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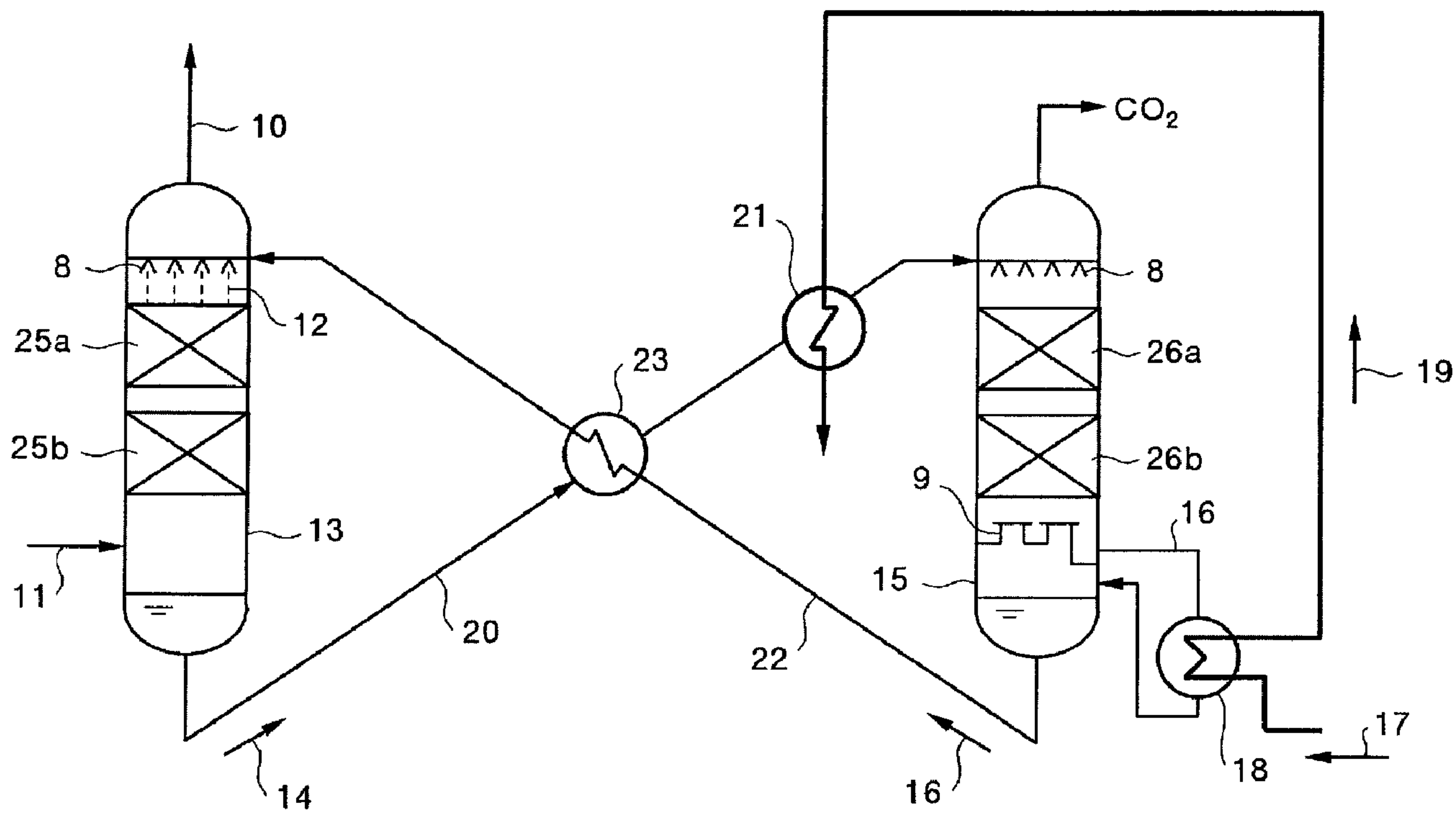


(57) Abrégé/Abstract:
A CO_2 recovery system includes an absorption tower and a regeneration tower. A CO_2 rich solution is produced in the absorption tower by absorbing CO_2 from a CO_2-containing gas. The CO_2 rich solution is conveyed to the regeneration tower where a lean solution is produced from the rich solution by removing CO_2. A regeneration heater heats the lean solution that accumulates near a bottom portion of the regeneration tower with saturated steam thereby producing steam condensate from the saturated steam. A steam-condensate heat exchanger heats the rich solution conveyed from the absorption tower to the regeneration tower with the steam condensate.

ABSTRACT

A CO_2 recovery system includes an absorption tower and a regeneration tower. A CO_2 rich solution is produced in the absorption tower by absorbing CO_2 from a CO_2-containing gas. The CO_2 rich solution is conveyed to the regeneration tower where a lean solution is produced from the rich solution by removing CO_2. A regeneration heater heats the lean solution that accumulates near a bottom portion of the regeneration tower with saturated steam thereby producing steam condensate from the saturated steam. A steam-condensate heat exchanger heats the rich solution conveyed from the absorption tower to the regeneration tower with the steam condensate.

DESCRIPTION

CO_2 RECOVERY SYSTEM AND METHOD

TECHNICAL FIELD

[0001] This specification describes a CO_2 recovery system and a method for achieving energy saving. In fact, a plurality of inventions are disclosed in this specification. Claimed, however, in this application is such CO_2 recovery system and method described hereinunder in which a steam-condensate heat exchanger is employed which heats, with steam condensate, a rich solution that is supplied from an absorption tower to a regeneration tower. Other inventions may be claimed in one or more divisional applications. However, it should be understood that the expression "the present invention" encompasses subject matter of not only this application but also of divisional applications.

BACKGROUND ART

[0002] In recent years the greenhouse effect due to CO_2 has been pointed out as one of causes of the global warming, and a countermeasure against it is urgently required internationally to protect global environment. CO_2 sources range various fields of human activities, including burning of fossil fuels, and demands to suppress their CO_2 emission from these sources are on constant increase. In association with this, people have energetically studied means and methods for suppressing emission of CO_2 from power generation facilities such as power plants which use an enormous amount of fossil fuels. One of the methods includes bringing combustion exhaust gas of boilers into contact with an amine-based CO_2-absorbing solution. This method allows removal and recovery of CO_2 from the combustion exhaust gas.

Another method includes storing recovered CO_2, i.e., not returning the recovered CO_2 to the atmosphere.

[0003] Various methods are known to remove and recover CO_2 from combustion exhaust gas using the CO_2-absorbing solution. One of the methods includes contacting the combustion exhaust gas with the CO_2-absorbing solution in an absorption tower, heating an absorbing solution having absorbed CO_2 in a regeneration tower, and releasing CO_2, regenerating the absorbing solution, and circulating the regenerated absorbing solution to the absorption tower again to be reused (Patent document 1).

[0004] Patent document 1: Japanese Patent Application Laid-Open No. H7-51537

DISCLOSURE OF INVENTION

PROBLEM TO BE SOLVED BY THE INVENTION

[0005] In the conventional method, however, the steps of removing, and recovering CO_2 from CO_2-containing gas are provided additionally in combustion facilities, and hence, the operation costs should be reduced as much as possible. Particularly, among the processes, a regenerating process consumes a large amount of heat energy, and therefore, the regenerating process needs to be provided as an energy saving process as much as possible.

[0006] The present invention has been achieved to solve the problems, and it is an object of the present invention to provide a CO_2 recovery system and method in which an energy efficiency is further improved.

MEANS FOR SOLVING PROBLEM

[0007] To solve the above problems, a first aspect of the present invention relates to a CO_2 recovery system which comprises: an absorption tower that receives a CO_2-containing gas and a CO_2-absorbing solution, and causes the CO_2-containing gas to come in contact with the CO_2-absorbing solution to produce a CO_2 rich solution; a regeneration tower that receives the rich solution and produces a lean solution from the rich solution by removing CO_2 from the rich solution; a bottom lean-solution extraction path that extracts the lean solution that accumulates near a bottom portion of the regeneration tower from a first point of the regeneration tower and returns the extracted lean solution to a second point of the regeneration tower that is downstream of the first point; a regeneration heater arranged in the bottom lean-solution extraction path that heats the lean solution in the bottom lean-solution extraction path with a saturated steam thereby producing a steam condensate from the saturated steam; and a steam-condensate heat exchanger that heats, with the steam condensate, any one of: the rich solution that is supplied from the absorption tower to the regeneration tower; and a semi-lean solution that is extracted outside from a middle portion of the regeneration tower and returned to the middle portion of the regeneration tower.

[0008] According to a second aspect of the present invention, the CO_2 recovery system further comprises: a rich-solution supply member that conveys the rich solution from the absorption tower to the regeneration tower, wherein the steam-condensate heat exchanger is provided in the rich-solution supply member and heats the rich solution in the rich-solution supply member with the steam condensate; and a flash drum provided upstream or downstream of the steam-condensate heat exchanger in the rich-solution supply member.

[0009] According to a third aspect of the present invention, in the invention according to the second aspect, the CO_2 recovery system further comprises: a branching node provided in the rich-solution supply member that divides the rich-solution supply member into a first rich-solution supply member and a second rich-solution supply member, wherein the steam-condensate heat exchanger is provided in the first rich-solution supply member and heats the rich solution in the first rich-solution supply member with the steam condensate, and the flash drum is provided downstream of the steam-condensate heat exchanger in the first rich-solution supply member, and produces the semi-lean solution; and a semi-lean-solution heat exchanger that is provided in the second rich-solution supply member, and heats the rich solution in the second rich-solution supply member with the semi-lean solution produced in the flash drum.

[0010] According to a fourth aspect of the present invention, in the invention according to the first aspect, the CO_2 recovery system further comprises: a rich-solution supply member that conveys the rich solution from the absorption tower to the regeneration tower; a branching node provided in the rich-solution supply member that divides the rich-solution supply member into a first rich-solution supply member and a second rich-solution supply member, wherein the steam-condensate heat exchanger is provided in the first rich-solution supply member and flashes the rich solution in the first rich-solution supply member to produce the semi-lean solution; a semi-lean-solution heat exchanger that is provided in the second rich-solution supply member, and heats the rich solution in the second rich-solution supply member with the semi-lean solution produced in the steam-condensate heat exchanger; and a semi-lean-solution supply member that conveys the semi-lean solution from the semi-lean-solution heat exchanger to a middle stage portion of the absorption tower.

[0011] According to a fifth aspect of the present invention, in the invention according to the fourth aspect, the steam-condensate heat exchanger comprises: a flash drum including a flash portion in an upper portion for flashing the rich solution; a filling layer in the flash drum; and a steam supply unit provided in a lower portion of the flash drum and to which steam obtained from the steam condensate is supplied.

[0012] According to a sixth aspect of the present invention, in the invention according to the first aspect, the regeneration tower of the CO_2 recovery system comprises an upper-portion regeneration tower and a lower-portion regeneration tower, and the CO_2 recovery system further comprises: a rich-solution supply member that conveys the rich solution from the absorption tower to the regeneration tower; a branching node provided in the rich-solution supply member that divides the rich-solution supply member into a first rich-solution supply member and a second rich-solution supply member, wherein the steam-condensate heat exchanger is provided in the first rich-solution supply member and heats the rich solution in the first rich-solution supply member with the steam condensate; a semi-lean-solution supply member that extracts the semi-lean solution from the upper-portion regeneration tower and conveys the extracted semi-lean solution to a middle stage portion of the absorption tower; a semi-lean-solution heat exchanger that is provided in the second rich-solution supply member and the semi-lean-solution supply member, and heats the rich solution in the second rich-solution supply member with the semi-lean solution in the semi-lean-solution supply member, wherein one end of the first rich-solution supply member is connected to the lower-portion regeneration tower, and one end of the second rich-solution supply member is connected to the upper-portion regeneration tower.

[0013] According to a seventh aspect of the present invention, the CO_2 recovery system further comprises: a rich-solution supply member that conveys the rich solution from the absorption tower to the regeneration tower; a lean-solution supply member that extracts the lean solution from the regeneration tower and conveys the extracted lean solution to the absorption tower; and a lean-solution heat exchanger that is provided in the rich-solution supply member and the lean-solution supply member, and heats the rich solution in the rich-solution supply member with the lean solution in the lean-solution supply member.

[0014] According to an eighth aspect of the present invention, the regeneration tower of the CO_2 recovery system comprises an upper-portion regeneration tower, a middle-portion regeneration tower, and a lower-portion regeneration tower, and the CO_2 recovery system further comprises: a rich-solution supply member that conveys the rich solution from the absorption tower to the regeneration tower; a branching node provided in the rich-solution supply member that divides the rich-solution supply member into a first rich-solution supply member and a second rich-solution supply member; a lean-solution heat exchanger that is provided in the first rich-solution supply member, and heats the rich solution with the lean solution produced in the regeneration tower; a semi-lean-solution supply member that extracts the semi-lean solution from the upper-portion regeneration tower and conveys the extracted semi-lean solution to a middle stage portion of the absorption tower; a semi-lean-solution heat exchanger that is provided in the second rich-solution supply member and the semi-lean-solution supply member, and heats the rich solution in the second rich-solution supply member with the semi-lean solution in the semi-lean-solution supply member; a middle semi-lean-solution extraction path that extracts the semi-lean solution from a third point of the middle-portion regeneration tower and returns the extracted semi-lean solution to a fourth point of the middle-portion regeneration tower that is downstream of the third point, wherein the steam-condensate heat exchanger is arranged in the middle semi-lean-solution extraction path and heats the semi-lean solution in the middle semi-lean-solution extraction path with the steam condensate, one end of the first rich-solution supply member is connected to the middle-portion regeneration tower, and one end of the semi-lean-solution supply member is connected to a middle stage portion of the absorption tower.

[0015] According to a ninth aspect of the present invention, the regeneration tower comprises an upper-portion regeneration tower and a lower-portion regeneration tower, and the CO_2 recovery system further comprises an upper semi-lean-solution extraction path that extracts the semi-lean solution from a fifth point of the upper-portion regeneration tower and returns the extracted semi-lean solution to a sixth point of the upper-portion regeneration tower that is downstream of the fifth point, wherein the steam-condensate heat exchanger is arranged in the upper semi-lean-solution extraction path and heats the semi-lean solution in the upper semi-lean-solution extraction path with the steam condensate.

[0016] According to a tenth aspect of the present invention, the regeneration tower comprises an upper-portion regeneration tower and a lower-portion regeneration tower, and the CO_2 recovery system further comprises: an upper semi-lean-solution extraction path that extracts the semi-lean solution from a seventh point of the upper-portion regeneration tower and returns the extracted semi-lean solution to an eighth point of the upper-portion regeneration tower that is downstream of the seventh point, wherein the steam-condensate heat exchanger is arranged in the upper semi-lean-solution extraction path and heats the semi-lean solution in the upper semi-lean-solution extraction path with the steam condensate; a rich-solution supply member that conveys the rich solution from the absorption tower to the regeneration tower; a lean-solution supply member that extracts the lean solution from the regeneration tower and conveys the extracted lean solution to the absorption tower; and a lean-solution heat exchanger that is provided in the rich-solution supply member and the lean-solution supply member, and heats the rich solution in the rich-solution supply member with the lean solution in the lean-solution supply member.

[0017] According to an eleventh aspect of the present invention, the regeneration tower comprises an upper-portion regeneration tower and a lower-portion regeneration tower, and the CO_2 recovery system further comprises: a semi-lean-solution supply member that extracts the semi-lean solution from a ninth point of the upper-portion regeneration tower and returns the extracted semi-lean solution to a tenth point of the upper-portion regeneration tower that is downstream of the ninth point; a rich-solution supply member that conveys the rich solution from the absorption tower to the regeneration tower; a first branching node provided in the rich-solution supply member that divides the rich-solution supply member into a first rich-solution supply member and a second rich-solution supply member; a lean-solution supply member that extracts the lean solution from the regeneration tower and conveys the extracted lean solution to the absorption tower; a lean-solution heat exchanger that is provided in the first rich-solution supply member and the lean-solution supply member, and heats the rich solution in the first rich-solution supply member with the lean solution in the lean-solution supply member; a semi-lean-solution heat exchanger that is provided in the second rich-solution supply member and the semi-lean-solution supply member, and heats the rich solution in the second rich-solution supply member with the semi-lean solution in the semi-lean-solution supply member; a solution supply path that supplies the rich solution heated in the semi-lean-solution heat exchanger to downstream of the lean-solution heat exchanger in the first rich-solution supply member; a second lean-solution heat exchanger arranged in the first rich-solution supply member and the lean-solution supply member downstream of where the solution supply path conveys the rich solution in the first rich-solution supply member; and a second branching node provided in the semi-lean-solution extraction path downstream of the semi-lean-solution heat exchanger that divides the semi-lean-solution extraction path into a first semi-lean-solution extraction path and a second semi-lean-solution extraction path, wherein the steam-condensate heat exchanger is arranged in the first semi-lean-solution extraction path and heats the semi-lean solution in the first semi-lean-solution extraction path with the steam condensate, and one end of the second semi-lean-solution extraction path is connected to a middle stage portion of the absorption tower.

[0018] According to a twelfth aspect of the present invention, the regeneration tower comprises an upper-portion regeneration tower and a lower-portion regeneration tower, the CO_2 recovery system further comprises: an upper semi-lean-solution extraction path that extracts the semi-lean solution from an eleventh point of the upper-portion regeneration tower and returns the extracted semi-lean solution to a twelfth point of the upper-portion regeneration tower that is downstream of the eleventh point; a lean-solution supply member that extracts the lean solution from the regeneration tower and conveys the extracted lean solution to the absorption tower; a lean-solution heat exchanger that is arranged in the upper semi-lean-solution extraction path and the lean-solution supply member and heats the semi-lean solution in the upper semi-lean-solution extraction path with the lean solution in the lean-solution supply member.

[0019] According to a thirteenth aspect of the present invention, the regeneration tower of the CO_2 recovery system comprises an upper-portion regeneration tower and a lower-portion regeneration tower, the CO_2 recovery system further comprises: an upper semi-lean-solution extraction path that extracts the semi-lean solution from a thirteenth point of the upper-portion regeneration tower and returns the extracted semi-lean solution to a fourteenth point of the upper-portion regeneration tower that is downstream of the thirteenth point; a lean-solution supply member that extracts the lean solution from the regeneration tower and conveys the extracted lean solution to the absorption tower; a first lean-solution heat exchanger that is arranged in the upper semi-lean-solution extraction path and the lean-solution supply member and heats the semi-lean solution in the upper semi-lean-solution extraction path with the lean solution in the lean-solution supply member, wherein the steam-condensate heat exchanger is arranged in the upper semi-lean-solution extraction path downstream of the first lean-solution heat exchanger and heats the semi-lean solution in the upper semi-lean-solution extraction path with the steam condensate; a rich-solution supply member that conveys the rich solution from the absorption tower to the regeneration tower; and a second lean-solution heat exchanger that is provided in the rich-solution supply member and the lean-solution supply member and heats the rich solution in the rich-solution supply member with the lean solution in the lean-solution supply member.

[0020] According to a fourteenth aspect of the present invention, the regeneration tower of the CO_2 recovery system comprises an upper-portion regeneration tower, a middle-portion regeneration tower, and a lower-portion regeneration tower, the CO_2 recovery system further comprises: an upper semi-lean-solution extraction path that extracts the semi-lean solution from a fifteenth point of the upper-portion regeneration tower and returns the extracted semi-lean solution to a sixteenth point of the upper-portion regeneration tower that is downstream of the fifteenth point; a lean-solution supply member that extracts the lean solution from the regeneration tower and conveys the extracted lean solution to an upper stage portion of the absorption tower; a first lean-solution heat exchanger that is arranged in the upper semi-lean-solution extraction path and the lean-solution supply member and heats the semi-lean solution in the upper semi-lean-solution extraction path with the lean solution in the lean-solution supply member; a semi-lean-solution extraction path that extracts the semi-lean solution from a seventeenth point of the middle-portion regeneration tower and returns the extracted semi-lean solution to an eighteenth point of the middle-portion regeneration tower that is downstream of the seventeenth point and also conveys the extracted semi-lean solution to a middle stage portion of the absorption tower; a first steam-condensate heat exchanger that is arranged in the semi-lean-solution extraction path between the seventeenth point and the eighteenth point and heats the semi-lean solution in the semi-lean-solution extraction path with the steam condensate; a rich-solution supply member that conveys the rich solution from the absorption tower to the regeneration tower; a semi-lean-solution heat exchanger that is provided in the rich-solution supply member and the semi-lean-solution extraction path and heats the rich solution in the rich-solution supply member with the semi-lean solution in the semi-lean-solution extraction path; and a second lean-solution heat exchanger that is provided downstream of the semi-lean-solution heat exchanger in the rich-solution supply member and downstream of the first lean-solution heat exchanger in lean-solution supply member, and heats the rich solution in the rich-solution supply member with the lean solution in the lean-solution supply member.

