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(54) **METHOD AND SYSTEM FOR SYNTHESIZING LIQUID HYDROCARBON COMPOUNDS**

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(57) **ABSTRACT**

Provided is a method for synthesizing liquid hydrocarbon compounds wherein synthesizing liquid hydrocarbon compounds from a synthesis gas by a Fisher-Tropsch synthesis reaction. The method includes a first absorption step of absorbing a carbon dioxide gas, which is contained in gaseous by-products generated in the Fisher-Tropsch synthesis reaction, with an absorbent, and a second absorption step of absorbing a carbon dioxide gas, which is contained in the synthesis gas, with the absorbent which is passed through the first absorption step.

FIG. 1

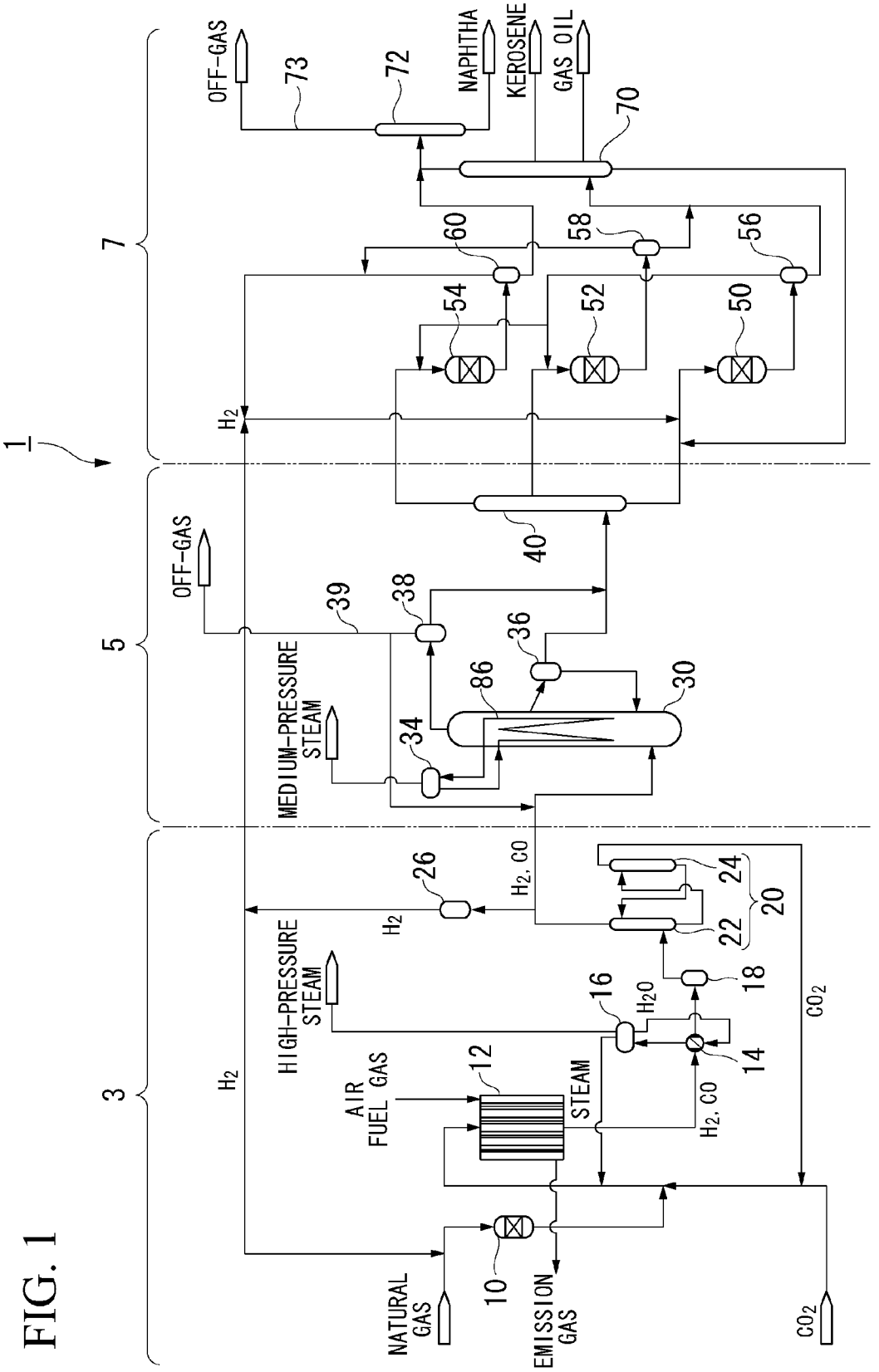

1
3
5
7
NATURAL GAS
AIR
FUEL GAS
HIGH-PRESSURE STEAM
MEDIUM-PRESSURE STEAM
OFF-GAS
EMISSION GAS
STEAM
H2
H2O
H2, CO
CO2
NAPHTHA
KEROSENE
GAS OIL
10
12
14
16
18
20
22
24
26
30
34
36
38
39
40
50
52
54
56
58
60
70
72
73
86

