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(72) Inventeurs/Inventors:
IIJIMA, MASAKI, JP;
TATSUMI, MASAHIKO, JP;
YAGI, YASUYUKI, JP

(73) Propriétaires/Owners:
MITSUBISHI HEAVY INDUSTRIES, LTD., JP;
THE KANSAI ELECTRIC POWER CO., INC., JP

(74) Agent: SMART & BIGGAR

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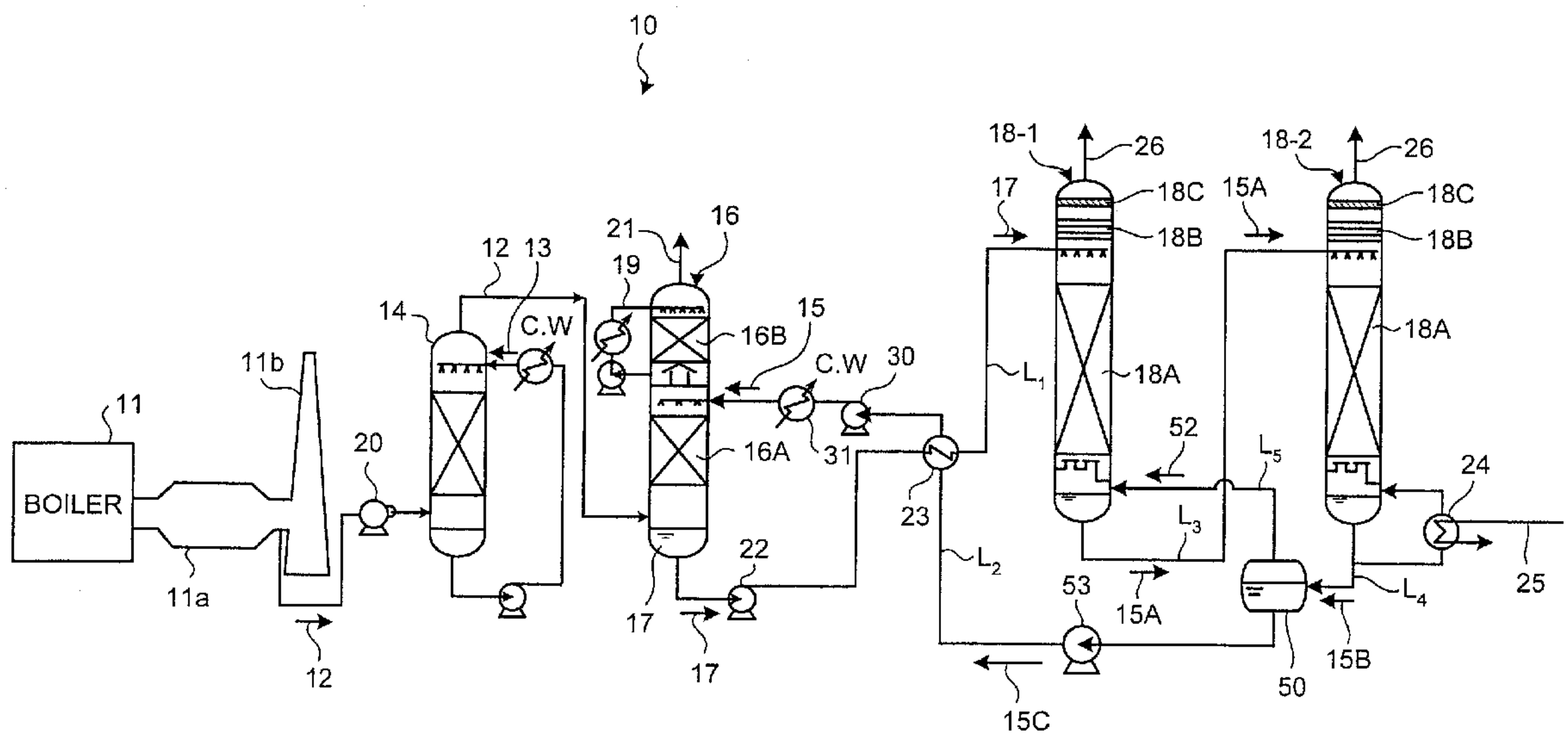



(57) Abrégé/Abstract:
A $CO_2$ recovery system according to the present invention includes: a cooling tower (14) that uses cooling water (13) to cool a $CO_2$-containing exhaust gas (12) discharged from industrial equipment such as a boiler (11) or a gas turbine; a $CO_2$ absorber (16) that brings the cooled $CO_2$-containing exhaust gas (12) into contact with a $CO_2$-absorbent (15) that absorbs $CO_2$, thereby removing the $CO_2$ from the exhaust gas (12); and a first absorbent regenerator (18-1) and a second absorbent regenerator (18- 2) that release $CO_2$ from a $CO_2$-absorbent that has absorbed $CO_2$ (rich solution) (17), thereby regenerating the $CO_2$-absorbent (15). A second lean solution at the outlet of the second absorbent regenerator is subjected to vacuum flash vaporization, and the resulting vapor is inputted to the first absorbent regenerator.

## ABSTRACT

A $CO_2$ recovery system according to the present invention includes: a cooling tower (14) that uses cooling water (13) to cool a $CO_2$-containing exhaust gas (12) discharged from industrial equipment such as a boiler (11) or a gas turbine; a $CO_2$ absorber (16) that brings the cooled $CO_2$-containing exhaust gas (12) into contact with a $CO_2$-absorbent (15) that absorbs $CO_2$, thereby removing the $CO_2$ from the exhaust gas (12); and a first absorbent regenerator (18-1) and a second absorbent regenerator (18-2) that release $CO_2$ from a $CO_2$-absorbent that has absorbed $CO_2$ (rich solution) (17), thereby regenerating the $CO_2$-absorbent (15). A second lean solution at the outlet of the second absorbent regenerator is subjected to vacuum flash vaporization, and the resulting vapor is inputted to the first absorbent regenerator.

# DESCRIPTION

## $CO_2$ RECOVERY SYSTEM

This application is a divisional application of Canadian National Phase Application No. 2,814,354 filed on 27th July, 2011.

## Field

[0001] The present invention relates to a $CO_2$ recovery system that uses an absorbent removing $CO_2$ contained in an exhaust gas.

## Background

[0002] In recent years, a greenhouse effect caused by $CO_2$ has been pointed out as one of causes of global warming. Accordingly, measures against the greenhouse effect have been urgently and internationally needed for the protection of the global environment. Since a source of $CO_2$ corresponds to the whole field of human activity using the combustion of fossil fuel, a demand for the suppression of $CO_2$ emission tends to become stronger. Accordingly, as measures against an ingredient (chemical use) such as urea, an increase in production of crude oil, and global warming, a method of removing and recovering $CO_2$, which is contained in a flue gas, by bringing a flue gas of a boiler into contact with an amine-based $CO_2$-absorbent and a method of storing recovered $CO_2$ without releasing recovered $CO_2$ to the atmosphere have been energetically studied for power generation facilities, such as thermoelectric power plants using a large amount of fossil fuel.

[0003] As a practical method of recovering and storing $CO_2$ contained in a large amount of flue gas, there is a chemical absorption technique that brings a flue gas into contact with a $CO_2$-absorbent such as an amine aqueous solution. A process for bringing a flue gas into contact with a $CO_2$-absorbent in a $CO_2$ absorber, a process for liberating $CO_2$ and regenerating an absorbent by heating the absorbent having absorbed $CO_2$ in an absorbent regenerator, and a process for circulating the absorbent in the $CO_2$

absorber again to reuse the absorbent are employed as processes for removing and recovering $CO_2$ from a flue gas by using the above-mentioned $CO_2$-absorbent (Patent Literature 1).

[0004] The operation of a $CO_2$ recovery apparatus using this chemical absorption technique in the related art causes an amine aqueous solution and $CO_2$ to be separated from each other in the absorbent regenerator by high-temperature steam, but the consumption of this steam (energy) has needed to be minimized. For this purpose, methods using a mixture of two or more kinds of different $CO_2$-absorbents (Patent Literatures 2 and 3) and a method of improving a process for feeding a $CO_2$-absorbent (Patent Literature 4) have been examined until now.

Citation List

Patent Literature

[0005] Patent Literature 1: Japanese Laid-open Patent Publication No. 7-51537

Patent Literature 2: Japanese Laid-open Patent Publication No. 2001-25627

Patent Literature 3: Japanese Laid-open Patent Publication No. 2005-254212

Patent Literature 4: U.S. 6,800,120

Summary

[0006] However, since a system, which absorbs, removes, and recovers $CO_2$ from a $CO_2$-containing exhaust gas such as a flue gas by using the above-mentioned $CO_2$-absorbent, is additionally installed on a combustion facility, the operating cost of the system also needs to be reduced as much as possible. In particular, since a large amount of heat energy is consumed in the absorbent regenerator that regenerates an absorbent, it is necessary to use a process for further reducing the energy of steam and saving energy as much as possible.

[0007] Further, if the size of the $CO_2$ recovery system in the related art is increased so that the amount of $CO_2$ to be recovered per day becomes, for example, 1000 t or more, a large amount of heat energy of a reboiler is consumed in a regeneration process. For this reason, it is necessary to reduce the energy of steam and to save energy.