[0021] According to a fifteenth aspect of the present invention, in the invention according to any one of the fourth, fifth, eighth, eleventh, and fourteenth aspects, the absorption tower is divided into an upper stage and a lower stage, and the semi-lean solution to be supplied to a portion between the upper stage and the lower stage of the absorption tower is joined with a semi-lean solution extracted from the upper-stage absorption tower, to be supplied to the lower-stage absorption tower.

[0022] A sixteenth aspect of the present invention relates to a CO_2 recovery system which comprises: an absorption tower that receives a CO_2-containing gas and a CO_2-absorbing solution, and causes the CO_2-containing gas to come in contact with the CO_2-absorbing solution to produce a CO_2 rich solution; a regeneration tower that receives the rich solution and produces a lean solution from the rich solution by removing CO_2 from the rich solution; a bottom lean-solution extraction path that extracts the lean solution that accumulates near a bottom portion of the regeneration tower and returns the extracted lean solution to the regeneration tower; a regeneration heater arranged in the bottom lean-solution extraction path and heats the lean solution in the bottom lean-solution extraction path with a saturated steam thereby producing a steam condensate from the saturated steam; a rich-solution supply member that conveys the rich solution from the absorption tower to the regeneration tower; and a steam-condensate heat exchanger that is provided in the rich-solution supply member and heats the rich solution in the rich-solution supply member with the steam condensate.

[0023] A seventeenth aspect of the present invention relates to a CO_2 recovery system which comprises: an absorption tower that receives a CO_2-containing gas and a CO_2-absorbing solution, and causes the CO_2-containing gas to come in contact with the CO_2-absorbing solution to produce a CO_2 rich solution; a regeneration tower that receives the rich solution and produces a lean solution form the rich solution by removing CO_2 from the rich solution; a bottom lean-solution extraction path that extracts the lean solution that accumulates near a bottom portion of the regeneration tower and returns the extracted lean solution to the regeneration tower; a regeneration heater arranged in the bottom lean-solution extraction path and heats the lean solution in the bottom lean-solution extraction path with a saturated steam thereby producing a steam condensate from the saturated steam; a semi-lean-solution extraction path that extracts a semi-lean solution from a middle portion of the regeneration tower and returns the extracted semi-lean solution to the middle portion of the regeneration tower; and a steam-condensate heat exchanger that is arranged in the semi-lean-solution extraction path and heats the semi-lean solution in the semi-lean-solution extraction path with the steam condensate.

[0024] An eighteenth aspect of the present invention relates to a CO_2 recovery system which comprises: an absorption tower that receives a CO_2-containing gas and a CO_2-absorbing solution, and causes the CO_2-containing gas to come in contact with the CO_2-absorbing solution to produce a CO_2 rich solution; a regeneration tower that receives the rich solution and produces a lean solution from the rich solution by removing CO_2 from the rich solution; a semi-lean-solution extraction path that extracts a semi-lean solution from a middle portion of the regeneration tower and returns the extracted semi-lean solution to the middle portion of the regeneration tower; a lean-solution supply member that extracts the lean solution from the regeneration tower and conveys the extracted lean solution to the absorption tower; and a lean-solution heat exchanger that is provided in the semi-lean-solution extraction path and the lean-solution supply member, and heats the semi-lean solution in the semi-lean-solution extraction path with the lean solution in the lean-solution supply member.

[0025] A nineteenth aspect of the present invention relates to a CO_2 recovery method which comprises: causing a CO_2-containing gas to come in contact with a CO_2-absorbing solution to produce a CO_2 rich solution in an absorption tower; conveying the rich solution to a regeneration tower, and producing a lean solution from the rich solution by removing CO_2 from the rich solution in the regeneration tower; extracting the lean solution that accumulates near a bottom portion of the regeneration tower; heating the extracted lean solution with a saturated steam to produce a steam condensate from the saturated steam, and returning the extracted lean solution after heating the saturated steam to the regeneration tower; and heating the rich solution that is conveyed from the absorption tower to the regeneration tower with the steam condensate.

[0026] A twentieth aspect of the present invention relates to a CO_2 recovery method which comprises: causing a CO_2-containing gas to come in contact with a CO_2-absorbing solution to produce a CO_2 rich solution in an absorption tower; conveying the rich solution to a regeneration tower, and producing a lean solution from the rich solution by removing CO_2 from the rich solution in the regeneration tower; extracting the lean solution that accumulates near a bottom portion of the regeneration tower; heating the extracted lean solution with a saturated steam to produce a steam condensate from the saturated steam, and returning the extracted lean solution after heating the saturated steam to the regeneration tower; and extracting the semi-lean solution from a middle portion of the regeneration tower; heating the extracted semi-lean solution with the steam condensate; and returning the extracted semi-lean solution that has been heated by the saturated steam to the regeneration tower.

[0027] A twenty-first aspect of the present invention relates to a CO_2 recovery method which comprises: causing a CO_2-containing gas to come in contact with a CO_2-absorbing solution to produce a CO_2 rich solution in an absorption tower; conveying the rich solution to a regeneration tower, and producing a lean solution from the rich solution by removing CO_2 from the rich solution in the regeneration tower; performing a transfer of heat from the lean solution to a semi-lean solution obtained by removing part of CO_2 from the rich solution, the semi-lean solution having been extracted from a middle portion of the regeneration tower; extracting the semi-lean solution from a middle portion of the regeneration tower; heating the extracted semi-lean solution with the lean solution extracted from the regeneration tower; returning the extracted semi-lean solution that has been heated by the lean solution to the regeneration tower; and conveying the lean solution after heating the semi-lean solution to the absorption tower.

EFFECT OF THE INVENTION

[0028] According to the present invention, it is possible to provide a CO_2 recovery system and method in which energy saving is achieved by using residual heat of steam condensate.

Furthermore, it is possible to provide a CO_2 recovery system and method with improved energy efficiency by heating a semi-lean solution with residual heat of a lean solution, the semi-lean solution obtained by removing part of CO_2 from a rich solution and extracted from the middle of the regeneration tower when the rich solution having absorbed CO_2 is regenerated in the regeneration tower.

BRIEF DESCRIPTION OF DRAWINGS

[0029] Fig. 1 is a schematic of a CO_2 recovery system according to a first embodiment;

Fig. 2 is a schematic of a CO_2 recovery system according to a second embodiment;

Fig. 3 is a schematic of a CO_2 recovery system according to a third embodiment;

Fig. 4 is a schematic of a CO_2 recovery system according to a fourth embodiment;

Fig. 5 is a schematic of a CO_2 recovery system according to a fifth embodiment;

Fig. 6 is a schematic of a CO_2 recovery system according to a sixth embodiment;

Fig. 7 is a schematic of a CO_2 recovery system according to a seventh embodiment;

Fig. 8 is a schematic of a CO_2 recovery system according to a eighth embodiment;

Fig. 9 is a schematic of a CO_2 recovery system according to a ninth embodiment;

Fig. 10 is a schematic of a CO_2 recovery system according to example 1;

Fig. 11 is a schematic of a CO_2 recovery system according to example 2;

Fig. 12 is a schematic of a CO_2 recovery system according to example 3;

Fig. 13 is a schematic of a CO_2 recovery system according to example 4;

Fig. 14 is a schematic of a CO_2 recovery system according to example 5;

Fig. 15 is a schematic of a CO_2 recovery system according to example 6;

Fig. 16 is a schematic of a CO_2 recovery system according to example 7;

Fig. 17 is a schematic of a CO_2 recovery system according to example 8;

Fig. 18 is a schematic of a CO_2 recovery system according to example 9;

Fig. 19 is a schematic of a CO_2 recovery system according to example 10;

Fig. 20 is a schematic of a CO_2 recovery system according to example 11;

Fig. 21 is a schematic of a CO_2 recovery system according to example 12; and

Fig. 22 is a schematic of a CO_2 recovery system according to a conventional example.

EXPLANATIONS OF LETTERS OR NUMERALS

[0030] 11 CO_2-containing gas

12 CO_2-absorbing solution

13 Absorption tower

14 Rich solution

15 Regeneration tower

16 Lean solution

17 Steam

18 Regeneration heater

19 Steam condensate
21 Steam-condensate heat exchanger
22 Lean-solution supply pipe
23 Lean-solution heat exchanger
8 Nozzle
9 Chimney tray
10 CO_2-removed exhaust gas

BEST MODE(S) FOR CARRYING OUT THE INVENTION

[0031] The present invention is explained in detail below with reference to the attached drawings. It is noted that the present invention is not limited by its exemplary embodiments and examples. It is also noted that components in the following embodiments and examples contain those persons skilled in the art can easily think of or those substantially equivalent thereto.

The embodiments of the present invention are explained first, and the exemplary examples are explained in detail next.

[0032] [First Embodiment]

Fig. 1 is a schematic of a CO_2 recovery system according to a first embodiment.

As shown in Fig. 1, the CO_2 recovery system according to the first embodiment of the present invention includes an absorption tower 13 that makes CO_2-containing gas 11 containing CO_2 to contact with a CO_2-absorbing solution 12 to produce a CO_2-rich solution 14; and a regeneration tower 15 that regenerates a rich solution 14 to produce a lean solution (regenerated solution) 16. The regenerated solution 16 is reused in the absorption tower 13. The CO_2 recovery system includes a regeneration heater 18 that implements heat exchange between the lean solution 16, which accumulates near the bottom of the regeneration tower

15, and high temperature steam 17; a rich-solution supply pipe 20 which supplies the rich solution 14 from the absorption tower 13 to the regeneration tower 15; a steam-condensate heat exchanger 21 that is provided in rich-solution supply pipe 20 and heats the rich solution 14 with the residual heat of steam condensate 19 fed from the regeneration heater 18.

[0033] In the first embodiment, the lean solution 16 being the regenerated solution is supplied from the regeneration tower 15 to the absorption tower 13 through a lean-solution supply pipe 22. A lean-solution heat exchanger 23, which heats the rich solution 14 with residual heat of the lean solution 16, is provided in the rich-solution supply pipe 20.

In Fig. 1, reference numeral 8 represents a nozzle, 9 a chimney tray, 10 CO_2-removed exhaust gas, 25a and 25b filling layers provided in the absorption tower 13, and 26a and 26b filling layers provided in the regeneration tower 15.

[0034] The heat exchanger used in the first embodiment is not particularly limited. In other words, a known heat exchanger such as a plate heat exchanger and a shell and tube heat exchanger can be used.

[0035] The CO_2-absorbing solution used in the present invention is not particularly limited. For example, an alkanolamine and a hindered amine group having alkanolamine and alcoholic hydroxyl can be exemplified. The alkanolamine can be exemplified by monoethanolamine, diethanolamine, triethanolamine, methyldiethanolamine, diisopropanolamine, diglycolamine, and the like, but generally, monoethanolamine (MEA) is preferably used. The hindered amine having alcoholic hydroxyl can be exemplified by 2-amino-2-methyl-1-propanol(AMP), 2-(ethylamino)-

ethanol(EAE), 2-(methylamino)-ethanol(MAE), and 2-(diethylamino)-ethanol(DEAE).

[0036] Thus, there is provided the steam-condensate heat exchanger 21 that heats the rich solution 14 with the residual heat of the steam condensate 19 fed from the regeneration heater 18. Thus, the residual heat of the steam condensate 19 can be effectively used to raise the supply temperature of the rich solution 14 to be supplied to the regeneration tower 15, so that reduction in the supply amount of steam used in the regeneration tower 15 can be achieved.

[0037] The CO_2-containing gas 11 to be supplied to the CO_2 recovery device is first cooled by a cooling device (not shown) to about 40°C to 50°C and supplied to the CO_2 recovery device. On the other hand, the lean solution 16 which is the absorbing solution 12 regenerated is cooled to about 40°C by a cooling device (not shown).

The rich solution 14 output from the absorption tower 13 of the CO_2 removal device is sent toward the regeneration tower 15 at about 50°C due to heat reaction. The rich solution 14 is then heated up to about 110°C in the lean-solution heat exchanger 23 and supplied to the regeneration tower 15. However, by providing the steam-condensate heat exchanger 21 in which the rich solution 14 is heat-exchanged with the heat (e.g., 137°C) of the steam condensate 19, the temperature of the rich solution 14 can be increased by several degrees.

[0038] In the configuration of Fig. 1, a flash drum for causing the rich solution to flash can be provided in either one of an upstream side and a downstream side of the steam-condensate heat exchanger 21, and the flash drum can be made to discharge CO_2 contained in the rich solution in the outside of the regeneration tower. According to such configuration, part of CO_2 in the rich solution 14 to be regenerated in the regeneration tower 15 is previously removed by the flash drum, and it becomes possible to reduce the supply amount of steam to be used for CO_2 removal in the regeneration tower 15.

[0039] [Second Embodiment]

Fig. 2 is a schematic of a CO_2 recovery system according to a second embodiment.

Components the same as those of the CO_2 recovery system according to the first embodiment are assigned with the same reference numerals, and explanation thereof is omitted.

As shown in Fig. 2, the CO_2 recovery system according to the second embodiment of the present invention further includes, in addition to the configuration of the first embodiment, a branching node 24 provided in the rich-solution supply pipe 20 that branches the rich solution 14 into the first rich-solution supply pipe 20-1 and the second rich-solution supply pipe 20-2; the steam-condensate heat exchanger 21 that is provided in the first rich-solution supply pipe 20-1 and heats the rich solution 14; a flash drum 27 provided in the downstream side of the steam-condensate heat exchanger 21; and a semi-lean-solution heat exchanger 29 that is provided in the second rich-solution supply pipe 20-2 and heats the rich solution 14 with the residual heat of a semi-lean solution 28 obtained by removing part of CO_2 from the rich solution in the flash drum 27. An end of a semi-lean-solution supply pipe 30 for supplying the semi-lean solution 28 is connected to a middle stage portion of the absorption tower 13. The second rich-solution supply pipe 20-2 is connected near the upper stage of the regeneration tower 15, and CO_2 is removed and recovered in the regeneration tower 15.

[0040] Thus, the steam-condensate heat exchanger 21 heats the rich solution 14 with the residual heat of the steam condensate 19 fed from the regeneration heater 18, in which the rich solution is heated with the residual heat of the steam condensate. therefore, the residual heat of the steam condensate 19 having been used in the regeneration heater 18 is effectively used. The rich solution 14 heated with the residual heat is introduced into the flash drum 27. Then, the rich solution 14 is caused to flash in the flash drum 27 to enable improvement of CO_2 removal efficiency. Moreover, the rich solution 14 is heat-exchanged with the residual heat of the semi-lean solution 28 obtained by removing part of CO_2 from the rich solution and fed from the flash drum 27, in the semi-lean-solution heat exchanger 29 interposed in the second rich-solution supply pipe 20-2 branched. Therefore, it is possible to increase the temperature of the rich solution 14 to be introduced into the regeneration tower 15, and as a result, the supply amount of steam to be used in the regeneration tower 15 can be reduced. Most of CO_2 is removed from the semi-lean solution 28, obtained by removing part of CO_2 from the rich solution, in the flash drum 27. Therefore, by supplying this semi-lean solution 28 to the middle stage portion of the absorption tower 13, CO_2 is absorbed without being regenerated in the regeneration tower 15.

Furthermore, CO_2 removed in the flash drum 27 joins CO_2 fed from the regeneration tower 15, to be recovered separately.

[0041] The ratio of division of the rich solution 14 into the first rich-solution supply pipe 20-1 and the second rich-solution supply pipe 20-2 at the branching node 24 is simply set to a range from 30:70 to 70:30, preferably

50:50.

[0042] The second embodiment is configured to further divide the inner side of the absorption tower 13 into two stages: an upper-stage filling layer 13-U and a lower-stage filling layer 13-L; to extract the absorbing solution 12 having absorbed CO_2, from the upper-stage filling layer 13-U to the outside; and to mix the absorbing solution 12 with the semi-lean solution 28 to be cooled. This is because it is preferable to decrease the temperature of a solution to be supplied because the absorption reaction is an exothermic reaction. In this embodiment, the temperature is decreased to about 40°C to 50°C.

[0043] [Third Embodiment]

Fig. 3 is a schematic of a CO_2 recovery system according to a third embodiment.

Components the same as those in each of the CO_2 recovery systems according to the first and the second embodiments are assigned with the same reference numerals, and explanation thereof is omitted.

As shown in Fig. 3, the CO_2 recovery system according to the third embodiment of the present invention further includes, in addition to the configuration of the first embodiment, the branching node 24 provided in the rich-solution supply pipe 20 and divides the rich solution 14 into the first rich-solution supply pipe 20-1 and the second rich-solution supply pipe 20-2; a steam-condensate heat exchanger 31 that is provided in an end of the first rich-solution supply pipe 20-1 and causes the rich solution 14 to flash; and the semi-lean-solution heat exchanger 29 that is provided in the second rich-solution supply pipe 20-2 and heats the rich solution 14 with the residual heat of the semi-lean solution 28 obtained by removing part of CO_2 from the rich solution in the steam-condensate heat exchanger 31. And the end of the semi-lean-solution supply pipe 30 for supplying the semi-lean solution 28 is connected to the middle stage portion of the absorption tower 13.

[0044] In the third embodiment, the steam-condensate heat exchanger 31 is not an exchanger such as the plate heat exchanger, but includes, as shown in Fig. 3, a first flash drum 33 in which a flash portion 32, for causing the rich solution 14 to flash, is provided in its upper side; a filling layer 34 provided in the first flash drum 33; and a steam supply portion 36 that is provided in the lower-portion of the flash drum and supplies steam 35 from the steam condensate 19.

If the steam condensate 19 is pressurized saturated steam, a second flash drum 37 is provided to make it as atmospheric pressure steam 35, and the steam 35 is supplied to the first flash drum 33, where CO_2 is removed from the rich solution 14 using the heat of the steam 35.

The semi-lean-solution heat exchanger 29 heats the rich solution 14 using the residual heat of the semi-lean solution 28 obtained by removing part of CO_2 from the rich solution in the first flash drum 33, and then, the rich solution is supplied to the middle stage portion of the absorption tower 13.

[0045] Thus, the steam-condensate heat exchanger 31 heats the rich solution 14 in the first rich-solution supply pipe 20-1, with the residual heat of the steam condensate 19 fed from the regeneration heater 18, in which the rich solution is heated with the steam 35. Therefore, the residual heat of the steam condensate 19 having been used in the regeneration heater 18 is effectively used. The rich solution 14 is heat-exchanged using the residual heat of the semi-lean solution 28 obtained by removing CO_2

by flash in the steam-condensate heat exchanger 31, in the semi-lean-solution heat exchanger 29 interposed in the second rich-solution supply pipe 20-2 branched. Therefore, it is possible to increase the temperature of the rich solution 14 to be introduced into the regeneration tower 15, and as a result, the supply amount of steam to be used in the regeneration tower 15 can be reduced.

Furthermore, CO_2 removed in the first flash drum 33 joins CO_2 fed from the regeneration tower 15, to be recovered separately.

The first flash drum 33 functions as an auxiliary regeneration tower for the regeneration tower 15.

[0046] [Fourth Embodiment]

Fig. 4 is a schematic of a CO_2 recovery system according to a fourth embodiment.

Components the same as those in each of the CO_2 recovery systems according to the first to the third embodiments are assigned with the same reference numerals, and explanation thereof is omitted.

As shown in Fig. 4, the CO_2 recovery system according to the fourth embodiment of the present invention further includes, in addition to the configuration of the first embodiment, an upper-portion regeneration tower 15-U and a lower-portion regeneration tower 15-L into which the inner side of the regeneration tower 15 is vertically divided; the branching node 24 provided in the rich-solution supply pipe 20 and dividing the rich solution 14; the steam-condensate heat exchanger 21 interposed in the first rich-solution supply pipe 20-1 branched; and the semi-lean-solution heat exchanger 29 that is provided in the second rich-solution supply pipe 20-2, and heats the rich solution 14 with the residual heat of the semi-lean solution 28 obtained by removing part of CO_2 from the rich solution in the upper-portion regeneration tower 15-U. And, the end of the first rich-solution supply pipe 20-1 is connected to the lower-portion regeneration tower 15-L, the end of the second rich-solution supply pipe 20-2 is connected to the upper-portion regeneration tower 15-U, and the end of the semi-lean-solution supply pipe 30 for supplying the semi-lean solution 28 is connected to the middle stage portion of the absorption tower 13.

[0047] The fourth embodiment is configured to provide the steam-condensate heat exchanger 21 that heats the rich solution 14 with the residual heat of the steam condensate 19 fed from the regeneration heater 18, in which the rich solution is heated with the residual heat of the steam condensate. Therefore, the residual heat of the steam condensate 19 having been used in the regeneration heater 18 is effectively used. Furthermore, the rich solution 14 heated with the residual heat is introduced into the lower-portion regeneration tower 15-L, where it is regenerated.

The semi-lean solution 28, obtained by removing part of CO_2 from the rich solution 14 in the upper-portion regeneration tower 15-U, is extracted to the outside through the semi-lean-solution supply pipe 30, and the rich solution 14 is heat-exchanged with the residual heat of the semi-lean solution in the semi-lean-solution heat exchanger 29 interposed in the second rich-solution supply pipe 20-2 branched. Therefore, it is possible to increase the temperature of the rich solution 14 to be introduced into the regeneration tower 15, and as a result, the supply amount of steam to be used in the regeneration tower 15 can be reduced.