FIG. 2

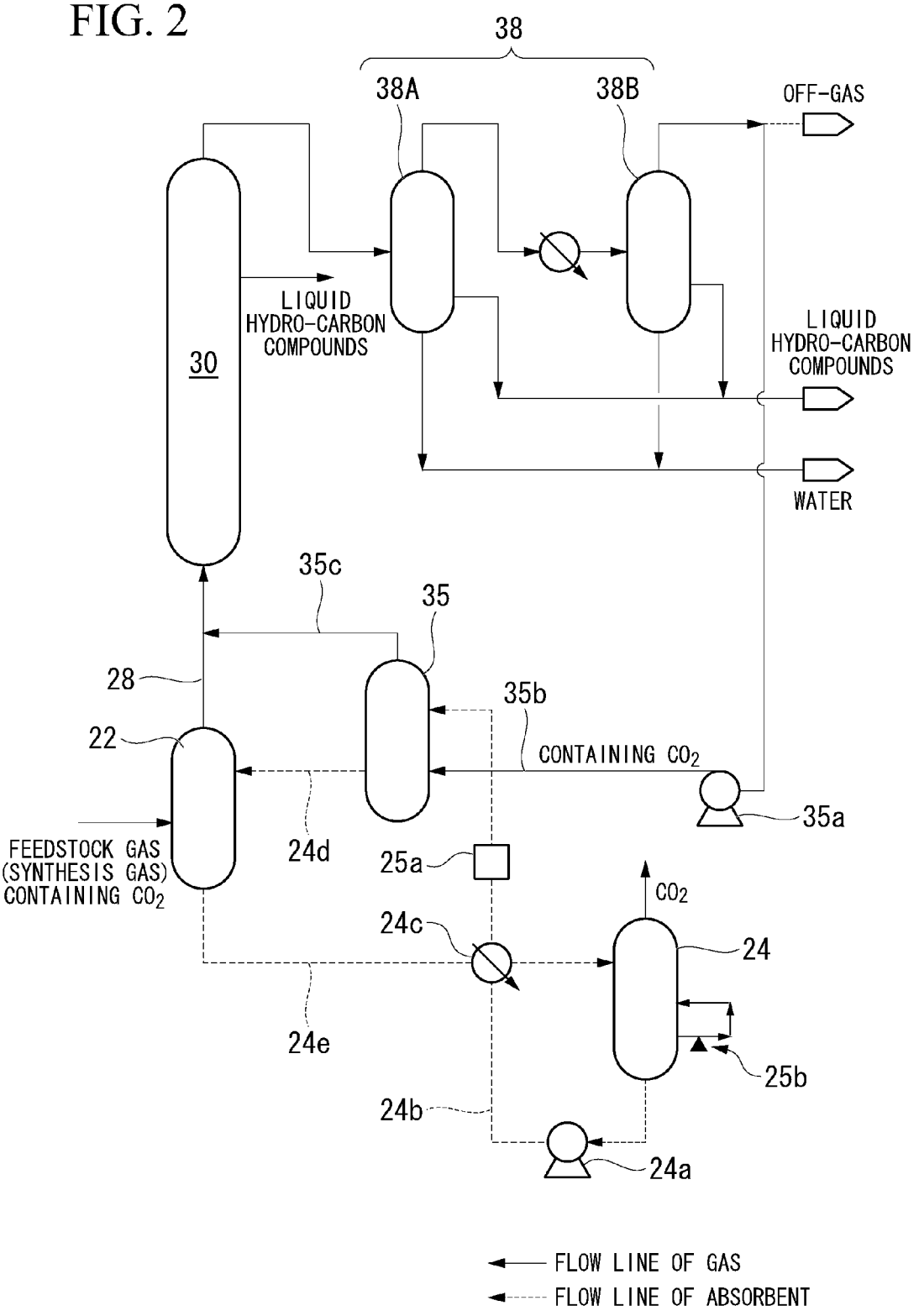
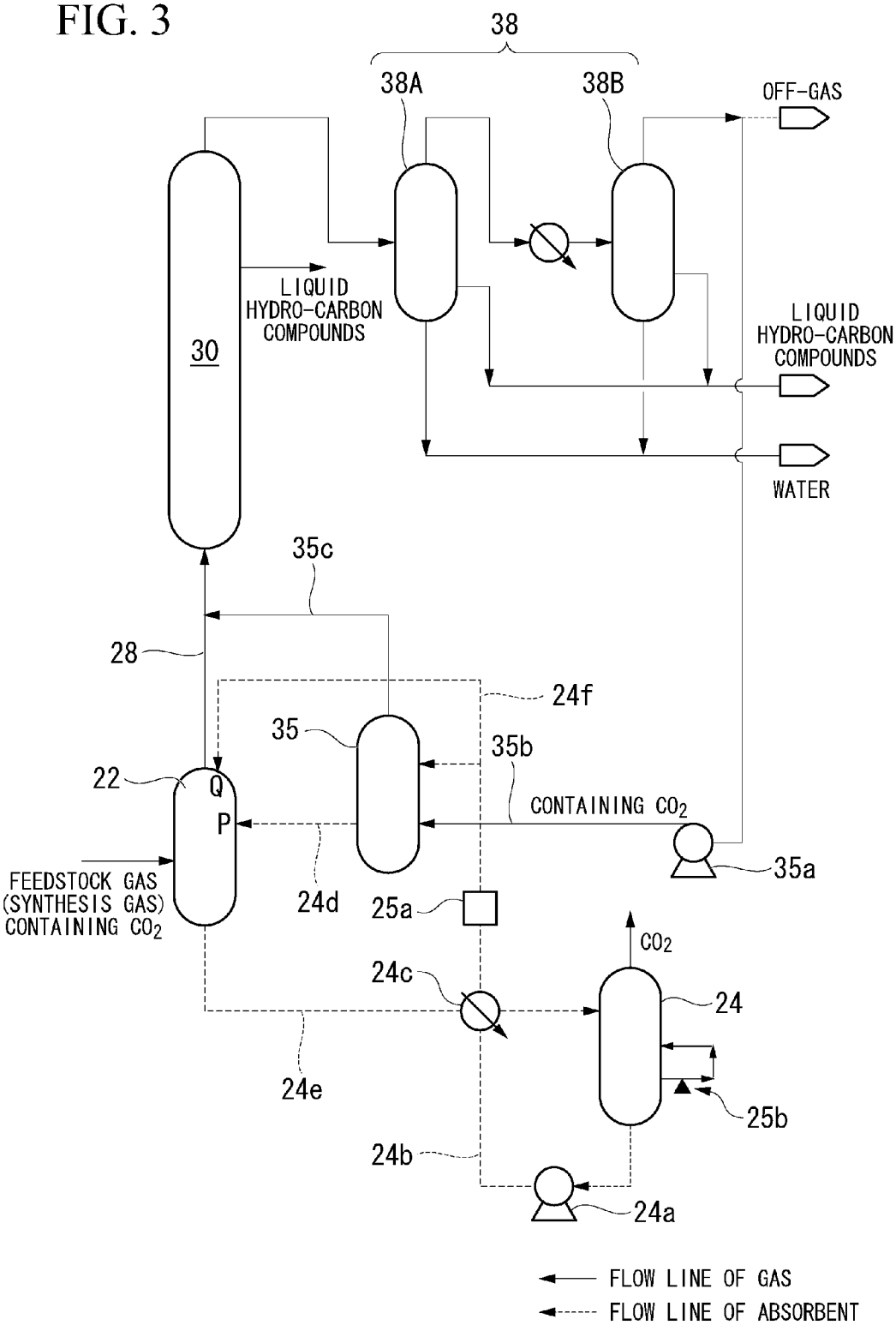

38
38A
38B
OFF-GAS
LIQUID HYDRO-CARBON COMPOUNDS
30
LIQUID HYDRO-CARBON COMPOUNDS
WATER
35c
35
28
35b
22
CONTAINING CO_2
35a
FEEDSTOCK GAS (SYNTHESIS GAS) CONTAINING CO_2
24d
25a
CO_2
24c
24
24e
25b
24b
24a
FLOW LINE OF GAS
FLOW LINE OF ABSORBENT

FIG. 3


38
38A
38B
OFF-GAS
LIQUID HYDRO-CARBON COMPOUNDS
30
LIQUID HYDRO-CARBON COMPOUNDS
WATER
35c
28
24f
35
35b
22
Q
P
CONTAINING CO_2
35a
FEEDSTOCK GAS (SYNTHESIS GAS) CONTAINING CO_2
24d
25a
CO_2
24c
24
24e
25b
24b
24a
FLOW LINE OF GAS
FLOW LINE OF ABSORBENT

METHOD AND SYSTEM FOR SYNTHESIZING LIQUID HYDROCARBON COMPOUNDS

TECHNICAL FIELD

[0001] The present invention relates to a method and a system for synthesizing liquid hydrocarbon compounds.

[0002] Priority is claimed on Japanese Patent Application No. 2009-080490, filed Mar. 27, 2009, the content of which is incorporated herein by reference.

BACKGROUND ART

[0003] As one of the methods for synthesizing liquid fuels from natural gas, the GTL (Gas To Liquids: liquid fuels synthesis) technique is known. The GTL technique is a technique of producing liquid fuel products, such as naphtha (raw gasoline), kerosene, gas oil, and wax, through the steps of reforming a natural gas to produce a synthesis gas containing a carbon monoxide gas (CO) and a hydrogen gas (H_2) as main components, synthesizing hydrocarbon compounds (hereinafter also refereed to as "FT synthesis hydrocarbons") using this synthesis gas as a feedstock of the Fischer-Tropsch synthesis reaction (hereinafter also referred to as "FT synthesis reaction"), and hydrogenating and fractionally distilling the FT synthesis hydrocarbons. The liquid fuel products using the FT synthesis hydrocarbons as a feedstock have high paraffin content, and do not include sulfur components, for example, as shown in Patent Document 1, the liquid fuel products have attracted attention as environment-friendly fuels.

[0004] As techniques of reforming natural gas, for example, reforming methods using carbon dioxide gas, such as steam and carbon dioxide gas reforming method and a carbon dioxide gas reforming method, are known. In case of reforming a natural gas using the carbon dioxide gas, an unreacted carbon dioxide gas is contained in the synthesis gas in a relatively high concentration. Therefore, a step of separating the carbon dioxide gas from the synthesis gas before the FT synthesis reaction may be adopted. The separated carbon dioxide gas is reused for reforming the natural gas.

[0005] In the FT synthesis reaction, heavy FT synthesis hydrocarbons with a relatively large carbon number are produced as a liquid, and various kinds of gases are generated as gaseous by-products. In the gaseous by-products, for example, a carbon dioxide gas, steam, hydrocarbon compounds with a carbon number of two or less, and hydrocarbon compounds with a carbon number of three or more are included. The gaseous by-products are discharged along with unreacted synthesis gas from a synthesis reactor which performs FT synthesis reaction. The discharged gaseous by-products are introduced into a separator and condensed light liquid hydrocarbon compounds are separated from the gaseous by-products. The remaining gas component is reused as necessary. For example, the unreacted synthesis gas is reused for the FT synthesis reaction, and the carbon dioxide gas is used for reforming the natural gas.

