil refining method according to claim 1, wherein the oil product obtained in the first mixing process is gas turbine fuel, and the mixing condition in the first mixing process is selected so as to achieve the vanadium content of 0.5 wt ppm or lower included in the gas turbine fuel.

4. An oil refining method according to claim 1, wherein the remainder of the HDMS refined oil is provided as an intermediate oil product to be used as a feed stock for fluid catalyst cracking or hydrocracking process.

5. An oil refining method for producing oil products including a plurality of intermediate oil products by refining a feed oil, comprising:

a fractional distillation process wherein the feed oil is distilled and separated into a distillate and a residue;

a hydrorefining process wherein at least a part of the distillate obtained in the fractional distillation process is refined and desulfurized by hydrogenation in the presence of hydrogen and a catalyst thereby to obtain a hydrorefined oil;

a solvent deasphalting process wherein the residue is deasphalted with a solvent thereby to obtain deasphalted oil as an extract and asphaltene (pitch) as the residue;

a hydrodemetalizating/desulfurizing process wherein at least a part of the deasphalted oil is demetalized and desulfurized by hydrogenation in the presence of hydrogen and a catalyst thereby to obtain an HDMS refined oil that has been demetalized and desulfurized;

a vacuum fractional distillation process wherein the HDMS refined oil is distilled in a vacuum and separated into vacuum gas oil and vacuum residue; and

a second mixing process wherein at least a part of the vacuum gas oil and at least a part of the hydrorefined oil are mixed thereby to obtain one of the oil products.

6. An oil refining method according to claim 5, wherein the oil product obtained in the second mixing process is gas turbine fuel, while the extraction ratio of the vanadium content included in the deasphalted oil to the vanadium content included in the residue as the feed oil is controlled to become 30% or lower in the solvent deasphalting process, and demetalizing and desulfurizing conditions for producing the HDMS refined oil from the deasphalted oil in the hydrodemetalizating/desulfurizing process are selected so as to achieve the vanadium content of 20 wt ppm or lower, and a sulfur content of 0.5 wt % or lower included in the HDMS refined oil, while the vanadium content in the vacuum gas oil obtained in the vacuum fractional distillation process is 1 wt ppm or lower.

7. An oil refining method according to claim 5, wherein the oil product obtained in the second mixing process is gas turbine fuel, and the mixing condition in the second mixing process is selected so as to achieve the vanadium content of 0.5 wt ppm or lower included in the gas turbine fuel.

8. An oil refining method according to claim 5, wherein the vacuum gas oil obtained by vacuum distillation of at least a part of the HDMS refined oil is provided as an intermediate oil product to be used as a feed stock for fluid catalyst cracking or hydrocracking process.

9. An oil refining method for producing oil products including a plurality of intermediate oil products by refining a feed oil, comprising:

a fractional distillation process wherein the feed oil is distilled and separated into a distillate and a residue;

a hydrorefining process wherein at least a part of the distillate obtained in the fractional distillation process is refined and desulfurized by hydrogenation in the presence of hydrogen and catalyst thereby to obtain a hydrorefined oil;

a vacuum fractional distillation process wherein the residue is distilled in a vacuum and separated into a vacuum gas oil and a vacuum residue;

a solvent deasphalting process wherein the vacuum residue is deasphalted with a solvent thereby to obtain deasphalted oil as an extract and asphaltene (pitch) as the residue;

a hydrodemetalizating/desulfurizing process wherein the vacuum gas oil and the deasphalted oil are mixed and the mixture is demetalized and desulfurized by hydrogenation in the presence of hydrogen and a catalyst thereby to obtain an HDMS refined oil that has been demetalized and desulfurized; and

a third mixing process wherein a part of the HDMS refined oil and at least a part of the hydrorefined oil are mixed thereby to obtain one of the oil products.

10. An oil refining method according to claim 9, wherein the oil product obtained in the third mixing process is gas turbine fuel, while the extraction ratio of vanadium content included in the deasphalted oil to the vanadium content included in the residue as the feed oil is controlled so as to be 15% or lower in the solvent deasphalting process, and demetalizing and desulfurizing conditions for producing the HDMS refined oil are selected so as to achieve the vanadium content of 2 wt ppm or lower and a sulfur content of 0.5 wt % or lower included in the HDMS refined oil.

11. An oil refining method according to claim 9, wherein the oil product obtained in the third mixing process is gas turbine fuel, and the mixing condition in the third mixing process is selected so as to achieve the vanadium content of 0.5 wt ppm or lower included in the gas turbine fuel.

12. An oil refining method according to claim 9, wherein the remainder of the HDMS refined oil is provided as an intermediate oil product to be used as a feed stock for fluid catalyst cracking or hydrocracking process.

13. An oil refining method according to any one of claims **1**, **5** and **9**, wherein the feed oil is a heavy oil having an API gravity of 20 or lower.

14. An oil refining method for producing oil products including a plurality of intermediate oil products by refining a feed oil, comprising:

a fractional distillation process wherein the feed oil is distilled and separated into a distillate and a residue;

a solvent deasphalting process wherein the residue obtained in the fractional distillation process is deasphalted with a solvent thereby to obtain deasphalted oil as an extract and asphaltene (pitch) as the residue;

a hydrodemetalizating/desulfurizing process wherein at least a part of the deasphalted oil is demetalized and desulfurized by hydrogenation in the presence of hydrogen and a catalyst thereby to obtain an HDMS refined oil that has been demetalized and desulfurized; and

a fourth mixing process wherein a part of the HDMS refined oil and at least a part of the distillate are mixed thereby to obtain one of the oil products.