[0008] An aspect of the present disclosure is to provide a $CO_2$ recovery system that further reduces the heat energy of a reboiler and saves energy.

[0008a] According to an aspect of the present invention, there is provided a $CO_2$ recovery system comprising: a $CO_2$ absorber that brings a cooled $CO_2$-containing exhaust gas into contact with a $CO_2$-absorbent for absorbing $CO_2$ to remove $CO_2$ from the exhaust gas; a first absorbent regenerator that regenerates an absorbent by releasing $CO_2$ from a $CO_2$-absorbent having absorbed $CO_2$; a second absorbent regenerator that regenerates an absorbent by releasing residual $CO_2$ from a first lean solution discharged from the first absorbent regenerator; a flash drum that flashes a second lean solution discharged from the second absorbent regenerator; and a lean/lean solution heat exchanger where the first lean solution exchanges heat with a third lean solution flashed in the flash drum, wherein

vapor generated in the flash drum is inputted to the first absorbent regenerator

[0009] According to a first aspect of the present disclosure, there is provided a $CO_2$ recovery system including: a $CO_2$ absorber that brings a cooled $CO_2$-containing exhaust gas into contact with a $CO_2$-absorbent absorbing $CO_2$ to remove $CO_2$ from the exhaust gas; a first absorbent regenerator that regenerates an absorbent by releasing $CO_2$ from a $CO_2$-absorbent having absorbed $CO_2$; a second absorbent regenerator that regenerates an absorbent by releasing residual $CO_2$ from a first lean solution discharged from the first absorbent regenerator; and a flash drum that flashes a second lean solution discharged from the second absorbent regenerator, wherein vapor generated in the flash drum is inputted to the first absorbent regenerator.

[0010] In some embodiments, the $CO_2$ recovery system according to the first aspect further includes a lean/lean solution heat exchanger where the first lean solution exchanges heat with a third lean solution flashed in the flash drum.

[0011] In some embodiments, the $CO_2$ recovery system according to the first aspect further includes a port which is provided in the first absorbent regenerator at a middle portion in a vertical axis direction of the first absorbent regenerator and through which a semi-lean solution is extracted, a circulation line to which the semi-lean solution is extracted and along which the semi-lean solution returns to a return port closer to the bottom than the extraction port, and a semi-lean/lean solution heat exchanger which is provided on the circulation line and where a third lean solution flashed in the flash drum exchanges heat with the semi-lean solution.

[0012] In some embodiments, the $CO_2$ recovery system according to the first aspect further includes a lean/lean solution heat exchanger where the first lean solution exchanges heat with a third lean solution flashed in the flash drum, a port which is provided in the first absorbent regenerator at a middle portion in a vertical axis direction of the first absorbent regenerator and through which a semi-lean solution is extracted, a circulation line to which the semi-lean solution is extracted and along which the semi-lean solution returns to a return port closer to the bottom than the extraction port, and a semi-lean/lean solution heat exchanger which is provided on the circulation line and where the third lean solution exchanges heat with the semi-lean solution.

[0013] In some embodiments, the $CO_2$ recovery system further includes a cooling tower that cools the $CO_2$-containing exhaust gas by cooling water.

[0014] According to some embodiments, a $CO_2$ recovery system includes first and second absorbent regenerators that regenerate an absorbent by releasing $CO_2$ from a $CO_2$-absorbent having absorbed $CO_2$ (rich solution), and a second lean solution at the outlet of the second absorbent regenerator is subjected to vacuum flash vaporization, and the resulting vapor is inputted to the first absorbent regenerator. Accordingly, it is possible to further reduce the heat energy of a reboiler and to save energy.

## Brief Description of Drawings

[0015] FIG. 1 is a schematic view of a $CO_2$ recovery system according to a first embodiment.

FIG. 2 is a diagram illustrating main parts of a first absorbent regenerator and a second absorbent regenerator according to the first embodiment.

FIG. 3 is a diagram illustrating main parts of a first absorbent regenerator and a second absorbent regenerator according to a second embodiment.

FIG. 4 is a diagram illustrating main parts of a first absorbent regenerator and a second absorbent regenerator according to a third embodiment.

FIG. 5 is a diagram illustrating main parts of a first absorbent regenerator and a second absorbent regenerator according to a fourth embodiment.

FIG. 6 is a schematic view of a $CO_2$ recovery system in the related art.

## Description of Embodiments

[0016] Examples of embodiments of the invention will be described in detail below with reference to the drawings. Meanwhile, the invention is not limited by these embodiments. Further, components of the following embodiments include components that can be easily supposed by those skilled in the art or substantially the same components.

First embodiment

[0017] A $CO_2$ recovery system according to an embodiment of the invention will be described with reference to the drawings. FIG. 1 is a schematic view of a $CO_2$ recovery system.

As illustrated in FIG. 1, a $CO_2$ recovery system 10 includes a cooling tower 14 that uses cooling water 13 to cool a $CO_2$-containing exhaust gas 12 discharged from industrial equipment such as a boiler 11 or a gas turbine, a $CO_2$ absorber 16 that brings the cooled $CO_2$-containing exhaust gas 12 into contact with a $CO_2$-absorbent 15 absorbing $CO_2$ to remove $CO_2$ from the exhaust gas 12, a first absorbent regenerator 18-1 that regenerates a first lean absorbent (first lean solution) 15A by releasing $CO_2$ from a $CO_2$-absorbent 17 having absorbed $CO_2$ (rich solution), and a second absorbent regenerator 18-2 that regenerates a second lean absorbent (second lean solution) 15B.

In this system, the first lean solution 15A, from which $CO_2$ has been removed in the first absorbent regenerator 18-1, is sent to the second absorbent regenerator 18-2. $CO_2$ is removed from the first lean solution 15A again in the second absorbent regenerator 18-2, so that a second lean solution 15B is generated. Then, the second lean solution 15B is subjected to vacuum flash vaporization in a flash drum 50, so that gas-side vapor 52 is used as a heat source of the first absorbent regenerator 18-1 and liquid-side vapor having been flashed in the flash drum 50 forms a third lean absorbent (third lean solution) 15C. After that, the vapor is cooled, sent to the $CO_2$ absorber 16, and is used as the $CO_2$-absorbent 15, which absorbs $CO_2$ contained in the exhaust gas 12, again.

[0018] In a $CO_2$ recovery method using the $CO_2$ recovery system 10, first, after the pressure of the $CO_2$-containing exhaust gas 12 is increased by an exhaust gas blower 20, the $CO_2$-containing exhaust gas 12 is sent to the cooling tower 14, is cooled by the cooling water 13 in the cooling tower 14, and is sent to the $CO_2$ absorber 16.

The $CO_2$ absorber 16 is provided with filling portions 16A and 16B therein, and the contact efficiency between the exhaust gas 12 and the $CO_2$-absorbent 15 is improved in the filling portion 16A that is provided at the lower portion of the $CO_2$ absorber 16. The contact efficiency between the exhaust gas 12 and a cooling water 13 is improved in the filling portion 16B that is provided at the upper portion of the $CO_2$ absorber 16.

[0019] In the $CO_2$ absorber 16, the exhaust gas 12 comes into contact with, for example, the amine-based $CO_2$-absorbent 15 and $CO_2$ contained in the exhaust gas 12 is absorbed in the $CO_2$-absorbent 15 by a chemical reaction ($R\text{-}NH_2+H_2O+CO_2 \rightarrow R\text{-}NH_3HCO_3$). Accordingly, a purified exhaust gas 21 from which $CO_2$ has been removed is released to the outside of the system. A $CO_2$-absorbent 17, which has absorbed $CO_2$, is also referred to as a "rich solution". The pressure of the rich solution 17 is increased by a rich solvent pump 22, and the rich solution 17 is heated by exchanging heat with a regenerated third lean absorbent 15C at a rich/lean solution heat exchanger 23. Then, the heated rich solution 17 is supplied to the first absorbent regenerator 18-1.

The rich solution 17 is supplied to the first absorbent regenerator 18-1 from the $CO_2$ absorber 16 through a rich solution supply line $L_1$. Further, the third lean solution 15C is supplied to the $CO_2$ absorber 16 from the second absorbent regenerator 18-2 through a lean solution supply line $L_2$, which has been flashed in the flash drum 50, via a lean solution pump 53. The rich/lean solution heat exchanger 23 is provided at an intersection between the rich solution supply line $L_1$ and the lean solution supply line $L_2$.

Meanwhile, the third lean solution 15C, which has been flashed in the flash drum 50, is cooled by a lean solvent cooler 31 and is introduced into the $CO_2$ absorber 16 as the $CO_2$-absorbent 15.

[0020] FIG. 2 is a diagram illustrating main parts of the first absorbent regenerator 18-1 and the second absorbent regenerator 18-2.