[0006] The separation of the carbon dioxide gas from the synthesis gas or gaseous by-products can be performed, for example, by using an absorbent which absorbs the carbon dioxide gas at room temperature, and releases the carbon dioxide gas when it is heated. For example, absorbing carbon dioxide gas included in the synthesis gas and the gaseous by-products by passing those gases through the absorbent at room temperature, and stripping the carbon dioxide gas from the absorbent by heating the absorbent. The absorbent which has released the carbon dioxide gas is reused for separating the carbon dioxide gas from the synthesis gas and the gaseous by-products. Conventionally, in a step of separating the carbon dioxide gas from the synthesis gas and in a step of separating the carbon dioxide gas from the gaseous by-products, circulation systems of the above absorbent are individually provided in the respective steps.

CITATION LIST

Patent Document

[0007] [Patent Document 1] Japanese Patent Unexamined Publication No. 2004-323626

SUMMARY OF INVENTION

Technical Problem

[0008] In recent years, in the GTL technique, each step including synthesis gas production, FT synthesis reaction, hydrogenation and fractional distillation is desired to be carried out at a low cost. Therefore, even in the above carbon dioxide gas separating step, it is desired to reduce the cost as much as possible.

[0009] In view of the above circumstances, the present invention is to provide a method and a system for synthesizing hydrocarbon compounds capable of reducing the cost for absorbing and removing a carbon dioxide gas from a synthesis gas that is a feedstock for the Fischer-Tropsch synthesis reaction and gaseous by-products generated in the Fischer-Tropsch synthesis reaction.

Solution to Problem

[0010] The method for synthesizing hydrocarbon compounds according to the present invention is a method for synthesizing liquid hydrocarbon compounds from a synthesis gas by a Fisher-Tropsch synthesis reaction, the method includes: a first absorption step of absorbing a carbon dioxide gas included in gaseous by-products with an absorbent, the gaseous by-products being generated in the Fisher-Tropsch synthesis reaction; and a second absorption step of absorbing a carbon dioxide gas included in the synthesis gas, with the absorbent which has passed through the first absorption step.

[0011] In the present invention, since the concentration of the carbon dioxide gas contained in the gaseous by-products is low, a common absorbent is used for the absorption of the carbon dioxide gas contained in the gaseous by-products and the absorption of the carbon dioxide gas included in the synthesis gas.

[0012] Therefore, according to the present invention, the cost for absorbing and removing the carbon dioxide gas contained in the synthesis gas and the carbon dioxide gas contained in the gaseous by-products can be reduced, compared to the case using separate absorbents individually for the synthesis gas and the gaseous by-products.

[0013] The above method for synthesizing hydrocarbon compounds may further include a merging step of merging the gaseous by-products which have passed through the first absorption step, into the synthesis gas which has passed through the second absorption step before supplying the synthesis gas to the Fisher-Tropsch synthesis reaction.

[0014] The gaseous by-products contain a synthesis gas which has not reacted in the Fisher-Tropsch synthesis reac-

tion. According to the present invention, the synthesis gas can be utilized without loss since the synthesis gas which is contained in the gaseous by-products can be reused for the Fisher-Tropsch synthesis reaction.

[0015] The above method for synthesizing hydrocarbon compounds may further include a regenerating step of stripping the carbon dioxide gas from the absorbent which has passed through the second absorption step.

[0016] In the present invention, the carbon dioxide gas absorbed by the absorbent in the first absorption step and the second absorption step can be stripped from the absorbent at once in the single regenerating step.

[0017] Therefore, according to the present invention an apparatus such as a regeneration tower which regenerates the absorbent can be used commonly, and the cost required for synthesizing the liquid hydrocarbon compounds can be reduced, compared to the case using separate absorbents for the synthesis gas and the gaseous by-products, and releasing the carbon dioxide gas individually from the different absorbents.

[0018] In the above method for synthesizing hydrocarbon compounds, the absorbent which has passed through the regenerating step may be used in the first absorption step.

[0019] In the present invention, stripping the carbon dioxide gas from the absorbent which has passed through first and second absorption steps to regenerate the absorbent, the regenerated absorbent can be reused. Therefore, according to the present invention, the absorbent can be used without loss.

[0020] In the above method for synthesizing hydrocarbon compounds, a part of the absorbent which has passed through the regenerating step may be also used in the second absorption step.

[0021] In the present invention, a clean absorbent regenerated in the regeneration step can be used as a part of the absorbent in the second absorption step. Accordingly, the carbon dioxide gas contain in the synthesis gas can be absorbed and removed more certainly.

[0022] In the above method for synthesizing hydrocarbon compounds, a first supplying position of the absorbent which has passed through the regenerating step may be downstream in a flow of the synthesis gas in the second absorption step with respect to a second supplying position of the absorbent which has passed through the first absorption step.

[0023] According to the present invention, the carbon dioxide gas can be absorbed more certainly, since a cleaner absorbent is supplied to a downstream in a flow of the synthesis gas.

[0024] In the above method for synthesizing hydrocarbon compounds, the synthesis gas may flow in a direction opposite to the absorbent in the second absorption step.

[0025] According to the present invention, the carbon dioxide gas can be more efficiently absorbed, since the synthesis gas flows in the direction opposite to the absorbent in the second absorption step.

[0026] The system for synthesizing hydrocarbon compounds according to the present invention is a system for synthesizing liquid hydrocarbon compounds from a synthesis gas by a Fisher-Tropsch synthesis reaction. The system includes: a first absorption tower which allows an absorbent to absorb carbon dioxide gas contained in gaseous by-products generated in the synthesis reaction; and a second absorption tower which allows the absorbent which has passed through the first absorption tower, to absorb carbon dioxide gas contained in the synthesis gas.

[0027] In the present invention, common absorbent is used in the first absorption tower and the second absorption tower. Accordingly, an apparatus such as a regeneration tower which regenerates the absorbent can be used commonly, and the cost can be reduced compared to the case where separate absorbents are individually circulated and used in the first and second absorption towers.

[0028] The above system for synthesizing hydrocarbon compounds may further include merging section which merges the gaseous by-products discharged from the first absorption tower into the synthesis gas discharged from the second absorption tower.

[0029] In the present invention, an unreacted synthesis gas contained in the gaseous by-products from which the carbon dioxide gas has been separated can be reused for the Fisher-Tropsch synthesis reaction. Accordingly, the partial pressure increase of the carbon dioxide gas in the Fisher-Tropsch synthesis reactor is avoided, so that the pressure in the Fisher-Tropsch synthesis reaction can be lowered, and the cost, for example, reactor cost can be reduced.

[0030] The above system for synthesizing hydrocarbon compounds may further include a regeneration tower which allows the absorbent which has passed through the second absorption tower to strip the carbon dioxide gas.

[0031] In the present invention, the carbon dioxide gas absorbed in the first absorption tower and the second absorption tower can be removed from the absorbent at once in one regeneration tower. Accordingly, the regeneration tower can be used commonly, and the cost, for example, the apparatus cost, can be reduced compared to the case where the carbon dioxide gas is individually removed from different absorbents.

[0032] The system for synthesizing hydrocarbon compounds may further include a first supplying section which supplies the absorbent which has passed through the regeneration tower, to the first absorption tower.

[0033] According to the present invention, the absorbent from which the carbon dioxide gas has been stripped can be reused, and the absorbent can be used without loss.

[0034] The above system for synthesizing hydrocarbon compounds may further include a second supplying section which supplies a part of the absorbent which has passed through the regeneration tower, to the second absorption tower.

[0035] In the present invention, the regenerated clean absorbent which has passed through the regeneration tower is supplied to the second absorption tower via the second supplying section, and then the regenerated clean absorbent can be used as a part of the absorbent in the second absorption tower. Accordingly, the carbon dioxide gas contained in the synthesis gas can be absorbed and removed more certainly.

[0036] In the above system for synthesizing hydrocarbon compounds, it may be adopted such that the first supplying section includes a first supplying port of the absorbent which is connected to the second absorption tower and through which the absorbent is supplied to the second absorption tower, the second supplying section includes a second supplying port of the absorbent which is connected to the second absorption tower and through which the absorbent is supplied to the second absorption tower, and the second supplying port is positioned at downstream in a flow of the synthesis gas in the second absorption tower with respect to the first supplying port.

