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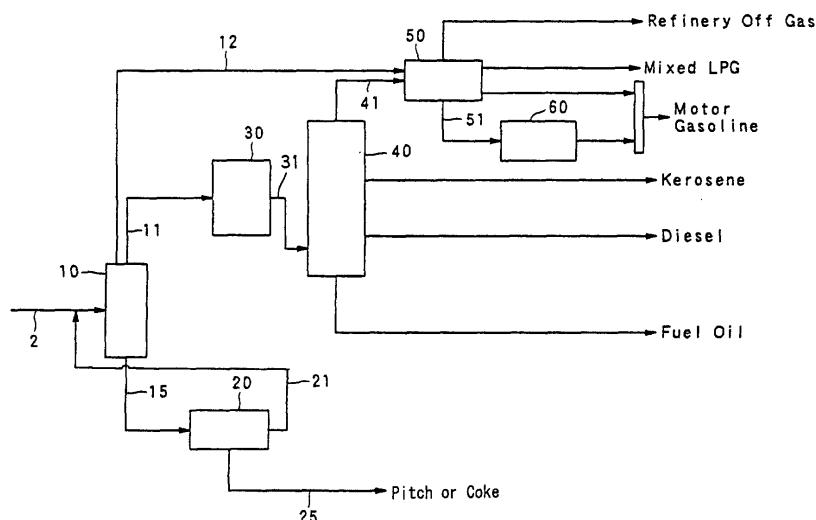
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(54) **PROCESS FOR TREATING CRUDE OIL**

(57) The present invention provides a method of treating a crude oil comprising a step of separating the crude oil by distillation where the crude oil is separated by distillation into a distillate oil and a heavy oil content, a step of thermal cracking where the heavy oil content separated at said step of separating the crude oil by distillation and obtained substantially from the bottom is thermally cracked to lighten the content, and a step of separating the thermal cracking product by distillation

where the thermal cracking product obtained by lightening at said step of thermal cracking is separated by distillation; wherein said step of separating the crude oil by distillation and step of separating the thermal cracking product by distillation are carried out, at the same time, in a distilling section comprising a vacuum distillation apparatus. Accordingly, it is possible to simplify the process and save the space, and thereby to reduce a cost for the treatment. In addition, the method is also applicable to a small-scale refining of petroleum.

**FIG. 1**



**Description**Technical Field

**[0001]** The present invention relates to a method of treating a crude oil, which particularly comprises, as an essential part, a so-called upgrading method of a heavy oil, where a heavy oil content contained in a crude oil is converted into a light fraction in refining of petroleum for producing value-added petroleum products from a crude oil.

Background Art

**[0002]** A conventional general treating process of a crude oil will be explained with reference to Figure 3.

**[0003]** A crude oil 2 received by a refinery and subjected to a prescribed pretreatment is separated by distillation in an atmospheric distillation apparatus 100 to afford, downward from the top of the column, a gas content 101, a kerosene content 103, a gas oil content 105, and the like as each distillate, whereby a heavy oil content 107 is separated at the bottom of the column as a residual oil.

**[0004]** The gas content 101 withdrawn from the top of the column is further separated into, for example, a light, gas content ( $H_2$ ,  $C_1$ ,  $C_2$ ) 111, an LPG content ( $C_3$ ,  $C_4$ ) 113, a  $C_5$ - $C_6$  content 115, a naphtha content 117 in a gas recovery section 110. In general, hydrogen sulfide is individually removed from the light gas content 111 and the LPG content 113 as well as the  $C_5$ - $C_6$  content 115 by means of a washing apparatus, and the light gas content 111 is used for a fuel of its own consumption, and the LPG content 113 is for an LPG product. The  $C_5$ - $C_6$  content 115 is used as a balancing agent for gasoline.

**[0005]** The naphtha content 117 is generally subjected to a treatment for removing sulfur contents and nitrogen contents by a hydrotreating apparatus 120, followed by catalytic reformation in a reforming apparatus 125 to enhance an octane value in order to form a balancing agent for gasoline.

**[0006]** The kerosene content 103 is subjected to hydrosulfurization and refining by a hydrotreating apparatus 130 (comprising a desulfurizing and cracking reactor R1 and a rectification part D1) to remove sulfur contents, nitrogen contents, etc., and is generally used as a kerosene product or a jet fuel.

**[0007]** The gas oil content 105 is also subjected to hydrosulfurization and refining by means of a hydrotreating apparatus 140 (comprising a desulfurizing and cracking reactor R2 and a rectification part D2) to remove sulfur contents, etc., and is generally used as a diesel gas oil.

**[0008]** The heavy oil content 107 withdrawn from the column bottom of an atmospheric distillation apparatus 100 is transferred to a vacuum distillation apparatus 200 in order to subject to a so-called upgrading treatment which converts it into a light fraction. In the apparatus, the heavy oil content 107 is separated into a vacuum gas oil 201 and a vacuum residue 205. The vacuum residue is dealt with a raw material for thermal cracking. The vacuum gas oil 201 is subjected to desulfurization, cracking, and refining and separation by means of a hydrogenating apparatus 210 (comprising a desulfurizing and cracking reactor R3 and a rectification part D3). Each fraction separated (separated into naphtha, kerosene, diesel gas oil, vacuum gas oil at the rectification part D3) is usually transferred to the above-mentioned gas recovery section 110 or combined with each line of the products such as kerosene and diesel gas oil to form products as illustrated in the drawing.

**[0009]** On the other hand, the vacuum residue 205 separated by means of the vacuum distillation apparatus 200 is fed to a thermal cracking section 220 (comprising a reactor R4 and a rectification part D4). In the thermal cracking section 220, a raw material for thermal cracking is thermally cracked to form thermal cracking products such as cracked gas and cracked oil, and residues such as pitch and coke. The thermally cracked oil is further subjected to secondary treatments such as hydrotreating, hydrocracking, catalytic cracking, and separation to form final products. At the secondary treatments of the thermally cracked oil, it is generally mixed with the kerosene content 103, the gas oil content 105, the vacuum gas oil fraction 201 separated in the atmospheric distillation apparatus 100 and the vacuum distillation apparatus 200 in advance. Therefore, in order to adjust to their boiling point ranges, the thermally cracked oil is further separated according to plural boiling point ranges at the rectification part (D4).