When being introduced into the first absorbent regenerator 18-1 from the upper portion of the first absorbent regenerator 18-1 and flowing downward in the first absorbent regenerator 18-1, the rich solution 17 subjected to heat exchange by the rich/lean solution heat exchanger 23 reacts endothermically with the vapor 52, releases most of $CO_2$, and is regenerated. The absorbent from which a part or most of $CO_2$ has been released in the first absorbent regenerator 18-1 is referred to as a "semi-lean solution". The absorbent, which has released a part or most of $CO_2$ in the first absorbent regenerator 18-1, is referred to as a "semi-lean solution". When reaching the lower portion of the first absorbent regenerator 18-1, the semi-lean solution becomes the first lean solution 15A from which most of $CO_2$ has been removed.

[0021] After that, when being introduced into the second absorbent regenerator 18-2 and flowing downward in the second absorbent regenerator 18-2, the first lean absorbent 15A reacts endothermically with the vapor, releases most of residual $CO_2$, and is regenerated. This second lean solution 15B, which is regenerated by the removal of $CO_2$, is indirectly superheated by saturated vapor 25 in a regenerating superheater 24, and supplies vapor into the tower.

[0022] Further, a $CO_2$ gas 26, which is released from the rich solution 17 and the semi-lean solution in the first and second absorbent regenerators and contains vapor, is discharged from the tops of the respective first and second absorbent regenerators 18-1 and 18-2; the vapor is condensed by a condenser 27; water 26b is separated by a separation drum 28; and a $CO_2$ gas 26a is discharged to the outside of the system. As a result, $CO_2$ is recovered. The water 26b, which is separated by the separation drum 28, is supplied to the upper portion of an absorbent regenerator 18 by a condensed water circulating pump 29.

[0023] Furthermore, a second lean solution 15B, which is regenerated in the second absorbent regenerator 18-2, is introduced to the flash drum 50 and flashed. Accordingly, the temperature of the lean solution 15 becomes 100°C; the temperature of the third lean solution 15C introduced into the rich/lean solution heat exchanger 23 becomes 100°C or less; and the temperature of the rich solution 17, which has been subjected to heat exchange after being introduced into the rich/lean solution heat exchanger 23 while having a temperature of 50°C, becomes 95°C. In FIG. 2, a reducing valve 51 is illustrated.

[0024] The third lean solution 15C, which is flashed in the flash drum 50, is cooled by the rich solution 17 at the rich/lean solution heat exchanger 23. Subsequently, the pressure of the third lean solution 15C is increased by a lean solvent pump 30. Then, after being further cooled by the lean solvent cooler 31, the third lean solution 15C is supplied to the $CO_2$ absorber 16 again and is reused as the $CO_2$-absorbent 15.

[0025] Meanwhile, in FIG. 1, a flue 11a of industrial equipment such as the boiler 11 or a gas turbine, a chimney 11b, filling portions 18A and 18B, and a mist eliminator 18C are illustrated. The $CO_2$ recovery system may be provided afterward in order to recover $CO_2$ from an existing source of the exhaust gas 12, and may be simultaneously provided together with a new source of the exhaust gas 12. A door, which can be opened and closed, is installed on the chimney 11b, and is closed when the $CO_2$ recovery system is operated. Further, the door is set to be opened when the source of the exhaust gas 12 is operating but the operation of the $CO_2$ recovery system is stopped.

[0026] In this embodiment, the first and second absorbent regenerators 18-1 and 18-2 are provided and the flash drum 50 is provided as a lean-solution temperature-reduction unit for recovering the heat of the second lean solution 15B discharged from the second absorbent regenerator 18-2. Accordingly, the heat of the second lean solution 15B is effectively used.

[0027] The first lean solution 15A is supplied to the second absorbent regenerator 18-2 from the first absorbent regenerator 18-1 through a first lean solution supply line $L_3$. Further, the second lean solution 15B is supplied to the flash drum 50 from the second absorbent regenerator 18-2 through a second lean solution supply line $L_4$.

[0028] The vapor 52, which is flashed from the flash drum 50, is supplied to the first absorbent regenerator 18-1 through a vapor supply line $L_5$ that extends from the flash drum 50.

One third lean solution 15C of which the pressure has been reduced is supplied to the $CO_2$ absorber 16 through the lean solution supply line $L_2$ that extends from the flash drum 50.

[0029] That is, since the second lean solution 15B is superheated by vapor that is indirectly heated by the saturated vapor 25 in the second absorbent regenerator 18-2, the second lean solution 15B is discharged to the outside of the system while having a temperature of about 120°C. Then, the second lean solution 15B is introduced into the flash drum 50.

In this case, since the heat of the second lean solution 15B is recovered by the flash drum 50 so that the temperature of the second lean solution 15B is lowered and the second lean solution 15B becomes the third lean solution 15C, it is possible to reduce the heat exchange capacity of the rich/lean solution heat exchanger 23.

[0030] Here, when the temperature $T_1$ of the second lean solution 15B discharged from the second absorbent regenerator 18-2 is, for example, 120°C, the second lean solution 15B is flashed in the flash drum 50. Accordingly, the temperature $T_2$ of the third lean solution 15C, which has been flashed, becomes about 100°C.

[0031] For example, when the temperature $T_3$ of the rich solution 17 is 50°C, heat exchange is performed while the temperature $T_2$ of the third lean solution 15C introduced into the rich/lean solution heat exchanger 23 is 100°C or less. Accordingly, the temperature $T_4$ of the rich solution 17 after heat exchange becomes 95°C. Further, the temperature $T_5$ of the third lean solution 15C after heat exchange is lowered to 55°C. Meanwhile, the temperature $T_6$ of a solution, which is discharged as vapor to the outside from the first absorbent regenerator 18-1, is 82.5°C, and the temperature $T_7$ of a solution, which is discharged to the outside from the second absorbent regenerator 18-2, is 85°C. Meanwhile, the temperature $T_8$ of the first lean solution 15A, which is supplied to the second absorbent regenerator 18-2 from the first absorbent regenerator 18-1, is 95°C.

Here, the pressure in the absorbent regenerator 18 is 0.9 $kg/cm^2G$.

[0032] Accordingly, since the temperature of the rich solution 17, which is introduced into the first absorbent regenerator 18-1, is lower than that in the past, it is possible to reduce the amount of reboiler heat at the first absorbent regenerator 18-1.

Here, the breakdown of the amount of reboiler heat of the first and second absorbent regenerators 18-1 and 18-2 corresponds to the sum $Q_R$ (621 $kcal/kgCO_2$) of (a) the amount Q1 of reaction heat that is required to regenerate the rich solution 17 (404 $kcal/kgCO_2$), (b) the amount Q2 of heat loss of a solution that is discharged from the absorbent regenerator 18 (55 $kcal/kgCO_2$), and (c) the amount Q3 of heat loss of vapor that is discharged together with $CO_2$ from the first and second absorbent regenerators 18-1 and 18-2 (162 $kcal/kgCO_2$).

[0033] In contrast, for example, if the temperature $T_3$ of a rich solution 17 is 50°C, when the heat of a lean solution 15 is not recovered as in a $CO_2$ recovery system 100 in the related art illustrated in FIG. 6, heat exchange is performed while the temperature $T_1$ of the lean solution 15 introduced into a rich/lean solution heat exchanger 23 is 120°C. Accordingly, the temperature $T_4$ of the rich solution 17 after heat exchange becomes 110°C. Further, the temperature $T_5$ of the lean solution 15 after heat exchange is lowered to 60°C. Meanwhile, the temperature $T_6$

of the solution, which is discharged as vapor to the outside, is 92.5°C.

[0034] Accordingly, the breakdown of the amount of reboiler heat corresponds to the sum $Q_R$ (665 kcal/kg$CO_2$) of (a) the amount $Q_1$ of reaction heat that is required to regenerate an absorbent (404 kcal/kg$CO_2$), (b) the amount $Q_2$ of heat loss of a solution that is discharged from an absorbent regenerator 18 (110 kcal/kg$CO_2$), and (c) the amount $Q_3$ of heat loss of vapor that is discharged together with $CO_2$ from the absorbent regenerator 18 (151 kcal/kg$CO_2$).

[0035] Since the amount of reboiler heat of first and second absorbent regenerators 18-1 and 18-2 of a $CO_2$ recovery system 10A according to the invention illustrated in FIG. 2 is 621 kcal/kg$CO_2$ and the amount of reboiler heat of the absorbent regenerator 18 of the $CO_2$ recovery system 100 in the related art illustrated in FIG. 6 is 665 kcal/kg$CO_2$ as described above, it has been found out that the amount of reboiler heat can be significantly reduced.

[0036] As described above, according to the invention, it is possible to significantly reduce the sum of the amount of heat at the absorbent regenerators and running cost is significantly reduced since the heat of the lean solution is effectively recovered.

[0037] Meanwhile, a technique for reducing the amount of reboiler heat in the tower by raising the temperature of the rich solution 17 supplied into the absorbent regenerator 18 has been mainly examined in a proposal in the related art. However, in the invention, the amount of reboiler heat is reduced as a whole in consideration of not only the amount of heat in the tower but also (b) the amount $Q_2$ of heat loss of the solution (lean solution) that is discharged from the absorbent regenerator 18 and (c) the amount $Q_3$ of heat loss of vapor that is discharged together with $CO_2$ from the absorbent regenerator 18. Accordingly, it is possible to improve the energy efficiency of the entire system by recovering the heat of the lean solution 15.