[0037] According to the present invention, the carbon dioxide gas can be absorbed by the absorbent more certainly, since a cleaner absorbent is supplied to the downstream in the flow of the synthesis gas in the second absorption tower.

[0038] In the above system for synthesizing hydrocarbon compounds, the synthesis gas may flow in a direction opposite to the absorbent in the second absorption tower.

[0039] In the present invention, the carbon dioxide gas can be more efficiently absorbed, since the synthesis gas flows in the direction opposite to the absorbent in the second absorption tower.

Advantageous Effects of Invention

[0040] According to the present invention, there is provided a method and a system for synthesizing hydrocarbon compounds capable of reducing the cost for absorbing and removing carbon a dioxide gas from a synthesis gas that is a feedstock for the Fischer-Tropsch synthesis reaction and gaseous by-products generated in the Fischer-Tropsch synthesis reaction.

BRIEF DESCRIPTION OF THE DRAWINGS

[0041] FIG. **1** is an overall schematic diagram showing the configuration of a liquid fuel synthesizing system according to an embodiment of the present invention.

[0042] FIG. **2** is a partial schematic diagram showing the configuration of the hydrocarbon compounds synthesizing system.

[0043] FIG. **3** is a partial schematic diagram showing another configuration of the hydrocarbon compounds synthesizing system according to the present invention.

DESCRIPTION OF EMBODIMENTS

[0044] An embodiment of the present invention will be described below in detail, referring to the accompanying drawings. In the present specification and drawings, duplicate descriptions will be omitted by giving the same reference numbers to components having substantially the same configurations.

[0045] First, with reference to FIG. **1**, the overall configuration of a liquid fuel synthesizing system **1** which carries out a GTL (Gas To Liquids) process according to the present embodiment will be described. FIG. **1** is a schematic view showing the overall configuration of the liquid fuel synthesizing system **1** according to the present embodiment.

[0046] As shown in FIG. **1**, the liquid fuel synthesizing system **1** according to the present embodiment is a plant facility which carries out the GTL process which converts a hydrocarbon feedstock, such as a natural gas, into liquid fuels. The liquid fuel synthesizing system **1** includes a synthesis gas production unit **3**, an FT synthesis unit **5**, and an upgrading unit **7**. The synthesis gas production unit **3** reforms a natural gas, which is a hydrocarbon feedstock, to produce a synthesis gas including a carbon monoxide gas and a hydrogen gas. The FT synthesizing unit **5** synthesizes liquid hydrocarbon compounds from the produced synthesis gas by the FT synthesis reaction. The upgrading unit **7** hydrogenates and fractionates the liquid hydrocarbon compounds synthesized by the FT synthesis reaction to produce liquid fuels and other products (for example, naphtha, kerosene, gas oil, and wax). Hereinafter, components of these respective units will be described.

[0047] First, the synthesis gas production unit **3** will be described. The synthesis gas production unit **3** mainly includes, for example, a desulfurization reactor **10**, a reformer **12**, a waste heat boiler **14**, gas-liquid separators **16** and **18**, a CO_2 removal unit **20**, and a hydrogen separator **26**. The desulfurization reactor **10** is composed of, for example, a hydrodesulfurizer and removes sulfur components from a natural gas that is a feedstock. The reformer **12** reforms the natural gas supplied from the desulfurization reactor **10** to produce a synthesis gas including a carbon monoxide gas (CO) and a hydrogen gas (H_2) as main components. The waste heat boiler **14** recovers waste heat of the synthesis gas produced in the reformer **12** to generate a high-pressure steam. The gas-liquid separator **16** separates the water heated by the heat exchange with the synthesis gas in the waste heat boiler **14** into gas (high-pressure steam) and liquid. The gas-liquid separator **18** removes a condensed component from the synthesis gas cooled down in the waste heat boiler **14**, and supplies a gas component to the CO_2 removal unit **20**. The CO_2 removal unit **20** has an absorption tower (second absorption tower) **22** and a regeneration tower **24**. In the absorption tower **22**, carbon dioxide gas contained in the synthesis gas supplied from the gas-liquid separator **18** is absorbed by an absorbent. In the regeneration tower **24**, absorbent which has absorbed the carbon dioxide gas releases the carbon dioxide gas, and the absorbent is regenerated. The hydrogen separator **26** separates a part of the hydrogen gas included in the synthesis gas, from which the carbon dioxide gas has been separated by the CO_2 removal unit **20**. However, the above CO_2 removal unit **20** may not be provided depending on circumstances.

[0048] In the reformer **12**, for example, by using steam and carbon dioxide gas reforming method described by the chemical reaction formulas (1) and (2), a natural gas is reformed by a carbon dioxide and a steam, and a high temperature synthesis gas which includes a carbon monoxide gas and a hydrogen gas as main components is produced. In addition, the reforming method in this reformer **12** is not limited to the above steam and carbon dioxide gas reforming method. For example, a steam reforming method, a partial oxidation reforming method (POX) using oxygen, an autothermal reforming method (ATR) that is a combination of the partial oxidation method and the steam reforming method, or a carbon dioxide gas reforming method can also be utilized.

$$CH_4+H_2O\rightarrow CO+3H_2 \quad (1)$$

$$CH_4+CO_2\rightarrow 2CO+2H_2 \quad (2)$$

[0049] The hydrogen separator **26** is provided on a branch line branching from a main line **28** which connects the CO_2 removal unit **20** or gas-liquid separator **18** with the bubble column reactor **30**. The hydrogen separator **26** can be composed of, for example, a hydrogen PSA (Pressure Swing Adsorption) device which performs adsorption and desorption of hydrogen by using a pressure difference. The hydrogen PSA device has adsorbents (for example, zeolitic adsorbent, activated carbon, alumina, silica gel) within adsorption towers (not shown) which are arranged in parallel. The hydrogen PSA device can continuously supply a high-purity hydrogen gas (for example, about 99.999%) separated from synthesis gas by sequentially repeating pressurizing, adsorption, desorption (depressurizing), and purging of hydrogen in each adsorption tower.

[0050] The hydrogen gas separating method in the hydrogen separator **26** is not limited to the pressure swing adsorp-

tion method by the above hydrogen PSA device. For example, a hydrogen storing alloy adsorption method, a membrane separation method, or a combination thereof can be used.

[0051] The hydrogen storing alloy method is, for example, a technique for separating hydrogen gas using a hydrogen storing alloy (for example, TiFe, $LaNi_5$, $TiFe_{0.7}$ to $TiFe_{0.9}$, $Mn_{0.3}$ to $Mn_{0.1}$, $TiMn_{1.5}$) having a property which adsorbs or releases a hydrogen by being cooled or heated respectively. In the hydrogen storing alloy method, for example, within adsorption towers which contains a hydrogen storing alloy, absorption of a hydrogen by cooling the hydrogen storing alloy and releasing of a hydrogen by heating the hydrogen storing alloy are alternately repeated. In this way, hydrogen gas in the synthesis gas can be separated and recovered.

[0052] The membrane separation method is a method using a membrane made of a polymer material, such as aromatic polyimide to separate a hydrogen gas, which has superior membrane permeability, from a mixed gas. Since the membrane separation method does not require a phase change of the objective materials for separation, less energy is required for the operation, and the operation cost is small. Additionally, since the structure of a membrane separation device is simple and compact, low facility cost is required and the required facility area is also small. Moreover, since there is no driving device in a separation membrane, and a stable operating range is wide, there is an advantage that maintenance is easy.

[0053] Next, the FT synthesis unit **5** will be described. The FT synthesis unit **5** mainly includes, for example, the bubble column reactor **30**, a gas-liquid separator **34**, a separator **36**, a gas-liquid separator **38**, and a first fractionator **40**. The bubble column reactor **30** synthesizes liquid hydrocarbon compounds by the FT synthesis reaction from the synthesis gas produced in the above synthesis gas production unit **3**, more specifically, from a carbon monoxide gas and a hydrogen gas. The gas-liquid separator **34** separates the water, which is heated while passing through the heat transfer tube **86** provided within the bubble column reactor **30**, into a steam (medium-pressure steam) and liquid. The separator **36** is connected to a middle part of the bubble column reactor **30** to separate a catalyst and liquid hydrocarbon compounds. The gas-liquid separator **38** is connected to the top of the bubble column reactor **30** to cool down an unreacted synthesis gas and gaseous hydrocarbon compounds (gaseous by-products). The first fractionator **40** fractionally distills the liquid hydrocarbon compounds, which are supplied via the separator **36** and the gas-liquid separator **38** from the bubble column reactor **30**, into respective fractions.

