Office de la Propriété Intellectuelle du Canada
Un organisme d'Industrie Canada

Canadian Intellectual Property Office
An agency of Industry Canada

CA 2947254 A1 2015/11/19

(21) **2 947 254**

(12) **DEMANDE DE BREVET CANADIEN**
CANADIAN PATENT APPLICATION

(13) **A1**

(86) **Date de dépôt PCT/PCT Filing Date:** 2015/04/24
(87) **Date publication PCT/PCT Publication Date:** 2015/11/19
(85) **Entrée phase nationale/National Entry:** 2016/10/27
(86) **N° demande PCT/PCT Application No.:** JP 2015/062473
(87) **N° publication PCT/PCT Publication No.:** 2015/174246
(30) **Priorité/Priority:** 2014/05/15 (JP2014-101758)

(51) **Cl.Int./Int.Cl.** ***F02C 3/30*** (2006.01), ***F01D 25/32*** (2006.01), ***F02C 6/00*** (2006.01), ***F02C 6/18*** (2006.01), ***F02C 7/08*** (2006.01), ***F02C 7/143*** (2006.01)

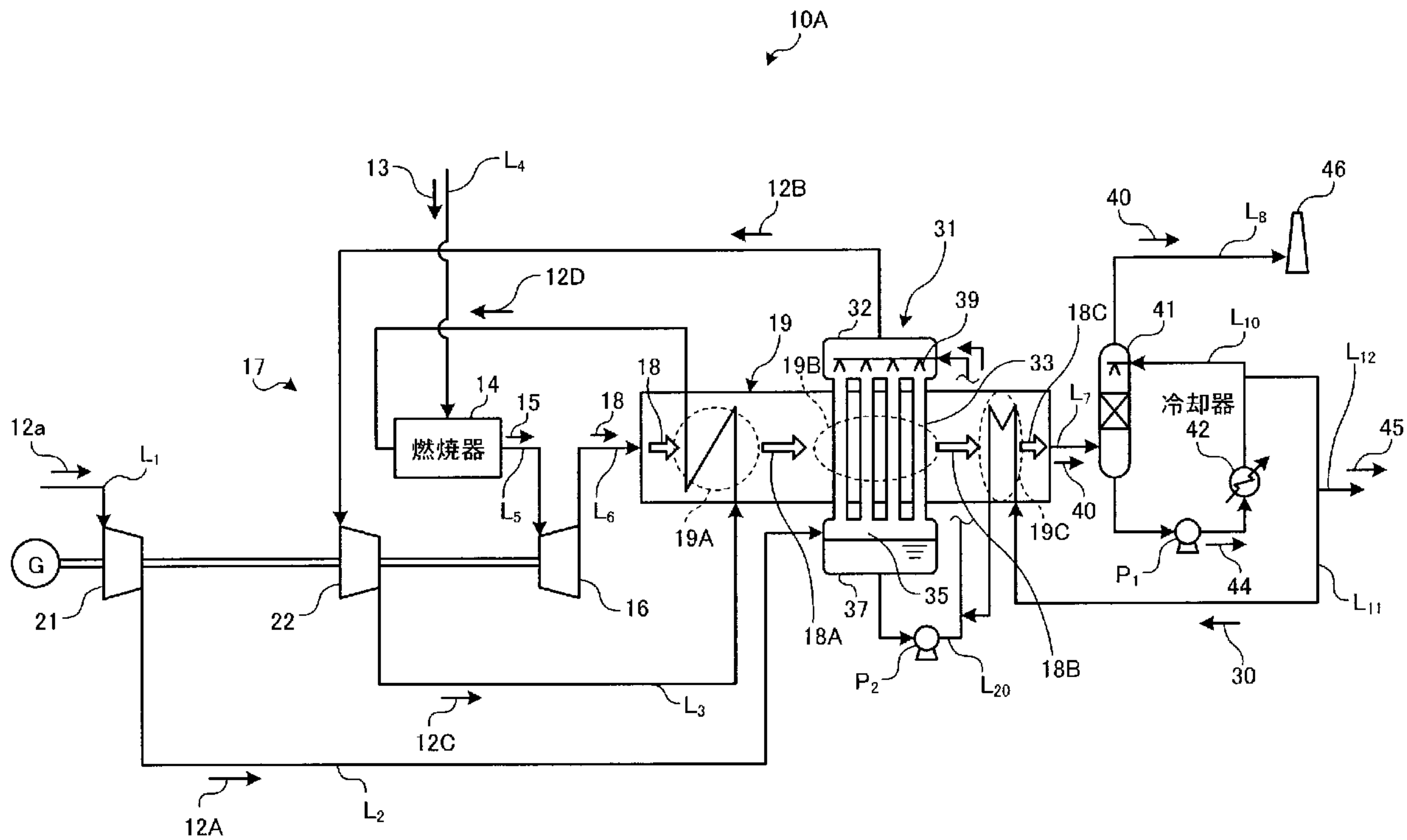
(71) **Demandeur/Applicant:**
MITSUBISHI HEAVY INDUSTRIES, LTD., JP

(72) **Inventeur/Inventor:**
IIJIMA, MASAKI, JP

(74) **Agent:** SMART & BIGGAR

(54) **Titre : EQUIPEMENT A CYCLE DE TURBINE A GAZ, EQUIPEMENT POUR RECUPERER DU CO2 A PARTIR DE GAZ D'ECHAPPEMENT, ET PROCEDE POUR RECUPERER UNE CHALEUR D'ECHAPPEMENT A PARTIR DE GAZ D'ECHAPPEMENT DE COMBUSTION**

(54) **Title: GAS TURBINE CYCLE EQUIPMENT, EQUIPMENT FOR RECOVERING CO2 FROM FLUE GAS, AND METHOD FOR RECOVERING EXHAUST HEAT FROM COMBUSTION FLUE GAS**



14 Combustor
42 Cooler

(57) **Abrégé/Abstract:**
By using a combustion exhaust gas (18) from a power turbine (16), a high-pressure secondary compressed air (12C) is subjected to heat exchange in a first heat exchange unit (19A) of an exhaust heat recovery device (19), and by using resultant heat-

(57) **Abrégé(suite)/Abstract(continued):**
exchanged exhaust gas (18A), a low-pressure primary compressed air (12A) is subjected to heat recovery in a second heat exchange unit (19B) of an air saturation tank (31). Then, a primary compressed air (12B) that has been subjected to heat recovery in the second heat exchange unit (19B) is introduced into a secondary air compressor (22) to increase the pressure of the air, and then the high-pressure air is subjected to heat recovery in the first heat exchange unit (19A), producing a secondary compressed air (12D). The secondary compressed air (12D) is introduced into a combustor (14) and combusted using fuel.

Abstract

By using a combustion flue gas (18) from a power turbine (16), a high-pressure secondary compressed air (12C) is subjected to heat exchange in a first heat exchange unit (19A) of an exhaust heat recovery device (19), and by using resultant heat-exchanged flue gas (18A), a low-pressure primary compressed air (12A) is subjected to heat recovery in a second heat exchange unit (19B) of a saturator (31). Then, a primary compressed air (12B) that has been subjected to heat recovery in the second heat exchange unit (19B) is introduced into a secondary air compressor (22) to increase the pressure of the air, and then the high-pressure air is subjected to heat recovery in the first heat exchange unit (19A), producing a secondary compressed air (12D). The secondary compressed air (12D) is introduced into a combustor (14) and combusted using fuel.

DESCRIPTION

Title of Invention

GAS TURBINE CYCLE EQUIPMENT, EQUIPMENT FOR RECOVERING CO_2 FROM FLUE GAS, AND METHOD FOR RECOVERING EXHAUST HEAT FROM COMBUSTION FLUE GAS

Technical Field

[0001]

The present invention relates to gas turbine cycle equipment, equipment for recovering CO_2 from flue gas, and a method for recovering exhaust heat from combustion flue gas that improve cycle efficiency.