[0048] The ratio of division of the rich solution 14 into the first rich-solution supply pipe 20-1 and the second rich-solution supply pipe 20-2 at the branching node

24 is simply set to a range from 25:75 to 75:25.

[0049] [Fifth Embodiment]

Fig. 5 is a schematic of a CO_2 recovery system according to a fifth embodiment.

Components the same as those in each of the CO_2 recovery systems according to the first to the fourth embodiments are assigned with the same reference numerals, and explanation thereof is omitted.

As shown in Fig. 5, the CO_2 recovery system according to the fifth embodiment of the present invention includes the upper-portion regeneration tower 15-U, a middle-portion regeneration tower 15-M, and the lower-portion regeneration tower 15-L, which are obtained by dividing the regeneration tower 15 into three: upper, middle, and lower portions; the branching node 24 provided in the rich-solution supply pipe 20 and dividing the rich solution 14; the lean-solution heat exchanger 23 interposed in the first rich-solution supply pipe 20-1 branched; the semi-lean-solution heat exchanger 29 that is provided in the second rich-solution supply pipe 20-2, and heats the rich solution with the residual heat of the semi-lean solution 28 obtained by removing part of CO_2 from the rich solution in the upper-portion regeneration tower 15-U; and the steam-condensate heat exchanger 21 that extracts the semi-lean solution 28 obtained by removing part of CO_2 from the rich solution in the middle-portion regeneration tower 15-M, to the outside of the regeneration tower through an extraction pipe 41, and that heats the semi-lean solution 28 with the residual heat of the steam condensate 19. And, the end of the first rich-solution supply pipe 20-1 is connected to the middle-portion regeneration tower 15-M, the end of the second rich-solution supply pipe 20-2 is connected to the upper-portion regeneration tower 15-U, the extraction pipe 41 is connected to the lower-portion regeneration tower 15-L, and the end of the supply pipe 30 for supplying the semi-lean solution 28 is connected to the middle stage portion of the absorption tower 13.

[0050] The fifth embodiment is configured to provide the steam-condensate heat exchanger 21 that heats the semi-lean solution 28 extracted through the extraction pipe 41, in which the semi-lean solution 28 is heated with the residual heat of the steam condensate 19. Therefore, the residual heat of the steam condensate 19 having been used in the regeneration heater 18 is effectively used, and as a result, the supply amount of steam to be used in the regeneration tower 15 can be reduced.

Furthermore, the rich solution 14 is heat-exchanged, using the lean solution 16 regenerated in the regeneration tower 15, in the lean-solution heat exchanger 23 interposed in the first rich-solution supply pipe 20-1, and the rich solution 14 heated with the residual heat is introduced into the middle-portion regeneration tower 15-M, which allows reduction in the supply amount of steam to be used in the regeneration tower.

The semi-lean solution 28, obtained by removing part of CO_2 from the rich solution in the upper-portion regeneration tower 15-U, is extracted to the outside through the semi-lean-solution supply pipe 30, and the rich solution 14 is heat-exchanged with the residual heat of the semi-lean solution 28 in the semi-lean-solution heat exchanger 29 interposed in the second rich-solution supply pipe 20-2 branched. Therefore, it is possible to increase the temperature of the rich solution 14 to be introduced into the upper-portion regeneration tower 15-U, and as a result, the supply amount of steam to be used in the regeneration tower 15 can be reduced.

[0051] The ratio of division of the rich solution 14 into the first rich-solution supply pipe 20-1 and the second rich-solution supply pipe 20-2 at the branching node 24 is simply set to a range from 25:75 to 75:25.

[0052] [Sixth Embodiment]

Fig. 6 is a schematic of a CO_2 recovery system according to a sixth embodiment.

Components the same as those in each of the CO_2 recovery systems according to the first to the fifth embodiments are assigned with the same reference numerals, and explanation thereof is omitted.

As shown in Fig. 6, the CO_2 recovery system according to the sixth embodiment of the present invention includes the upper-portion regeneration tower 15-U and the lower-portion regeneration tower 15-L, which are obtained by dividing the regeneration tower at least into two portions; and the steam-condensate heat exchanger 21 that heats the semi-lean solution 28, obtained by removing part of CO_2 from the rich solution, with the residual heat of the steam condensate, the semi-lean solution 28 having been extracted from the upper-portion regeneration tower 15-U through the extraction pipe 41. And the semi-lean solution 28 heated is supplied to the lower-portion regeneration tower 15-L.

[0053] The sixth embodiment is configured to provide the steam-condensate heat exchanger 21 that heats the semi-lean solution 28 extracted through the extraction pipe 41, with the residual heat of the steam condensate 19 fed from the regeneration heater 18, in which the semi-lean solution 28 is heated with the residual heat of the steam condensate. Therefore, the residual heat of the steam condensate 19 having been used in the regeneration heater 18 is effectively used, and as a result, the supply amount of steam to be used in the regeneration tower 15 can be reduced.

[0054] [Seventh Embodiment]

Fig. 7 is a schematic of a CO_2 recovery system according to a seventh embodiment.

Components the same as those in each of the CO_2 recovery systems according to the first to the sixth embodiments are assigned with the same reference numerals, and explanation thereof is omitted.

As shown in Fig. 7, the CO_2 recovery system according to the seventh embodiment of the present invention includes, in addition to the system of the sixth embodiment, a first branching node 24-1 provided in the rich-solution supply pipe 20 and dividing the rich solution 14; a first lean-solution heat exchanger 23-1 interposed in the first rich-solution supply pipe 20-1 branched at the first branching node 24-1; the semi-lean-solution heat exchanger 29 that is provided in the second rich-solution supply pipe 20-2 branched at the first branching node 24-1, and heats the rich solution 14 with the residual heat of the semi-lean solution 28 obtained by removing part of CO_2 from the rich solution in the upper-portion regeneration tower 15-U; a second lean-solution heat exchanger 23-2 in which the rich solution 14 joined at a joint 42 between the first rich-solution supply pipe 20-1 and the second rich-solution supply pipe 20-2, is heat-exchanged after the heat exchange in the semi-lean-solution heat exchanger 29; a second branching node 24-2 provided in the downstream side of the semi-lean-solution heat exchanger 29 provided in the supply pipe 30 for supplying the semi-lean solution 28; and the steam-condensate heat exchanger 21 interposed in a first semi-lean-solution supply pipe 30-1 branched at the second branching node 24-2. And the end of the first semi-lean-solution supply pipe 30-1 is connected to the lower-portion regeneration tower 15-L, and the end of a second semi-lean-solution supply pipe 30-2 branched at the second branching node 24-2 is connected to the middle stage portion of the absorption tower 13.

[0055] In the seventh embodiment, the semi-lean-solution heat exchanger 29 uses the residual heat of the semi-lean solution 28 extracted from the upper-portion regeneration tower 15-U to heat the rich solution 14, and the residual heat of the semi-lean solution 28 is thereby effectively used. Moreover, because the steam-condensate heat exchanger 21 is provided in the way in which part of the semi-lean solution 28 is returned again to the lower-portion regeneration tower 15-L through the first semi-lean-solution supply pipe 30-1, the semi-lean solution 28 can be heated with the residual heat of the steam condensate 19. The residual heat of the steam condensate 19 having been used in the regeneration heater 18 is thereby effectively used, and as a result, the supply amount of steam to be used in the regeneration tower 15 can be reduced.

[0056] One part of the rich solution 14 once divided is heat-exchanged in the semi-lean-solution heat exchanger 29, and the other part of the rich solution 14 divided is also heat-exchanged in the first lean-solution heat exchanger 23-1, and these parts of the rich solution 14 are jointed at the joint 42, and are further heat-exchanged in the second lean-solution heat exchanger 23-2, to be supplied to the upper-portion regeneration tower 15-U. The temperature of the rich solution 14 to be introduced into the regeneration tower thereby increases, and as a result, the supply amount of steam to be used in the regeneration tower 15 can be reduced.

[0057] [Eighth Embodiment]

Fig. 8 is a schematic of a CO_2 recovery system according to an eighth embodiment.

Components the same as those in each of the CO_2 recovery systems according to the first to the seventh embodiments are assigned with the same reference numerals, and explanation thereof is omitted.

As shown in Fig. 8, the CO_2 recovery system according to the eighth embodiment of the present invention includes the upper-portion regeneration tower 15-U and the lower-portion regeneration tower 15-L, which are obtained by dividing the regeneration tower at least into two portions; the first lean-solution heat exchanger 23-1 that is interposed in the extraction pipe 41 for extracting the semi-lean solution 28, obtained by removing part of CO_2 from the rich solution, from the upper-portion regeneration tower 15-U divided, and heats the semi-lean solution 28 with the residual heat of the lean solution 16 that flows through the lean-solution supply pipe 22; and the steam-condensate heat exchanger 21 that is provided in the downstream side of and adjacent to the first lean-solution heat exchanger 23-1 in the extraction pipe 41, and reheats the semi-lean solution 28 having been heated once, with the steam condensate 19. And the second lean-solution heat exchanger 23-2, which heats the rich solution 14 with the residual heat of the lean solution after the semi-lean solution 28 is heated, is provided in the rich-solution supply pipe 20.

[0058] In the eighth embodiment, the semi-lean solution 28 extracted from the upper-portion regeneration tower 15-U is heated in the first lean-solution heat exchanger 23-1, and further heated in the steam-condensate heat exchanger 21, and the residual heat of the steam condensate 19 having been used in the regeneration heater 18 is thereby effectively used. As a result, the supply amount of steam to be used in the regeneration tower 15 can be reduced.

[0059] Furthermore, when the inside of the regeneration tower is divided into a plurality of stages and the semi-lean solution 28, extracted from each stage of the regeneration tower divided, is returned to the regeneration tower on the lower stage side, the semi-lean solution 28 is heat-exchanged in the lean-solution heat exchanger and the steam-condensate heat exchanger respectively. This causes the temperature of the semi-lean solution 28, which is regenerated in the regeneration tower 15, to be increased, and consequently, the supply amount of steam to be used in the regeneration tower 15 can be reduced.

[0060] [Ninth Embodiment]

Fig. 9 is a schematic of a CO_2 recovery system according to a ninth embodiment.

Components the same as those in each of the CO_2 recovery systems according to the first to the eighth embodiments are assigned with the same reference numerals, and explanation thereof is omitted.

As shown in Fig. 9, the CO_2 recovery system according to the ninth embodiment of the present invention includes the upper-portion regeneration tower 15-U, the middle-portion regeneration tower 15-M, and the lower-portion regeneration tower 15-L, which are obtained by dividing the regeneration tower 15 into three: upper, middle, and lower portions; the first lean-solution heat exchanger 23-1 that heats the semi-lean solution 28, obtained by removing part of CO_2 from the rich solution and extracted from the upper-portion regeneration tower 15-U through a first extraction pipe 41-1, with the lean solution fed from the regeneration tower; the steam-condensate heat exchanger 21 that heats the semi-lean solution 28, obtained by removing part of CO_2

from the rich solution and extracted from the middle-portion regeneration tower 15-M through a second extraction pipe 41-2, with the steam condensate; the semi-lean-solution heat exchanger 29 that is provided in the rich-solution supply pipe 20, and heats the rich solution 14 with the part of the semi-lean solution 28 extracted from the middle-portion regeneration tower 15-M; and the second lean-solution heat exchanger 23-2 that is provided in the downstream side of the semi-lean-solution heat exchanger 29 in the rich-solution supply pipe 20, and heats the rich solution 14 with the residual heat of the lean solution 16 after the semi-lean solution 28 is heated. And the semi-lean solution heated is supplied to the lower stage side of the regeneration tower, and the semi-lean solution 28 after heat exchange is performed in the semi-lean-solution heat exchanger 29 is supplied to the middle stage portion of the absorption tower 13 through the semi-lean-solution supply pipe 30.

[0061] In the ninth embodiment, the semi-lean solution 28 respectively extracted from the upper-portion regeneration tower 15-U and the middle-portion regeneration tower 15-M is heated in the first lean-solution heat exchanger 23-1 or in the steam-condensate heat exchanger 21, and the residual heat of the lean solution 16 and of the steam condensate 19 is thereby effectively used. As a result, the supply amount of steam to be used in the regeneration tower 15 can be reduced.

The residual heat of the semi-lean solution 28 after heat exchange is performed in the steam-condensate heat exchanger 21 is used for heating the rich solution, and the residual heat of the lean solution heat-exchanged in the first lean-solution heat exchanger 23-1 is used for heating the rich solution in the second lean-solution heat exchanger 23-2. It is thereby possible to increase the temperature of the rich solution 14 to be supplied to the regeneration tower 15, and as a result, the supply amount of steam to be used in the regeneration tower 15 can be reduced.

[0062] The exemplary examples indicating the effect of the present invention are explained below, but the present invention is not limited by the examples.

Example 1

[0063] A CO_2 recovery system according to example 1 of the present invention is explained below with reference to the following drawing.

Fig. 10 is a schematic of the CO_2 recovery system according to example 1.

As shown in Fig. 10, the CO_2-containing exhaust gas 11 supplied to the CO_2 absorption tower 13 is brought into countercurrent contact with the absorbing solution 12 in a filling portion, the absorbing solution 12 having predetermined concentration and being supplied from the nozzle 8. CO_2 in the combustion exhaust gas is absorbed and removed by the CO_2-absorbing solution 12, and the remaining CO_2-removed exhaust gas 10, from which CO_2 has been absorbed and removed, is fed to the outside. The absorbing solution 12 supplied to the CO_2 absorption tower 13 absorbs CO_2, and reaction heat due to the absorption causes the temperature of the absorbing solution 12 to become higher than normal temperature in a tower head. The absorbing solution having absorbed CO_2 is sent by a discharge pump 51 for the absorbing solution, as the rich solution 14, to the lean-solution heat exchanger 23 and the steam-condensate heat exchanger 21, where it is heated, to be introduced into the regeneration tower 15.

[0064] In the regeneration tower 15, the absorbing solution is regenerated by being heated with the steam 17 by the regeneration heater 18, cooled as the lean solution 16 by the lean-solution heat exchanger 23 and a cooler 52 provided as necessary, and is returned to the CO_2 absorption tower 13. In the upper portion of the regeneration tower 15, CO_2 separated from the absorbing solution is cooled by a regeneration-tower reflux condenser 53, the steam associated with CO_2 is separated from condensed reflux water in a CO_2 separator 54, and output to the outside of the system through a recovered-CO_2 discharge line 55. Reflux water 56 is flowed back to the regeneration tower 15 by a reflux pump 57.

[0065] In the example 1, the steam used in the regeneration heater 18 is introduced into a separator to be flashed, and the residual heat of the steam flashed as the steam condensate 19 is used for heating the rich solution 14 in the steam-condensate heat exchanger 21.

[0066] As a comparison, the case where the steam-condensate heat exchanger 21 is not provided is shown in Fig. 22.

[0067] If the temperature of the rich solution 14 to be discharged from the absorption tower 13 was 50.5°C, the temperature was 114.2°C when only the lean-solution heat exchanger 23 was provided, while in the example 1, the steam-condensate heat exchanger 21 was provided, and the temperature thereby increased to 116.7°C, consequently, the amount of steam consumed in the regeneration tower 15 became 97.96 MMkcal/h.

In Fig. 10, temperature (°C) is surrounded by a rectangle, flow rate (t/h) is surrounded by a parallelogram, and the amount of heat (MMkcal/h) is represented with angled brackets. The same goes for Fig. 11 to Fig. 21.

[0068] The amount of steam consumed in the comparative example of Fig. 22 was 98.77 MMkcal/h. Assuming the comparative example is 100, the amount of steam consumed in this example becomes 99.2%. Therefore, the reduction rate of specific steam consumption (improvement effect) was 0.8%.

Example 2

[0069] A CO_2 recovery system according to example 2 of the present invention is explained below with reference to the following drawing.

Fig. 11 is a schematic of the CO_2 recovery system according to example 2. Components the same as those of example 1 are assigned with the same reference numerals and explanation thereof is omitted.

In example 2, a flash drum 61 is provided in the downstream side of the steam-condensate heat exchanger 21 that heats the rich solution 14. In the upstream side of the flash drum 61, the rich solution 14 is heated in the steam-condensate heat exchanger 21, and therefore, CO_2 in the rich solution 14 can be removed in the flash drum 61.

The temperature of the rich solution fed from the flash drum 61 is 103.9°C, but because part of CO_2 has been removed, decreasing inlet temperature of the regeneration tower 15 causes the steam discharged from the tower head to be reduced, which is preferable.

In example 2, as the result, the amount of steam consumed in the regeneration tower 15 became 97.64 MMkcal/h. Assuming the comparative example is 100, the amount of steam consumed in this example becomes 98.9%. Therefore, the reduction rate of specific steam consumption (improvement effect) was 1.1%.

Example 3

[0070] A CO_2 recovery system according to example 3 of the present invention is explained below with reference to the following drawing.

Fig. 12 is a schematic of the CO_2 recovery system according to example 3. Components the same as those of example 1 are assigned with the same reference numerals and explanation thereof is omitted.

In example 3, the flash drum 61 is provided in the upstream side of the steam-condensate heat exchanger 21 that heats the rich solution 14. In the downstream side of the flash drum 61, the rich solution 14 was heated in the steam-condensate heat exchanger 21, to thereby increase the temperature of the rich solution 14 to be supplied to the regeneration tower 15.

In example 3, as the result, the amount of steam consumed in the regeneration tower 15 became 97.27 MMkcal/h. Assuming the comparative example is 100, the amount of steam consumed in this example becomes 98.5%. Therefore, the reduction rate of specific steam consumption (improvement effect) was 1.5%.

Example 4

[0071] A CO_2 recovery system according to example 4 of the present invention is explained below with reference to the following drawing.

Fig. 13 is a schematic of the CO_2 recovery system according to example 4. Components the same as those of example 1 are assigned with the same reference numerals and explanation thereof is omitted.

In example 4, the rich solution 14 was divided, part of the rich solution 14 divided was sent to the heat exchanger 31 of flash drum type, where the rich solution 14 was heat-exchanged with the steam from the steam condensate and CO_2 was removed from the rich solution 14. Using the residual heat of the semi-lean solution 28 after the heat exchange, the other part of the rich solution 14 divided was heat-exchanged in the semi-lean-solution heat exchanger 29, to increase the temperature of the rich solution 14 to be supplied to the regeneration tower 15.

In example 4, as the result, the amount of steam consumed in the regeneration tower 15 became 97.56 MMkcal/h. Assuming the comparative example is 100, the amount of steam consumed in this example becomes 98.8%. Therefore, the reduction rate of specific steam consumption (improvement effect) was 1.2%.

Example 5

[0072] A CO_2 recovery system according to example 5 of the present invention is explained below with reference to the following drawing.

Fig. 14 is a schematic of the CO_2 recovery system according to example 5. Components the same as those of example 1 are assigned with the same reference numerals and explanation thereof is omitted.

In example 5, the rich solution 14 was divided, and part of the rich solution 14 divided was sent to the heat exchanger 31 of flash drum type, but on the way to the heat exchanger 31, the rich solution 14 was heat-exchanged with the residual heat of the steam condensate in the steam-condensate heat exchanger 21, to improve the removal rate of CO_2 from the rich solution 14 in the flash drum 31. Using the residual heat of the semi-lean solution 28 after the heat exchange, the other part of the rich solution 14 divided was heat-exchanged in the semi-lean-solution heat exchanger 29, to thereby increase the temperature of the rich solution 14 to be supplied to the regeneration tower 15.

In example 5, as the result, the amount of steam consumed in the regeneration tower 15 became 95.52 MMkcal/h. Assuming the comparative example is 100, the amount of steam consumed in this example becomes 96.7%. Therefore, the reduction rate of specific steam consumption (improvement effect) was 3.3%.

Example 6

[0073] A CO_2 recovery system according to example 6 of the present invention is explained below with reference to the following drawing.

Fig. 15 is a schematic of the CO_2 recovery system according to example 6. Components the same as those of example 1 are assigned with the same reference numerals and explanation thereof is omitted.

In example 6, the regeneration tower 15 was divided into two portions, the semi-lean solution 28 extracted from the upper-portion regeneration tower 15-U was heat-exchanged with the residual heat of the steam condensate 19 in the steam-condensate heat exchanger 21, and the semi-lean solution 28 heat-exchanged was returned to the lower-portion regeneration tower 15-L. This caused an increase in the temperature of the semi-lean solution to be supplied to the lower portion side of the regeneration tower 15.

In example 6, as the result, the amount of steam consumed in the regeneration tower 15 became 93.65 MMkcal/h. Assuming the comparative example is 100, the amount of steam consumed in this example becomes 94.8%. Therefore, the reduction rate of specific steam consumption (improvement effect) was 5.2%.