[0054] The bubble column reactor **30**, which is an example of a reactor which synthesizes liquid hydrocarbon compounds from the synthesis gas, functions as an FT synthesis reactor which synthesizes liquid hydrocarbon compounds from the synthesis gas by the FT synthesis reaction. The bubble column reactor **30** is composed of, for example, a bubble column slurry bed type reactor in which slurry consisting of a catalyst and a medium oil is contained inside a column type vessel. This bubble column reactor **30** synthesizes liquid hydrocarbon compounds from the synthesis gas by the FT synthesis reaction. In detail, the synthesis gas supplied to the bubble column reactor **30** flows through the slurry consisting of a catalyst and medium oil. And in a suspended state, a hydrogen gas and a carbon monoxide gas included in the synthesis gas react with each other to synthesize hydrocarbon compounds, as shown in the following chemical reaction formula (3).

$$2nH_2+nCO\rightarrow(-CH_2-)_n+nH_2O \quad (3)$$

[0055] Since this FT synthesis reaction is an exothermic reaction, the bubble column reactor **30** is a heat exchanger type reactor within which the heat transfer tube **86** is provided. The bubble column reactor **30** is supplied with, for example, water (BFW: Boiler Feed Water) as a coolant, so that the reaction heat of the above FT synthesis reaction can be recovered as a medium-pressure steam by the heat exchange between the slurry and the water.

[0056] Next, the upgrading unit **7** will be described. The upgrading unit **7** includes, for example, a wax fraction hydrocracking reactor **50**, a middle distillate hydrotreating reactor **52**, a naphtha fraction hydrotreating reactor **54**, gas-liquid separators **56**, **58**, and **60**, a second fractionator **70**, and a naphtha stabilizer **72**. The wax fraction hydrocracking reactor **50** is connected to the bottom of the first fractionator **40**. The middle distillate hydrotreating reactor **52** is connected to a middle part of the first fractionator **40**. The naphtha fraction hydrotreating reactor **54** is connected to the top of the first fractionator **40**. The gas-liquid separators **56**, **58** and **60** are provided so as to correspond to the hydrogenation reactors **50**, **52** and **54**, respectively. The second fractionator **70** fractionally distills the liquid hydrocarbon compounds supplied from the gas-liquid separators **56** and **58**. The naphtha stabilizer **72** rectifies liquid hydrocarbon compounds of a naphtha fraction which are supplied from the gas-liquid separator **60** and fractionally distilled in the second fractionator **70**. As the result, the naphtha stabilizer **72** discharges butane and components lighter than butane as a off-gas, and recovers components having a carbon number of five or more as a naphtha product.

[0057] Next, a process for synthesizing liquid fuels from a natural gas (GTL process) by the liquid fuel synthesizing system **1** configured as above will be described.

[0058] A natural gas (the main component of which is CH_4) as a hydrocarbon feedstock is supplied to the liquid fuel synthesizing system **1** from an external natural gas supply source (not shown), such as a natural gas field or a natural gas plant. The above synthesis gas production unit **3** reforms the natural gas to produce a synthesis gas (mixed gas including a carbon monoxide gas and a hydrogen gas as main components).

[0059] Specifically, at first, the natural gas is introduced into the desulfurization reactor **10** along with the hydrogen gas separated by the hydrogen separator **26**. In the desulfurization reactor **10**, sulfur components included in the natural gas are converted into a hydrogen sulfide by the introduced hydrogen gas and the hydrodesulfurization catalyst. Further, in the desulfurization reactor **10**, the generated hydrogen sulfide is absorbed by a desulfurizing agent, for example, ZnO. By desulfurizing the natural gas in advance in this way, reduction in activity of catalysts used in the reformer **12** and the bubble column reactor **30** due to sulfur can be prevented.

[0060] The natural gas (may also include a carbon dioxide) desulfurized in this way is supplied to the reformer **12** after the carbon dioxide (CO_2) gas supplied from a carbon dioxide supply source (not shown) and the steam generated in the waste heat boiler **14** are mixed together. In the reformer **12**, the natural gas is reformed by the carbon dioxide and the steam, and a high-temperature synthesis gas including a carbon monoxide gas and a hydrogen gas as main components is

produced, for example, by the above steam and carbon dioxide gas reforming method. At this time, a fuel gas and an air for a burner installed in the reformer **12** are supplied to the reformer **12**. And by the combustion heat of the fuel gas in the burner, reaction heat required for the above steam and carbon dioxide gas reforming reaction that is an endothermic reaction is provided.

[0061] The high-temperature synthesis gas (for example, 900° C., 2.0 MPaG) produced in the reformer **12** in this way is supplied to the waste heat boiler **14**, and is cooled down by the heat exchange with the water which circulates through the waste heat boiler **14** (for example, 400° C.). And the waste heat of the synthesis gas is recovered by the water. At this time, the water heated by the synthesis gas in the waste heat boiler **14** is supplied to the gas-liquid separator **16**. In the gas-liquid separator **16**, the water heated by the synthesis gas is separated into a high pressure steam (for example, 3.4 to 10.0 MPaG) and water. The separated high pressure steam is supplied to the reformer **12** or other external devices, and separated water is returned to the waste heat boiler **14**.

[0062] Meanwhile, the synthesis gas cooled down in the waste heat boiler **14** is supplied to the absorption tower **22** of the CO_2 removal unit **20**, or the bubble column reactor **30**, after a condensed liquid fraction is separated and removed from the synthesis gas in the gas-liquid separator **18**. In the absorption tower **22**, a carbon dioxide gas contained in the synthesis gas is absorbed by the absorbent which is contained in the absorption tower **22**, and the carbon dioxide gas is removed from the synthesis gas. The absorbent which has absorbed the carbon dioxide gas within this absorption tower **22** is discharged from the absorption tower and introduced into the regeneration tower **24**. The absorbent which is introduced into the regeneration tower **24** is heated with, for example, a steam and subjected to stripping treatment to release the carbon dioxide gas. The released carbon dioxide gas is discharged from the regeneration tower **24** and introduced into the reformer **12**, and is reused for the above reforming reaction.

[0063] The synthesis gas produced in the synthesis gas production unit **3** in this way is supplied to the bubble column reactor **30** of the above FT synthesis unit **5**. At this time, the composition ratio of the synthesis gas supplied to the bubble column reactor **30** is adjusted to a composition ratio suitable for the FT synthesis reaction (for example, H_2:CO=2:1 (molar ratio)). In addition, the synthesis gas supplied to the bubble column reactor **30** is pressurized to a pressure suitable for the FT synthesis reaction (for example, about 3.6 MPaG) by a compressor (not shown) provided in a line which connects the CO_2 removal unit **20** with the bubble column reactor **30**.

[0064] Additionally, a part of the synthesis gas, the carbon dioxide gas of which has been separated by the above CO_2 removal unit **20**, is also supplied to the hydrogen separator **26**. In the hydrogen separator **26**, the hydrogen gas contained in the synthesis gas is separated by the adsorption and desorption utilizing a pressure difference (hydrogen PSA) as described above. The separated hydrogen is continuously supplied from, for example, a gas holder (not shown) via a compressor (not shown) to various hydrogen-utilizing reaction devices (for example, the desulfurization reactor **10**, the wax fraction hydrocracking reactor **50**, the middle distillate hydrotreating reactor **52**, the naphtha fraction hydrotreating reactor **54**) which perform predetermined reactions by utilizing hydrogen within the liquid fuel synthesizing system **1**.

[0065] Next, the above FT synthesis unit **5** synthesizes liquid hydrocarbon compounds by the FT synthesis reaction from the synthesis gas produced by the above synthesis gas production unit **3**.