Background Art

[0002]

For example, in order to improve gas turbine (G/T) combined cycle efficiency, a heat recovery steam generator for effectively utilizing combustion flue gas from a gas turbine is used. This heat recovery steam generator (HRSG) is an apparatus that generates steam using a high-temperature combustion flue gas discharged from an exhaust heat generation source, such as a gas turbine, and is widely used in, for example, a gas turbine combined cycle (GTCC) power generation plant that supplies steam generated in the heat recovery steam generator to a steam turbine (S/T) and drives a power generator (PTLs 1 and 2).

Citation List

Patent Literature

[0003]

[PTL 1] Japanese Unexamined Patent Application Publication No. 2003-83003

[PTL 2] Japanese Unexamined Patent Application Publication No. 2013-171001

Summary of Invention

[0004]

However, in the related-art heat recovery steam generator, the heat recovery from a high-temperature combustion flue gas is performed at a temperature below a critical pressure using a plurality of stages, for example, high-pressure/medium-pressure/low-pressure individual economizers, an evaporator, a superheater, a reheater, and the like. Thus, heat exchange is performed so as not to reach a temperature falling line and a pinch point of the combustion flue gas. Additionally, there is a problem that reheating in the reheater is also only reheating at a temperature of about 600°C.

[0005]

Hence, even in a case where a gas turbine inlet temperature is a high pressure/high temperature of, for example, 1500°C class, the gas turbine efficiency (% LHV) is about 60%. In addition, in a case where the gas turbine inlet temperature is raised to, for example, 1700°C, there is a problem that there are various barriers against a turbine cooling technique, a heat shield coating technique, a heat-resisting material technique, and the like.

[0006]

Hence, even in gas turbine equipment in which the inlet temperature is, for example, 1500°C class, the appearance of a system that improves system efficiency is desired.

[0007]

An aspect of the present disclosure is directed to the provision of gas turbine cycle equipment, equipment for recovering CO_2 from flue gas, and a method for recovering exhaust heat from combustion flue gas that can improve gas turbine cycle efficiency in view of the above problems.

[0008]

According to a first aspect of the present invention, there is provided gas turbine cycle equipment including a gas turbine having a combustor that combusts fuel with compressed air and a power turbine that is driven by a high-temperature/high-pressure combustion gas from the combustor; and an exhaust heat recovery device that recovers heat energy from combustion flue gas that has driven the power turbine. The compressed air includes primary compressed air that is compressed by a primary air compressor that compresses air, and secondary compressed air that is compressed by a secondary air compressor that further compresses the primary compressed air. The exhaust heat recovery device includes a first heat exchange unit that performs indirect heat exchange between the combustion flue gas and the secondary compressed air, and a second heat exchange unit that passes through the first heat exchange unit, performs indirect heat exchange between combustion flue gas after first heat exchange, and the primary compressed air and supply water, in a saturator, and entrains steam in the primary compressed air. The primary compressed air, which entrains the steam that has performed heat exchange in the saturator of the second heat exchange unit, is introduced into the secondary air compressor, thereby producing high-pressure/low-temperature secondary compressed air, then heat exchange of the high-pressure/low-temperature secondary compressed air is performed in the first heat exchange unit, thereby producing high-pressure high-temperature secondary compressed air, and then, the high-pressure high-temperature secondary compressed air is introduced into the combustor.

[0009]

In some embodiments, the saturator of the second heat exchange unit includes a supply water header that introduces the supply water thereinto, a plurality of heat exchange tubes that communicate with the supply water header at one end and are arranged within the exhaust heat recovery device, a storage header that communicates with the heat exchange tubes at the other end, stores the supply water, and has an introducing part that introduces the primary compressed air into a space of a storage part, and a supply water circulation line along which the supply water is circulated. The primary compressed air is passed through tube spaces for supply water that circulates in the shape of a wet wall along inner wall surfaces of the heat exchange tubes, the primary compressed air is subjected to heat exchange with the combustion flue gas that abuts against outer peripheries of the heat exchange tubes, steam is generated while heating the supply water, and the generated steam is entrained in the primary compressed air subjected to the heat exchange.

[0010]

Some embodiments further include a cooling tower that cools a flue gas after heat exchange discharged from the exhaust heat recovery device; and a supply water supply line along which condensed water is supplied as the supply water to a supply water circulation line along which supply water circulates through the saturator.

[0011]

In some embodiments, the exhaust heat recovery device further includes a third heat exchange unit that performs indirect heat exchange between the combustion flue gas after passing through the second heat exchange unit, and the supply water in the supply water supply line.

[0012]

According to a second aspect of the present invention, there is provided equipment for recovering CO_2 from flue gas including the gas turbine cycle equipment according to the first aspect or any of the embodiments thereof, and a CO_2 recovery unit that recovers CO_2 in flue gas from the cooling tower.

[0013]

In some embodiments, the CO_2 recovery unit includes a CO_2 absorption tower that absorbs CO_2 in flue gas with an absorbing liquid, and an absorbing liquid regeneration tower that regenerates the absorbing liquid which has absorbed CO_2, and the absorbing liquid is circulated and reused.

[0014]

According to another aspect of the present invention, there is provided a method for recovering exhaust heat from combustion flue gas. The method includes using the gas turbine cycle equipment according to the first aspect described above, and subjecting the combustion flue gas from the gas turbine to heat exchange with high-pressure secondary compressed air in the first heat exchange unit of the exhaust heat recovery device, performing heat recovery of low-pressure primary compressed air, using the heat-exchanged flue gas, in the second heat exchange unit of the saturator, introducing the primary compressed air, which has recovered the heat in the second heat exchange unit, into the secondary air compressor, thereby producing high-pressure primary compressed air, then recovering heat in the first heat exchange unit, thereby producing secondary compressed air, and introducing the secondary compressed air into the combustor to combust fuel using the secondary compressed air.

[0015]

According to some embodiments, by using the combustion flue gas from the gas turbine, the high-pressure secondary compressed air is subjected to the heat exchange in the first heat exchange unit of the exhaust heat recovery device, and by using the heat-exchanged flue gas, the low-pressure primary compressed air is subjected to the heat recovery in the second heat exchange unit of the saturator. Then, the primary compressed air that has recovered the heat in the second heat exchange unit is introduced into the secondary air compressor, thereby producing the high-pressure primary compressed air, and then the high-pressure primary compressed air is subjected to the heat recovery in the first heat exchange unit, producing the secondary compressed air. The secondary compressed air is introduced into the combustor and fuel is combusted using the secondary compressed air, and thereby, temperature is increased up to, for example, 1500°C. Accordingly, the exhaust heat recovery efficiency of the exhaust heat recovery device can be made very high. As a result, the gas turbine cycle efficiency can be improved.

Brief Description of Drawings

[0016]

FIG. 1A is a schematic view of a gas turbine cycle equipment related to Example 1.

FIG. 1B is a schematic view illustrating an example of the temperature/pressure conditions of the gas turbine cycle equipment related to Example 1.

FIG. 2 is an enlarged view of main parts of the gas turbine cycle equipment related to Example 1.

FIG. 3 is a perspective view of a heat exchange tube.

FIG. 4 is a schematic sectional view of the heat exchange tube.

FIG. 5 is a schematic sectional view of the heat exchange tube.

FIG. 6 is a relationship view between temperature and enthalpy in a temperature falling line of combustion flue gas and in a rising line of supply water temperature and compressed air.

FIG. 7 is a schematic view of another gas turbine cycle equipment of Example 1.

FIG. 8 is a schematic view of equipment for recovering CO_2 from flue gas related to Example 2.

Description of Embodiments

[0017]

Preferable examples of the invention will be described below in detail with reference to the accompanying drawings. In addition, the invention is not limited by the examples and includes those configured by combining respective examples in a case where there are a plurality of examples.

Example 1

[0018]

FIG. 1A is a schematic view of a gas turbine cycle equipment related to Example 1. FIG. 1B is a schematic view illustrating an example of the temperature/pressure conditions of the gas turbine cycle equipment related to Example 1.