Example 7

[0074] A CO_2 recovery system according to example 7 of the present invention is explained below with reference to the following drawing.

Fig. 16 is a schematic of the CO_2 recovery system according to example 7. Components the same as those of example 1 are assigned with the same reference numerals and explanation thereof is omitted.

In example 7, the regeneration tower 15 was divided into two portions, and the rich solution 14 was divided. The lean-solution heat exchanger 23 was provided in the first rich-solution supply pipe 20-1, and in the downstream side thereof, the steam-condensate heat exchanger 21 was provided, to thereby increase the temperature of the rich solution 14 to be supplied to the lower-portion regeneration tower 15-L. Furthermore, the semi-lean-solution heat exchanger 29, which uses the residual heat of the semi-lean solution 28 fed from the upper-portion regeneration tower 15-U, was provided in the second rich-solution supply pipe 20-2, to thereby increase the temperature of the rich solution to be supplied to the upper-portion regeneration tower 15-U.

[0075] The ratio of division of the rich solution 14 is such that the first rich solution was set to 70% and the second rich solution was set to 30%.

In example 7, as the result, the amount of steam consumed in the regeneration tower 15 became 93.58 MMkcal/h. Assuming the comparative example is 100, the amount of steam consumed in this example becomes 94.8%. Therefore, the reduction rate of specific steam consumption (improvement effect) was 5.2%.

Example 8

[0076] A CO_2 recovery system according to example 8 of the present invention is explained below with reference to the following drawing.

Fig. 17 is a schematic of the CO_2 recovery system according to example 8. Components the same as those of example 1 are assigned with the same reference numerals and explanation thereof is omitted.

In example 8, the regeneration tower 15 was divided

into two portions, and the semi-lean solution 28 extracted from the upper-portion regeneration tower 15-U was first heat-exchanged in the first lean-solution heat exchanger 23-1, and then, was heat-exchanged with the residual heat of the steam condensate 19 in the steam-condensate heat exchanger 21, and the semi-lean solution 28 heat-exchanged was returned to the lower-portion regeneration tower 15-L. This caused an increase in the temperature of the semi-lean solution to be supplied to the lower portion side of the regeneration tower 15.

In example 8, as the result, the amount of steam consumed in the regeneration tower 15 became 91.1 MMkcal/h. Assuming the comparative example is 100, the amount of steam consumed in this example becomes 92.3%. Therefore, the reduction rate of specific steam consumption (improvement effect) was 7.7%.

Example 9

[0077] A CO_2 recovery system according to example 9 of the present invention is explained below with reference to the following drawing.

Fig. 18 is a schematic of the CO_2 recovery system according to example 9. Components the same as those of example 1 are assigned with the same reference numerals and explanation thereof is omitted.

In example 9, the regeneration tower 15 was divided into four portions such as a first regeneration tower 15-1, a second regeneration tower 15-2, a third regeneration tower 15-3, and a fourth regeneration tower 15-4. The semi-lean solution 28 respectively extracted from the first regeneration tower 15-1 and the third regeneration tower 15-3 was heat-exchanged with the respective residual heat of the steam condensate in a first steam-condensate heat exchanger 21-1 and a second steam-condensate heat exchanger

21-2, respectively. Because the temperature in the lower portion side of the regeneration tower was high, the residual heat of the steam condensate 19 was effectively used.

[0078] Furthermore, the semi-lean solution extracted from the second regeneration tower 15-2 was heat-exchanged with the residual heat of the lean solution 16 in the first lean-solution heat exchanger 23-1. The semi-lean solution 28 extracted from the first regeneration tower 15-1, before being returned to the second regeneration tower 15-2 in the lower stage side, was heat-exchanged in the second lean-solution heat exchanger 23-2 in which the semi-lean solution 28 was heat-exchanged with the residual heat of the lean solution 16 that had been heat-exchanged in the first lean-solution heat exchanger 23-1. In example 9, after the heat exchange, the rich solution 14 fed from the absorption tower 13 was heat-exchanged in a third lean-solution heat exchanger 23-3.

In example 9, as the result, the amount of steam consumed in the regeneration tower 15 became 85.49 MMkcal/h. Assuming the comparative example is 100, the amount of steam consumed in this example becomes 86.6%. Therefore, the reduction rate of specific steam consumption (improvement effect) was 13.4%.

Example 10

[0079] A CO_2 recovery system according to example 10 of the present invention is explained below with reference to the following drawing.

Fig. 19 is a schematic of the CO_2 recovery system according to example 10. Components the same as those of example 1 are assigned with the same reference numerals and explanation thereof is omitted.

In example 10, the regeneration tower 15 was divided

into three portions such as the upper-portion regeneration tower 15-U, the middle-portion regeneration tower 15-M, and the lower-portion regeneration tower 15-L. The semi-lean solution 28 extracted from the middle-portion regeneration tower 15-M was heat-exchanged with the residual heat of the steam condensate in the steam-condensate heat exchanger 21. Part of the semi-lean solution 28 extracted was supplied to the semi-lean-solution heat exchanger 29 that heats the rich solution 14, where the residual heat of the semi-lean solution was effectively used.

Furthermore, the semi-lean solution 28 extracted from the upper-portion regeneration tower 15-U was heat-exchanged with the residual heat of the lean solution 16 in the first lean-solution heat exchanger 23-1.

The rich solution 14 heat-exchanged in the semi-lean-solution heat exchanger 29 was heat-exchanged in the second lean-solution heat exchanger 23-2 in which the rich solution 14 was heat-exchanged with the residual heat of the lean solution 16 that had been heat-exchanged in the first lean-solution heat exchanger 23-1.

In example 10, as the result, the amount of steam consumed in the regeneration tower 15 became 91.9 MMkcal/h. Assuming the comparative example is 100, the amount of steam consumed in this example becomes 93.0%. Therefore, the reduction rate of specific steam consumption (improvement effect) was 7%.

Example 11

[0080] A CO_2 recovery system according to example 11 of the present invention is explained below with reference to the following drawing.

Fig. 20 is a schematic of the CO_2 recovery system according to example 11. Components the same as those of example 1 are assigned with the same reference numerals and explanation thereof is omitted.

In example 11, the regeneration tower 15 was divided into two portions such as the upper-portion regeneration tower 15-U and the lower-portion regeneration tower 15-L. The semi-lean solution 28, extracted from the upper-portion regeneration tower 15-U, was used to heat the rich solution in the second rich-solution supply pipe 20-2, in the semi-lean-solution heat exchanger 29. Thereafter, the semi-lean solution 28 was divided, to be heat-exchanged with the residual heat of the steam condensate in the steam-condensate heat exchanger 21 before being supplied to the lower-portion regeneration tower 15-L.

The rich solution in the first rich-solution supply pipe 20-1 was heat-exchanged in the first lean-solution heat exchanger 23-1, was jointed with the other one to be heat-exchanged with the residual heat of the lean solution 16 in the second lean-solution heat exchanger 23-2, and was supplied to the regeneration tower 15.

In example 11, as the result, the amount of steam consumed in the regeneration tower 15 became 93.96 MMkcal/h. Assuming the comparative example is 100, the amount of steam consumed in this example becomes 95.1%. Therefore, the reduction rate of specific steam consumption (improvement effect) was 4.9%.

Example 12

[0081] A CO_2 recovery system according to example 12 of the present invention is explained below with reference to the following drawing.

Fig. 21 is a schematic of the CO_2 recovery system according to example 12. Components the same as those of example 1 are assigned with the same reference numerals and explanation thereof is omitted.

In example 12, the regeneration tower 15 was divided

into three portions such as the upper-portion regeneration tower 15-U, the middle-portion regeneration tower 15-M, and the lower-portion regeneration tower 15-L. The semi-lean solution 28 extracted from the middle-portion regeneration tower 15-M was heat-exchanged with the residual heat of the steam condensate in the steam-condensate heat exchanger 21.

Furthermore, the rich solution 14 was divided, and the lean-solution heat exchanger 23 was provided in the first rich-solution supply pipe 20-1. The semi-lean-solution heat exchanger 29 was provided in the second rich-solution supply pipe 20-2 where heat exchange was performed using the semi-lean solution 28 extracted from the upper-portion regeneration tower 15-U, so that the residual heat of the semi-lean solution was effectively used.

In example 12, as the result, the amount of steam consumed in the regeneration tower 15 became 91.14 MMkcal/h. Assuming the comparative example is 100, the amount of steam consumed in this example becomes 92.3%. Therefore, the reduction rate of specific steam consumption (improvement effect) was 7.7%.

INDUSTRIAL APPLICABILITY

[0082] The CO_2 recovery system according to the present invention is suitable for reduction in the supply amount of heated steam used in the regeneration tower by effectively using the residual heat of the steam condensate and the residual heat of the semi-lean solution.

CLAIMS:

1. A CO_2 recovery system which comprises:

an absorption tower that receives a CO_2-containing gas and a CO_2-absorbing solution, and causes the CO_2-containing gas to come in contact with the CO_2-absorbing solution to produce a CO_2 rich solution;

a regeneration tower that receives the rich solution and produces a lean solution from the rich solution by removing CO_2 from the rich solution;

a bottom lean-solution extraction path that extracts the lean solution that accumulates near a bottom portion of the regeneration tower from a first point of the regeneration tower and returns the extracted lean solution to a second point of the regeneration tower that is downstream of the first point;

a regeneration heater arranged in the bottom lean-solution extraction path that heats the lean solution in the bottom lean-solution extraction path with saturated steam thereby producing a steam condensate from the saturated steam; and

a steam-condensate heat exchanger that heats, with the steam condensate, the rich solution that is supplied from the absorption tower to the regeneration tower.

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

a rich-solution supply member that conveys the rich solution from the absorption tower to the regeneration tower, wherein the steam-condensate heat exchanger is provided in the rich-solution supply member and heats the rich solution in the rich-solution supply member with the steam condensate; and

a flash drum provided upstream or downstream of the steam-condensate heat exchanger in the rich-solution supply member.

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

a branching node provided in the rich-solution supply member that divides the rich-solution supply member into a first rich-solution supply member and a second rich-solution supply member,

wherein the steam-condensate heat exchanger is provided in the first rich-solution supply member and heats the rich solution in the first rich-solution supply member with the steam condensate, and the flash drum is provided downstream of the steam-condensate heat exchanger in the first rich-solution supply member, and produces a semi-lean solution; and

a semi-lean-solution heat exchanger that is provided in the second rich-solution supply member, and heats the rich solution in the second rich-solution supply member with the semi-lean solution produced in the flash drum.

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

a rich-solution supply member that conveys the rich solution from the absorption tower to the regeneration tower;

a branching node provided in the rich-solution supply member that divides the rich-solution supply member into a first rich-solution supply member and a second rich-solution supply member, wherein the steam-condensate heat exchanger is provided in the first rich-solution supply member and flashes the rich solution in the first rich-solution supply member to produce a semi-lean solution;

a semi-lean-solution heat exchanger that is provided in the second rich-solution supply member, and heats the rich solution in the second rich-solution supply member with the semi-lean solution produced in the steam-condensate heat exchanger; and

a semi-lean-solution supply member that conveys the semi-lean solution from the semi-lean-solution heat exchanger to a middle stage portion of the absorption tower.

5. The CO_2 recovery system according to claim 4, wherein the steam-condensate heat exchanger comprises:

a flash drum including a flash portion in an upper portion for flashing the rich solution;

a filling layer in the flash drum; and

a steam supply unit provided in a lower portion of the flash drum and to which steam obtained from the steam condensate is supplied.

6. The CO_2 recovery system according to claim 1, wherein the regeneration tower comprises an upper-portion regeneration tower and a lower-portion regeneration tower, and the CO_2 recovery system further comprises:

a rich-solution supply member that conveys the rich solution from the absorption tower to the regeneration tower;

a branching node provided in the rich-solution supply member that divides the rich-solution supply member into a first rich-solution supply member and a second rich-solution supply member, wherein the steam-condensate heat exchanger is provided in the first rich-solution supply member and heats the rich solution in the first rich-solution supply member with the steam condensate;

a semi-lean-solution supply member that extracts a semi-lean solution from the upper-portion regeneration tower and conveys the extracted semi-lean solution to a middle stage portion of the absorption tower;

a semi-lean-solution heat exchanger that is provided in the second rich-solution supply member and the semi-lean-solution supply member, and heats the rich solution in the second rich-solution supply member with the semi-lean solution in the semi-lean-solution supply member,

wherein one end of the first rich-solution supply member is connected to the lower-portion regeneration tower, and one end of the second rich-solution supply member is connected to the upper-portion regeneration tower.

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

a rich-solution supply member that conveys the rich solution from the absorption tower to the regeneration tower;

a lean-solution supply member that extracts the lean solution from the regeneration tower and conveys the extracted lean solution to the absorption tower; and

a lean-solution heat exchanger that is provided in the rich-solution supply member and the lean-solution supply member, and heats the rich solution in the rich-solution supply member with the lean solution in the lean-solution supply member.

8. The CO_2 recovery system according to claim 1, wherein the regeneration tower comprises an upper-portion regeneration tower and a lower-portion regeneration tower, the CO_2 recovery system further comprises:

an upper semi-lean-solution extraction path that extracts a semi-lean solution from an eleventh point of the upper-portion regeneration tower and returns the extracted semi-lean solution to a twelfth point of the upper-portion regeneration tower that is downstream of the eleventh point;

a lean-solution supply member that extracts the lean solution from the regeneration tower and conveys the extracted lean solution to the absorption tower;

a lean-solution heat exchanger that is arranged in the upper semi-lean-solution extraction path and the lean-solution supply member and heats the semi-lean solution in the upper semi-lean-solution extraction path with the lean solution in the lean-solution supply member.

9. The CO_2 recovery system according to claim 4, wherein:

the absorption tower is divided into an upper stage and a lower stage, and the semi-lean solution to be supplied to a portion between the upper stage and the lower stage of the absorption tower is joined with a semi-lean solution extracted from the upper-stage absorption tower, to be supplied to the lower-stage absorption tower.

10. A CO_2 recovery system which comprises:

an absorption tower that receives a CO_2-containing gas and a CO_2-absorbing solution, and causes the CO_2-containing gas to come in contact with the CO_2-absorbing solution to produce a CO_2 rich solution;

a regeneration tower that receives the rich solution and produces a lean solution from the rich solution by removing CO_2 from the rich solution;

a bottom lean-solution extraction path that extracts the lean solution that accumulates near a bottom portion of the regeneration tower and returns the extracted lean solution to the regeneration tower;

a regeneration heater arranged in the bottom lean-solution extraction path and heats the lean solution in the bottom lean-solution extraction path with a saturated steam thereby producing a steam condensate from the saturated steam;

a rich-solution supply member that conveys the rich solution from the absorption tower to the regeneration tower; and

a steam-condensate heat exchanger that is provided in the rich-solution supply member and heats the rich solution in the rich-solution supply member with the steam condensate.

11. A CO_2 recovery method which comprises:

causing a CO_2-containing gas to come in contact with a CO_2-absorbing solution to produce a CO_2 rich solution in an absorption tower;

conveying the rich solution to a regeneration tower, and producing a lean solution from the rich solution by removing CO_2 from the rich solution in the regeneration tower;

extracting the lean solution that accumulates near a bottom portion of the regeneration tower;

heating the extracted lean solution with a saturated steam to produce a steam condensate from the saturated steam, and returning the extracted lean solution after heating the saturated steam to the regeneration tower; and

heating the rich solution that is conveyed from the absorption tower to the regeneration tower with the steam condensate.

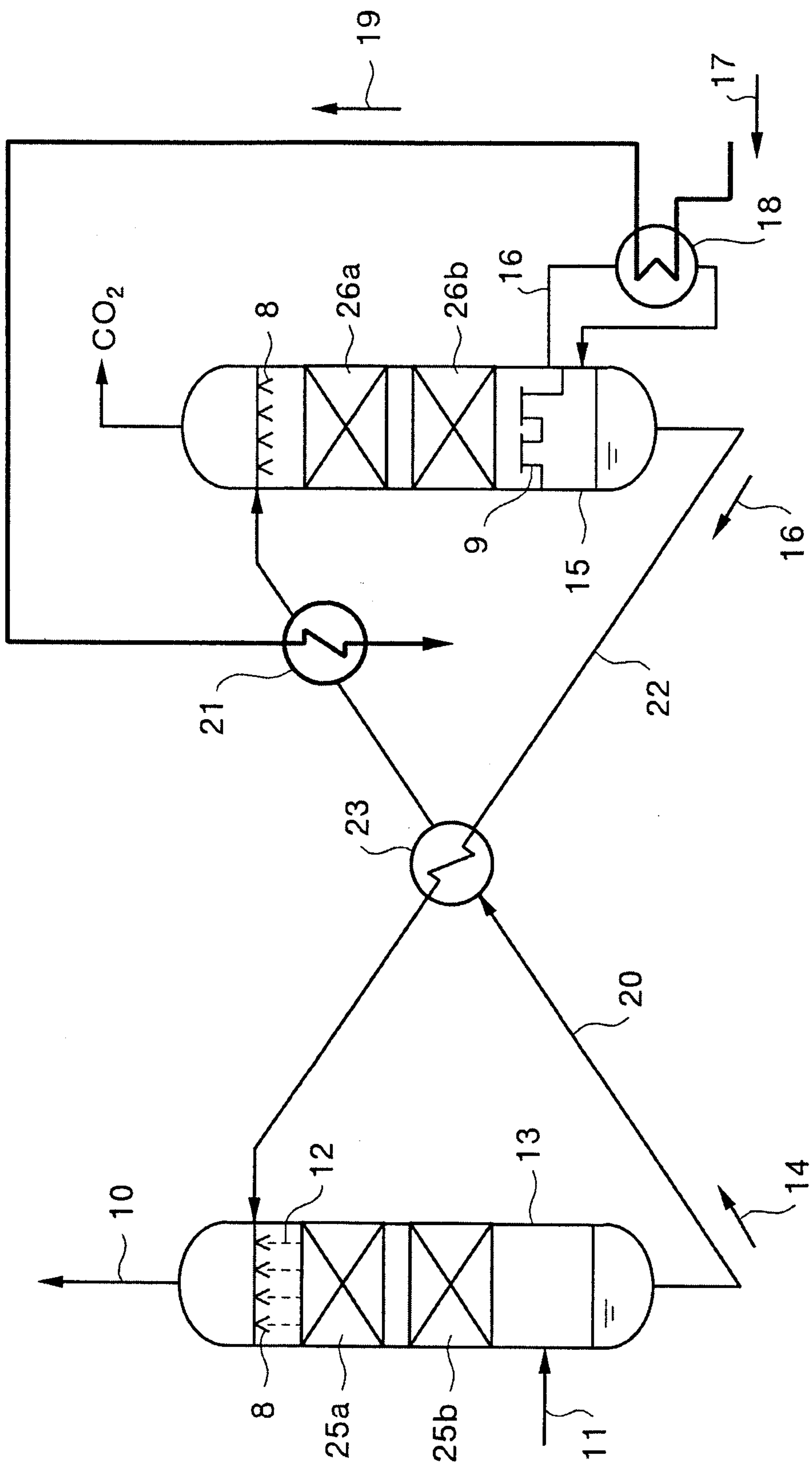
12. The CO_2 recovery system according to any one of claims 1 to 6 or claim 8 or 9, which further comprises:

a lean-solution supply member that extracts the lean solution from the regeneration tower and conveys the extracted lean solution to the absorption tower.