[0066] Specifically, the synthesis gas, from which the carbon dioxide gas has been separated in the above CO_2 removal unit **20**, is introduced into the bubble column reactor **30**, and flows through the slurry including the catalyst contained in the bubble column reactor **30**. At this time, within the bubble column reactor **30**, the carbon monoxide and hydrogen gas which are included in the synthesis gas react with each other by the aforementioned FT synthesis reaction, and hydrocarbon compounds are produced. Moreover, while the FT synthesis reaction, the reaction heat of the FT synthesis reaction is recovered by the water flowing through the heat transfer tube **86** of the bubble column reactor **30**, and the water heated by the reaction heat is vaporized into a steam. The steam is supplied to the gas-liquid separator **34** and separated into condensed water and a gas fraction, the water is returned to the heat transfer tube **86**, and the gas fraction is supplied to an external device as a medium-pressure steam (for example, 1.0 to 2.5 MPaG).

[0067] The liquid hydrocarbon compounds synthesized in the bubble column reactor **30** in this way are discharged from the middle part of the bubble column reactor **30** as a slurry including catalyst particles, and are introduced into the separator **36**. In the separator **36**, the introduced slurry is separated into catalysts (solid particle) and a liquid component including a liquid hydrocarbon compounds. A part of the separated catalyst is returned to the bubble column reactor **30**, and the liquid component is introduced into the first fractionator **40**. From the top of the bubble column reactor **30**, gaseous by-products, which include an unreacted synthesis gas in the FT synthesis reaction and gaseous hydrocarbon compounds generated in the FT synthesis reaction, are discharged. The gaseous by-products discharged from the bubble column reactor **30** are introduced into the gas-liquid separator **38**. In the gas-liquid separator **38**, the gaseous by-products are cooled down, and are separated into condensed liquid hydrocarbon compounds and gas component. Separated liquid hydrocarbon compounds are discharged from the gas-liquid separator **38**, and are introduced into the first fractionator **40**. A part of the separated gas component discharged from the gas-liquid separator **38** is reintroduced into the bubble column reactor **30**, and the unreacted synthesis gases (CO and H_2) contained in this gas component are reused for the FT synthesis reaction. Further, the off-gas discharged from the gas-liquid separator **38** including gaseous hydrocarbon compounds, which have a small carbon number (C_4 or less) that is other than target products as a main component, is used as a fuel gas, or fuels equivalent to LPG (Liquefied Petroleum Gas) is recovered.

[0068] In the first fractionator **40**, the liquid hydrocarbon compounds (with variety of carbon number), which are supplied via the separator **36** and the gas-liquid separator **38** from the bubble column reactor **30** as described above, are fractionally distilled into a naphtha fraction (the boiling point of which is lower than about 150° C.), a middle distillate (the boiling point of which is about 150 to 350° C.), and a wax fraction (the boiling point of which exceeds about 350° C.). The liquid hydrocarbon compounds of the wax fraction (mainly C_{21} or more) discharged from the bottom of the first fractionator **40** are introduced into the wax fraction hydrocracking reactor **50**. The liquid hydrocarbon compounds of the

middle distillate equivalent to kerosene and gas oil (mainly C_{11} to C_{20}) discharged from the middle part of the first fractionator **40** are introduced into the middle distillate hydrotreating reactor **52**. The liquid hydrocarbon compounds of the naphtha fraction (mainly C_5 to C_{10}) discharged from the top of the first fractionator **40** are introduced into the naphtha fraction hydrotreating reactor **54**.

[0069] The wax fraction hydrocracking reactor **50** hydrocracks the liquid hydrocarbon compounds of the wax fraction with a large carbon number (approximately C_{21} or more), which are discharged from the bottom of the first fractionator **40**, by using the hydrogen gas supplied from the above hydrogen separator **26**, to reduce the carbon number to C_{20} or less. In this hydrocracking reaction, C—C bonds of hydrocarbon compounds with a large carbon number are cleaved by the action of catalysts and heat. As the result, the hydrocarbon compounds with a large carbon number are converted into hydrocarbon compounds with a small carbon number. Additionally, in the wax fraction hydrocracking reactor **50**, the reaction which hydroisomerizes straight chain saturated hydrocarbon compounds (normal paraffins) to produced branched saturated hydrocarbon compounds (isoparaffins) also proceeds simultaneously with the hydrocracking reaction. This improves the low-temperature fluidity of a wax fraction hydrocracking product which is required as a base stock of fuel oil. Moreover, in the wax fraction hydrocracking reactor **50**, a hydrodeoxygenation reaction of oxygen-containing compounds, such as alcohols, and a hydrogenation reaction of olefins, both of which are contained in a wax fraction that is a feedstock, also proceed. The hydrocracked products including the liquid hydrocarbon compounds discharged from the wax fraction hydrocracking reactor **50** are introduced into gas-liquid separator **56**, and separated into gas and liquid. The separated liquid hydrocarbon compounds are introduced in to the second fractionator **70**, and the separated gas component (including a hydrogen gas) is introduced into the middle distillate hydrotreating reactor **52** and the naphtha fraction hydrotreating reactor **54**.

[0070] In the middle distillate hydrotreating reactor **52**, liquid hydrocarbon compounds of the middle distillate equivalent to kerosene and gas oil having a middle carbon number (approximately C_{11} to C_{20}), which are discharged from the middle part of the first fractionator **40**, are hydrotreated. In the middle distillate hydrotreating reactor **52**, a hydrogen gas supplied from the hydrogen separator **26** via the wax fraction hydrocracking reactor **50** is used for the hydrotreating. In this hydrotreating reaction, the olefins contained in the above liquid hydrocarbon compounds is hydrogenated to produce saturated hydrocarbon compounds, and the oxygen-containing compounds, such as alcohols contained in the above liquid hydrocarbon compounds are hydrodeoxygenated and converted into saturated hydrocarbon compounds and water. Moreover, in this hydrotreating reaction, a hydroisomerization reaction which isomerizes straight chain saturated hydrocarbon compounds (normal paraffins) to convert the saturated hydrocarbon compounds into branched saturated hydrocarbon compounds (isoparaffins) proceeds, and the low-temperature fluidity of the produced oil which is required as a fuel oil is improved. A product including the hydrotreated liquid hydrocarbon compounds is separated into gas and liquid in the gas-liquid separator **58**. The separated liquid hydrocarbon compounds are introduced into the second fractionator **70**, and the separated gas fraction (including a hydrogen gas) is reused for the above hydrogenation reaction.

[0071] In the naphtha fraction hydrotreating reactor **54**, liquid hydrocarbon compounds of the naphtha fraction with a low carbon number (approximately C_{10} or less), which are discharged from the top of the first fractionator **40**, are hydrotreated. In the naphtha fraction hydrotreating reactor **54**, the hydrogen gas supplied from the hydrogen separator **26** via the wax fraction hydrocracking reactor **50** is used for the hydrotreating. As a result, a product including the hydrotreated liquid hydrocarbon compounds is separated into gas and liquid in the gas-liquid separator **60**. The separated liquid hydrocarbon compounds are introduced into the naphtha stabilizer **72**, and the separated gas fraction (including hydrogen gas) is reused for the above hydrogenation reaction. In this naphtha fraction hydrotreating, hydrogenation of olefins, and hydrodeoxygenation of oxygen-containing compounds such as alcohols mainly proceed.

[0072] In the second fractionator **70**, the liquid hydrocarbon compounds, which are supplied from the wax fraction hydrocracking reactor **50** and the middle distillate hydrotreating reactor **52** as described above, are fractionally distilled into hydrocarbon compounds of C_{10} or less (the boiling point of which is lower than about 150° C.), a kerosene fraction (the boiling point of which is about 150 to 250° C.), a gas oil (the boiling point of which is about 250 to 350° C.), and an uncracked wax fraction (the boiling point of which exceeds 350° C.) from the wax fraction hydrocracking reactor **50**. The uncracked wax fraction is obtained from the bottom of the second fractionator **70**, and this is recycled to the upstream of the wax fraction hydrocracking reactor **50**. Kerosene and gas oil are discharged from the middle part of the second fractionator **70**. Meanwhile, gaseous hydrocarbon compounds of C_{10} or less is discharged from the top of the second fractionator **70**, and is introduced into the naphtha stabilizer **72**.