**[0010]** When attention is focused on the above process, especially upgrading of the heavy oil in the conventional thermal cracking section, two-step operation of distillation at the atmospheric distillation apparatus 100 and the vacuum distillation apparatus 200 is required for obtaining raw material for thermal cracking 205 (the vacuum residue 205). Moreover, in order to recover thermally cracked oil by subjecting to the secondary treatments, it is necessary to separate the oil into each fraction having a boiling point range similar to the range of each distillate oil from the atmospheric distillation apparatus 100 and the vacuum distillation apparatus 200 (for example, 101, 105, and 201) and mix it with each distillate oil. Accordingly, addition of the distillation part D4 to the thermal cracking section 220 becomes necessary and thus at least three distillation columns 100, 200, and D4 are required in total.

**[0011]** Therefore, the constitution of the apparatus for upgrading of a heavy oil by thermal cracking becomes complex and expensive. In addition, it is necessary to secure a wide space for the placement. Since these problems directly

connect with an increase in cost of refined each product, it is extremely difficult to introduce new facilities for the process under the present circumstances.

**[0012]** From the above-mentioned reasons, in order to solve the above problems, it has been desired to have a proposal for an inexpensive method of the treatment capable of simplifying the process with regard to upgrading of a heavy oil by thermal cracking.

**[0013]** Moreover, when whole conventional process according to Figure 3 is considered, after the crude oil 2 introduced has been separated into each component by two-times distilling operations, a similar operation of hydrodesulfurization and refining is repeatedly carried out on the separated individual component by means of a combination of a desulfurization and cracking reactor (R1 to R4), a rectification part (D1 to D4) and the like. Such conventional treating system is considered to directly result in an increase in cost of each refined product, and thus, like the above-mentioned upgrading of a heavy oil by thermal cracking, proposal of an inexpensive method of the treatment capable of simplifying the whole process has been desired.

**[0014]** The present invention is contrived under the above circumstances, and object thereof is to provide a method of treating a crude oil capable of improving the complexity of conventional constitution of the apparatus, simplifying the process and saving the space, and thereby reducing a cost for the treatment. In addition, the object is to provide a method of treating a crude oil also applicable to a small-scale refining of petroleum.

#### Disclosure of the Invention

**[0015]** For solving these problems, the present invention provides a method of treating a crude oil comprising:

a step of separating the crude oil by distillation where the crude oil is separated by distillation into a distillate oil and a heavy oil content,

a step of thermal cracking where the heavy oil content separated at said step of separating the crude oil by distillation and obtained substantially from the bottom is thermally cracked to lighten the content, and

a step of separating the thermal cracking product by distillation where the thermal cracking product obtained by lightening at said step of thermal cracking is separated by distillation; which comprises

said step of separating the crude oil by distillation and step of separating the thermal cracking product by distillation being carried out, at the same time, in a distilling section comprising a vacuum distillation apparatus.

**[0016]** In a preferred embodiment of the present invention, the distilling section in which said step of separating the crude oil by distillation and step of separating the thermal cracking product by distillation carried out at the same time comprises a pre-separation apparatus and a main separation apparatus.

**[0017]** In a preferred embodiment of the present invention, the heavy oil content separated in said distilling section and withdrawn from the bottom amounts 15 to 55 parts by weight relative to 100 parts by weight of a distillate oil from the distilling section.

**[0018]** In a preferred embodiment of the present invention, the heavy oil content separated at said step of separating the crude oil, withdrawn from the bottom, and fed to the step of thermal cracking contains substantially neither gas oil content nor vacuum gas oil content.

**[0019]** In a preferred embodiment of the present invention, no heavy oil content is contained in thermal cracking residue at said step of thermal cracking.

**[0020]** In a preferred embodiment of the present invention, the distillate oil separated at the step of separating the crude oil by distillation and the step of separating the thermal cracking product by distillation carried out at the same time in said distilling section is collectively subjected to desulfurization, cracking, and hydrogenation treatment in identical one hydrotreating section.

#### Brief Description of the Drawings

**[0021]**

Figure 1 is a process flow illustrating a preferred embodiment of the present invention;  
Figure 2 is a detailed flowchart illustrating the distilling section 10 in Figure 1 in detail; and  
Figure 3 is a process flow illustrating a conventional general mode for treating a crude oil.

#### Best Mode for carrying out the Invention

**[0022]** The following will explain a preferred mode of the present invention in detail with reference to the process flow illustrated in Figure 1.

**[0023]** In general, crude oil received by a refinery is permitted to stand in a crude oil tank, and water and sludge content are removed by means of desalter. The crude oil 2 subjected to such pretreatment is, as a preferred embodiment of the present invention, introduced into a distilling section 10. Figure 2 illustrates a preferred detailed flowchart of the distilling section 10.

**[0024]** As illustrated in Figure 2, the crude oil 2 is first introduced into a pre-separating apparatus, for example, a simple flash vessel 3 and then separated into a gas content 3a and a liquid fraction 3b. The liquid fraction 3b is introduced into a vacuum distillation apparatus 10', and then separated into an extract oil 11a extracted from the upper part of the column and a vacuum residue which is a heavy oil content 15 from the bottom of the column (the step of separating crude oil by distillation). The gas content 3a from the flash vessel 3 is cooled and further separated into a gas content 12 and a liquid fraction 11b. The liquid fraction 11b is mixed with the extract oil 11a from the vacuum distillation apparatus 10' to form a raw material oil for hydrotreating (distillate oil) 11. The distillate oil 11 contains a vacuum gas oil content, a gas oil content, a kerosene content, and a naphtha content, while the gas content 12 contains an LPG (liquefied Petroleum gas) content, a light gas content and the like.