[Second embodiment]

[0038] A $CO_2$ recovery system according to an embodiment of the invention will be described with reference to the drawings. FIG. 3 is a diagram illustrating main parts of a first absorbent regenerator and a second absorbent regenerator according to a second embodiment. The same members as the members of the first embodiment are denoted by the same reference numerals, and the description thereof will not be made.

As illustrated in FIG. 3, a $CO_2$ recovery system 10B includes a lean/lean solution heat exchanger 61 in the $CO_2$ recovery system 10A illustrated in FIG. 2. The lean/lean solution heat exchanger 61 is provided at an intersection between the first lean solution supply line $L_3$ through which the first lean solution 15A is supplied to the second absorbent regenerator 18-2 from the first absorbent regenerator 18-1 and a supply line $L_6$ through which the third lean solution 15C is supplied from the flash drum 50, and exchanges heat between the first lean solution 15A and the third lean solution 15C.

[0039] Here, a second lean solution 15B, which is regenerated in the second absorbent regenerator 18-2, is introduced into the flash drum 50 and flashed, so that the temperature of the third lean solution 15C becomes 100°C. However, the third lean solution 15C is subjected to heat exchange by the lean/lean solution heat exchanger 61, so that the temperature of the third lean solution 15C is further lowered. Then, the third lean solution 15C is introduced into the rich/lean solution heat exchanger 23, and exchanges heat with a rich solution 17.

[0040] For example, since the temperature $T_2$ of the third lean solution 15C is 100°C when the temperature $T_8$ of the first lean solution 15A is 95°C, the temperature $T_9$ of the first lean solution 15A rises to 97.5°C. In contrast, the temperature $T_{10}$ of the third lean solution 15C is lowered to 97.5°C.

Further, when the temperature $T_3$ of the rich solution 17 is 50°C, heat exchange is performed by the third lean solution 15C which is introduced into the rich/lean solution heat exchanger 23 and of which the temperature $T_{10}$ is 97.5°C. Accordingly, the temperature $T_4$ of the rich solution 17 after heat exchange becomes 92.5°C. Furthermore, the temperature $T_5$ of the third lean solution 15C after heat exchange is lowered to 55°C. Meanwhile, the temperature $T_6$ of a solution, which is discharged as vapor to the outside from the first absorbent regenerator 18-1, is 80°C, and the temperature $T_7$ of a solution, which is discharged to the outside from the second absorbent regenerator 18-2, is 85°C.

Here, the pressure in the absorbent regenerator 18 is 0.9 $kg/cm^2G$.

[0041] Accordingly, since the temperature of the rich solution 17, which is introduced into the first absorbent regenerator 18-1, is lower than that in the past, it is possible to reduce the amount of reboiler heat at the first absorbent regenerator 18-1.

Here, the breakdown of the amount of reboiler heat of the first and second absorbent regenerators 18-1 and 18-2 corresponds to the sum $Q_R$ (601 kcal/kg$CO_2$) of (a) the amount Q1 of reaction heat that is required to regenerate the rich solution 17 (404 kcal/kg$CO_2$), (b) the amount Q2 of heat loss of a solution that is discharged from the absorbent regenerator 18 (55 kcal/kg$CO_2$), and (c) the amount Q3 of heat loss of vapor that is discharged together with $CO_2$ from the first and second absorbent regenerators 18-1 and 18-2 (142 kcal/kg$CO_2$).

[Third embodiment]

[0042] A $CO_2$ recovery system according to an embodiment of the invention will be described with reference to the drawings. FIG. 4 is a diagram illustrating main parts of a first absorbent regenerator and a second absorbent regenerator according to a third embodiment. The same members as the members of the first embodiment are denoted by the same reference numerals, and the description thereof will not be made.

As illustrated in FIG. 4, a $CO_2$ recovery system 10C includes a port A which is provided in the first absorbent regenerator 18-1 at a middle portion in a vertical axis direction of the first absorbent regenerator and through which a semi-lean solution 55 is extracted; a circulation line $L_7$ to which the semi-lean solution 55 is extracted and along which the semi-lean solution 55 returns to a return port B closer to the bottom than the extraction port A; and a semi-lean/lean solution heat exchanger 62 which is provided on the circulation line $L_7$ and where a third lean solution 15C exchanges heat with the semi-lean solution 55 in the $CO_2$ recovery system 10A illustrated in FIG. 2. In FIG. 4, filling portions 18A-1 and 18A-2 and a chimney tray 18D are illustrated.

[0043] Here, a second lean solution 15B, which is generated in the second absorbent regenerator 18-2, is introduced into the flash drum 50 and flashed, so that the temperature of a lean solution 15 becomes 100°C.

A semi-lean solution 55 is extracted from the extraction port A of the circulation line $L_7$, and the third lean solution 15C exchanges heat with the semi-lean solution 55 at the semi-lean/lean solution heat exchanger 62, so that the temperature of the semi-lean solution 55 rises. After that, the semi-lean solution 55 is introduced into the first absorbent regenerator 18-1 through the port B. Accordingly, it is possible to reduce the amount of vapor in the first absorbent regenerator 18-1.

[0044] In contrast, the temperature of the third lean solution 15C is made to be lower than the case of the first embodiment by the semi-lean/lean solution heat exchanger 62. After the temperature of the third lean solution 15C is lowered, the third lean solution 15C is introduced into the rich/lean solution heat exchanger 23 and exchanges heat with a rich solution 17.

[0045] Here, when the temperature $T_1$ of the second lean solution 18B discharged from the second absorbent regenerator 18-2 is, for example, 120°C, the second lean solution 15B is flashed in the flash drum 50. Accordingly, the temperature $T_2$ of the third lean solution 15C, which has been flashed, becomes about 100°C.

The semi-lean solution 55 is extracted from the extraction port A of the circulation line $L_7$, and the third lean solution 15C exchanges heat with the semi-lean solution 55 at the semi-lean/lean solution heat exchanger 62, so that the temperature $T_{12}$ of the semi-lean solution 55, which has a temperature $T_{11}$ of 85°C, rises to 97.5°C. After that, the semi-lean solution 55 is introduced into the first absorbent regenerator 18-1 through the port B. Accordingly, it is possible to reduce the amount of vapor in the first absorbent regenerator 18-1.

[0046] In contrast, the temperature of the third lean solution 15C is made to be lower than the case of the first embodiment by the semi-lean/lean solution heat exchanger 62, so that temperature $T_{13}$ is lowered to 87.5°C.

[0047] For example, when the temperature $T_3$ of the rich solution 17 is 50°C, heat exchange is performed by the third lean solution 15C which is introduced into the rich/lean solution heat exchanger 23 and of which the temperature $T_{13}$ is 87.5°C. Accordingly, the temperature $T_4$ of the rich solution 17 after heat exchange becomes 82.5°C. Furthermore, the temperature $T_5$ of the third lean solution 15C after heat exchange is lowered to 55°C. Meanwhile, the temperature $T_6$ of a solution, which is discharged as vapor to the outside from the first absorbent regenerator 18-1, is 77.5°C, and the temperature $T_7$ of a solution, which is discharged to the outside from the second absorbent regenerator 18-2, is 87.5°C.

Here, the pressure in the absorbent regenerator 18 is 0.9 $kg/cm^2G$.

[0048] Accordingly, since the temperature of the rich solution 17, which is introduced into the first absorbent regenerator 18-1, is lower than that in the past, it is possible to reduce the amount of reboiler heat at the first absorbent regenerator 18-1.

Here, the breakdown of the amount of reboiler heat of the first and second absorbent regenerators 18-1 and 18-2 corresponds to the sum $Q_R$ (593 kcal/kg$CO_2$) of (a) the amount Q1 of reaction heat that is required to regenerate the rich solution 17 (404 kcal/kg$CO_2$), (b) the amount Q2 of heat loss of a solution that is discharged from the absorbent regenerator 18 (55 kcal/kg$CO_2$), and (c) the amount Q3 of heat loss of vapor that is discharged together with $CO_2$ from the first and second absorbent regenerators 18-1 and 18-2 (134 kcal/kg$CO_2$).

[0049] Since the amount of reboiler heat of the first and second absorbent regenerators 18-1 and 18-2 of the $CO_2$ recovery system 10C according to the invention illustrated in FIG. 4 is 593 kcal/kg$CO_2$ and the amount of reboiler heat of the absorbent regenerator 18 of the $CO_2$ recovery system 100 in the related art illustrated in FIG. 6 is 665 kcal/kg$CO_2$ as described above, it has been found out that the amount of reboiler heat can be significantly reduced.

[Fourth embodiment]

[0050] A $CO_2$ recovery system according to an embodiment of the invention will be described with reference to the drawings. FIG. 5 is a diagram illustrating main parts of a first absorbent regenerator and a second absorbent regenerator according to a fourth embodiment. The same members as the members of the first to third embodiments are denoted by the same reference numerals, and the description thereof will not be made.