As illustrated in FIG. 1A, the gas turbine cycle equipment 10A related to the present example includes a gas turbine 17 that has a combustor 14 that combusts fuel 13 with compressed air and a power turbine 16 that is driven by a high-temperature/high-pressure combustion gas 15 from the combustor 14, and an exhaust heat recovery device 19 that recovers heat energy from combustion flue gas 18 that has driven the power turbine 16. The compressed air 12 includes primary compressed air 12A that is compressed by a primary air compressor 21 that compresses air 12a, and secondary compressed air 12C that is compressed by a secondary air compressor 22 that further compresses the primary compressed air 12A. The exhaust heat recovery device 19 includes a first heat exchange unit 19A that performs indirect heat exchange between the combustion flue gas 18 and the secondary compressed air 12C, and a second heat exchange unit 19B that passes through the first heat exchange unit 19A, performs indirect heat exchange between combustion flue gas 18A after first heat exchange and the primary compressed air 12A and the supply water 30 in an saturator 31, and entrain steam 38 in the primary compressed air 12A. The primary compressed air 12B, which entrains the steam that has been subjected to heat exchange in the saturator 31 of the second heat exchange unit 19B, is introduced into the secondary air compressor 22, thereby producing high-pressure secondary compressed air (low temperature) 12C, then heat exchange of the high-pressure secondary compressed air (low temperature) 12C in the first heat exchange unit 19A is performed, thereby producing high-pressure secondary compressed air (high temperature) 12D, and then, the high-pressure secondary compressed air (high temperature) 12D is introduced into the combustor 14 as compressed air for combustion.

[0019]

In the present example, a third heat exchange unit 19C that performs heat exchange of the supply water 30, using the combustion flue gas 18B after being subjected to heat exchange in the second heat exchange unit 19B, is further provided on a downstream side of the second heat exchange unit 19B of the exhaust heat recovery device 19.

[0020]

Additionally, in the present example, a cooling line

L_{10} including a cooling tower 41 that cools the flue gas 40 after heat exchange discharged from the exhaust heat recovery device 19, and a cooler 42 that circulates the cooling tower 41 with a pump P1, and a supply water supply line L_{11} along which condensed water 44 condensed within the cooling tower 41 is supplied as the supply water 30 to the saturator 31.

In addition, in FIGS. 1A and 1B, reference sign 45 represents discharge water, 46 represents a chimney, G represents a power generator that is coupled to the power turbine 16 and generates power, L_1 represents an air introduction line, L_2 represents a primary compressed air supply line, L_3 represents a secondary compressed air supply line, L_4 represents a fuel supply line, L_5 represents a combustion gas supply line, L_6 represents a combustion flue gas discharge line, L_7 represents a flue gas line, L_8 represents a flue gas discharge line along which the flue gas 40 is to be discharged to the chimney 46, and L_{12} represents a wastewater line.

[0021]

The gas turbine 17 includes the primary and secondary air compressors 21 and 22, the combustor 14, and the power turbine 16. The air 12a introduced from the outside is compressed in the primary and secondary air compressors 21 and 22, and the compressed air 12 made to have high temperature/high pressure is guided to the combustor 14 side. In the combustor 14, the high-temperature/high-pressure compressed air 12, and the fuel 13 are injected and combusted, and a high-temperature (for example, 1500°C) combustion gas 15 is generated. The combustion gas 15 is injected into the power turbine 16, and the heat energy of the high-temperature high-pressure combustion gas 15 is converted into rotational energy in the power turbine 16. The coaxial primary/secondary air compressors 21 and 22 are driven with this rotational energy, and the power generator G is driven with the rotational energy remaining after being used to drive this compressor, and generates power.

[0022]

Next, the combustion flue gas 18 that has driven the power turbine 16 is guided to the exhaust heat recovery device 19 in order to recover the heat energy thereof.

[0023]

This exhaust heat recovery device 19 includes the first heat exchange unit 19A and the second heat exchange unit 19B. In the first heat exchange unit 19A, as illustrated in FIG. 1B, the secondary compressed air (a low temperature of 275°C and a pressure of 21 ata (2.1 MPa)) 12C is subjected to heat exchanged using the high-temperature (for example, 617°C) combustion flue gas 18 discharged from the power turbine 16. Additionally, in the second heat exchange unit 19B on the downstream side of the first heat exchange unit 19A, the primary compressed air (a temperature of 224°C and a pressure of 6 ata (0.6 MPa)) 12A is introduced into the saturator 31 and is subjected to heat exchange.

[0024]

FIG. 2 is an enlarged view of main parts of FIG. 1. FIG. 3 is a perspective view of the heat exchange tube, and FIGS. 4 and 5 are schematic sectional views of the heat exchange tube.

As illustrated in FIG. 2, the saturator 31 includes a supply water header 32 that introduces the supply water 30 condensed in the cooling tower 41 thereinto, a plurality of heat exchange tubes 33 that communicate with the supply water header 32 on one end 33a side and are arranged within the exhaust heat recovery device 19, a storage header 37 that communicates with the heat exchange tubes 33 on the other end 33b side, stores the supply water 30 within a storage part 34, and has an introducing part 36 that introduces the primary compressed air 12A into a space 35 on an upper side of the storage part 34, and a supply water circulation line L_{20} along which the supply water 30 is circulated with a pump P_2.

[0025]

FIGS. 4 and 5 are views illustrating an aspect in which supply water is supplied to each heat exchange tube 33 within the supply water header 32.

Referring to FIG. 4, a supply nozzle 39 provided in the supply water header 32 is used for the supply of the supply water 30, and the supply water 30 sprayed from the supply nozzle 39 is dropped while forming a water screen 30a in the shape of a wet wall along a wall surface 33d within the heat exchange tube 33.

Referring to FIG. 5, the supply water 30 is made to overflow from the storage part 32a of the supply water header 32 as the supply of the supply water 30, and the overflowed supply water 30 is dropped while forming the water screen 30a in the shape of a wet wall along the wall surface 33d within the heat exchange tube 33.

[0026]

Then, as illustrated in FIGS. 3, 4, and 5, the primary compressed air 12A is passed from a lower side into a tube space 33c for the supply water 30 dropped and circulated by the water screen 30a along the wall surface 33d of each of the plurality of heat exchange tube 33. Then, when the primary compressed air 12A passes, the primary compressed air is subjected to heat exchange with the combustion flue gas 18A that abuts against an outer periphery of each heat exchange tube 33. In the case of this heat exchange, the steam 38 is generated while heating the supply water 30 that flows down, this generated steam 38 is entrained in the primary compressed air 12A subjected to heat exchange, and is created as the primary compressed air (water steam) 12B.

[0027]

Then, for example, as illustrated in FIG. 4, the supply water 30 is injected by the supply nozzle 39 and IS made to flow into the heat exchange tube 33. The supply water 30 that has flowed into the heat exchange tube 33 is dropped while forming the water screen 30a in the shape of a wet wall along the wall surface 33d of the heat exchange tube 33, and is stored on the storage header 37 on the downstream side. The stored supply water 30 is again circulated through the supply water header 32 by the supply water circulation line L_{20} via the pump P_2.

[0028]

Then, the wet wall-like water screen 30a that flows through the inside of the heat exchange tube 33 is indirectly heated by the heat of the combustion flue gas 18A from the outside, and the supply water 30 becomes the steam 38 by heat exchange, is entrained in the primary compressed air 12A, and becomes the primary compressed air (water steam) 12B. The second heat exchange unit 19B performs heat exchange using the combustion flue gas 18A that has contributed to the heat exchange in the first heat exchange unit 19A.

[0029]

Here, the primary compressed air (a pressure of 6 ata (0.6 MPa)) 12A introduced into the space 35 within the storage header 37 of the saturator 31 is cooled by the supply water 30 to be introduced, and the temperature thereof falls from 224°C to 84°C within the space 35.