**[0025]** Preferred conditions for operating the distilling section 10 including the vacuum distillation apparatus 10' are as follows: a pressure of about 1 to 10 kPa and a temperature of about 350 to 400°C. Furthermore, separation ratio of the vacuum residue (15) to the distillate oil 11 in the distilling section 10 is made 15 to 55 parts by weight relative to 100 parts by weight of the distillate oil 11. The separation ratio is determined according to kind of oil. For example, in the case of Arabian heavy crude oil, the vacuum residue (15) is preferably made 45 to 55 parts. When the vacuum residue (15) becomes less than 45 parts, a metal content and a residual carbon content contained in a heavy oil are transferred to a hydrotreating section 30 which exists downstream, and fine pores of a catalyst for desulfurization and cracking in the hydrotreating section 30 is blocked by the metal content and coke. As a result, inconveniences that activity of the catalyst is degraded and life of the catalyst is shortened occur. When the vacuum residue (15) exceeds 55 parts, owing to a decrease in the reaction rate of thermal cracking of the vacuum residue, severe conditions such as extending the residence time for reaction in the thermal cracking section or elevation of the reaction temperature are needed and, as a result, efficient cracking is inhibited. On the other hand, in the case of Arabian extra light crude oil, it is preferred to make the vacuum residue (15) 15 to 30 parts for the same reasons as above.

**[0026]** The crude oil to be fed to the distilling section 10 may be an ultra-heavy crude oil such as oil sand bitumen from Canada and Orinoco tar from Venezuela. In this case, separating ratio of the distillate oil 11 and the vacuum residue (15) in the distilling section 10 may be preferably adjusted so that suitable raw material can be fed to the thermal cracking section and the hydrotreating section. Moreover, the crude oil to be fed to the distilling section 10 may be an atmospheric distillation residue, and, in this case, the separating ratio may be again adjusted as mentioned above.

**[0027]** In addition, at the step for separating the crude oil by distillation according to the present invention, the process is operated so that the heavy oil content 15 contains substantially neither gas oil content nor vacuum gas oil content. The operation of the step for separating the crude oil by distillation is carried out so that the gas oil content and the vacuum gas oil content are withdrawn at the line of said distillate oil 11.

**[0028]** As illustrated in Figure 1, substantially direct introduction of the crude oil 2 to the distilling section 10 including the vacuum distillation apparatus 10' enables to fulfill the purposes of adjusting vacuum residue oil that is a raw material oil for the thermal cracking section, and adjusting a mixed oil composed of naphtha, kerosene, gas oil and vacuum gas oil, that is a raw material oil for collective hydrotreating section. Accordingly, since it is not necessary to separate the crude oil into each fraction of naphtha, kerosene, gas oil and vacuum gas oil by distillation, the conventional large-scale atmospheric distillation apparatuses become unnecessary.

**[0029]** The heavy oil content 15 (vacuum residue (15)) separated at such step of separating a crude oil by distillation where the distilling section 10 is used and obtained substantially from the bottom of the distilling section 10 is introduced to the thermal cracking section 20, in which the heavy oil content 15 is thermally cracked and separated into a lightened thermal cracking product 21 and a thermal cracking residue 25 (the step of thermal cracking).

**[0030]** The lightened thermal cracking product 21 is returned to the above-mentioned distilling section 10, in which the product is distilled under reduced pressure to effectively recover a low-boiling content (the step of separating thermal cracking product by distillation). That is, first characteristic of the present invention is to carry out said step of separating a crude oil by distillation and step of separating a thermal cracking product by distillation in identical one distilling section 10 at the same time, and feed a suitable raw material oil to the thermal cracking section and feed a suitable raw material oil to the hydrotreating section. Namely, with regard to separated composition in the distilling section 10, a mixture of the distillate oil (containing gas content) derived from the crude oil and the thermally cracked oil (containing gas content) is withdrawn from the column top of the distilling section 10 collectively or fractionally at plural boiling ranges (symbol 11). On the other hand, a mixture of a distillation residue derived from the crude oil and a part of a cracked heavy oil is withdrawn from the column bottom of the distilling section 10 and used as a raw material for thermal cracking (15). Such first characteristic contributes to simplify the process and to minimize the apparatus.

**[0031]** In addition, since the present invention aims to reduce heavy oil products to zero, the thermal cracking section 20 is operated so that the thermal cracking residue 25 at the step of thermal cracking contains no heavy oil content.

**[0032]** In the above-mentioned thermal cracking section 20, the raw material for thermal cracking is generally pre-heated or, in some cases, pre-cracked at a tube-type heating furnace, followed by further thermal cracking by means of a reactor of vessel-type (EUREKA, delayed coker) or fluid bed-type (flexicoker, fluid coker) to form thermal cracking products such as a cracked gas and a cracked oil, and residues such as pitch and coke, which are separated from each other.

**[0033]** In the thermal cracking step of the present invention, although hitherto known various thermal cracking sections can be used, use of a so-called EUREKA is particularly preferable in view of the combination of downstream hydrotreating step.