As illustrated in FIG. 5, a $CO_2$ recovery system 10D is obtained from the integration of the $CO_2$ recovery system 10B illustrated in FIG. 3 and the $CO_2$ recovery system 10C illustrated in FIG. 4. The $CO_2$ recovery system 10D includes a lean/lean solution heat exchanger 61 where a first lean solution 15A exchanges heat with a third lean solution 15C, and a semi-lean/lean solution heat exchanger 62 where a third lean solution 15C exchanges heat with a semi-lean solution 55.

[0051] Here, when the temperature $T_1$ of a second lean solution 15B discharged from a second absorbent regenerator 18-2 is, for example, 120°C, the second lean solution 15B is flashed in the flash drum 50. Accordingly, the temperature $T_2$ of the third lean solution 15C, which has been flashed, becomes about 100°C.

A semi-lean solution 55 is extracted from an extraction port A of a circulation line $L_7$, and the third lean solution 15C exchanges heat with the semi-lean solution 55 at the semi-lean/lean solution heat exchanger 62, so that and the temperature $T_{12}$ of the semi-lean solution 55, which has a temperature $T_{11}$ of 85°C, rises to 97.5°C. After that, the semi-lean solution 55 is introduced into a first absorbent regenerator 18-1 through a port B. Accordingly, it is possible to reduce the amount of vapor in the first absorbent regenerator 18-1.

[0052] In contrast, the temperature of the third lean solution 15C is made to be lower than the case of the first embodiment by the semi-lean/lean solution heat exchanger 62, so that temperature $T_{13}$ is lowered to 87.5°C.

[0053] Since the temperature $T_{13}$ of the third lean solution 15C is 87.5°C when the temperature $T_8$ of the first lean solution 15A is 95°C, the temperature $T_9$ of the first lean solution 15A is lowered to 90°C. In contrast, the temperature $T_{10}$ of the third lean solution 15C rises to 92.5°C.

Further, when the temperature $T_3$ of a rich solution 17 is 50°C, heat exchange is performed by a third lean solution 15C which is introduced into the rich/lean solution heat exchanger 23 and of which the temperature $T_{10}$ is 92.5°C. Accordingly, the temperature $T_4$ of the rich solution 17 after heat exchange becomes 87.5°C. Furthermore, the temperature $T_5$ of the third lean solution 15C after heat exchange is lowered to 55°C. Meanwhile, the temperature $T_6$ of a solution, which is discharged as vapor to the outside from the first absorbent regenerator 18-1, is 80°C, and the temperature $T_7$ of a solution, which is discharged to the outside from the second absorbent regenerator 18-2, is 85°C.

Here, the pressure in the absorbent regenerator 18 is 0.9 kg/cm$^2$G.

[0054] Accordingly, since the temperature of the rich solution 17, which is introduced into the first absorbent regenerator 18-1, is lower than that in the past, it is possible to reduce the amount of reboiler heat at the first absorbent regenerator 18-1.

Here, the breakdown of the amount of reboiler heat of the first and second absorbent regenerators 18-1 and 18-2 corresponds to the sum $Q_R$ (601 kcal/kg$CO_2$) of (a) the amount Q1 of reaction heat that is required to regenerate the rich solution 17 (404 kcal/kg$CO_2$), (b) the amount Q2 of heat loss of a solution that is discharged from the absorbent regenerator 18 (55 kcal/kg$CO_2$), and (c) the amount Q3 of heat loss of vapor that is discharged together with $CO_2$ from the first and second absorbent regenerators 18-1 and 18-2 (142 kcal/kg$CO_2$).

[0055] Since the amount of reboiler heat of the first and second absorbent regenerators 18-1 and 18-2 of the $CO_2$ recovery system 10D according to the invention illustrated in FIG. 5 is 601 kcal/kg$CO_2$ and the amount of reboiler heat of the absorbent regenerator 18 of the $CO_2$ recovery system 100 in the related art illustrated in FIG. 6 is 665 kcal/kg$CO_2$ as described above, it has been found out that the amount of reboiler heat can be significantly reduced.

[0056] The relation between the above-mentioned amounts of reboiler heat is illustrated in Table 1.

[0057]

Table 1

| | Amount | Amount | Amount | Sum ($Q_R$) |
|---|---|---|---|---|

| | ($Q_1$) of reaction heat | ($Q_2$) of heat loss | ($Q_3$) of heat loss | |
|---|---|---|---|---|
| First embodiment | 404 | 55 | 162 | 621 |
| Second embodiment | 404 | 55 | 142 | 601 |
| Third embodiment | 404 | 55 | 134 | 593 |
| Fourth embodiment | 404 | 55 | 142 | 601 |
| Related art | 404 | 110 | 151 | 665 |

(Unit kcal/kg·$CO_2$)

As illustrated in Table 1, it has been found out that the energy efficiency of the system of the third embodiment is highest.

[0058] As described above, according to the $CO_2$ recovery system of the invention, it is possible to significantly reduce the heat energy of reboiler that is required to regenerate an absorbent when the size of the $CO_2$ recovery system is increased so that the amount of $CO_2$ to be recovered per day becomes, for example, 1000 t or more. Accordingly, it is possible to save the energy of the entire system.

Reference Signs List

[0059] 10, 10A to 10D $CO_2$ RECOVERY SYSTEM

11 BOILER

12 EXHAUST GAS

15 $CO_2$-ABSORBENT (LEAN SOLUTION)

15A FIRST LEAN ABSORBENT (FIRST LEAN SOLUTION)

15B SECOND LEAN ABSORBENT (SECOND LEAN SOLUTION)

15C THIRD LEAN ABSORBENT (THIRD LEAN SOLUTION)

16 $CO_2$ ABSORBER

17 RICH SOLUTION

18-1 FIRST ABSORBENT REGENERATOR

18-2 SECOND ABSORBENT REGENERATOR

CLAIMS:

1. A $CO_2$ recovery system comprising:

a $CO_2$ absorber that brings a cooled $CO_2$-containing exhaust gas into contact with a $CO_2$-absorbent for absorbing $CO_2$ to remove $CO_2$ from the exhaust gas;

a first absorbent regenerator that regenerates an absorbent by releasing $CO_2$ from a $CO_2$-absorbent having absorbed $CO_2$;

a second absorbent regenerator that regenerates an absorbent by releasing residual $CO_2$ from a first lean solution discharged from the first absorbent regenerator;

a flash drum that flashes a second lean solution discharged from the second absorbent regenerator; and

a lean/lean solution heat exchanger where the first lean solution exchanges heat with a third lean solution flashed in the flash drum,

wherein vapor generated in the flash drum is inputted to the first absorbent regenerator.

2. The $CO_2$ recovery system according to claim 1, further comprising:

a cooling tower that cools the $CO_2$-containing exhaust gas by cooling water.