The primary compressed air 12A made to have this low temperature (84°C) is indirectly subjected to heat exchange with the combustion flue gas 18A after the first heat exchange, in the saturator 31 of the second heat exchange unit 19B, and becomes the primary compressed air (water steam) 12B of which the temperature reaches 107°C (a pressure of 6 ata).

[0030]

Next, the primary compressed air (water steam) 12B is introduced into the secondary air compressor 22, is subjected to second compression, and becomes the high-pressure (a pressure of 21 ata (2.1 MPa)) secondary compressed air (low temperature: 275°C) 12C.

[0031]

The secondary compressed air 12C is low (275°C) in temperature, is capable of being subjected to heat exchange with the high-temperature (for example, 617°C) combustion flue gas 18 in the first heat exchange unit 19A of the exhaust heat recovery device 19, and becomes the high-pressure secondary compressed air (a high temperature of 565°C) 12D.

[0032]

In the related art, in a case where one compressor is installed to perform compressing, the primary compressed air (a temperature of 224°C) compressed by the primary air compressor is introduced into the same secondary air compressor as it is, and is introduced into the combustor as high-pressure (21 ata)/high-temperature (400°C) compressed air.

[0033]

In contrast, in the present invention, a total amount of the low-pressure (a pressure of 6 ata) primary compressed air 12A, which has passed through the primary air compressor 21 is introduced into the second heat exchange unit 19B of the exhaust heat recovery device 19, is subjected to heat exchange with the combustion flue gas 18A after being subjected to heat exchange in the first heat exchange unit 19A, in the saturator 31.

[0034]

In this case, in the saturator 31, the supply water 30 is introduced so as to lower (275°C → 84°C) the temperature of the low-pressure (a pressure of 6 ata) primary compressed air 12A, is subjected to heat exchange with the exhaust heat of the combustion flue gas (a temperature of 336°C) 18A after being subjected to heat exchange in the first heat exchange unit 19A, and becomes the low-pressure primary compressed air (water steam) 12B of which the temperature has been raised (107°C). The primary compressed air (water steam) (107°C) 12B is further compressed by the secondary air compressor 22 next, and becomes the high-pressure (a pressure of 21 ata) secondary compressed air (low temperature: 275°C) 12C. In the case of this secondary compression, the capacity of the compressor can be made small because the temperature falls unlike a case where compression is continuous as in the related art.

[0035]

Moreover, the high-pressure secondary compressed air (low temperature: 275°C) 12C is introduced into the first heat exchange unit 19A of the exhaust heat recovery device 19, becomes the high-pressure secondary compressed air (high temperature: 565°C) 12D, and is introduced into the combustor 14.

[0036]

In the present example, since the amount of the steam 38 to be entrained is small in the case of the heat exchange of the primary compressed air 12A in the second heat exchange unit 19B, it is possible to raise combustion temperature in the combustor 14 to a high temperature of, for example, 1500°C.

[0037]

Additionally, in the present example, the third heat exchange unit 19C is installed, and performs heat exchange so as to further improve the exhaust heat recovery efficiency of the combustion flue gas 18 when condensed water that has condensed moisture in the combustion flue gas 18C in the cooling tower 41 is supplied to the saturator 31 as the supply water 30. That is, since the temperature of the supply water 30 that is cooled and condensed in the cooling tower 41 is about 40°C, the supply water 30 at 40°C is passed through the third heat exchange unit 19C, is subjected to heat exchange with the combustion flue gas (120°C) 18B, and is supplied to the storage header 37 side as the supply water 30 at a temperature of 88°C.

[0038]

In this way, when exhaust heat is recovered by performing heat exchange of the combustion flue gas 18, in the exhaust heat recovery device 19 of the present example, efficient heat exchange is performed in the first heat exchange unit 19A, the second heat exchange unit 19B, and the third heat exchange unit 19C, respectively. Thus, the heat of the high-temperature (617°C) combustion flue gas 18 is recovered to a low temperature (95°C), and the heat recovery efficiency improves.

Additionally, since the amount of the steam 38 entrained in the primary compressed air (water steam) 12B is small, exhaust loss becomes little.

[0039]

FIG. 6 is a relationship view between temperature and enthalpy in a temperature falling line of an combustion flue gas and in a rising line of supply water temperature and compressed air.

As illustrated in FIG. 6, the temperature of the combustion flue gas 18 falls gradually (the first heat exchange unit 19A (617°C → 336°C), the second heat exchange unit 19B (336°C → 120°C), and the third heat exchange unit 19C (120°C → 95°C)) in the first heat exchange unit 19A, the second heat exchange unit 19B, and the third heat exchange unit 19C.

[0040]

In contrast, the supply water 30 rises from 40°C to 88°C in the third heat exchange unit 19C, and rises from 84°C to 107°C because the temperature of the primary compressed air 12A falls in the saturator 31. Next, the secondary compressed air 12C rises from 275°C to 565°C in the first heat exchange unit 19A.

[0041]

Additionally, as shown in Table 1, gas turbine cycle efficiency reaches 66.76% (LHV base) depending on a relationship between input heat and exhaust loss. This made it possible to achieve a significant improvement of about 6.7% or more greater than 60% that is the gas turbine cycle efficiency of a related-art 1500°C class.

[0042]

[Table 1]

1. Input of Heat	Air: 2,158T/Hx(1500-565°C)x0.285=575.05x10^6kcal/H Water: 378.0T/Hx(1500-565°C)x0.556=196.51x10^6kcal/H Fuel: 55.3T/Hx(1500-15°C)x0.50=41.06x10^6kcal/H 812.62x10^6kcal/H
2. Flue Gas Loss	Air: 2,158T/Hx(95-15°C)x0.24=41.43x10^6kcal/H Water: 378.0T/Hx(639.3-40.0°C)=226.5x10^6kcal/H Fuel: 55.3T/Hx(95-15°C)x0.50=2.21x10^6kcal/H 270.14x10^6kcal/H
3. Gas Turbine Efficiency	$\eta = \frac{(812.62 - 270.14) \times 106 \times 100}{812.62 \times 106} = 66.76\%(LHV\ Base)$

[0043]

As described above, in a gas turbine combined cycle (GTCC) power generation plant including the related-art exhaust heat recovery steam generator using a high-pressure/medium-pressure/low-pressure boiler, the efficiency (LHV) thereof that is about 60% can be markedly raised.

[0044]

In the present example, when exhaust heat is recovered by performing heat exchange of the combustion flue gas 18, in the exhaust heat recovery device 19 of the present example, efficient heat exchange is performed in the first heat exchange unit 19A, the second heat exchange unit 19B, and the third heat exchange unit 19C, respectively. However, the third heat exchange unit 19C may be omitted as illustrated in the gas turbine cycle equipment 10B illustrated in FIG. 7.

In this case, heat of the high-temperature (617°C) combustion flue gas 18 is recovered to a low temperature (120°C). As a result, the heat recovery efficiency becomes slightly lower than that of the gas turbine cycle equipment 10A of FIG. 1. However, the equipment can be simplified.

Example 2

[0045]

Next, equipment for recovering CO_2 from flue gas related to Example 2 of the present invention will be described with reference to FIG. 8. FIG. 8 is a schematic view of the equipment for recovering CO_2 from flue gas related to Example 2. In addition, the same members as those of Example 1 will be designated by the same reference signs, and the description thereof will be omitted. The equipment 50 for recovering CO_2 from flue gas related to the present example includes the gas turbine cycle equipment 10A of Example 1, and a CO_2 recovery unit

51 that recovers CO_2 in the flue gas 40 from which the moisture from the cooling tower 41 has been removed. The CO_2 recovery unit 51 includes a CO_2 absorption tower 53 that remove CO_2 in the flue gas 40 after cooling in the cooling tower 41, using an absorbing liquid 52, and an absorbing liquid regeneration tower 54 that regenerates the absorbing liquid 52.