FETHERSTONHAUGH & CO.
OTTAWA, CANADA

PATENT AGENTS

FIG.1



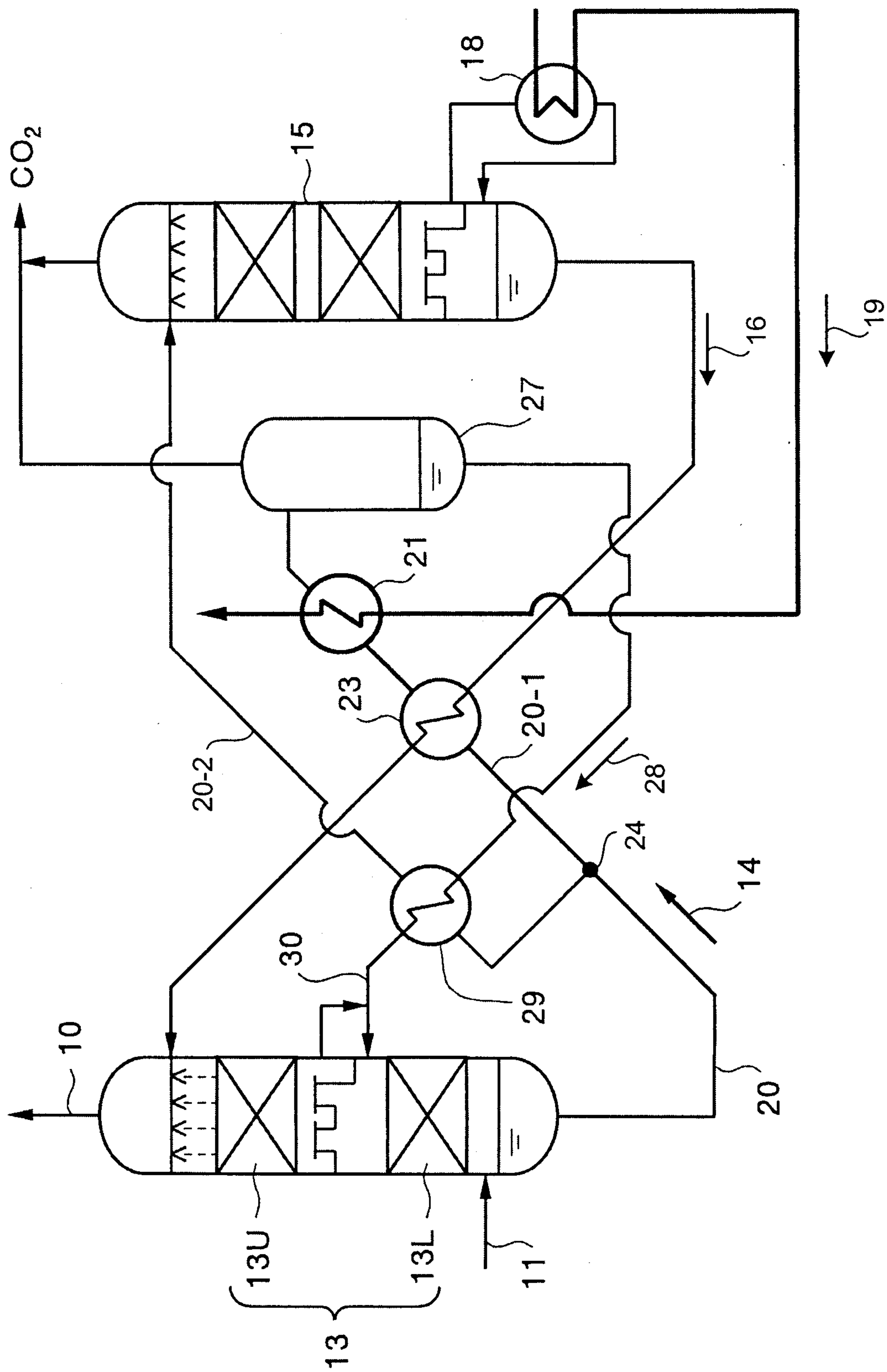


FIG.2

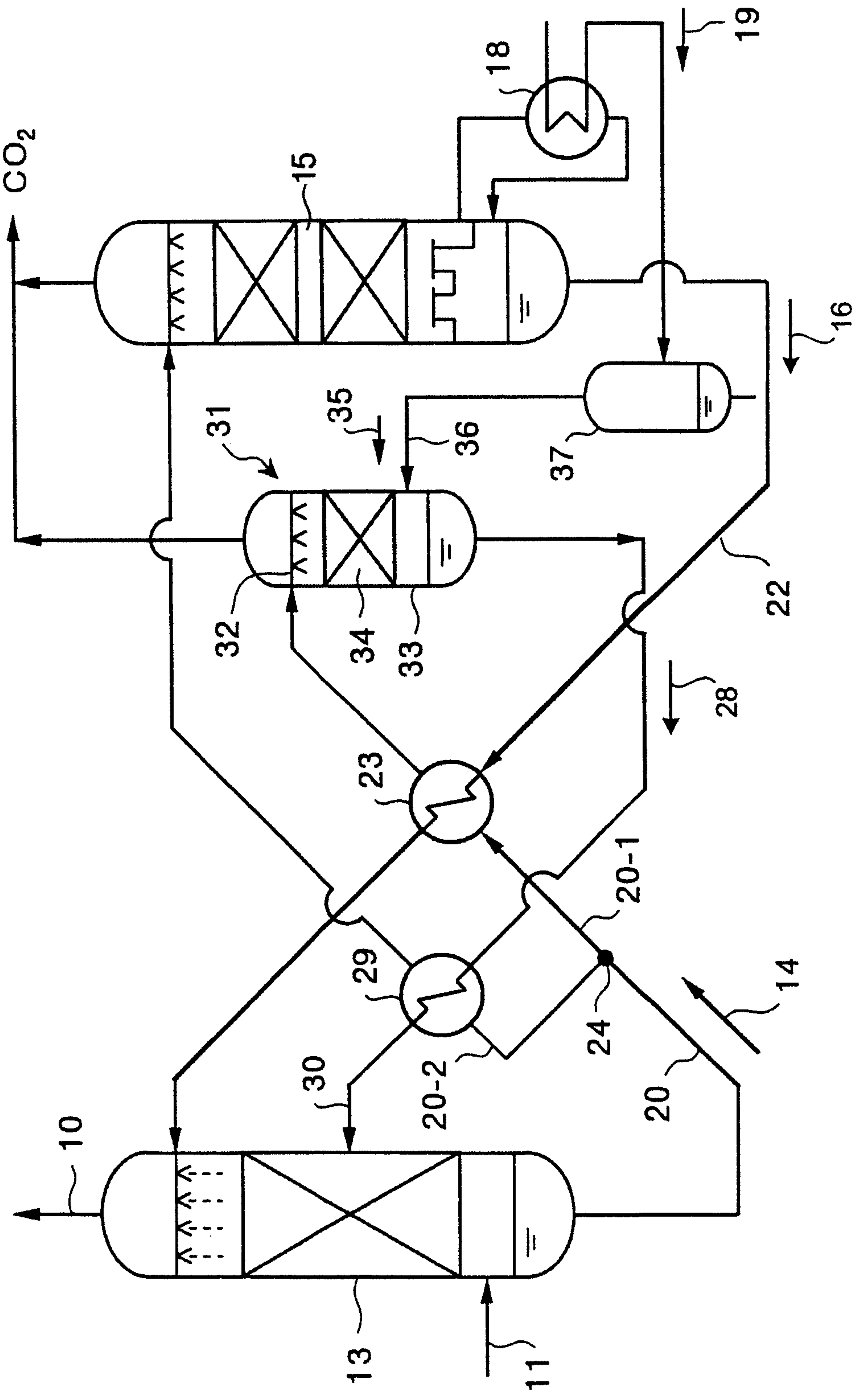
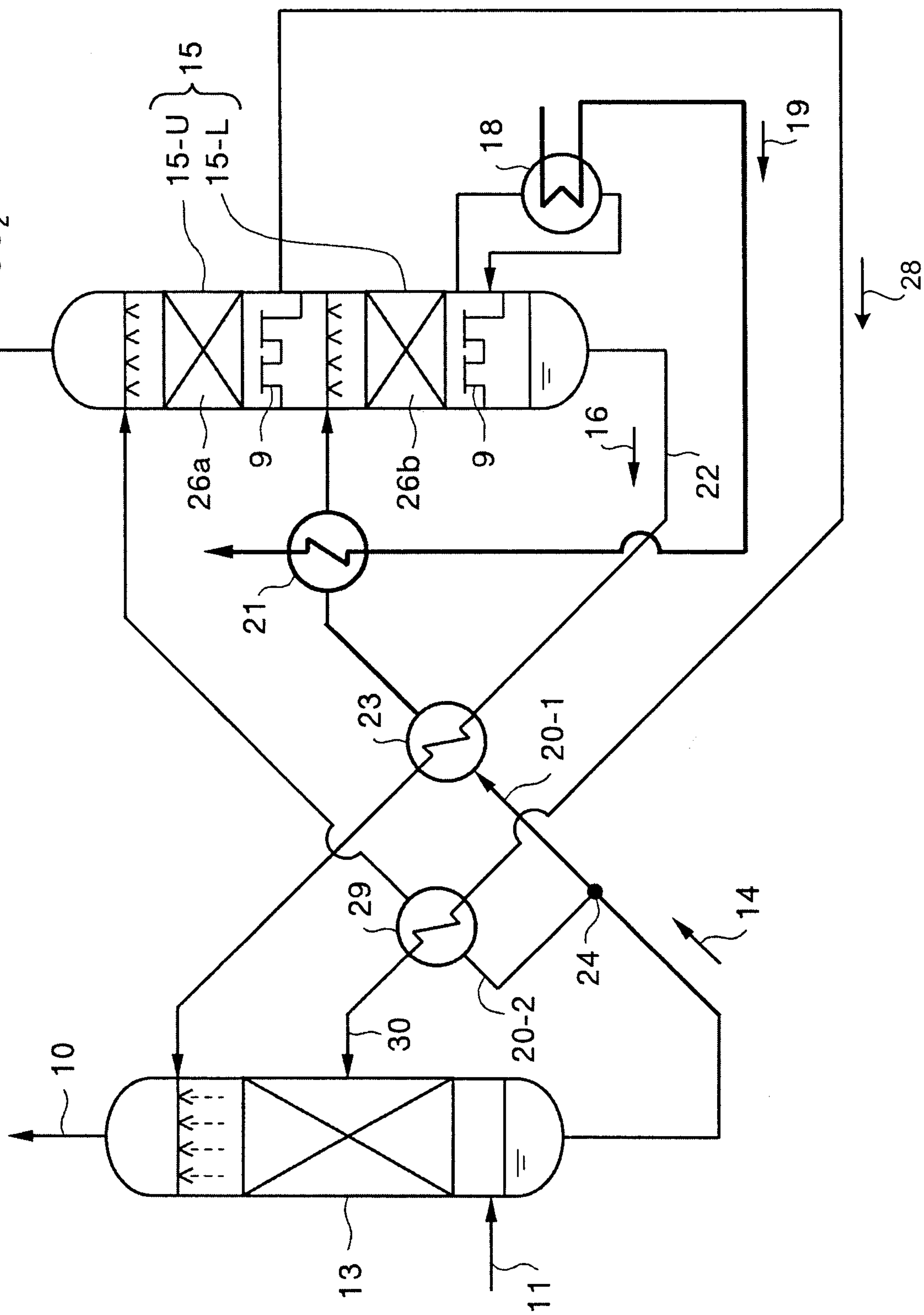

CO2
15
18
19
16
31
35
36
37
32
34
33
22
28
23
29
20-1
24
14
30
20-2
20
10
13
11

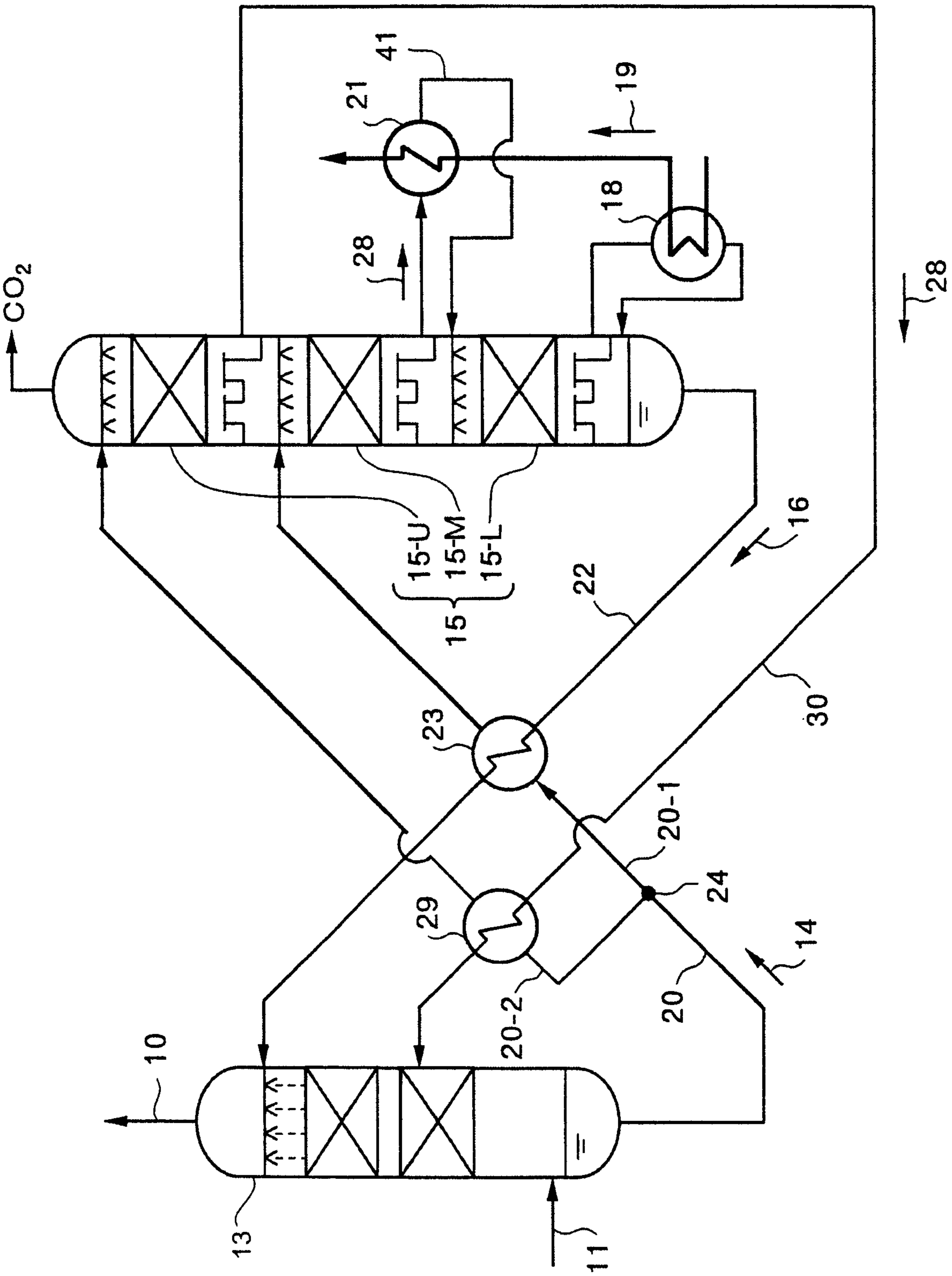
FIG.3

FIG.4



CO_2
15-U
15-L
15
18
19
28
26a
9
26b
9
16
22
21
23
20-1
29
14
24
20-2
30
10
13
11

FIG.5



CO_2
41
21
19
18
28
28
15-U
15-M
15-L
15
16
22
23
30
20-1
24
29
14
20
20-2
10
13
11

FIG.6

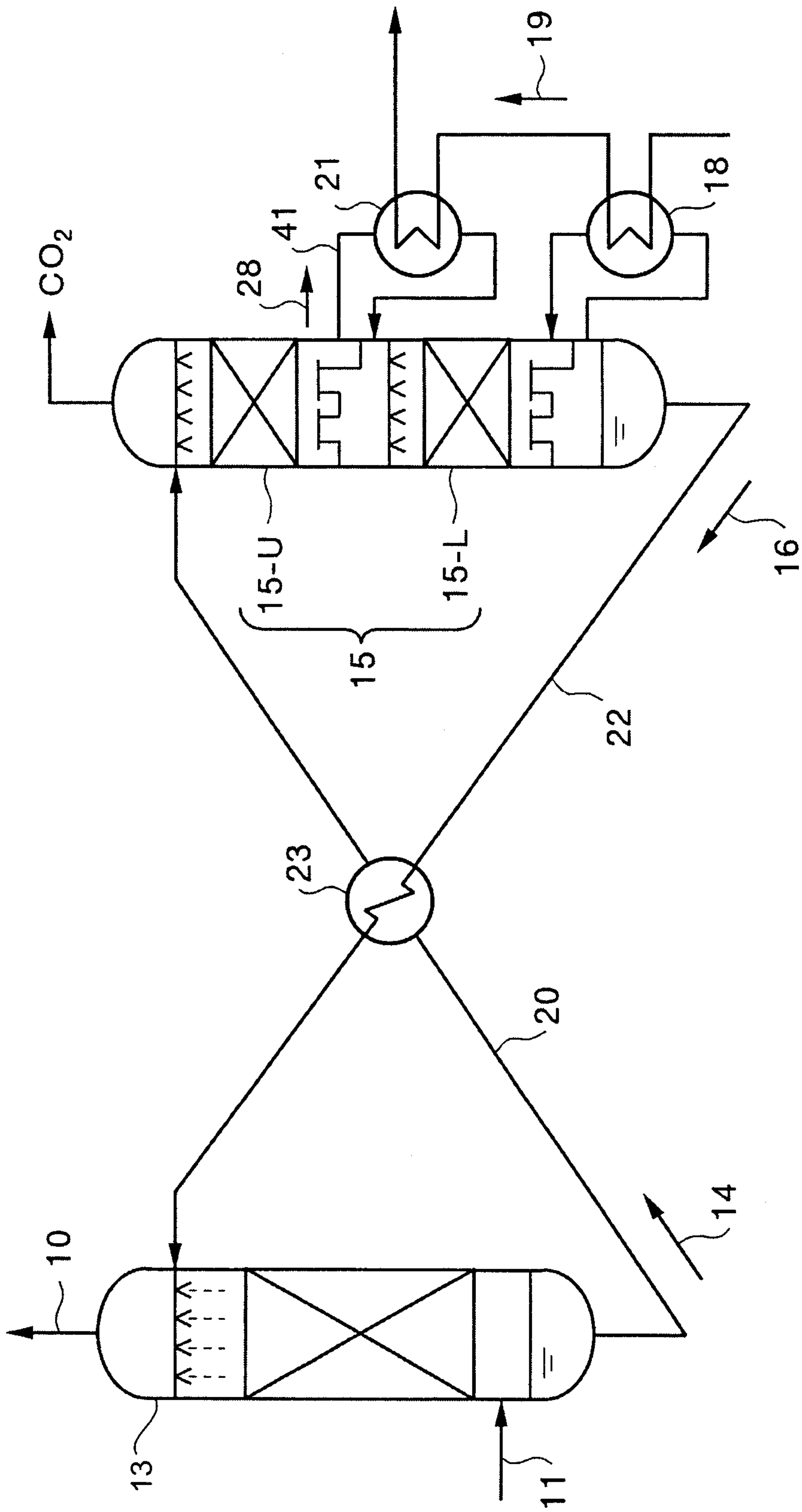
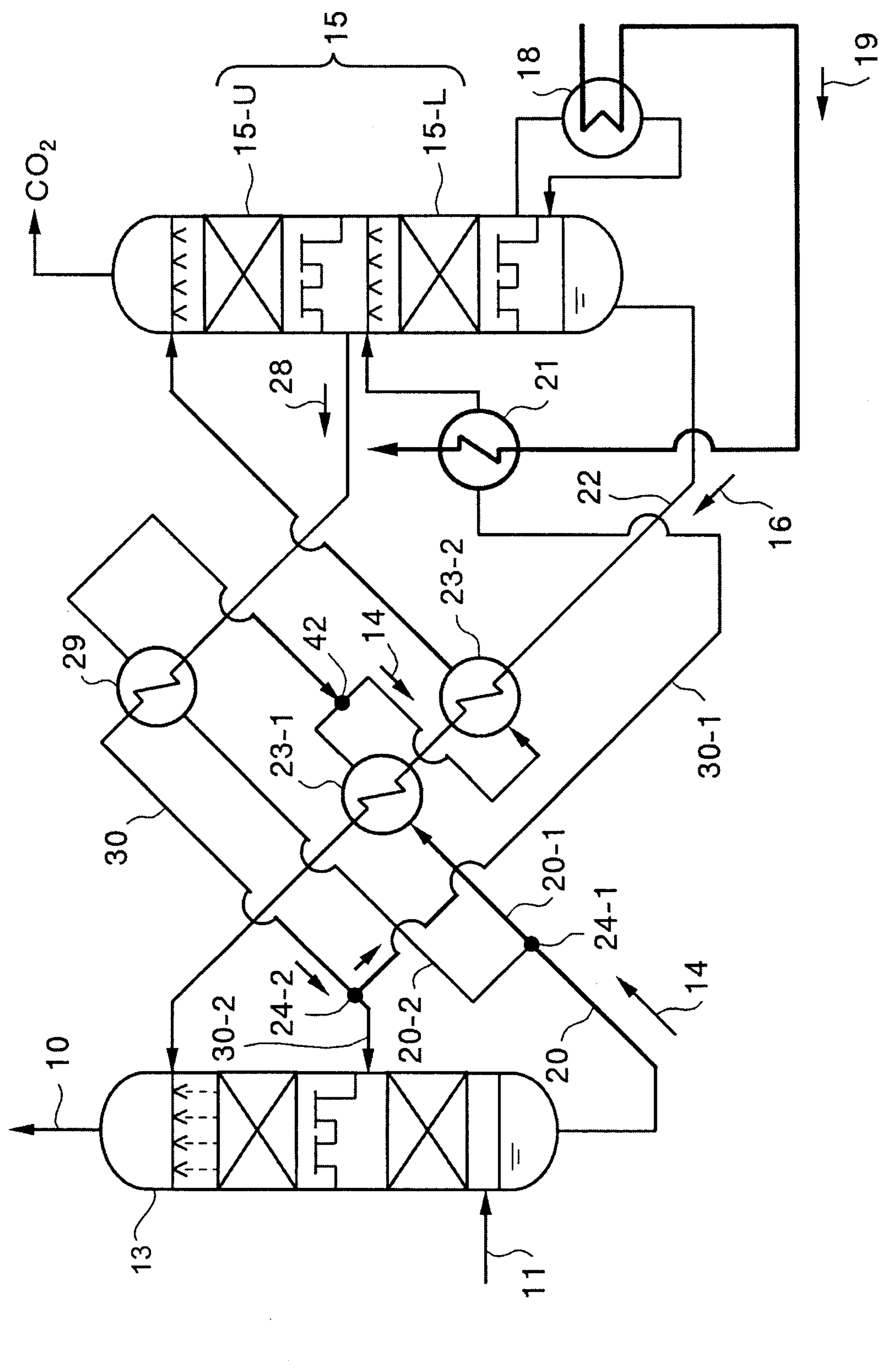