FIG.1

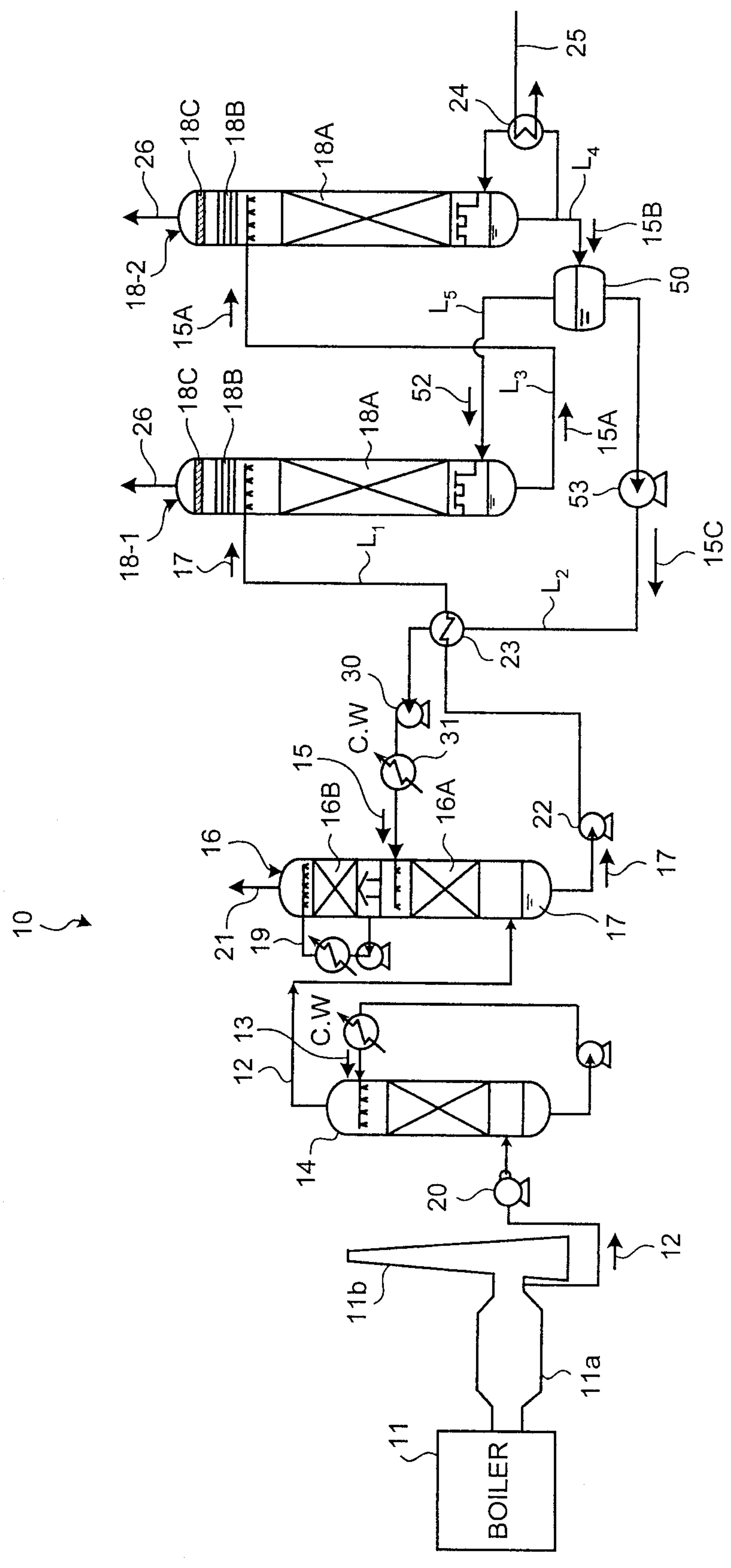

BOILER
C.W
C.W
10
11
11a
11b
12
13
14
15
15A
15B
15C
16
16A
16B
17
18-1
18-2
18A
18B
18C
19
20
21
22
23
24
25
26
30
31
50
52
53
L1
L2
L3
L4
L5

FIG.2

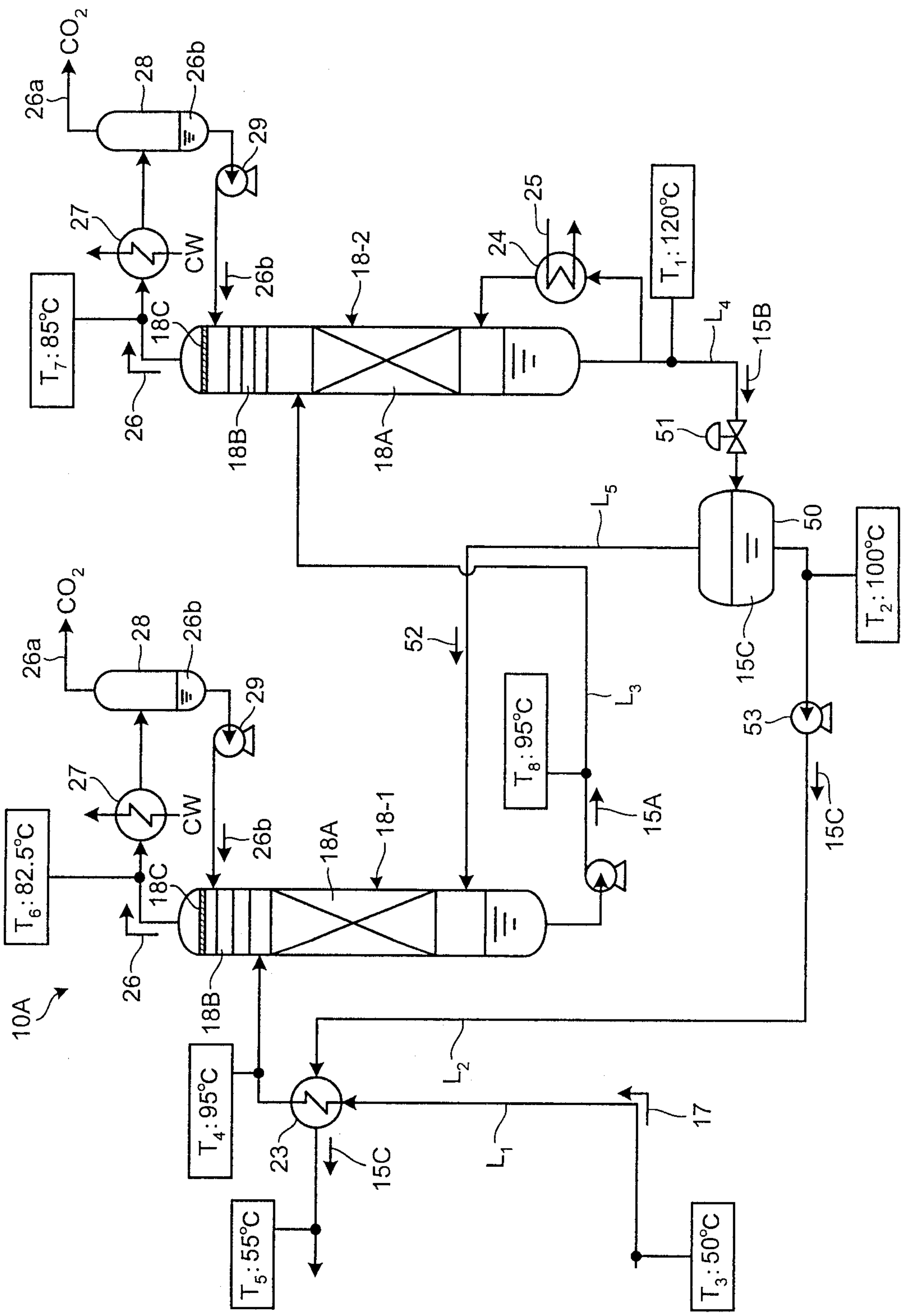

$CO_2$
26a
28
26b
29
27
CW
$T_7$: 85°C
18C
26
18B
18A
18-2
24
25
$T_1$: 120°C
$L_4$
15B
51
50
$L_5$
$T_2$: 100°C
15C
53
52
$L_3$
$T_8$: 95°C
15A
18-1
$T_6$: 82.5°C
10A
$T_4$: 95°C
23
$L_2$
$L_1$
17
$T_5$: 55°C
$T_3$: 50°C