[0073] Moreover, in the naphtha stabilizer **72**, the hydrocarbon compounds of C_{10} or less, which have been supplied from the above naphtha fraction hydrotreating reactor **54** and fractionally distilled in the second fractionator **70**, are distilled, and naphtha (C_5 to C_{10}) is obtained as a product. Accordingly, high-purity naphtha is discharged from the bottom of the naphtha stabilizer **72**. Meanwhile, the off-gas including hydrocarbon compounds with a predetermined carbon number or less (C_4 or less), which is other than the product, is discharged from the top of the naphtha stabilizer **72**. This off-gas is used as a fuel gas, or a fuel equivalent to LPG is recovered.

[0074] The process (GTL process) of the liquid fuel synthesizing system **1** has been described hitherto. By this GTL process, a natural gas can be easily and economically converted into clean liquid fuels, such as high-purity naphtha (C_5 to C_{10}), kerosene (C_{11} to C_{15}), and gas oil (C_{16} to C_{20}).

[0075] Next, a configuration of a part of the liquid fuel synthesis system **1**, which removes a carbon dioxide gas from a synthesis gas and gaseous by-products, will be described with reference to FIG. **2**. In the present embodiment, a configuration using an absorbent to remove the carbon dioxide gas will be described as an example. The absorbent used in the present embodiment has a feature of absorbing a carbon dioxide gas at room temperature, and releasing the absorbed carbon dioxide gas when it is heated. In FIG. **2**, lines shown in a solid-line arrow are those of the gases, and lines shown in a broken-line arrow are those of the absorbent. In addition, the

above absorbent includes, for example, aqueous solutions of amine compounds given as the following general formulas (4) to (6).

$$R_1R_2N(CH_2)_nOH \quad (4)$$

$$R_1N((CH_2)_nOH)_2 \quad (5)$$

$$N((CH_2)_nOH)_3 \quad (6)$$

[0076] Here, in the formulas (4) to (6), R_1 is a hydrogen atom or an alkyl group of C_1 to C_{10}, and R_2 is a hydrogen atom or an alkyl group of C_1 to C_4. Additionally, n=1 to 5. Moreover, hydroxyalkyl groups in Formula (5) and Formula (6) shall include a case where the carbon numbers of alkylene groups are different from each other.

[0077] Such amine compounds include, for example, alkanolamines, such as monoethanolamine, diethanolamine, triethanolamine, 2-methylamino ethanol, 2-ethylamino ethanol, 2-propylamino ethanol, n-butylamino ethanol, 2-(isopropyl amino)ethanol, 3-ethylamino propanol, and dipropanol amine. The concentration of the amine compounds in an aqueous solution is set to 20 to 80 mass %, and is more preferably set to 30 to 50 mass %.

[0078] Additionally, absorbents other than the aqueous solution of the amine compounds may be used.

[0079] First, the flow lines of the gaseous by-products separated by the gas-liquid separator **38** will be described. The gas-liquid separator **38** is connected to a main line **28** via a gaseous by-product line **35***b*, a first absorption tower **35**, and a merging line **35***c*. The gaseous by-product line **35***b* is provided with, for example, a compressor **35***a*. The gaseous by-product line **35***b* is connected to the first absorption tower **35**. In the first absorption tower **35**, a carbon dioxide gas, which is contained in the gaseous by-products supplied through the gaseous by-product line **35***b*, is absorbed by the above absorbent (first absorption step). The merging line **35***c* connects the top of the first absorption tower **35** and the main line **28**. The merging line **35***c* is a merging section which merges the gaseous by-products, from which the carbon dioxide gas is removed while passing through the first absorption tower **35**, into the synthesis gas flowing in the main line **28**.

[0080] Next, the flow lines of the absorbent will be described. The absorbent is circulated between the regeneration tower **24** (refer to FIG. **1**), the first absorption tower **35**, and the second absorption tower **22**. The regeneration tower **24** is connected to the upper part of the first absorption tower **35** via first supplying line (first supplying section) **24***b*. The supplying line **24***b* is provided with a pump **24***a*, a heat exchanger **24***c*, and a cooler **25***a*. The bottom of the regeneration tower **24** is provided with a circulation path of the absorbent. A heating part **25***b* which heats the absorbent is provided on the circulation lines.

[0081] The first absorption tower **35** is connected to an upper part of the second absorption tower **22** via second supplying line (second supplying section) **24***d*. One end of the second supplying line **24***d* is connected to a lower part of the first absorption tower **35**, and the other end of the second supplying line **24***d* is connected to an upper part of the second absorption tower **22**. The second absorption tower **22** is connected to the regeneration tower **24** via third supplying line **24***e*. One end of the third supplying line **24***e* is connected to a lower part of the second absorption tower **22** and the other end of the third supplying line **24***e* is connected to the regeneration tower **24**. The third supplying line **24***e* is passing through inside of the above heat exchanger **24***c*.

[0082] Next, a step of absorbing carbon dioxide gas will be described while describing the flow lines of the gaseous by-products and the flow lines of the absorbent, and the flow lines of the synthesis gas.

[0083] The gaseous by-products separated by the gas-liquid separator **38** are supplied to the bottom of the first absorption tower **35** via the gaseous by-product line **35***b*. The gaseous by-products supplied to the first absorption tower **35** move within the first absorption tower **35** from its lower part to its upper part. Meanwhile, the absorbent is supplied to the upper part of the first absorption tower **35** via the supplying line **24***b* from the regeneration tower **24**. The absorbent is cooled down in the cooler **25***a* while passing through the supplying line **24***b*. The absorbent supplied to the upper part of the first absorption tower **35** moves within the first absorption tower **35** from its upper part to its lower part.

[0084] In the first absorption tower **35**, the carbon dioxide gas in the gaseous by-products which move within the first absorption tower **35** from its lower part to its upper part is absorbed by the absorbent which moves within the first absorption tower **35** from its upper part to its lower part (first absorption step). As such, in the first absorption tower **35**, a flow direction of the absorbent and a flow direction of the gaseous by-products are opposite, that is a counter flow, while absorbing the carbon dioxide gas in the gaseous by-products by the absorbent.

[0085] The gaseous by-products, from which the carbon dioxide gas has been absorbed and removed, are discharged from the first absorption tower **35** through the merging line **35***c* which is connected to the first absorption tower **35**. Meanwhile, the absorbent which has absorbed the carbon dioxide gas is discharged from the first absorption tower **35** through the second supplying line **24***d* which is connected to the lower part of the first absorption tower **35**.

[0086] The volume content of the carbon dioxide gas in the gaseous by-products is, for example, about 0.5% with respect to the whole gaseous by-products, which is a relatively low concentration. For this reason, the absorbent which has absorbed the carbon dioxide gas in the gaseous by-products still has sufficient remained absorption capacity of the carbon dioxide gas. The absorbent which has the sufficient absorption capacity in this way is discharged from the first absorption tower **35**.

[0087] The absorbent which is discharged from the first absorption tower **35** is introduced into the upper part of the second absorption tower **22** via the second supplying line **24***d*. The absorbent introduced into the upper part of the second absorption tower **22** moves within the second absorption tower **22** from its upper part to its lower part. Meanwhile, the synthesis gas discharged from the gas-liquid separator **18** (refer to FIG. **1**) that is a feedstock for the FT synthesis reaction step is introduced into the lower part of the second absorption tower **22**. The synthesis gas introduced into the second absorption tower **22** moves within the second absorption tower **22** from its lower part to its upper part.

[0088] In the second absorption tower **22**, the carbon dioxide gas in the synthesis gas which moves within the second absorption tower **22** from its lower part to its upper part is absorbed by the absorbent which moves within the second absorption tower **22** from its upper part to its lower part (second absorption step). As such, in the second absorption tower **22**, a flow direction of the absorbent and a flow direc-

tion of the synthesis gas are opposite, that is a counter flow, while absorbing the carbon dioxide gas in the synthesis gas by the absorbent.

[0089] The absorbent used in the second absorption tower **22** is an absorbent which has absorbed the carbon dioxide gas in the gaseous by-products in the first absorption tower **35**. That is, a common absorbent is used in the first absorption tower **35** and the second absorption tower **22**. As mentioned above, the absorbent has sufficient carbon dioxide gas absorption capacity even after the absorbent has absorbed the carbon dioxide gas in the gaseous by-products. The volume content of the carbon dioxide gas in the synthesis gas is about 5.8% of the whole synthesis gas, which is a relatively high concentration. However, the carbon dioxide gas absorption capacity of the absorbent supplied from the first absorption tower **35** is still sufficient. Therefore, in the second absorption tower **22**, the high-concentration carbon dioxide gas in this synthesis gas can be sufficiently absorbed by the absorbent.