[0046]

Generally, in a case where an amine-based absorbing liquid, for example, is used as the absorbing liquid 52, the CO_2 recovery unit 51 makes the amine absorbing liquid to absorb and remove CO_2 contained in the flue gas 40 within the CO_2 absorption tower 53, and discharges the removed CO_2 as a treated flue gas 55 from a top side of the CO_2 absorption tower 53. Additionally, the absorbing liquid 52 that has absorbed CO_2 is regenerated by steam stripping using a reboiler 59, in the absorbing liquid regeneration tower 54, and forms closed-system circulation lines L_{21} and L_{22} to be again reused in the CO_2 absorption tower 53. In addition, within the CO_2 absorption tower 53, the amine-based absorbing liquid is, for example, brought into opposed contact with the flue gas 40 so as to take CO_2 into the amine absorbing liquid. Here, on the absorbing liquid regeneration tower 54 side, the gas 56 containing CO_2 removed by the steam stripping is discharged, moisture is removed by a gas-liquid separator, and CO_2 is recovered as gas.

[0047]

In the related art, in a case where CO_2 in flue gas is recovered, a cooling tower is separately provided on a preceding stage side of the CO_2 recovery unit so as to cool the flue gas. However, in Example 1, the flue gas 40 is cooled by the cooling tower 41 for obtaining the supply water 30. Thus, it becomes unnecessary to separately install cooling equipment in the equipment 50 for recovering CO_2 from flue gas in the present example. Additionally, in ordinary gas turbines, CO_2 concentration in flue gas is as low as 3.5 to 4.0 Vol.%. However, in the present gas turbine cycle, CO_2 concentration in flue gas rises as high as 5 to 7 Vol.%. As a result, the amount of the flue gas can be reduced, and the CO_2 recovery unit can be made compact.

[0048]

In addition, in the present example, a case including the CO_2 absorption tower 53 that absorbs CO_2 in the flue gas 40 with the absorbing liquid 52, and the absorbing liquid regeneration tower 54 that regenerates the absorbing liquid 52 that has absorbed CO_2 has been described as the CO_2 recovery unit 51. However, the present invention is not limited to this. Arbitrary equipment may be used as long as the equipment can recover CO_2 in flue gas.

Reference Signs List

[0049]

10A, 10B: GAS TURBINE CYCLE EQUIPMENT

12a: AIR

12: COMPRESSED AIR

12A: PRIMARY COMPRESSED AIR

12B: PRIMARY COMPRESSED AIR (WATER STEAM)

12C: SECONDARY COMPRESSED AIR (LOW TEMPERATURE)

12D: SECONDARY COMPRESSED AIR (HIGH TEMPERATURE)

13: FUEL

14: COMBUSTOR

15: COMBUSTION GAS

16: POWER TURBINE

17: GAS TURBINE

18, 18A to 18C: COMBUSTION FLUE GAS

19: EXHAUST HEAT RECOVERY DEVICE

19A: FIRST HEAT EXCHANGE UNIT

19B: SECOND HEAT EXCHANGE UNIT

19C: THIRD HEAT EXCHANGE UNIT

21: PRIMARY AIR COMPRESSOR

22: SECONDARY AIR COMPRESSOR

31: SATURATOR

32: SUPPLY WATER HEADER

33: HEAT EXCHANGE TUBE

34: STORAGE PART

35: SPACE

37: STORAGE HEADER

38: STEAM

40: FLUE GAS

50: EQUIPMENT FOR RECOVERING CO_2 FROM FLUE GAS

51: CO_2 RECOVERY UNIT

Claims

[Claim 1]

Gas turbine cycle equipment comprising:

a gas turbine having a combustor that combusts fuel with compressed air and a power turbine that is driven by a high-temperature/high-pressure combustion gas from the combustor; and

an exhaust heat recovery device that recovers heat energy from combustion flue gas that has driven the power turbine,

wherein the compressed air includes primary compressed air that is compressed by a primary air compressor that compresses air, and secondary compressed air that is compressed by a secondary air compressor that further compresses the primary compressed air,

wherein the exhaust heat recovery device includes a first heat exchange unit that performs indirect heat exchange between the combustion flue gas and the secondary compressed air, and a second heat exchange unit that passes through the first heat exchange unit, performs indirect heat exchange between combustion flue gas after first heat exchange, and the primary compressed air and supply water, in a saturator, and entrains steam in the primary compressed air, and

wherein the primary compressed air, which entrains the steam that has performed heat exchange in the saturator of the second heat exchange unit, is introduced into the secondary air compressor, thereby producing high-pressure/low-temperature secondary compressed air, then heat exchange of the high-pressure/low-temperature secondary compressed air is performed in the first heat exchange unit, thereby producing high-pressure/high-temperature secondary compressed air, and then, the high-pressure/high-temperature secondary compressed air is introduced into the combustor.

[Claim 2]

The gas turbine cycle equipment according to Claim 1,

wherein the saturator of the second heat exchange unit includes

a supply water header that introduces the supply water thereinto,

a plurality of heat exchange tubes that communicate with the supply water header at one end and are arranged within the exhaust heat recovery device,

a storage header that communicates with the heat exchange tubes at the other end, stores the supply water, and has an introducing part that introduces the primary compressed air into a space of a storage part, and

a supply water circulation line along which the supply water is circulated, wherein the primary compressed air is passed through tube spaces for supply water that circulates in the shape of a wet wall along inner wall surfaces of the heat exchange tubes, the primary compressed air is subjected to heat exchange with the combustion flue gas that abuts against outer peripheries of the heat exchange tubes, steam is generated while heating the supply water, and the generated steam is entrained in the primary compressed air subjected to the heat exchange.

[Claim 3]

The gas turbine cycle equipment according to Claim 1 or 2, further comprising:

a cooling tower that cools a flue gas after heat exchange discharged from the exhaust heat recovery device; and

a supply water supply line along which condensed water is supplied as the supply water to a supply water circulation line along which supply water circulates through the saturator.

[Claim 4]

The gas turbine cycle equipment according to any one of Claims 1 to 3,

wherein the exhaust heat recovery device further includes a third heat exchange unit that performs indirect heat exchange between the combustion flue gas after passing through the second heat exchange unit, and the supply water in the supply water supply line.

[Claim 5]

Equipment for recovering CO_2 from flue gas comprising:

the gas turbine cycle equipment according to any one of Claims 1 to 4; and

a CO_2 recovery unit that recovers CO_2 in flue gas from the cooling tower.

[Claim 6]

The equipment for recovering CO_2 from flue gas according to Claim 5,

wherein the CO_2 recovery unit includes a CO_2 absorption tower that absorbs CO_2 in flue gas with an absorbing liquid, and an absorbing liquid regeneration tower that regenerates the absorbing liquid which has absorbed CO_2, and the absorbing liquid is circulated and reused.