**[0034]** EUREKA process is a process which generally produces gas, cracked oil and pitch by thermal cracking of a vacuum residue oil. The detail is shown in "Specification of Japanese Patent Publication No. 15795/1982", "Thermal and Nuclear Power Generation (Karyoku Genshiryoku Hatsuden)", Vol. 36, No. 2, pp. 151-166 (1985), "Proceedings of 17th Panel Discussion on the Petroleum Refining, Petroleum Society (Sekiyu Gakkai Dai 17 Kai Seisei Paneru Touronkai Kaigiroku)", pp. 93-102 (1992), "Catalysts in Petroleum Refining and Petrochemical Industries 1995", pp. 293-301 (1995), "Process for Petroleum Refining (Sekiyu Seisei Purosesu)", pp. 202-203 (1998, published by Petroleum Society(Sekiyu gakkai)), and the like. The reaction system of EUREKA process adopts a semi-batch method combining a tube-type cracking furnace and a vessel-type reactor, and thereby aims to cope with both production of thermo-melting pitch which has a property of homogeneous and of narrow in distribution of reaction residence time and economy of the process. The reactor is composed of two pieces of apparatus per 1 set and charge of the raw material is switched alternatively at about 90 minutes intervals by means of an automatic switching valve. It is operated at a temperature of 400°C to 450°C under a pressure of 30 to 70 kPaG, that is almost atmospheric pressure. Moreover, by blowing overheated steam of about 600 to 700°C to the bottom of the reactor, a cracked oil is purged promptly to the outside of the reaction system to suppress excessive cracking and polycondensation. Accordingly, the cracked oil has a characteristic that it contains less polycondensate molecules as compared with the product of other cracking apparatus. When the polycondensate molecules are present in the raw material oil, severer conditions are required in downstream desulfurization, cracking, or hydrogenation. In the present invention whose characteristic is combination with the hydrotreating step, it is desirable to use a method where the formation of these polycondensate molecules at the thermal cracking step is as little as possible.

**[0035]** As mentioned above, the distillate oil 11 separated in the distilling section 10 contains a vacuum gas oil content, a gas oil content, a kerosene content, a naphtha content and the like. These contents are collectively introduced to identical one hydrotreating section 30 without separating into each content having prescribed boiling range, where they are collectively subjected to desulfurization, cracking, and hydrogenation treatment. Since the thermally cracked oil formed at the thermal cracking step contains unsaturated hydrocarbons, quality of the oil is unsettled without further treatment. Therefore, hydrotreating is necessarily conducted in order to saturate them with hydrogen for purpose of the settlement. Accordingly, when upgrading scheme of the residual oil is carried out by thermal cracking according to a conventional technique, the thermally cracked oil is, in general, separated into each fraction by rectification and, after each fraction is mixed with each distillate oil such as naphtha, kerosene, gas oil, or vacuum gas oil, each fraction is individually subjected to hydrotreating. When attention is focused on the pressure of individual hydrotreating reaction part of the distillate oil, the pressure is usually set up so as to increase as the fraction of a raw material oil changes from light one to heavy one in the case that the thermal cracking of the residual oil is not carried out. On the contrary, in the case that thermal cracking of the residual oil is accompanied as discussed in the present invention, the pressure is set up high even for a light oil and therefore, the pressure at hydrotreating tends to flat throughout the treatment of from a light fraction to a heavy fraction. Concretely, when the thermal cracking of the residual oil is not carried out, the pressure for hydrotreating ranges 500 to 3000 kPaG for naphtha, 1000 to 4000 kPaG for kerosene, 4000 to 7000 kPaG for gas oil, or 5000 to 7000 kPaG for vacuum gas oil, typically 2000 to 3000 kPaG for naphtha and kerosene, 5000 kPaG for gas oil, or 6000 kPaG for vacuum gas oil. On the other hand, when the thermal cracking of the residual oil is accompanied, the pressure for hydrotreating of each fraction of naphtha, kerosene, gas oil, or vacuum gas oil is set up typically the same level, i.e., 6000 kPaG. Accordingly, in the refining scheme incorporating the thermal cracking of the residual oil, there are low technical necessity of individual hydrotreating and high technical rationality of collective hydrotreating. The collective hydrotreatment in the present invention is different from that of the case not accompanying the residual oil cracking (for example, the specification of Japanese Patent Application Laid-Open No. 82573/1995 etc.) in the technical background, and is a peculiar technique in the thermal cracking scheme of the residual oil.

**[0036]** In addition, from the viewpoint of economy, when the distillate oil is subjected to collective hydrotreating in refining scheme without the residual oil cracking, it is especially necessary to procure a light crude oil fitting demand for heavy oil products and treat it. In this case, in order to suitably collect capital for an investment in new facilities, the profit obtainable from the difference between the cost of the crude oil, and the prices of the products must be enough. However, at the present time when the prices of the crude oil and the products are determined by market principles, it is extremely difficult to make the new facilities economically feasible without the residual oil cracking in the case of such light crude oil treatment since the price difference between the crude oil and the products is small in the case of

such light crude oil treatment. On the other hand, in the case accompanying the residual oil cracking, economical advantage is enhanced by low price of the raw material heavy oil and the price difference between light oil products and heavy oil products and thus capital collecting for investment in the new facilities can be secured.

**[0037]** The collective hydrotreating in the present invention is different from the general technique of collective hydrotreating of the distillate oil from a crude oil, and is characterized by the technical and economical significances found in the integration with the thermal cracking of residual oil.

**[0038]** The reaction style is not particularly limited, and can include various embodiments such as fixed bed, fluid bed, moving bed, and the like. Generally, the composition unnecessary to treat in the hydrotreating section 30 is excluded from the compositions for collective treatment.

**[0039]** The refined oil 31 collectively subjected to desulfurization, cracking and hydrogenation treatment in the hydrotreating section 30 is a synthetic crude oil of low sulfur content containing no vacuum residual oil fraction and having high added value, and is treated in the downstream refining scheme according to a conventional technique.

**[0040]** In addition to the aforementioned first characteristic, the present invention aims to simplify whole process and reduce a cost for the treatment by collectively subjecting the distillate oil 11 including the refined product after thermal cracking to desulfurization, cracking, and hydrogenation treatment, and also collectively operating the separation by distillation after said treatment.

**[0041]** Part of the lightened thermal cracking product 21 may be transferred to the hydrotreating section 30 without returning to the distilling section 10.