15. An oil refining method according to claim 14, wherein the oil product obtained in the fourth mixing process is gas turbine fuel, while the extraction ratio of the deasphalted oil in the solvent deasphalting process is controlled so that vanadium content thereof becomes 25 wt ppm or lower, and demetalizing and desulfurizing conditions for producing the HDMS refined oil are selected so as to achieve the vanadium content of 2 wt ppm or lower and a sulfur content of 0.5 wt % or lower included in the HDMS refined oil.

16. An oil refining method according to claim 14, wherein the oil product obtained in the fourth mixing process is gas turbine fuel, and the mixing condition in the fourth mixing process is selected so as to achieve the vanadium content of 0.5 wt ppm or lower included in the gas turbine fuel.

17. An oil refining method according to claim 14, wherein the remainder of the HDMS refined oil is provided as an intermediate oil product to be used as a feed stock for fluid catalyst cracking or a hydrocracking process.

18. An oil refining method for producing oil products including a plurality of intermediate oil products by refining a feed oil, comprising:

a fractional distillation process wherein the feed oil is distilled and separated into a distillate and a residue;

a solvent deasphalting process wherein the residue obtained in the fractional distillation process is deasphalted with a solvent thereby to obtain deasphalted oil as an extract and asphaltene (pitch) as the residue;

a hydrodemetalizating/desulfurizing process wherein at least a part of the deasphalted oil is demetalized and desulfurized by hydrogenation in the presence of hydrogen and a catalyst thereby to obtain an HDMS refined oil that has been demetalized and desulfurized;

a vacuum fractional distillation process wherein the HDMS refined oil is distilled in a vacuum and separated into a vacuum gas oil and a vacuum residue; and

a fifth mixing process wherein at least a part of the vacuum gas oil and at least a part of the distillate are mixed thereby to obtain one of the oil products.

19. An oil refining method according to claim 18, wherein the oil product obtained in the fifth mixing process is gas turbine fuel, while the extraction ratio of the deasphalted oil in the solvent deasphalting process is controlled so that vanadium content included in the deasphalted oil becomes 50 wt ppm or lower, and demetalizing and desulfurizing conditions for producing the HDMS refined oil are selected so as to achieve the vanadium content of 20 wt ppm or lower and a sulfur content of 0.5 wt % or lower included in the HDMS refined oil, while vanadium content included in the vacuum gas oil obtained in the vacuum fractional distillation process is set to 1 wt ppm or lower.

20. An oil refining method according to claim 18, wherein the oil product obtained in the fifth mixing process is gas turbine fuel, and the mixing condition in the fifth mixing process is selected so as to achieve the vanadium content of 0.5 wt ppm or lower included in the gas turbine fuel.

21. An oil refining method according to claim 18, wherein the vacuum gas oil obtained by vacuum distillation of at least a part of the HDMS refined oil is provided as an intermediate oil product to be used as a feed stock for fluid catalyst cracking or a hydrocracking process.

22. An oil refining method for producing oil products including a plurality of intermediate oil products by refining a feed oil, comprising:

a fractional distillation process wherein the feed oil is distilled and separated into distillate and a residue;

a vacuum fractional distillation process wherein the residue obtained in the fractional distillation process is distilled in a vacuum and separated into a vacuum gas oil and a vacuum residue;

a solvent deasphalting process wherein the vacuum residue is deasphalted with a solvent thereby to obtain deasphalted oil as an extract and asphaltene (pitch) as the residue;

a hydrodemetalizating/desulfurizing process wherein the vacuum gas oil and the deasphalted oil are mixed and the mixture is demetalized and desulfurized by hydrogenation in the presence of hydrogen and a catalyst thereby to obtain an HDMS refined oil that has been demetalized and desulfurized; and

a sixth mixing process wherein a part of the HDMS refined oil and at least a part of the distillate are mixed thereby to obtain one of the oil products.

23. An oil refining method according to claim 22, wherein the oil product obtained in the sixth mixing process is gas turbine fuel, while the extraction ratio of the deasphalted oil in the solvent deasphalting process is controlled so that vanadium content included in the deasphalted oil becomes 70 wt ppm or lower, and demetalizing and desulfurizing conditions for producing the HDMS refined oil are selected so as to achieve the vanadium content of 2 wt ppm or lower and a sulfur content of 0.5 wt % or lower included in the HDMS refined oil.

24. An oil refining method according to claim 22, wherein the oil product obtained in the sixth mixing process is gas turbine fuel, and the mixing condition in the sixth mixing process is selected so as to achieve the vanadium content of 0.5 wt ppm or lower included in the gas turbine fuel.

25. An oil refining method according to claim 22, wherein the remainder of the HDMS refined oil is provided as an intermediate oil product to be used as a feed stock for fluid catalyst cracking or hydrocracking process.

26. An oil refining method according to any one of claims **14**, **18** and **22**, wherein the feed oil is a low-sulfur crude that includes a sulfur content of 2.0 wt % or lower.

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