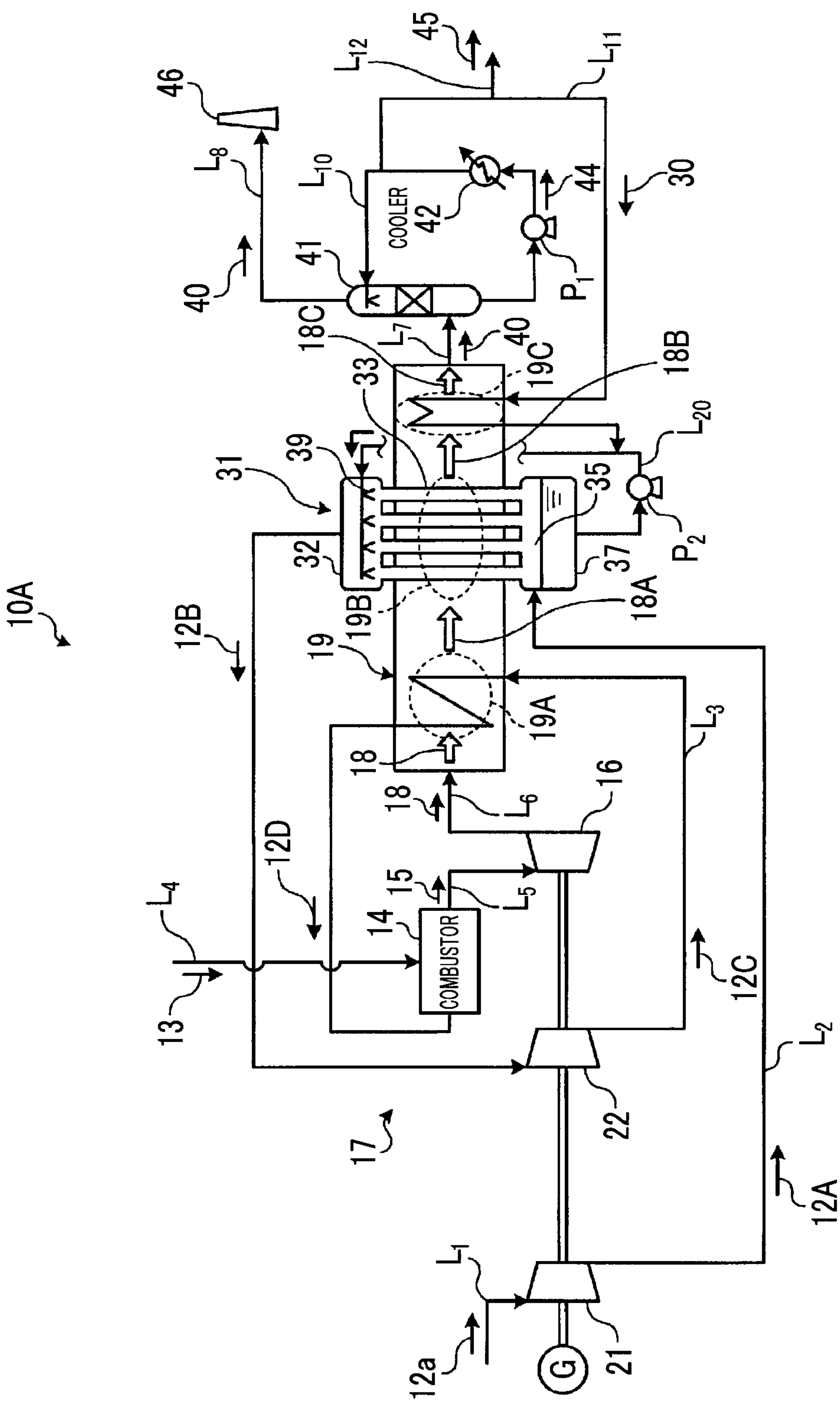
[Claim 7]

A method for recovering exhaust heat from combustion flue gas, the method comprising:

using the gas turbine cycle equipment according to Claim 1, and

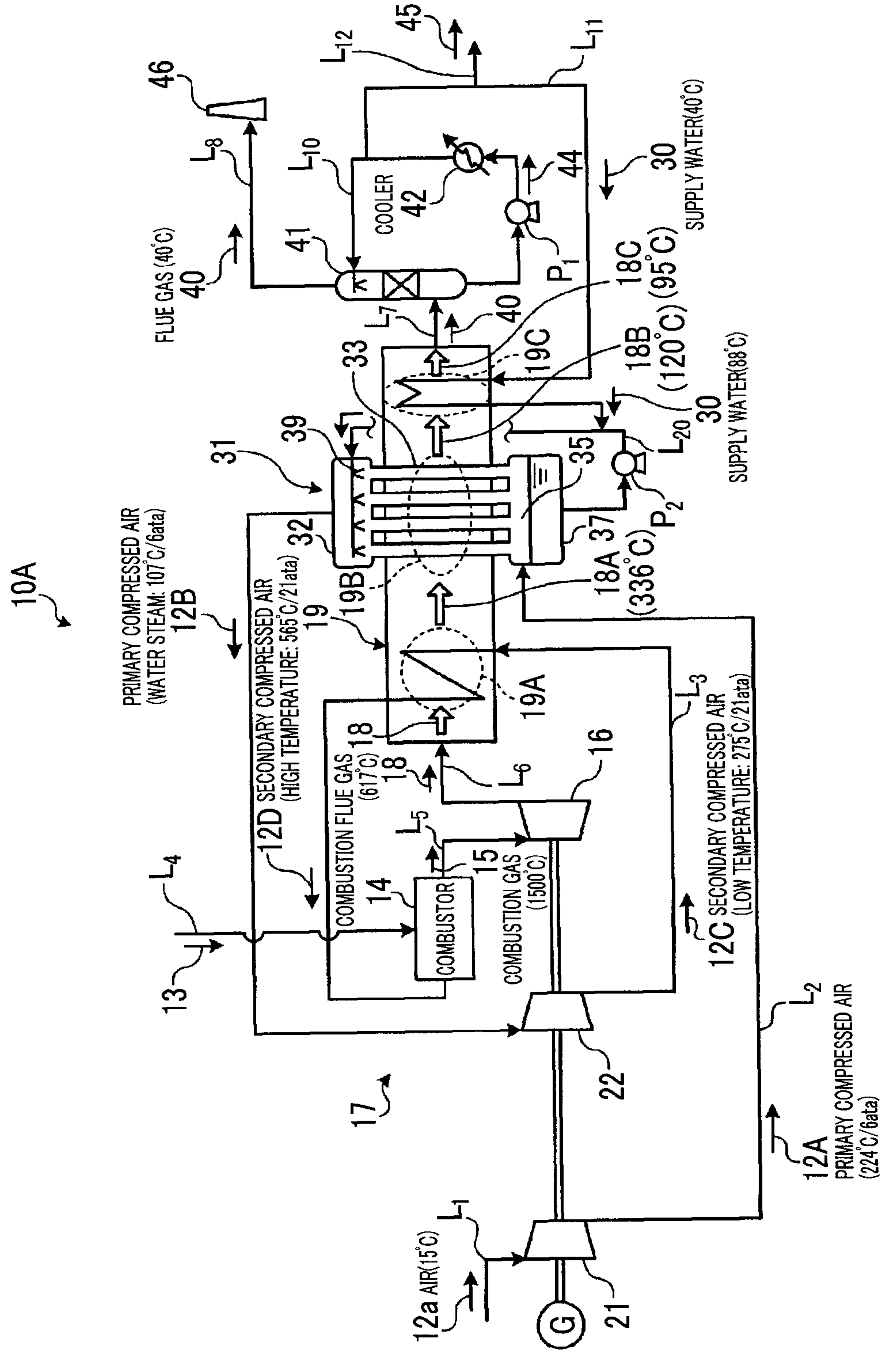
subjecting the combustion flue gas from the gas turbine to heat exchange with high-pressure secondary compressed air in the first heat exchange unit of the exhaust heat recovery device, performing heat recovery of low-pressure primary compressed air, using the heat-exchanged flue gas, in the second heat exchange unit of the saturator, introducing the primary compressed air, which has recovered the heat in the second heat exchange unit, into the secondary air compressor, thereby producing high-pressure primary compressed air, then recovering heat in the first heat exchange unit, thereby producing secondary compressed air, and introducing the secondary compressed air into the combustor to combust fuel using the secondary compressed air.