[0090] The synthesis gas, from which the carbon dioxide gas has been absorbed and removed, is discharged from the second absorption tower **22** to the main line **28**. In the main line **28**, the gaseous by-products discharged from the first absorption tower **35** merge into the synthesis gas flowing in the main line **28** through the merging line **35***c* which is connected to the main line **28** (merging step). The merged gaseous by-products and the synthesis gas are introduced into the bubble column reactor **30** through the main line **28**. The synthesis gas and an unreacted synthesis gas component contained in the gaseous by-products are used for the FT synthesis reaction in the bubble column reactor **30**.

[0091] Meanwhile, the absorbent which has absorbed the carbon dioxide gas is discharged from the lower part of the second absorption tower **22** to the third supplying line **24***e*. The absorbent discharged from the second absorption tower **22** is introduced into the regeneration tower **24** through the third supplying line **24***e*. In the regeneration tower **24**, the absorbent is heated by the heating part **25***b*, the carbon dioxide gas is removed from the absorbent, and the absorbent is regenerated (regenerating step). The absorbent which has released the carbon dioxide gas and been regenerated is again supplied to the first absorption tower **35** through the supplying line **24***b*. In the first absorption tower **35**, the absorbent which is regenerated by the regenerating step is used, and the carbon dioxide gas in the gaseous by-products is absorbed by the regenerated absorbent (the first absorption step). Thereafter, the carbon dioxide gas contained in the gaseous by-products and the synthesis gas is absorbed by circulating the absorbent as above.

[0092] In the method for synthesizing liquid hydrocarbon compounds using the liquid fuel synthesizing system **1** of the present embodiment, focusing on the fact that the concentration of the carbon dioxide gas contained in the gaseous by-products is low, the method for synthesizing hydrocarbon compounds includes the first absorption step of absorbing the carbon dioxide gas contained in the gaseous by-products by the absorbent, and the second absorption step of absorbing the carbon dioxide gas contained in the synthesis gas by the absorbent used in the first absorption step. Thus, the common absorbent can be used for the absorption of the carbon dioxide gas contained in the gaseous by-products and the absorption of the carbon dioxide gas included in the synthesis gas. Accordingly, the cost can be reduced compared to the case where absorbents are individually circulated and used for a step of absorbing the carbon dioxide gas contained in the gaseous by-products, and a step of absorbing the carbon dioxide gas contained in the synthesis gas.

[0093] Additionally, according to the present embodiment, the gaseous by-products discharged from the first absorption tower **35** are merged into the synthesis gas discharged from the second absorption tower **22**. As the result, unreacted synthesis gas contained in the gaseous by-products, from which the carbon dioxide gas has been absorbed and removed, can be reused for the FT synthesis reaction. Accordingly, the synthesis gas can be utilized without loss. Additionally, the method further includes a regenerating step of heating the absorbent after the second absorption step, stripping the carbon dioxide gas from the absorbent, and regenerating the absorbent. As the result, the carbon dioxide gas absorbed by the absorbent in the first absorption step and the second absorption step can be stripped from the absorbent at once in a single regenerating step. Accordingly, compared to the case where absorbents which have absorbed the carbon dioxide gas in respective absorption steps are individually heated and the carbon dioxide gas are stripped, for example, the regeneration tower **24** can be shared, and the apparatus cost can be reduced.

[0094] The technical scope of the present invention is not limited to the above embodiment, but various modifications may be made without departing from the gist of the present invention.

[0095] For example, although the configuration in which the absorbent discharged from the regeneration tower **24** is introduced into only the first absorption tower **35** has been described as an example in the above embodiment, the present invention is not limited thereto. For example, as shown in FIG. **3**, a configuration in which a part of the absorbent discharged from the regeneration tower **24** is introduced into the second absorption tower **22** may be adopted.

[0096] In a configuration shown in FIG. **3**, fourth supplying line **24***f* branches from the supplying line **24***b*, in the flow line of the absorbent. The end of the fourth supplying line **24***f* (second supplying port) Q is connected to the upper part of the second absorption tower **22**. The end of the fourth supplying line **24***f* Q is arranged at a higher position of the second absorption tower **22** than the end of the second supplying line **24***d* (first supplying port) P which is connected to the second absorption tower. That is, the end of the fourth supplying line **24***f* Q, which supplies the absorbent passed through the regeneration tower **24**, is located at downstream in a flow direction of the synthesis gas in the second absorption tower than the end of the second supplying line P, which supplies the absorbent passed through the first absorption tower **35**. For this reason, a clean absorbent will be supplied to further downstream in the flow direction of the synthesis gas.

[0097] By adopting such a configuration, a part of the absorbent which has released the carbon dioxide gas and been regenerated can be used in the second absorption step. Thus, a clean absorbent can also be used in the second absorption step. Additionally, a cleaner absorbent is introduced into the downstream in the flow direction of the synthesis gas. Therefore, the carbon dioxide gas which is contained in the synthesis gas can be certainly absorbed. Additionally, the flow of the absorbent and the flow of the synthesis gas are in a counter flow. Thus, the carbon dioxide gas contained in the synthesis gas can be more efficiently absorbed by the absorbent.

INDUSTRIAL APPLICABILITY

[0098] According to the method and the system of the present invention, the cost for absorbing and removing a carbon dioxide gas from a synthesis gas that is a feedstock of the Fischer-Tropsch synthesis reaction and gaseous by-products generated in the Fischer-Tropsch synthesis reaction can be reduced

REFERENCE SIGNS LIST

[0099] **30**: BUBBLE COLUMN REACTOR
[0100] **22**: SECOND ABSORPTION TOWER
[0101] **24**: REGENERATION TOWER
[0102] **24***b*: SUPPLYING LINE
[0103] **24***d*: SECOND SUPPLYING LINE
[0104] **35**: FIRST ABSORPTION TOWER
[0105] **35***c*: MERGING LINE

1-7. (canceled)

8. A system for synthesizing liquid hydrocarbon compounds, comprising:

a reactor configured to synthesize liquid hydrocarbon compounds from a synthesis gas containing carbon monoxide gas and hydrogen gas by a Fischer-Tropsch synthesis reaction;

a first absorption tower in which a first absorbent absorbs carbon dioxide gas contained in gaseous by-products generated in the reactor;

a second absorption tower in which a second absorbent absorbs a carbon dioxide gas included in the synthesis gas to be supplied to the reactor; and

a second supplying section through which the first absorbent discharged from the first absorption tower is supplied to the second absorption tower.

9. The system for synthesizing liquid hydrocarbon compounds according to claim **8**, further comprising

a merging section configured to merge the gaseous by-products from which the carbon dioxide gas removed by the first absorbent in the first absorption tower into the synthesis gas from which the carbon dioxide gas removed by the second absorbent in the second absorption tower, and which is to be supplied to the reactor.

10. The system for synthesizing liquid hydrocarbon compounds according to claim **8**, further comprising

a regeneration tower in which the carbon dioxide gas is stripped from the second absorbent discharged from the second absorption tower to regenerate the second absorbent.

11. The system for synthesizing liquid hydrocarbon compounds according to claim **10**, further comprising

a first supplying section through which the second absorbent discharged from the regeneration tower is supplied to the first absorption tower to use as the first absorbent in the first absorption tower.

12. (canceled)

13. The system for synthesizing liquid hydrocarbon compounds according to claim **12**, wherein

the first supplying section includes a first supplying port of the absorbent which is connected to the second absorption tower and through which the absorbent is supplied to the second absorbent tower from the first absorption tower,

the second supplying section includes a second supplying port of the absorbent which is connected to the second absorption tower and through which the absorbent is supplied to the second absorbent tower from the regeneration tower, and

the second supplying port is located downstream in a flow of the synthesis gas in the second absorption tower with respect to the first supplying port on the second absorption tower.

14. The system for synthesizing liquid hydrocarbon compounds according to claim **8**,

wherein the second absorption tower is configured so that the synthesis gas flows in a direction opposite to the absorbent.

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