**[0042]** In the above, a preferable process of the present invention has been explained with reference to Figure 1 and Figure 2. As mentioned above, the distilling section 10 to which the crude oil 2 is introduced may comprise a pre-separating apparatus and a main separating apparatus as a preferable partially transformed example. In this case, examples of the pre-separating apparatus include a flash vessel, a simple distilling column, and the like, and examples of the main separating apparatus include a vacuum distilling apparatus. Since a part of vacuum gas oil can be also separated, the placement of the pre-separating apparatus in advance affords a merit that sizes of the heating furnace and the vacuum distilling tower can be reduced.

**[0043]** Among the pre-separating apparatus, the flash vessel is a more preferable embodiment than the distilling column. The reasons are as follows: the treatment in the downstream hydrotreating section 30 is carried out collectively, and thus, more precise separation is not only technically unnecessary but also economically undesirable.

**[0044]** The following shows concrete examples, which explain the present invention in detail.

[Experimental Example 1]

(Example 1)

**[0045]** According to the process of the present invention as illustrated in Figure 1, an experiment of refining a crude oil was carried out as described in the following.

#### Kind and Properties of the crude oil used

**[0046]** Used crude oil: Arabian heavy oil (100% by volume)

**[0047]** Specific gravity: 0.896

**[0048]** Concentration of sulfur: 3.07% by weight

#### Operating conditions in the distilling section 10

**[0049]** Pressure: 1 to 10 kPa

**[0050]** Temperature: 350 to 400°C

#### Operating conditions in the thermal cracking section 20 (EUREKA)

**[0051]** Pressure: 30 to 60 kPaG

**[0052]** Temperature: 425 to 440°C

#### Operating conditions in the hydrotreating section 30

**[0053]** Chemical hydrogen consumption: 55 to 60 Nm<sup>3</sup>/kL

**[0054]** Reaction tower temperature: 340 to 380°C

**[0055]** Partial pressure of hydrogen: 6000 kPa

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### Operating conditions in the separation by distillation section 40

**[0056]** Pressure: 60 to 100 kPa

**[0057]** Temperature: 330 to 360°C

**[0058]** Yields and qualities of the products obtained under the above operating conditions are shown in Tables 1 and 2.

Table 1

| Product Yields                    |                         |          |
|-----------------------------------|-------------------------|----------|
|                                   | Raw material            | Products |
|                                   | Arabian heavy crude oil | -        |
| Naphtha (% by volume)             | 19                      | 23       |
| Kerosene (% by volume)            | 9                       | 10       |
| Gas oil (% by volume)             | 21                      | 26       |
| Vacuum gas oil (% by volume)      | 26                      | 36       |
| Vacuum residual oil (% by volume) | 26                      | -        |
| Oils in total (% by volume)       | 100                     | 96       |
| Pitch (% by weight)               | -                       | 8        |

Table 2

| Product Qualities   |                               |                         |          |
|---------------------|-------------------------------|-------------------------|----------|
|                     |                               | Raw material            | Products |
|                     |                               | Arabian heavy crude oil | -        |
| Naphtha             |                               |                         |          |
|                     | Specific gravity (-)          | 0.722                   | 0.726    |
|                     | Sulfur content (% by weight)  | 0.02                    | 0.001    |
| Kerosene            |                               |                         |          |
|                     | Specific gravity (-)          | 0.800                   | 0.796    |
|                     | Sulfur content (% by weight)  | 0.30                    | 0.01     |
|                     | Smoke point (mm)              | 26                      | 22       |
| Gas oil             |                               |                         |          |
|                     | Specific gravity (-)          | 0.856                   | 0.847    |
|                     | Sulfur content (% by weight)  | 1.54                    | 0.05     |
|                     | Cetane index (-)              | 51                      | 54       |
| Vacuum gas oil      |                               |                         |          |
|                     | Specific gravity (-)          | 0.941                   | 0.925    |
|                     | Sulfur content (% by weight)  | 3.40                    | 0.63     |
| Vacuum residual oil |                               |                         |          |
|                     | Specific gravity (-)          | 1.053                   | -        |
|                     | Sulfur content (% by weight)  | 6.00                    | -        |
|                     | Metal content (ppm by weight) | 300                     | -        |

**[0059]** The yields and qualities of the products shown in the above tables were confirmed to be on the same level with those of the product fractions (sulfur content of not more than 500 ppm by weight in gas oil) obtained by the conventional process illustrated in Figure 3. It was also confirmed that 15% reduction of the cost for constructing plant can be attained as compared with the conventional process. Accordingly, it was confirmed that the process of the present invention enables simplification of the process and saving of the space, and thus reduction of the treating cost without lowering the product yields and qualities.

(Example 2)

**[0060]** In the above Example 1, operating conditions in the hydrotreating section 30 was changed as described in the following. Except for those points, an experiment of refining a crude oil was conducted as described in Example 1.

#### Operating conditions in the hydrotreating section 30

**[0061]** Chemical hydrogen consumption: 60 to 70 Nm<sup>3</sup>/kL

**[0062]** Reaction tower temperature: 340 to 380°C

**[0063]** Partial pressure of hydrogen: 6000 kPa

**[0064]** Reactor volume: two times of the volume in the above Example 1

**[0065]** Yields and qualities of the products obtained under the above operating conditions are shown in Tables 3 and 4.