FIG. 1A


10A
COMBUSTOR
COOLER
42
41
40
46
45
44
30
31
32
33
35
37
39
18
18A
18B
18C
19
19A
19B
19C
12a
12A
12B
12C
12D
13
14
15
16
17
21
22
G
P1
P2
L1
L2
L3
L4
L5
L6
L7
L8
L10
L11
L12
L20

PMHA-16076-PCT

FIG. 1B



PMHA-16076-PCT

FIG. 2

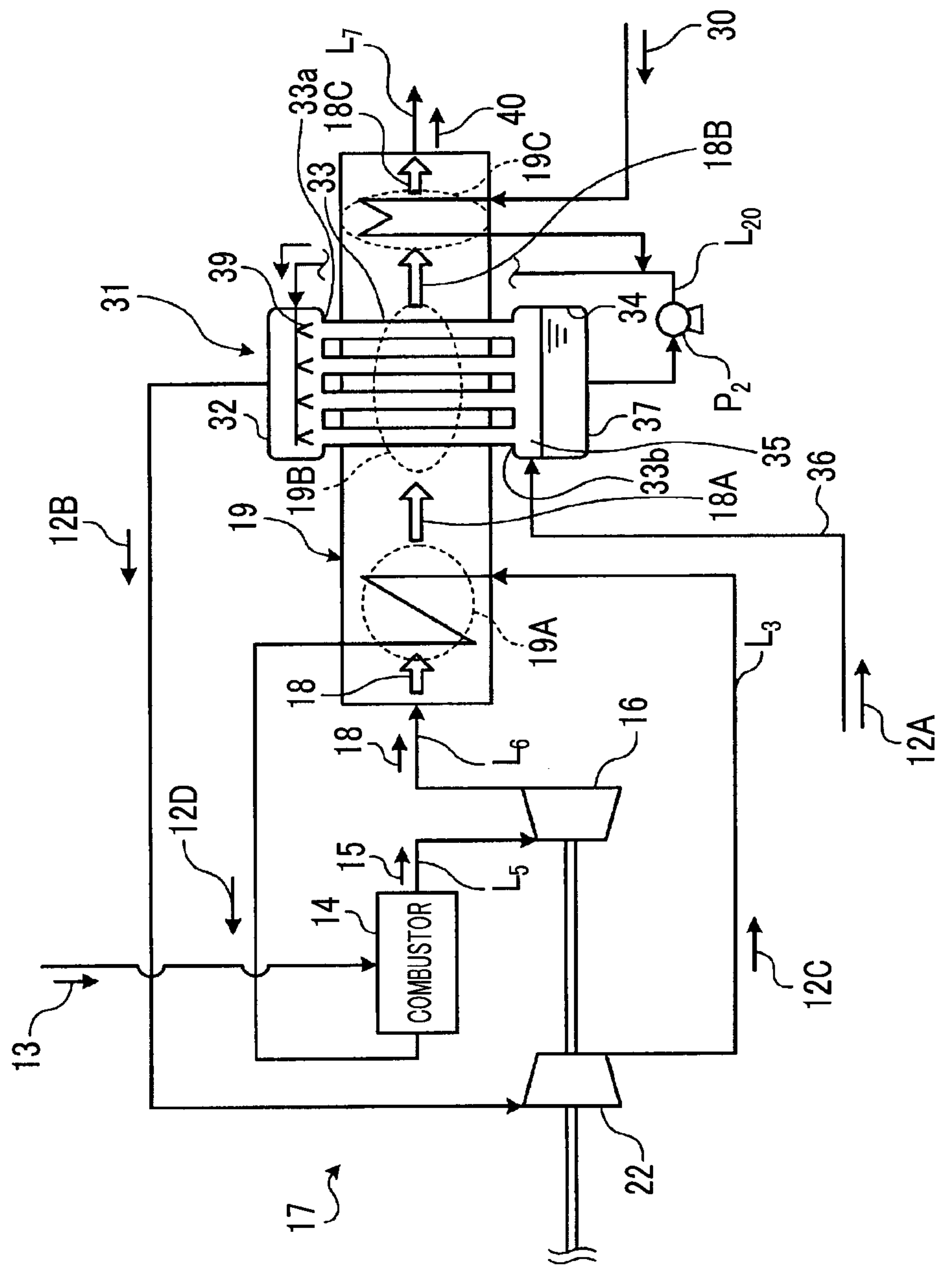


FIG. 3

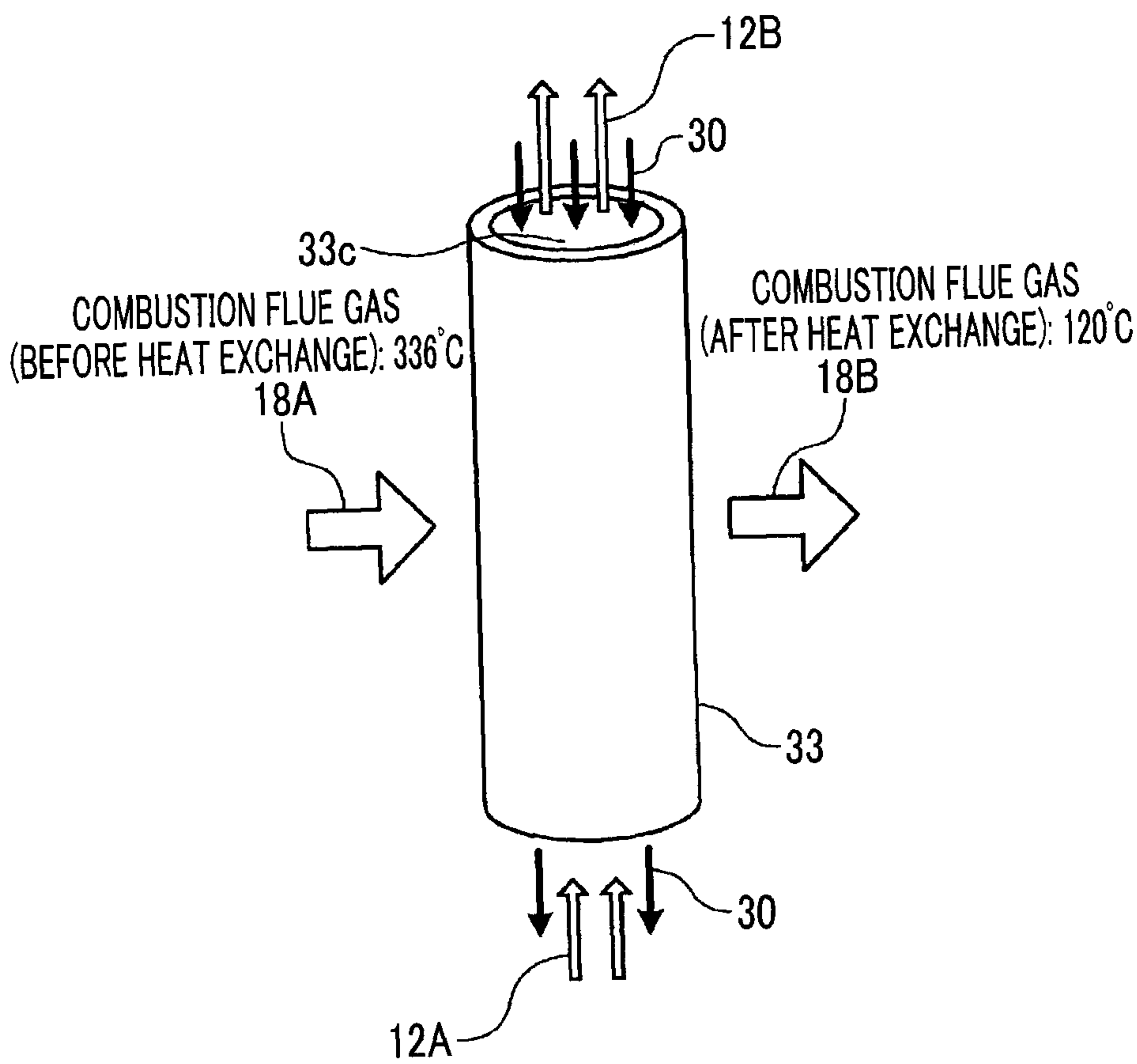

12B
30
33c
COMBUSTION FLUE GAS
(BEFORE HEAT EXCHANGE): 336°C
18A
COMBUSTION FLUE GAS
(AFTER HEAT EXCHANGE): 120°C
18B
33
30
12A