FIG.3

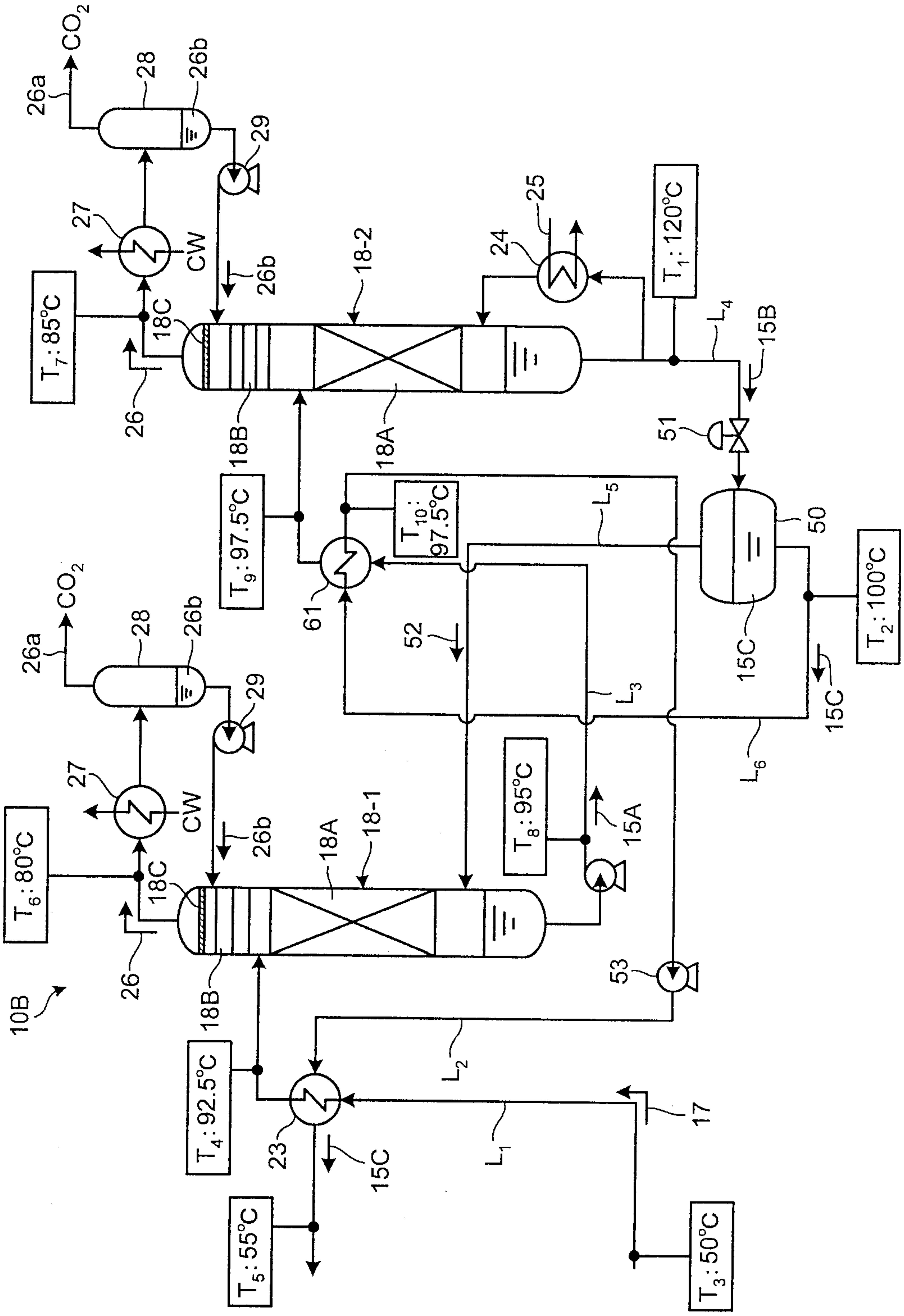
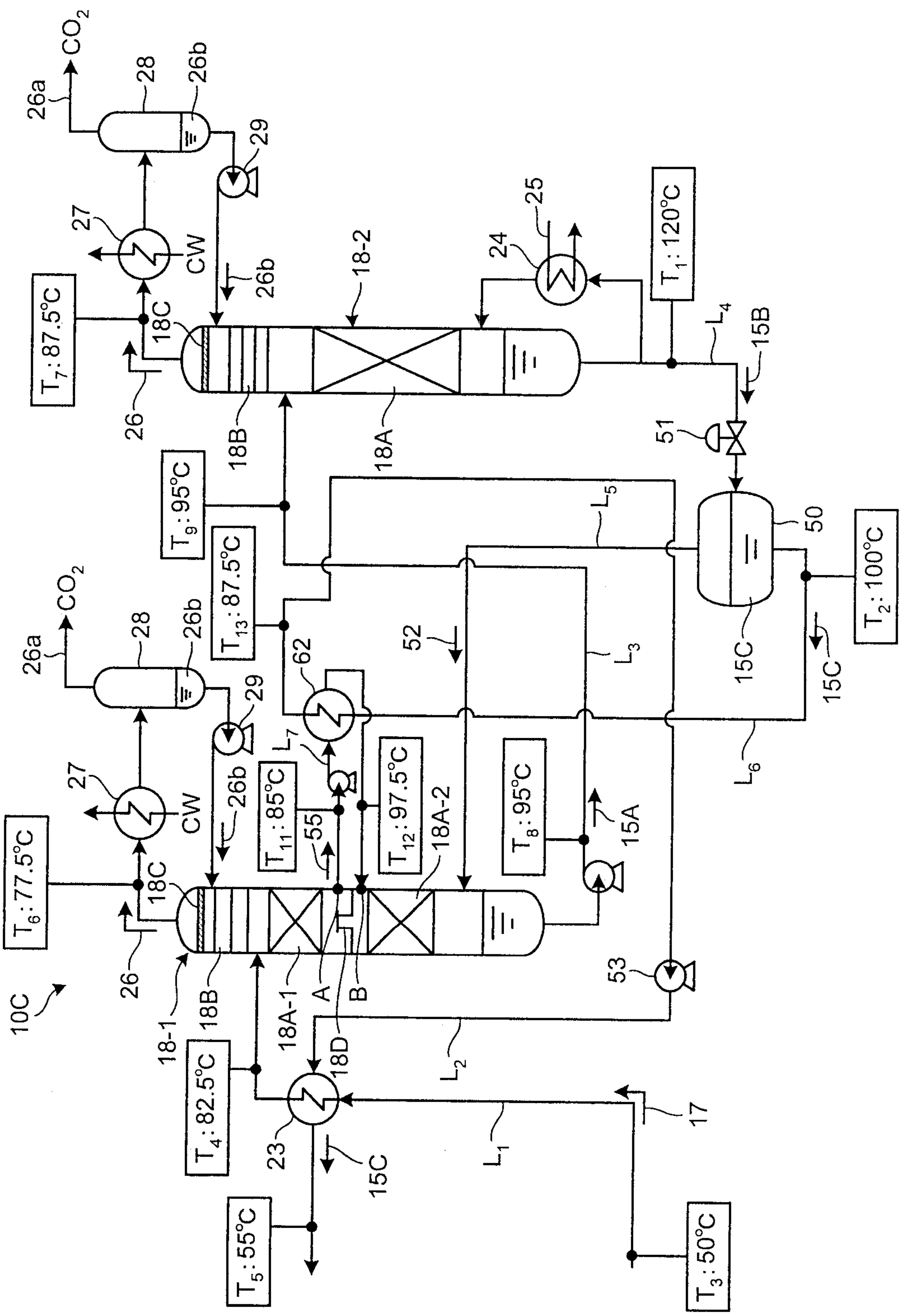

10B
18-1
18-2
18A
18B
18C
26
26a
26b
27
28
29
CW
$CO_2$
23
24
25
50
51
52
53
61
15A
15B
15C
17
$L_1$
$L_2$
$L_3$
$L_4$
$L_5$
$L_6$
$T_1$: 120°C
$T_2$: 100°C
$T_3$: 50°C
$T_4$: 92.5°C
$T_5$: 55°C
$T_6$: 80°C
$T_7$: 85°C
$T_8$: 95°C
$T_9$: 97.5°C
$T_{10}$: 97.5°C

FIG.4


10C
18-1
18-2
18A
18A-1
18A-2
18B
18C
18D
A
B
17
23
24
25
26
26a
26b
27
28
29
50
51
52
53
55
62
15A
15B
15C
CW
$CO_2$
$L_1$
$L_2$
$L_3$
$L_4$
$L_5$
$L_6$
$L_7$
$T_1$: 120°C
$T_2$: 100°C
$T_3$: 50°C
$T_4$: 82.5°C
$T_5$: 55°C
$T_6$: 77.5°C
$T_7$: 87.5°C
$T_8$: 95°C
$T_9$: 95°C
$T_{11}$: 85°C
$T_{12}$: 97.5°C
$T_{13}$: 87.5°C