FIG.7



CO_2
15
15-U
15-L
18
19
28
21
22
16
29
42
14
23-2
23-1
30
30-1
20-1
24-1
14
20
24-2
30-2
20-2
10
13
11

FIG.8

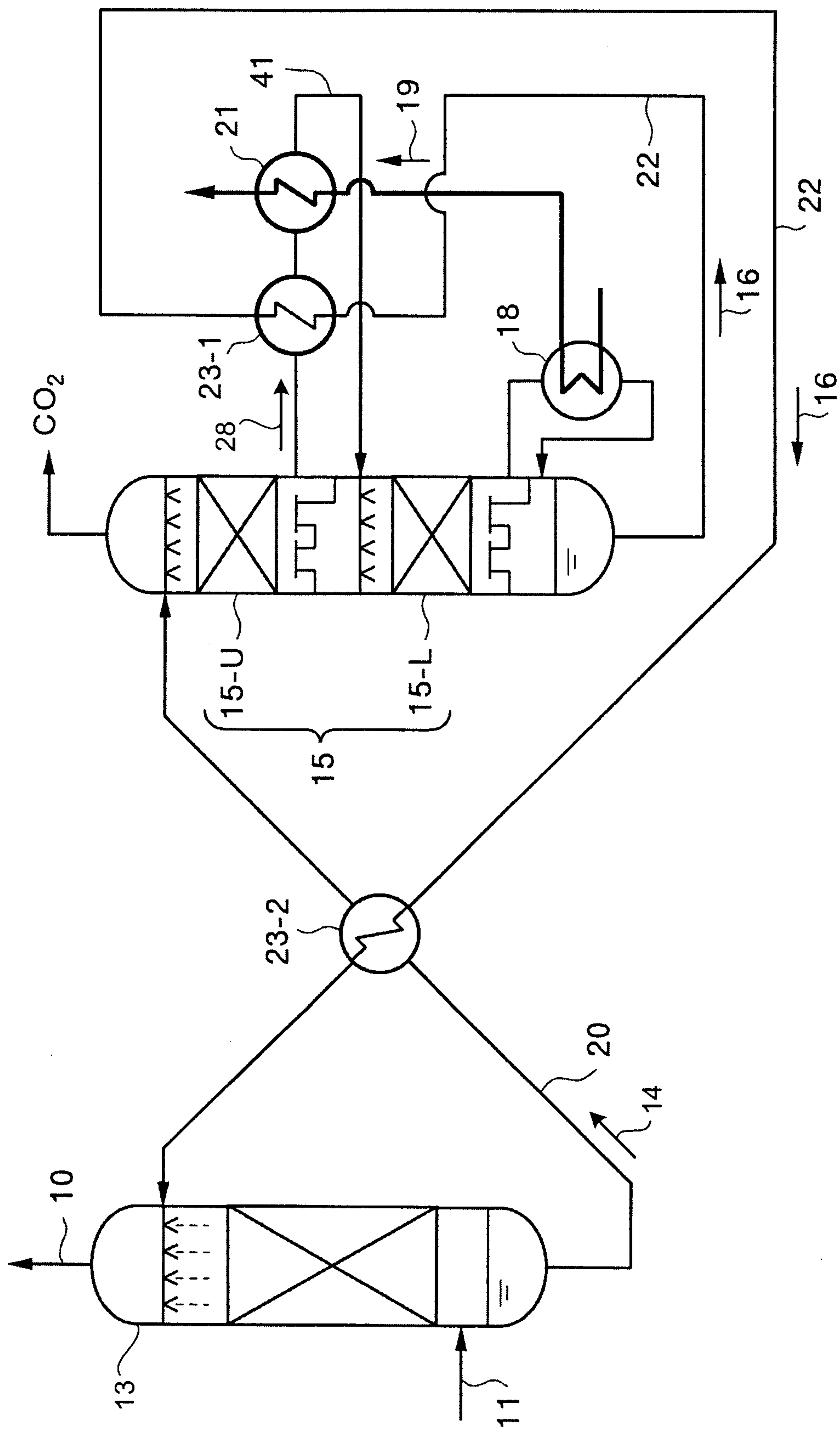


FIG.9

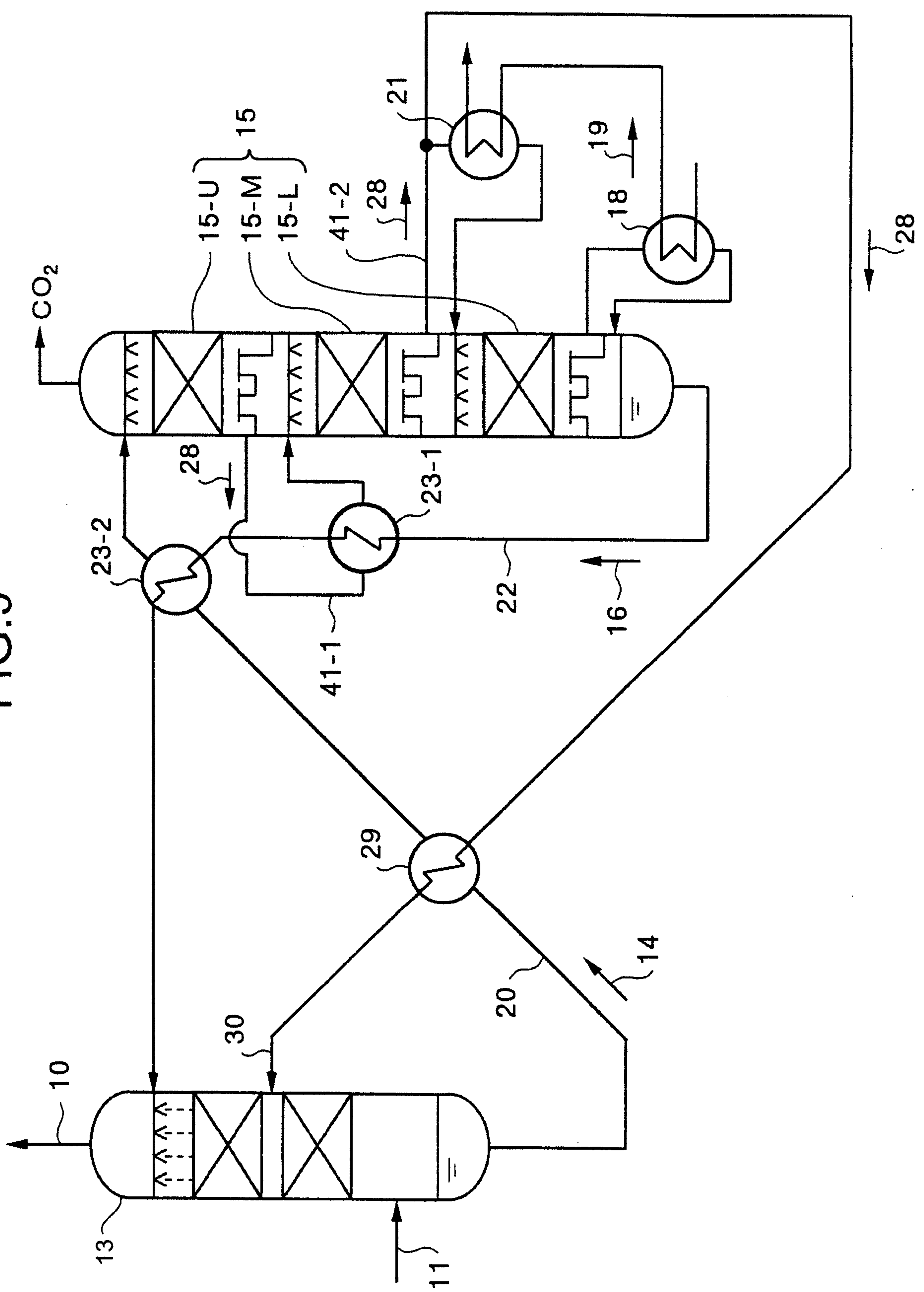

CO2
15-U
15-M
15-L
15
41-2
28
21
19
18
28
23-2
28
23-1
22
41-1
16
29
30
20
14
10
13
11

FIG.10

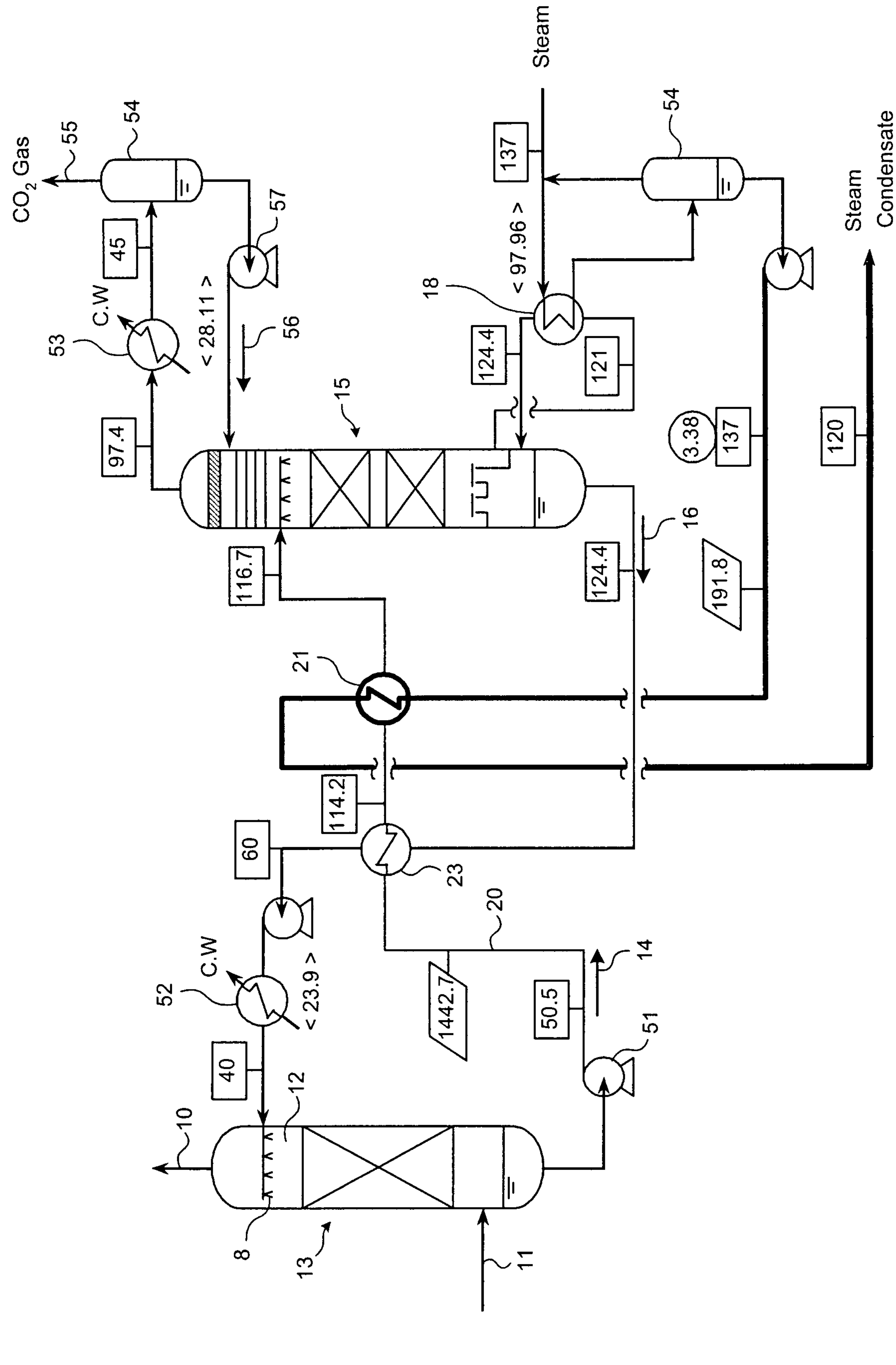

CO2 Gas
55
54
45
57
53
C.W
< 28.11 >
56
97.4
15
116.7
Steam
137
< 97.96 >
18
124.4
121
54
16
124.4
3.38
137
191.8
Steam
Condensate
120
21
114.2
60
23
20
14
50.5
51
1442.7
52
C.W
< 23.9 >
40
12
10
8
13
11

FIG.11

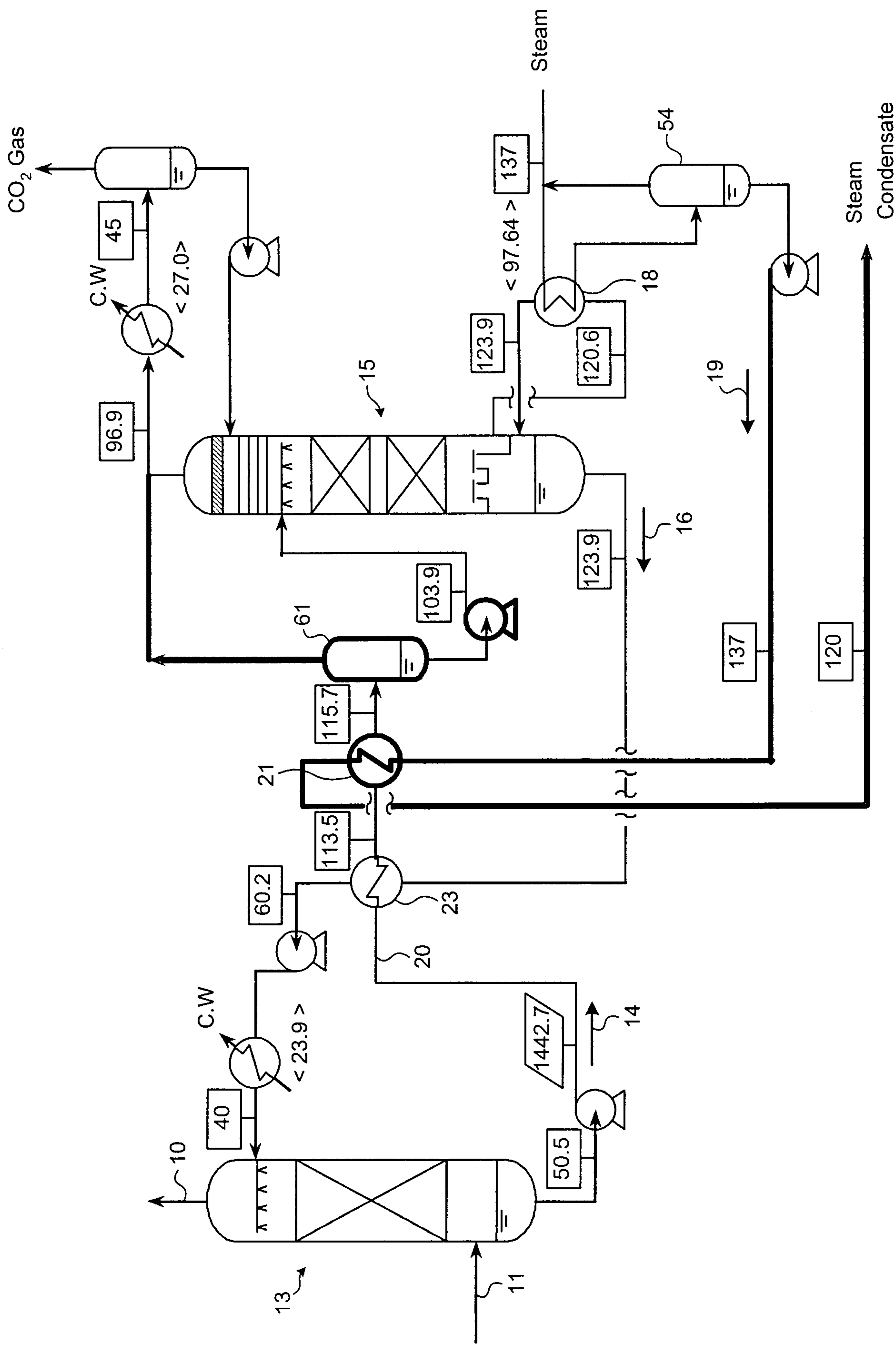

CO2 Gas
C.W
< 27.0>
45
96.9
15
Steam
137
54
< 97.64 >
18
123.9
120.6
19
Steam Condensate
16
123.9
103.9
61
137
120
115.7
21
113.5
60.2
23
20
C.W
< 23.9 >
40
1442.7
14
10
50.5
13
11

FIG.12

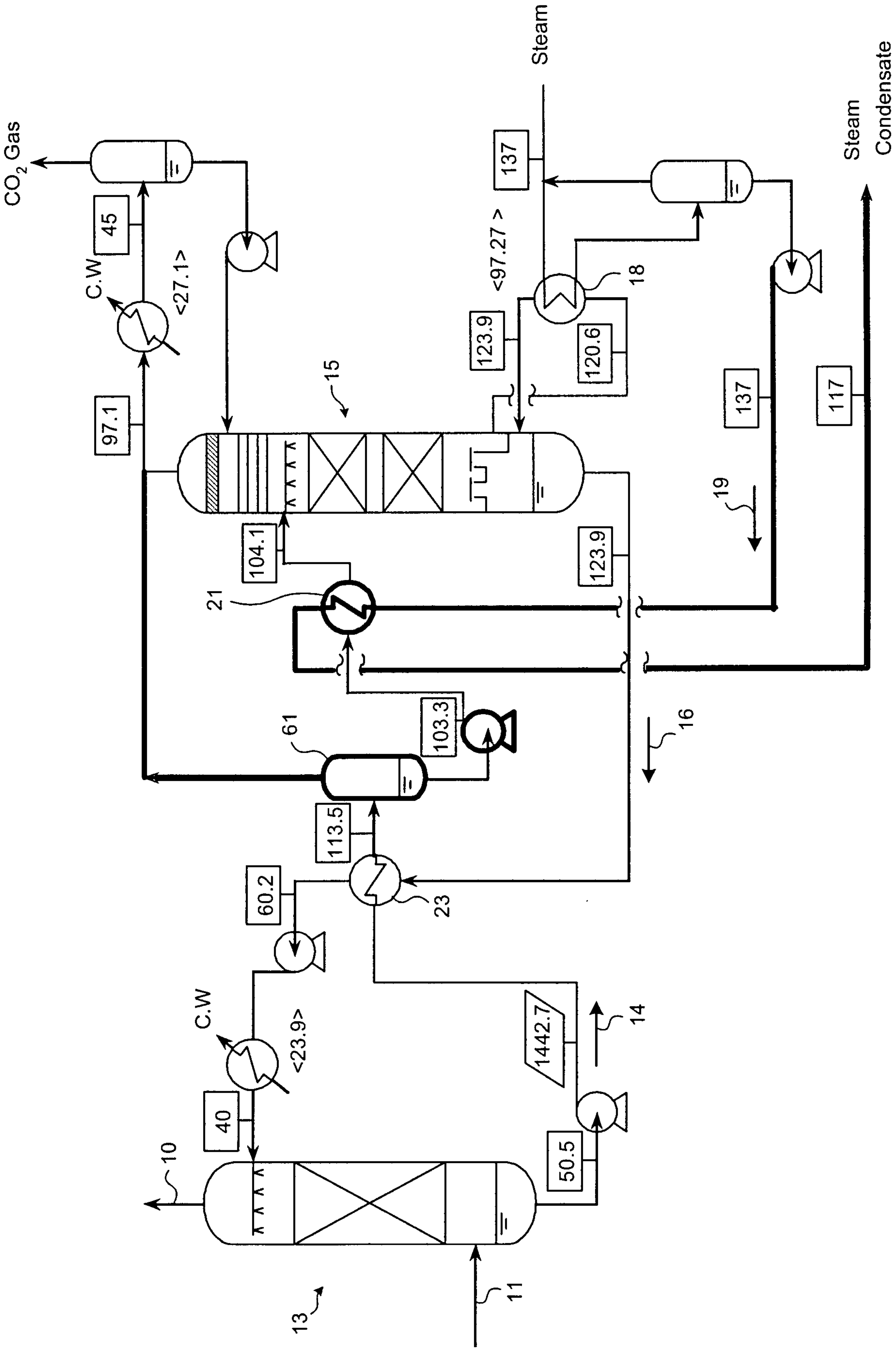

CO$_2$ Gas
C.W
45
<27.1>
97.1
15
Steam
137
<97.27 >
18
123.9
120.6
Steam Condensate
137
117
19
104.1
21
123.9
61
103.3
16
113.5
60.2
23
C.W
<23.9>
40
10
1442.7
14
50.5
13
11