Table 3

| Product Yields                    |                         |          |
|-----------------------------------|-------------------------|----------|
|                                   | Raw material            | Products |
|                                   | Arabian heavy crude oil | -        |
| Naphtha (% by volume)             | 19                      | 23       |
| Kerosene (% by volume)            | 9                       | 10       |
| Gas oil (% by volume)             | 21                      | 23       |
| Vacuum gas oil (% by volume)      | 26                      | 39       |
| Vacuum residual oil (% by volume) | 26                      | -        |
| Oils in total (% by volume)       | 100                     | 96       |
| Pitch (% by weight)               | -                       | 8        |

Table 4

| Product Qualities   |                               |                         |          |
|---------------------|-------------------------------|-------------------------|----------|
|                     |                               | Raw material            | Products |
|                     |                               | Arabian heavy crude oil | -        |
| Naphtha             |                               |                         |          |
|                     | Specific gravity (-)          | 0.722                   | 0.726    |
|                     | Sulfur content (% by weight)  | 0.02                    | 0.0005   |
| Kerosene            |                               |                         |          |
|                     | Specific gravity (-)          | 0.800                   | 0.796    |
|                     | Sulfur content (% by weight)  | 0.30                    | 0.001    |
|                     | Smqke point (mm)              | 26                      | 22       |
| Gas oil             |                               |                         |          |
|                     | Specific gravity (-)          | 0.856                   | 0.843    |
|                     | Sulfur content (% by weight)  | 1.54                    | 0.004    |
|                     | Cetane index (-)              | 51                      | 56       |
| Vacuum gas oil      |                               |                         |          |
|                     | Specific gravity (-)          | 0.941                   | 0.919    |
|                     | Sulfur content (% by weight)  | 3.4                     | 0.24     |
| Vacuum residual oil |                               |                         |          |
|                     | Specific gravity (-)          | 1.053                   | -        |
|                     | Sulfur content (% by weight)  | 6.00                    | -        |
|                     | Metal content (ppm by weight) | 300                     | -        |



**[0066]** The yields and qualities of the products shown in the above tables were confirmed to be on the same level with those of the product fractions (sulfur content of not more than 50 ppm by weight in gas oil) obtained by the conventional process illustrated in Figure 3. It is also confirmed that 15% reduction of the cost for constructing plant can be attained as compared with the conventional process. Accordingly, it was confirmed that the process of the present invention enables simplification of the process and saving of the space, and thus reduction of treating cost without lowering the product yields and qualities.

**[0067]** The above results clearly show the effects of the present invention. Namely, the present invention provides a method of treating a crude oil comprising a step of separating the crude oil by distillation where the crude oil is separated by distillation into a distillate oil and a heavy oil content, a step of thermal cracking where the heavy oil content separated at said step of separating the crude oil by distillation and obtained substantially from the bottom is thermally cracked to lighten the content, and a step of separating the thermal cracking product by distillation where the thermal cracking product obtained by lightening at said step of thermal cracking is separated by distillation; wherein said step of separating the crude oil by distillation and said step of separating the thermal cracking product by distillation are carried out at the same time in a distilling section comprising a vacuum distillation apparatus. Furthermore, the distillate oil separated at the step of separating the crude oil by distillation and the step of separating the thermal cracking product by distillation, which are carried out at the same time in said distilling section, is collectively subjected to desulfurization, cracking, and hydrogenation treatment in identical one hydrotreating section to produce a synthetic crude oil of low sulfur content containing no vacuum residual oil fraction and having high added value, followed by treatment in the downstream refining scheme according to a conventional technique. Accordingly, it is possible to simplify the process and save the space, and thereby to reduce a cost for the treatment. In addition, the method is also applicable to a small-scale refining of petroleum.

#### Industrial Applicability

**[0068]** The method of treating a crude oil according to the present invention is especially utilized as a so-called upgrading method of a heavy oil, which converts a heavy oil content contained in a crude oil into a light oil fraction in refining of petroleum producing value-added petroleum products from a crude oil.

#### **Claims**

1. A method of treating a crude oil comprising:

a step of separating the crude oil by distillation where the crude oil is separated by distillation into a distillate oil and a heavy oil content,  
a step of thermal cracking where the heavy oil content separated at said step of separating the crude oil by distillation and obtained substantially from the bottom is thermally cracked to lighten the content, and  
a step of separating the thermal cracking product by distillation where the thermal cracking product obtained by lightening at said step of thermal cracking is separated by distillation; wherein  
said step of separating the crude oil by distillation and said step of separating the thermal cracking product by distillation are carried out at the same time in a distilling section comprising a vacuum distillation apparatus.

2. The method of treating a crude oil according to claim 1, wherein the distilling section in which said step of separating the crude oil by distillation and said step of separating the thermal cracking product by distillation carried out at the same time comprises a pre-separation apparatus and a main separation apparatus.

3. The method of treating a crude oil according to claim 1, wherein the amount of the heavy oil content separated in said distilling section and withdrawn from the bottom is within a range of 15 to 55 parts by weight relative to 100 parts by weight of a distillate oil from the distilling section.

4. The method of treating a crude oil according to claim 1, wherein the heavy oil content separated in said step of separating a crude oil by distillation, withdrawn from the bottom, and fed to the step of thermal cracking contains substantially neither gas oil content nor vacuum gas oil content.

5. The method of treating a crude oil according to claim 1, wherein no heavy oil content is contained in thermal cracking residue in said step of thermal cracking.

6. The method of treating a crude oil according to claim 1, wherein the distillate oil separated in the step of separating

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the crude oil by distillation and said step of separating the thermal cracking product by distillation carried out at the same time in said distilling section is collectively subjected to desulfurization, cracking, and hydrogenation treatment in one identical hydrotreating section.