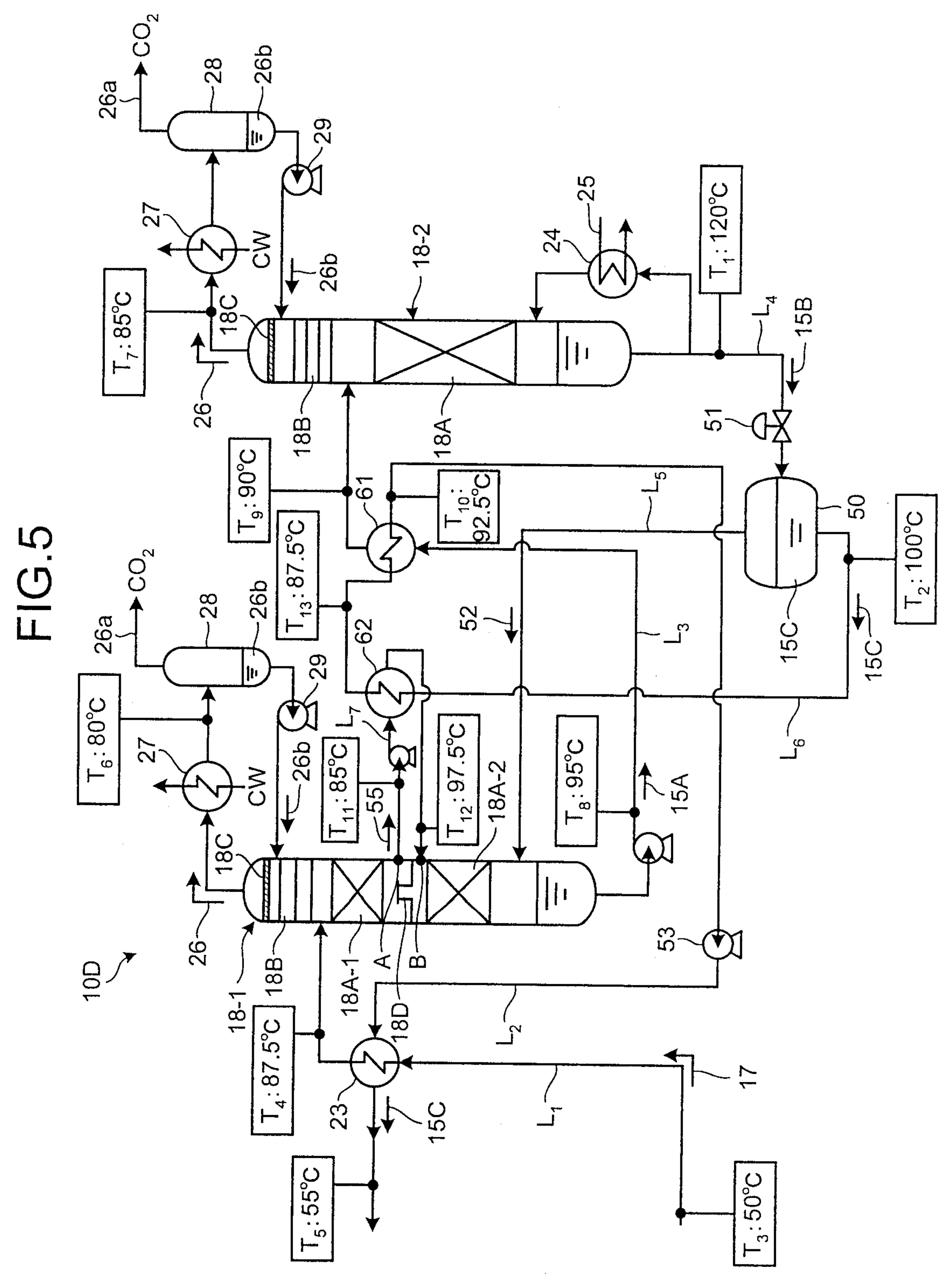
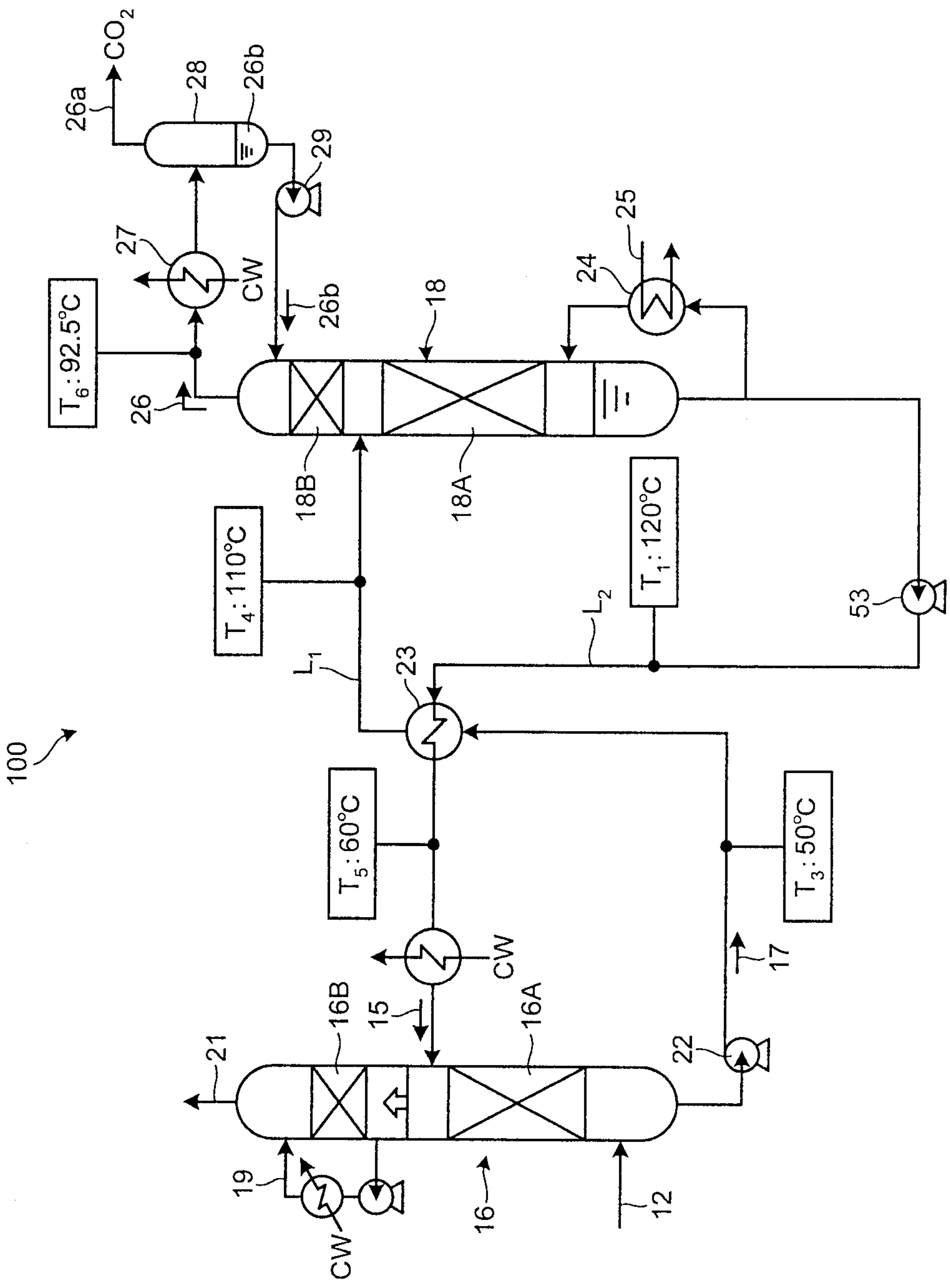
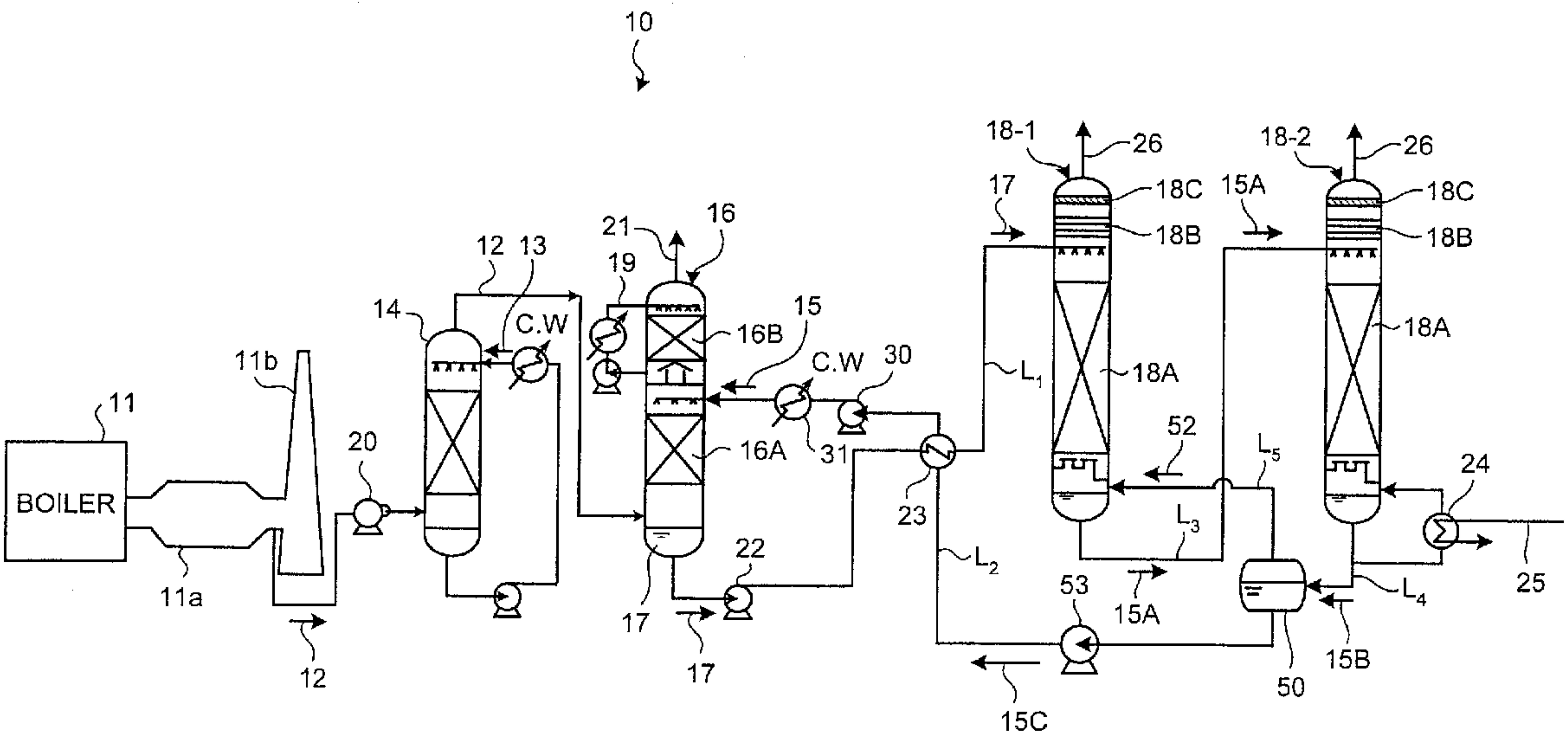

10D
CO2
26a
28
26b
29
27
CW
18C
18-2
24
25
T1: 120°C
T7: 85°C
26
18B
18A
L4
15B
51
T9: 90°C
61
T10: 92.5°C
L5
50
T2: 100°C
T13: 87.5°C
62
52
L3
15C
L6
T6: 80°C
L7
T11: 85°C
T12: 97.5°C
18A-2
T8: 95°C
15A
55
A
B
18-1
18A-1
18D
53
L2
T4: 87.5°C
23
L1
17
T5: 55°C
T3: 50°C

FIG.5

FIG.6


100
CO2
26a
28
26b
29
27
CW
26b
18
25
24
T6 : 92.5°C
26
18B
18A
T4 : 110°C
T1 : 120°C
L1
L2
23
53
T5 : 60°C
T3 : 50°C
CW
17
15
16B
16A
22
21
19
CW
16
12


10
BOILER
11
11a
11b
12
20
14
13
C.W
21
19
16
16A
16B
15
17
22
30
31
23
L1
L2
18-1
18-2
18A
18B
18C
26
15A
52
L3
L4
L5
53
50
15B
15C
24
25