FIG.13

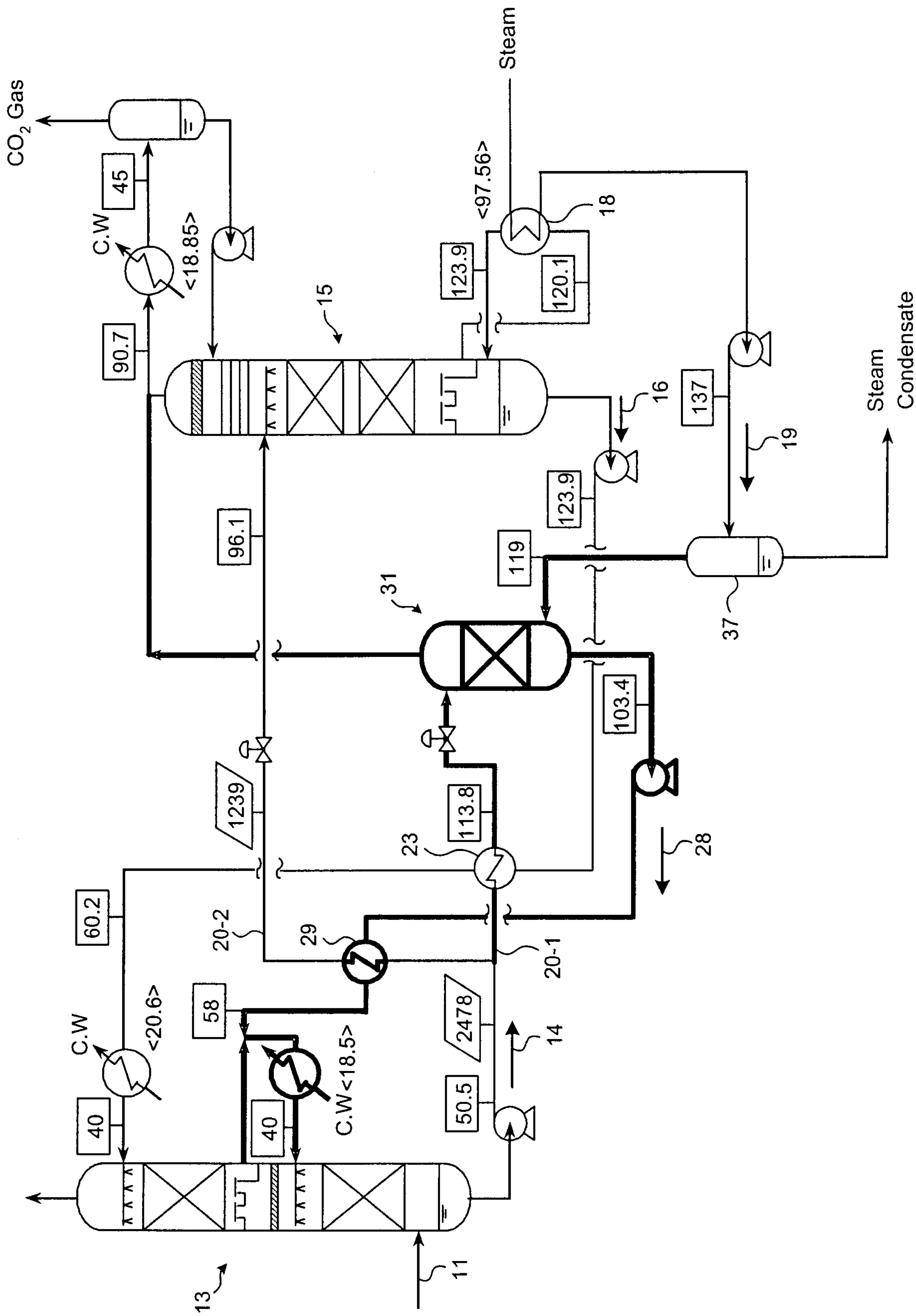
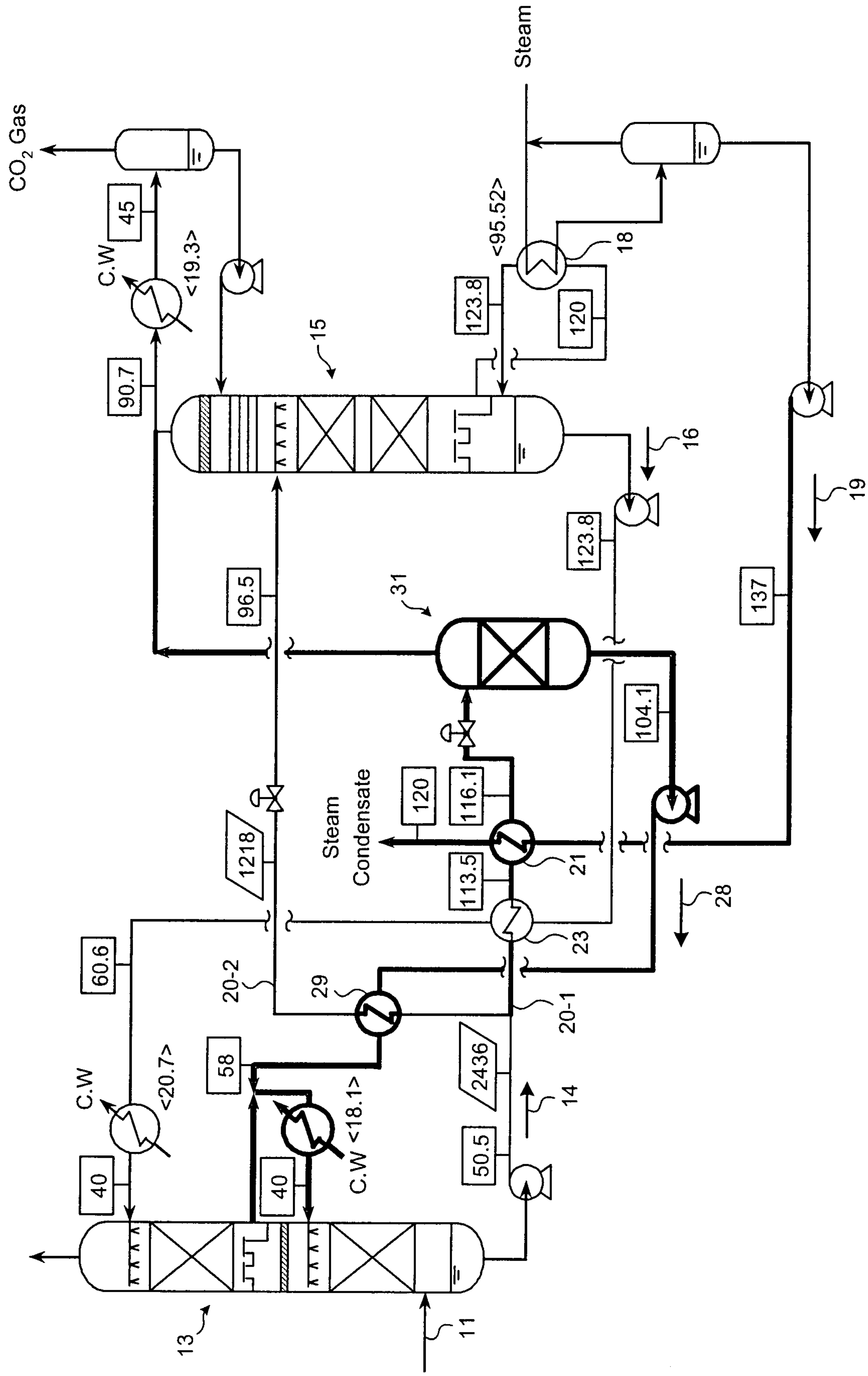

CO$_2$ Gas
Steam
C.W
<18.85>
45
90.7
15
<97.56>
123.9
18
120.1
Steam Condensate
137
19
16
123.9
119
37
31
96.1
1239
103.4
113.8
23
28
60.2
C.W
<20.6>
20-2
29
20-1
58
2478
14
C.W<18.5>
40
40
50.5
13
11

FIG.14



CO2 Gas
Steam
45
C.W
<19.3>
90.7
15
123.8
<95.52>
18
120
16
123.8
19
137
96.5
31
104.1
1218
Steam
Condensate
120
116.1
113.5
21
28
60.6
23
20-2
29
20-1
58
2436
14
C.W
<20.7>
40
C.W <18.1>
40
50.5
13
11

FIG.15

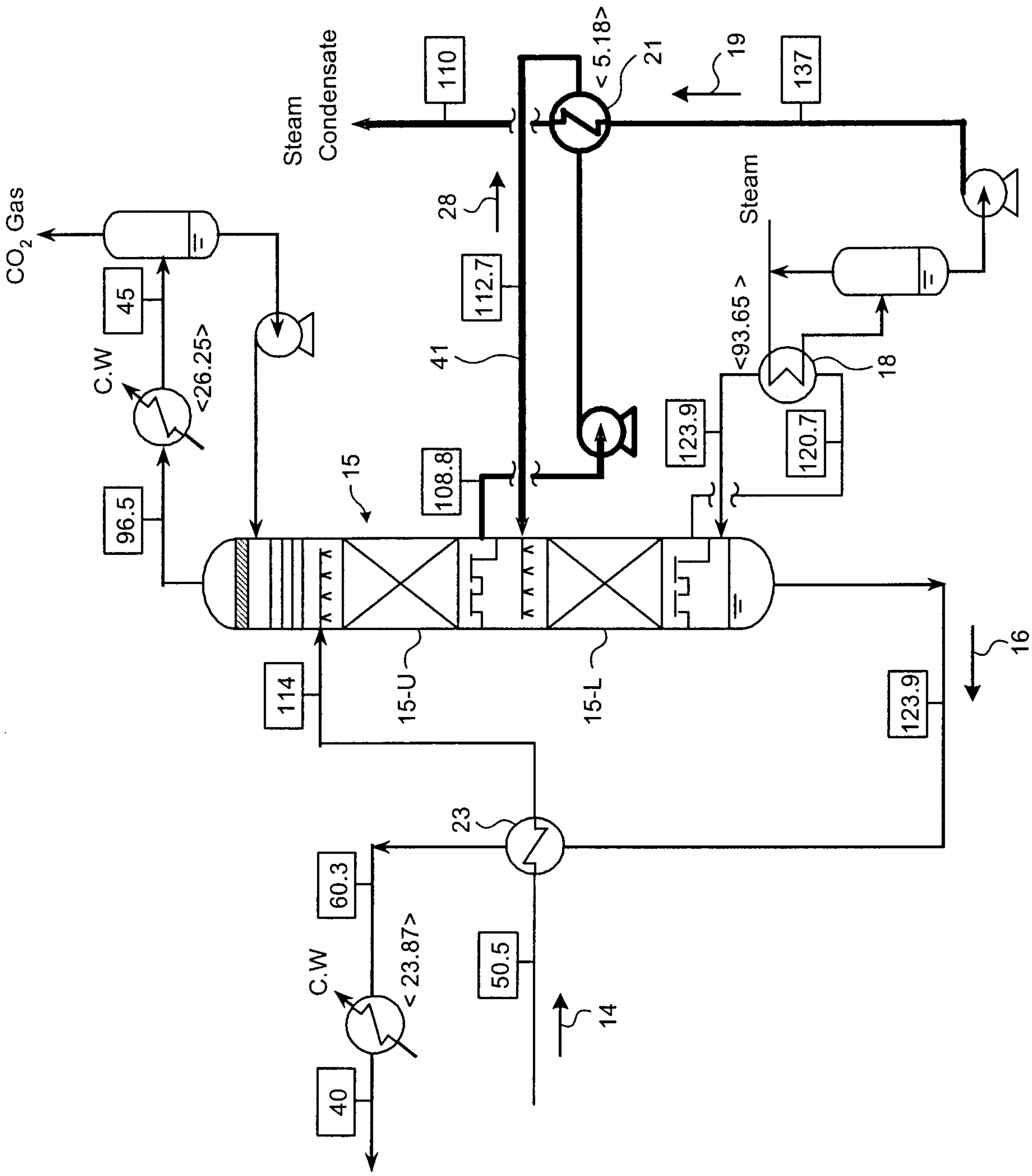
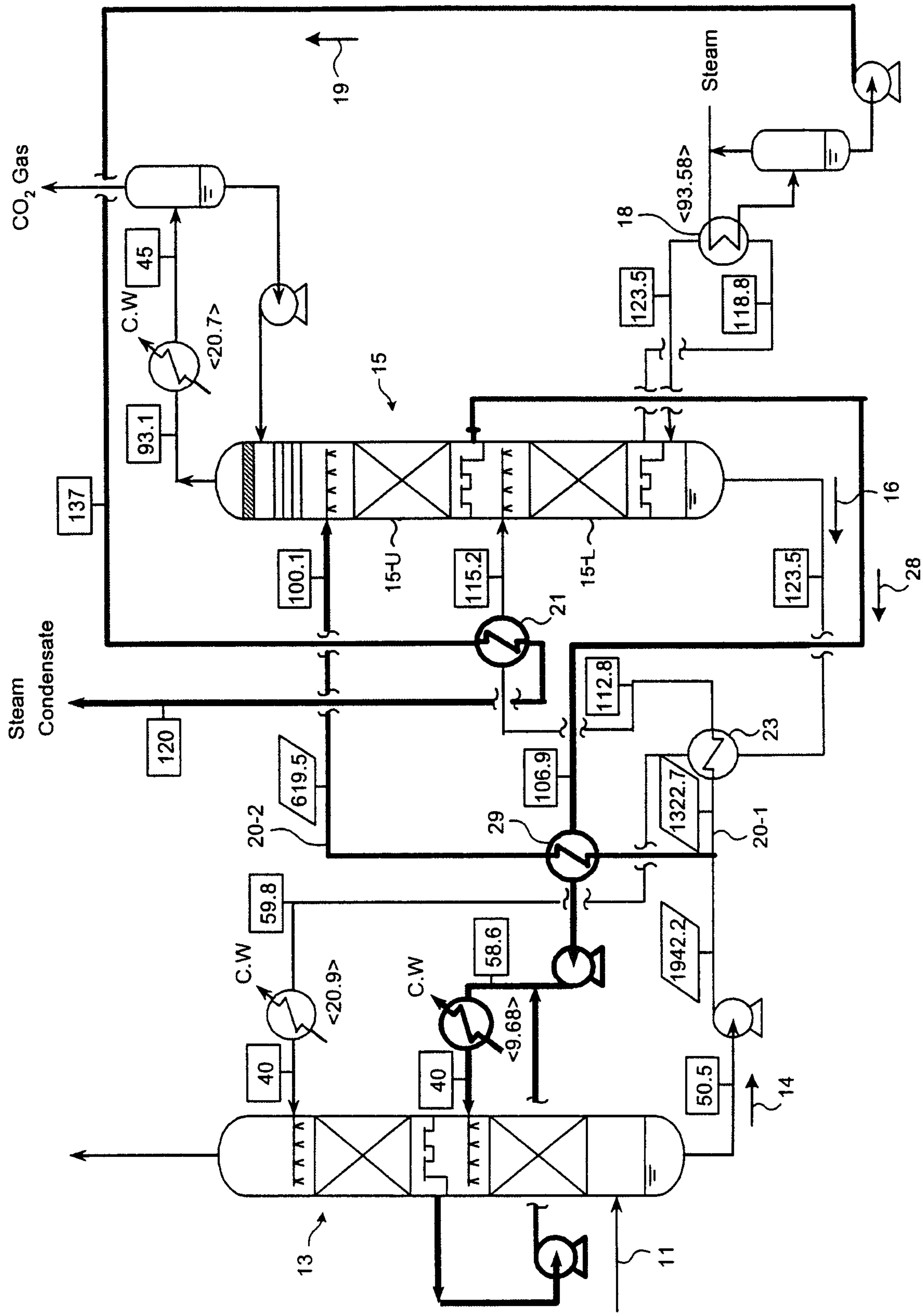

CO2 Gas
45
C.W
<26.25>
96.5
15
108.8
114
15-U
15-L
Steam
Condensate
110
28
112.7
41
< 5.18>
21
19
137
Steam
<93.65 >
18
123.9
120.7
16
123.9
23
60.3
C.W
< 23.87>
50.5
14
40

FIG.16



CO2 Gas
45
C.W
<20.7>
93.1
137
15
19
Steam
<93.58>
18
123.5
118.8
100.1
15-U
115.2
15-L
123.5
16
28
21
Steam
Condensate
120
619.5
20-2
112.8
106.9
29
1322.7
23
20-1
59.8
C.W
<20.9>
58.6
C.W
<9.68>
1942.2
40
40
50.5
14
13
11

FIG.17

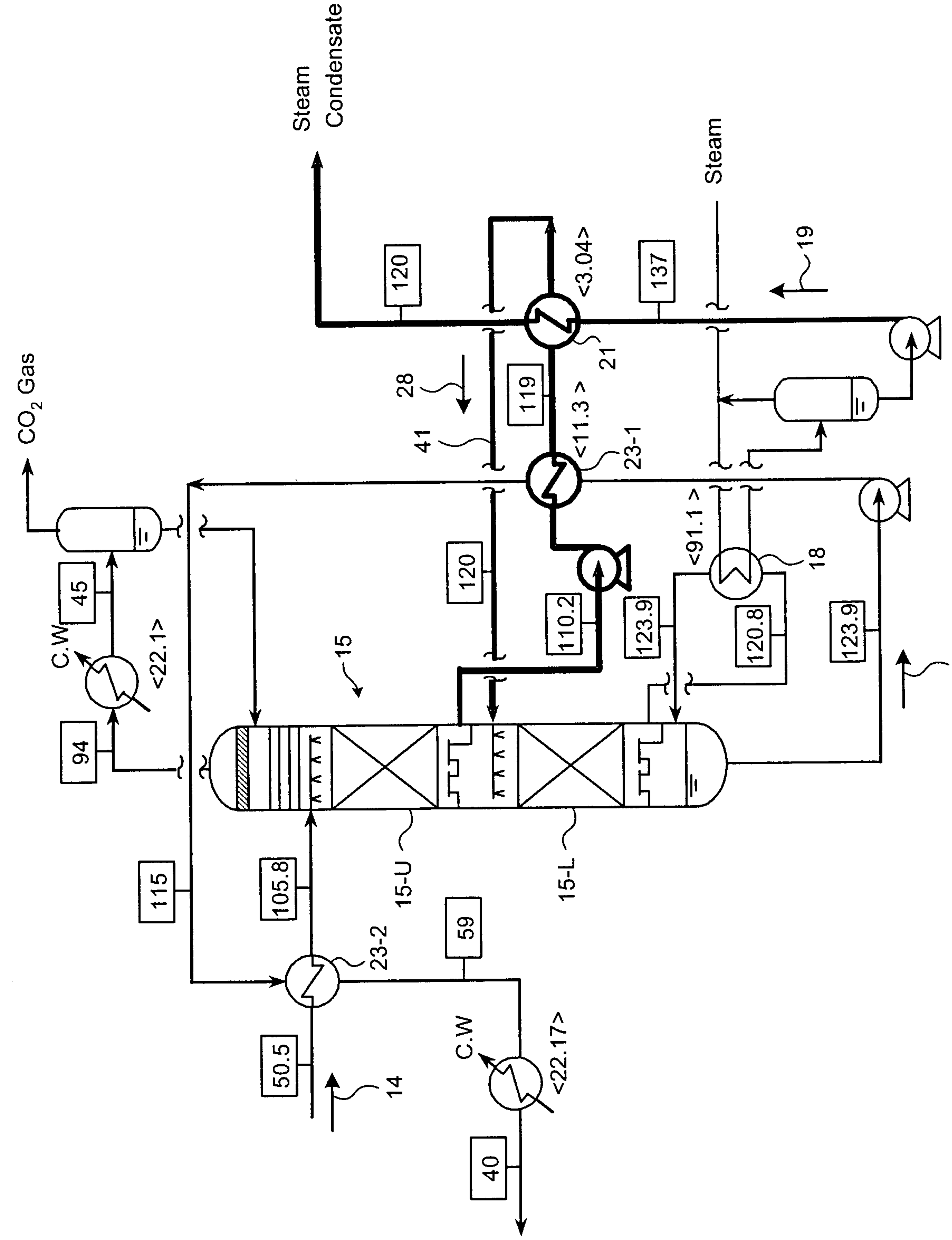

Steam
Condensate
Steam
120
137
<3.04>
19
28
41
119
<11.3 >
21
23-1
CO_2 Gas
45
C.W
<22.1>
94
15
120
110.2
123.9
<91.1 >
18
120.8
123.9
16
115
105.8
15-U
15-L
59
23-2
50.5
14
C.W
<22.17>
40