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FIG. 1

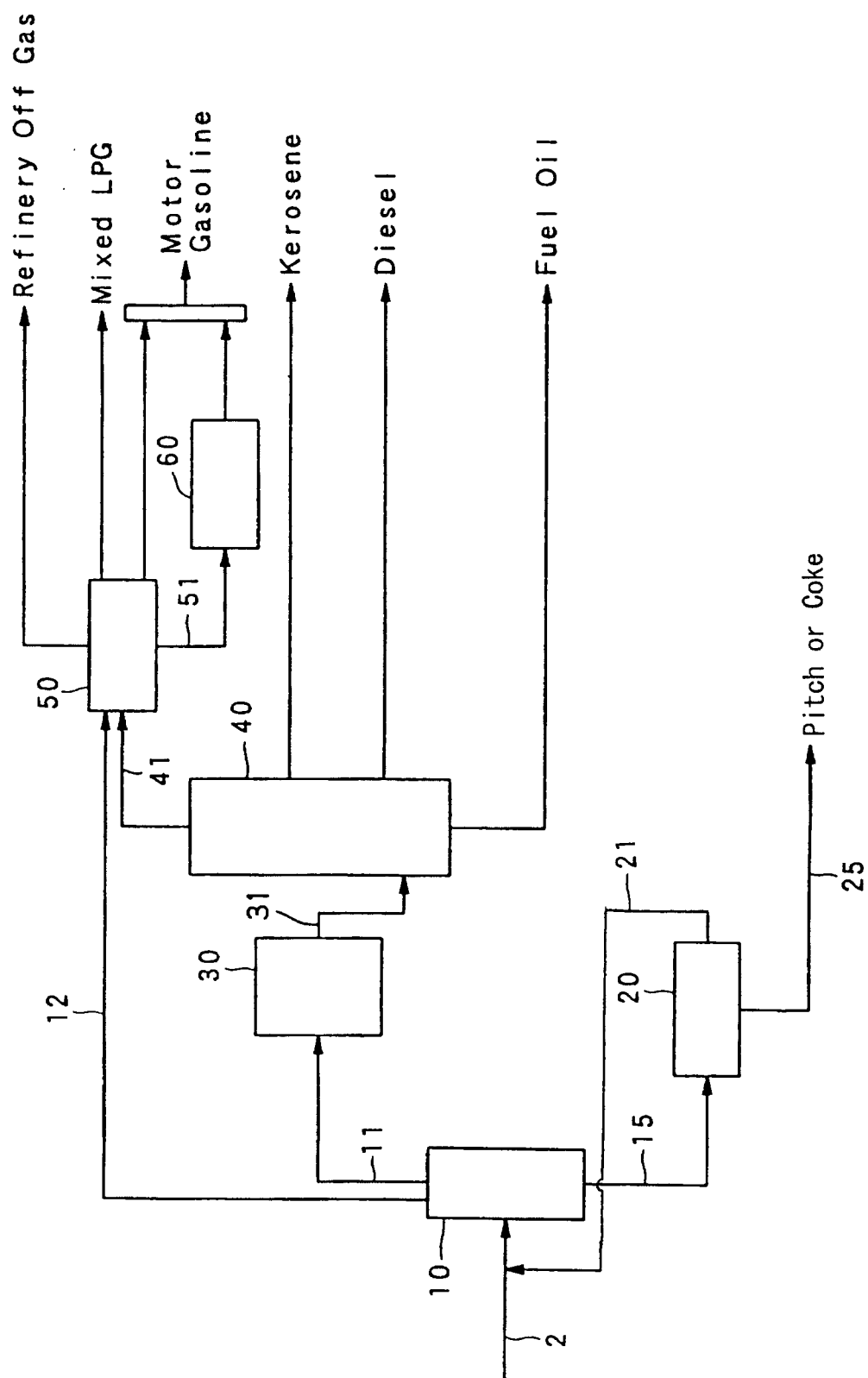


FIG. 2

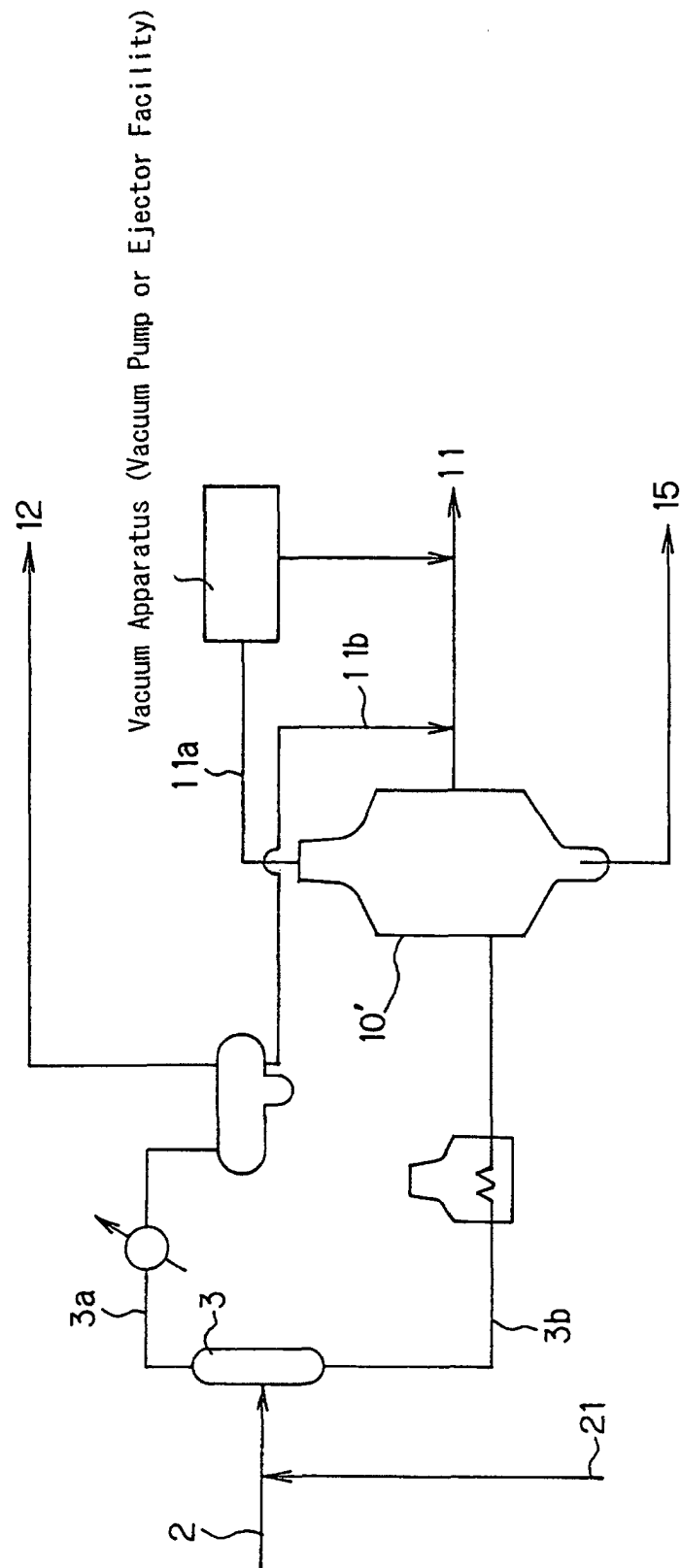
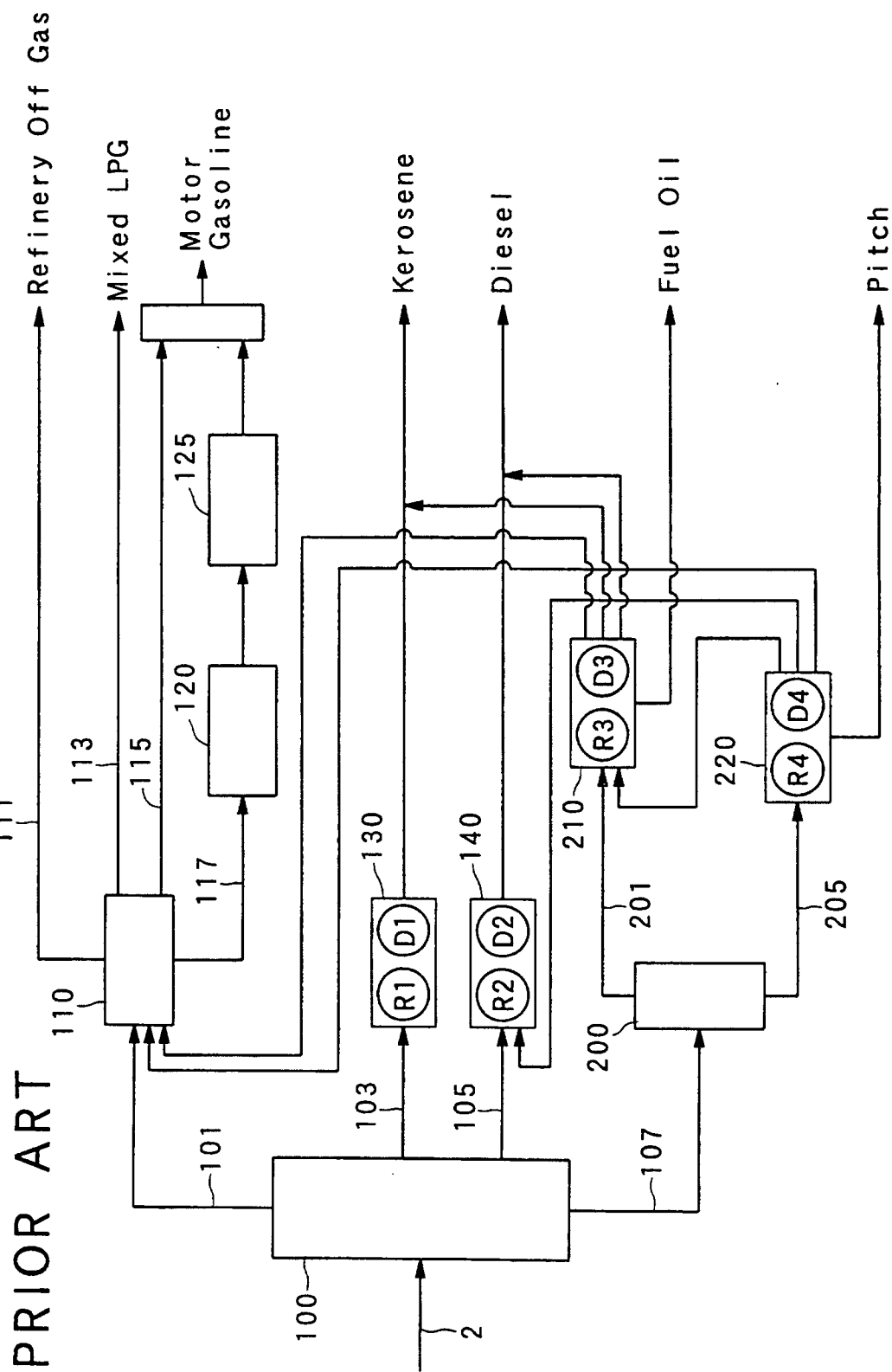


FIG. 3



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP00/03125

| A. CLASSIFICATION OF SUBJECT MATTER<br>Int.Cl <sup>7</sup> C10G55/02, C10G7/06, C10G9/00  |   |  |
|---|---|--|
| According to International Patent Classification (IPC) or to both national classification and IPC   |   |  |
| B. FIELDS SEARCHED  |   |  |
| Minimum documentation searched (classification system followed by classification symbols)<br>Int.Cl <sup>7</sup> C10G55/02, C10G7/06, C10G9/00  |   |  |
| Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched   |   |  |
| Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)  |   |  |
| C. DOCUMENTS CONSIDERED TO BE RELEVANT  |   |  |
| Category*   | Citation of document, with indication, where appropriate, of the relevant passages                                    | Relevant to claim No.  |
| A   | US, 3487006, A (The Lummus Company),<br>30 December, 1969 (30.12.69)<br>& JP, 53-28402, B1                            | 1-6  |
| A   | EP, 64447, A1 (COMPAGNIE FRANCAISE DE RAFFINAGE),<br>23 April, 1982 (23.04.82)<br>& JP, 57-185385, A & CA, 1178231, A | 1-6  |
| <input type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.   |   |  |
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| Date of the actual completion of the international search<br>18 August, 2000 (18.08.00)   |   | Date of mailing of the international search report<br>29 August, 2000 (29.08.00) |
| Name and mailing address of the ISA/<br>Japanese Patent Office  |   | Authorized officer   |
| Facsimile No.   |   | Telephone No.  |

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