FIG.18

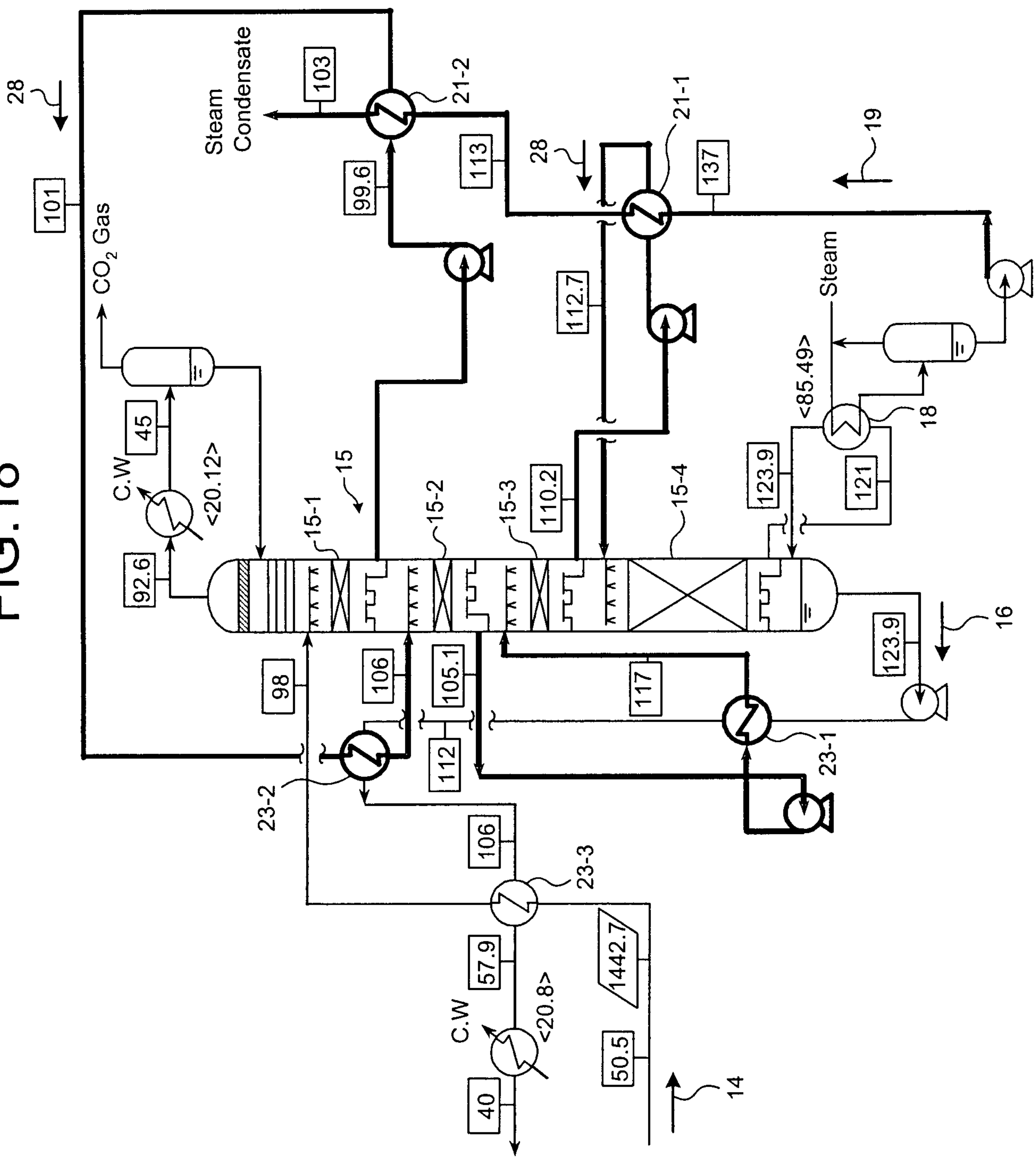

28
101
CO2 Gas
Steam
Condensate
103
21-2
99.6
113
28
21-1
137
19
112.7
Steam
<85.49>
18
C.W
45
<20.12>
92.6
15-1
15
15-2
15-3
110.2
15-4
123.9
121
16
123.9
98
106
105.1
112
117
23-1
23-2
106
23-3
57.9
1442.7
C.W
<20.8>
40
50.5
14

FIG.19

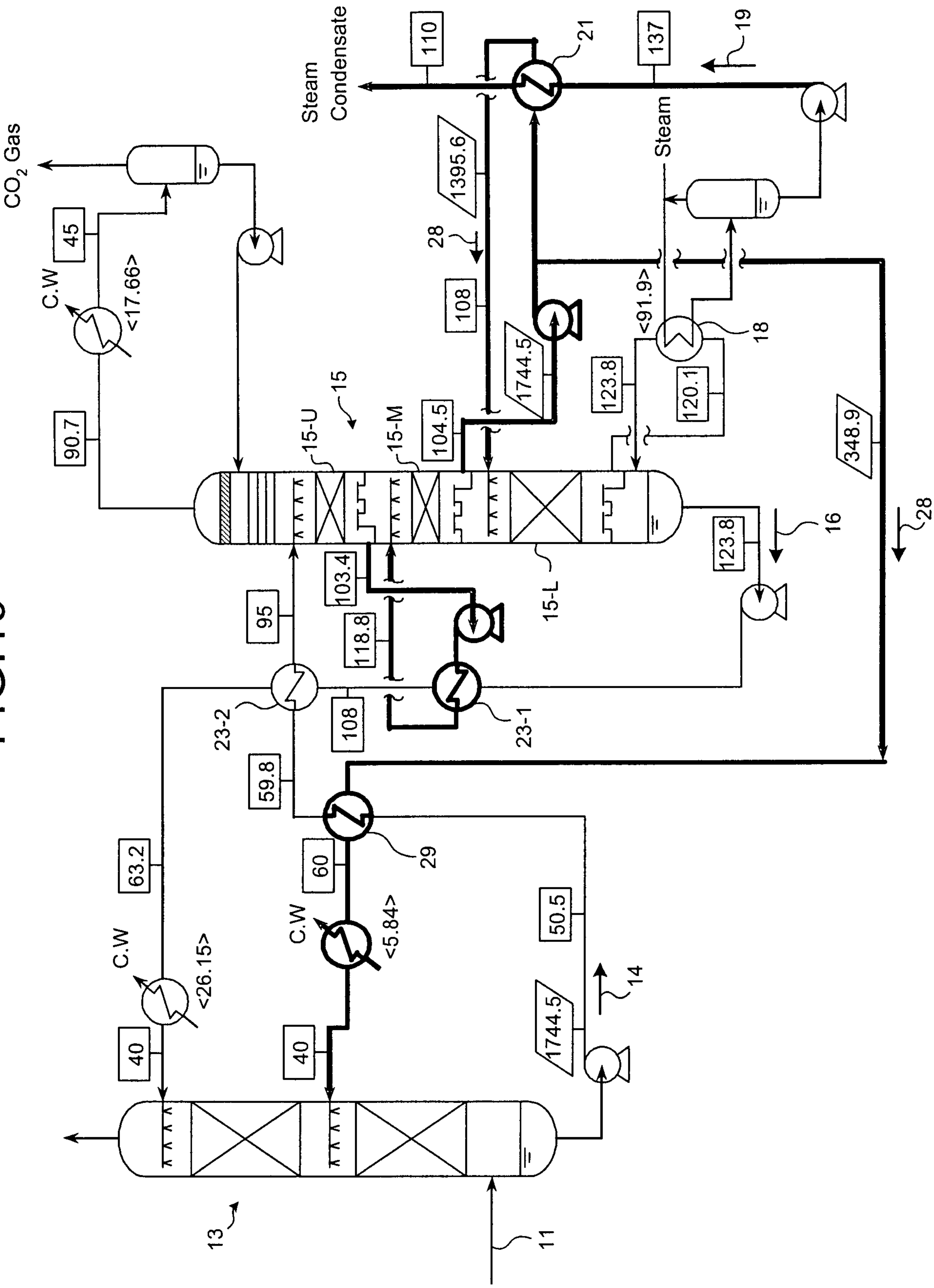

CO2 Gas
Steam Condensate
Steam
110
137
21
19
1395.6
28
108
1744.5
104.5
123.8
120.1
<91.9>
18
348.9
28
15
15-U
15-M
15-L
C.W
<17.66>
45
90.7
95
103.4
118.8
108
23-1
23-2
123.8
16
59.8
63.2
29
60
C.W
<5.84>
C.W
<26.15>
50.5
1744.5
14
40
40
13
11

FIG.20

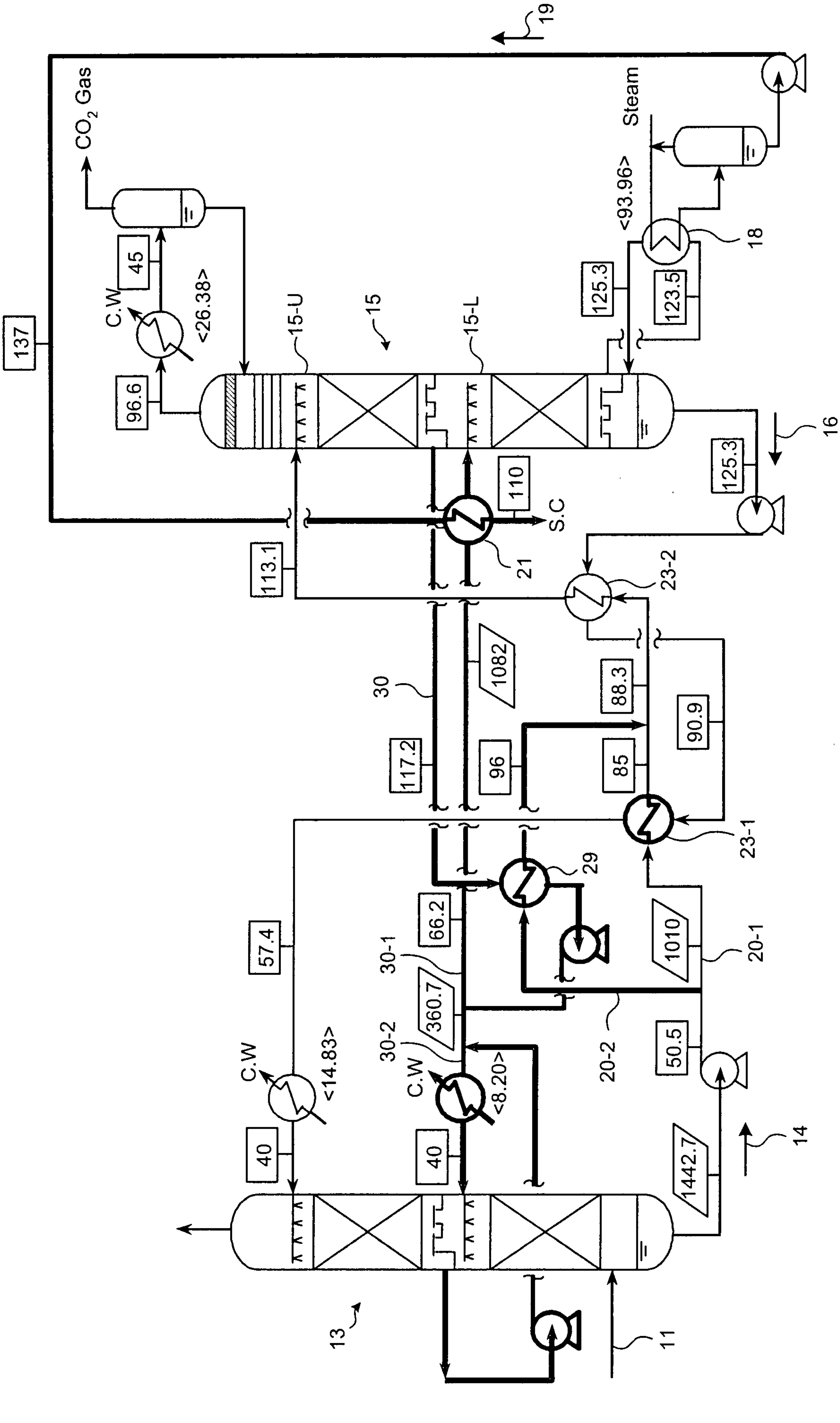

19
137
CO_2 Gas
Steam
45
C.W
<26.38>
96.6
15-U
15
15-L
<93.96>
125.3
123.5
18
16
125.3
110
S.C
21
113.1
23-2
30
1082
88.3
90.9
117.2
96
85
23-1
29
57.4
66.2
30-1
360.7
1010
20-1
30-2
20-2
50.5
C.W
<14.83>
C.W
<8.20>
40
40
1442.7
14
13
11

FIG.21

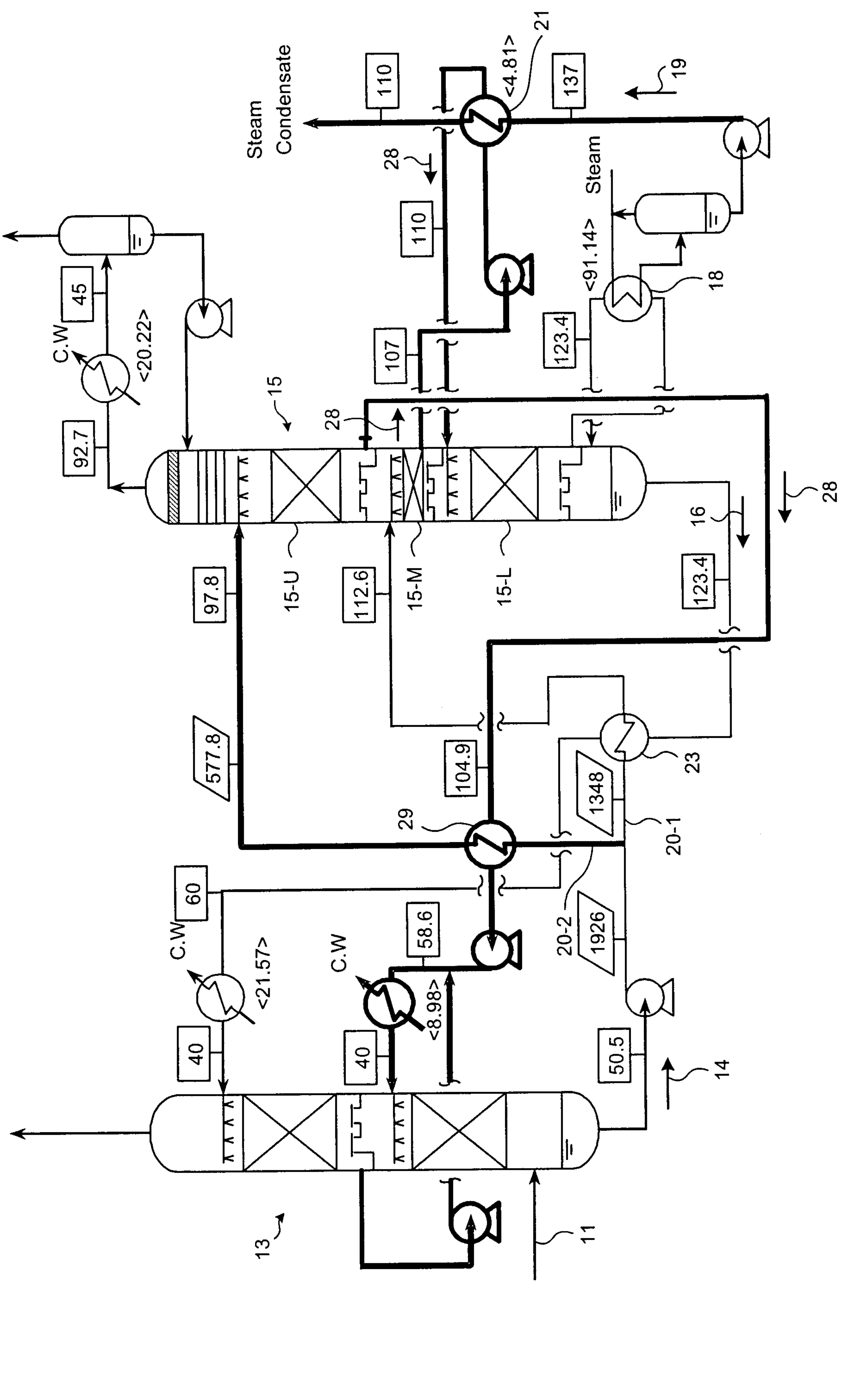
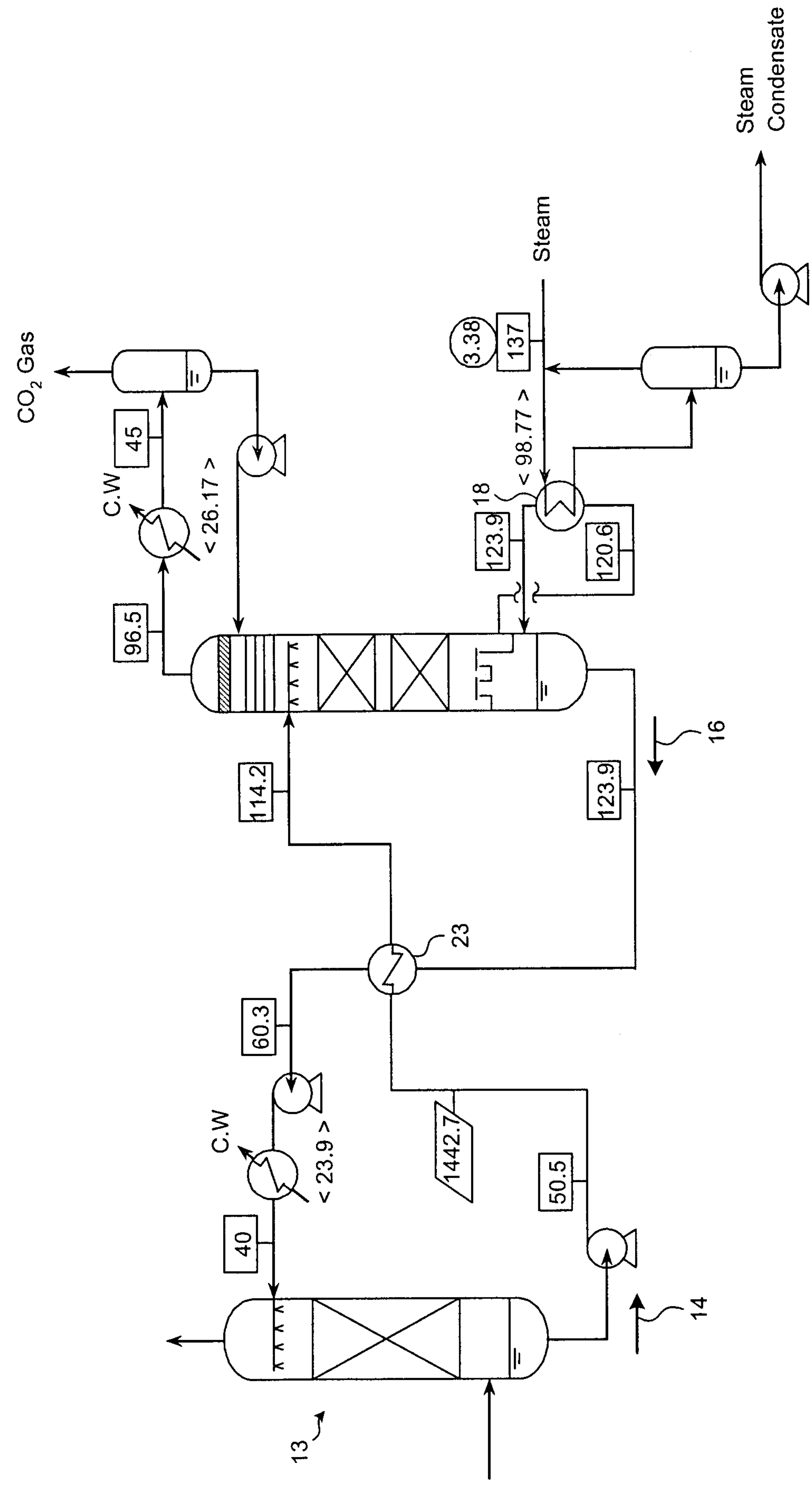

CO2 Gas
Steam Condensate
Steam
C.W
C.W
C.W
<20.22>
<4.81>
<91.14>
<21.57>
<8.98>
92.7
45
110
137
110
107
123.4
123.4
97.8
112.6
577.8
104.9
1348
1926
60
58.6
40
40
50.5
15
15-U
15-M
15-L
16
18
19
21
23
28
28
28
29
20-1
20-2
14
13
11

FIG.22



CO_2 Gas
45
C.W
< 26.17 >
96.5
Steam
Steam
Condensate
3.38
137
< 98.77 >
18
123.9
120.6
114.2
123.9
16
23
60.3
C.W
< 23.9 >
1442.7
50.5
40
14
13

10
CO_2
21
8
12
25a
25b
23
26a
19
26b
9
16
13
11
15
20
22
17
18
14
16