FIG. 4

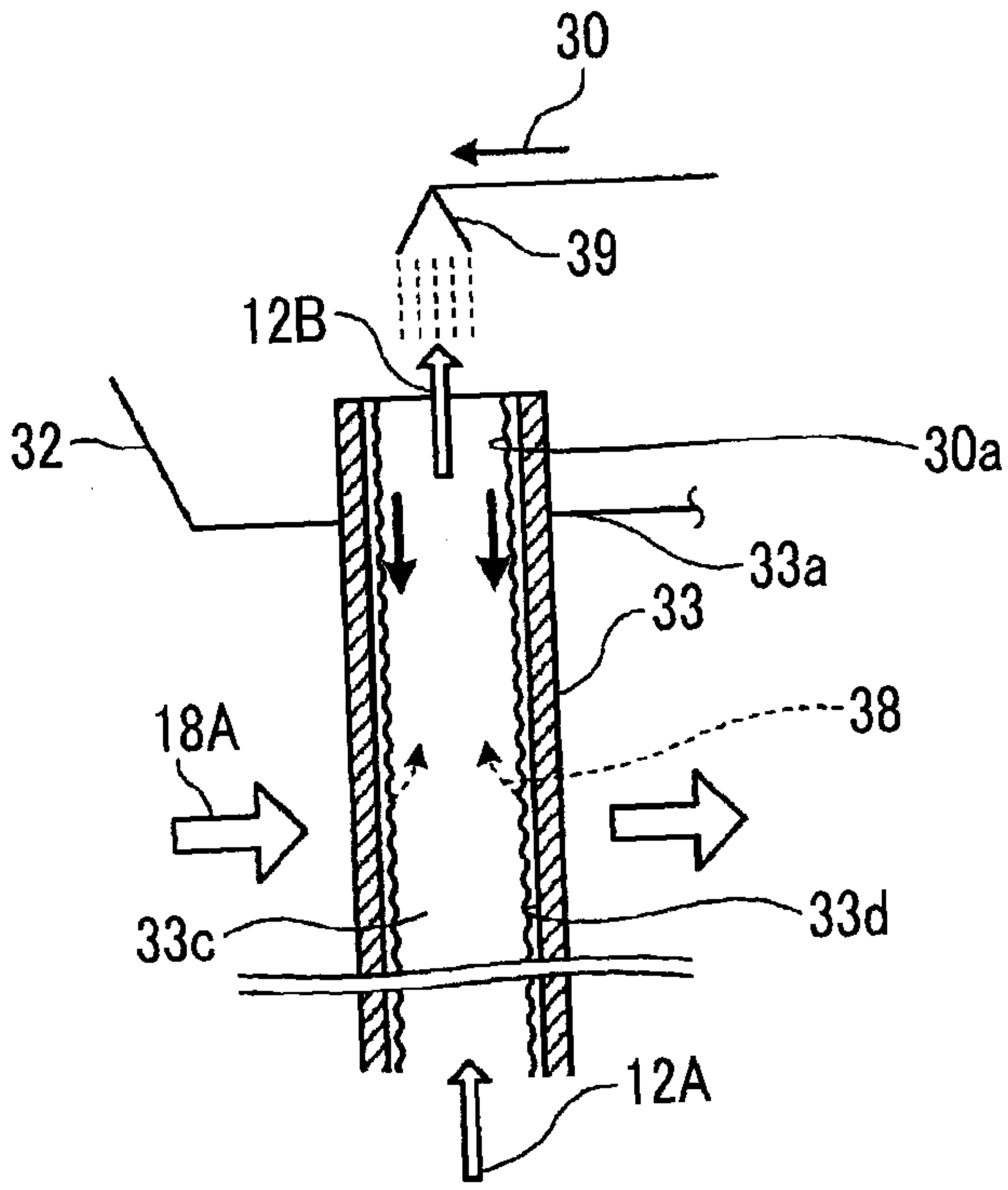

30
39
12B
32
30a
33a
33
38
18A
33c
33d
12A

FIG. 5

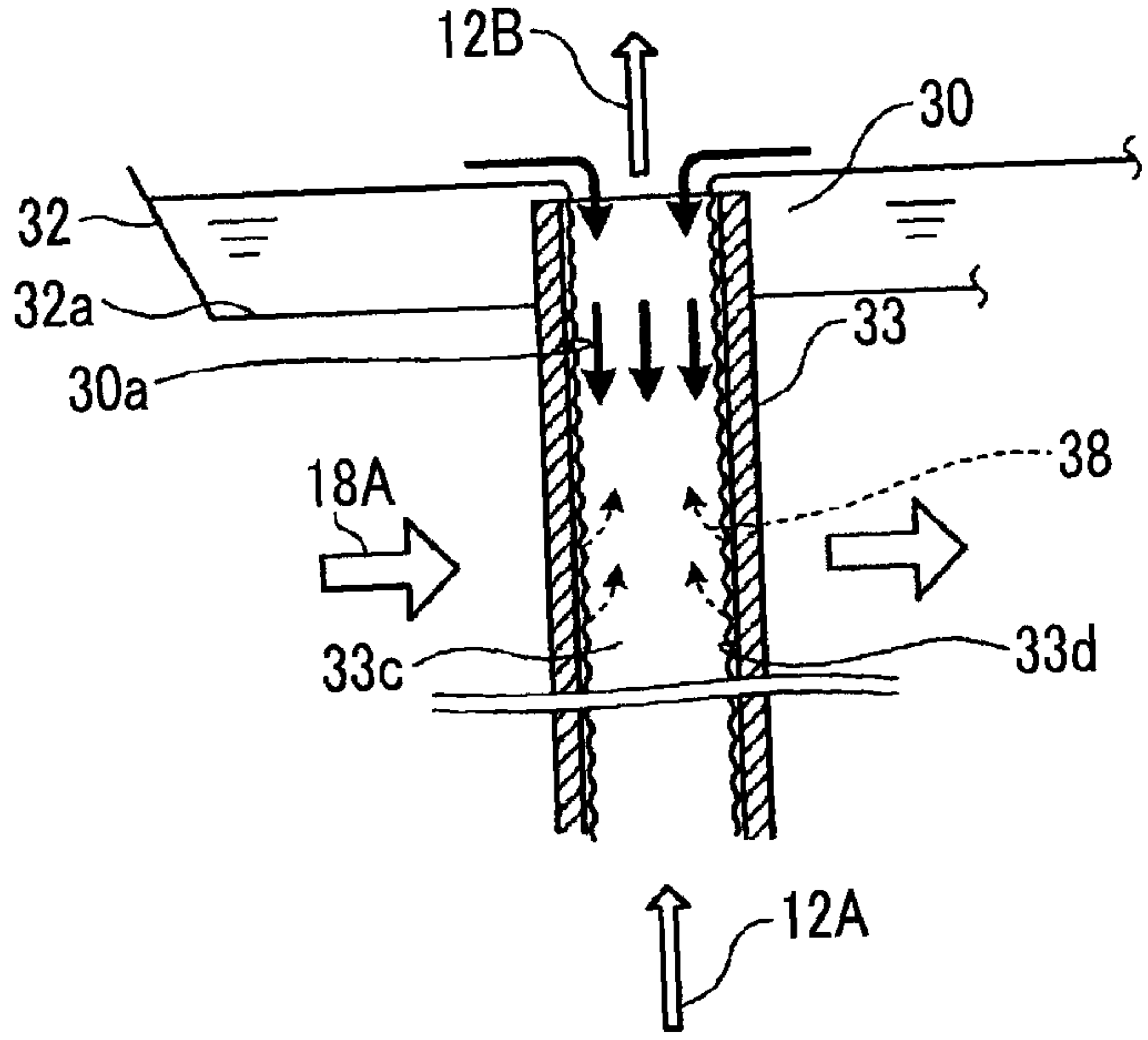

12B
30
32
32a
33
30a
38
18A
33c
33d
12A

FIG. 6

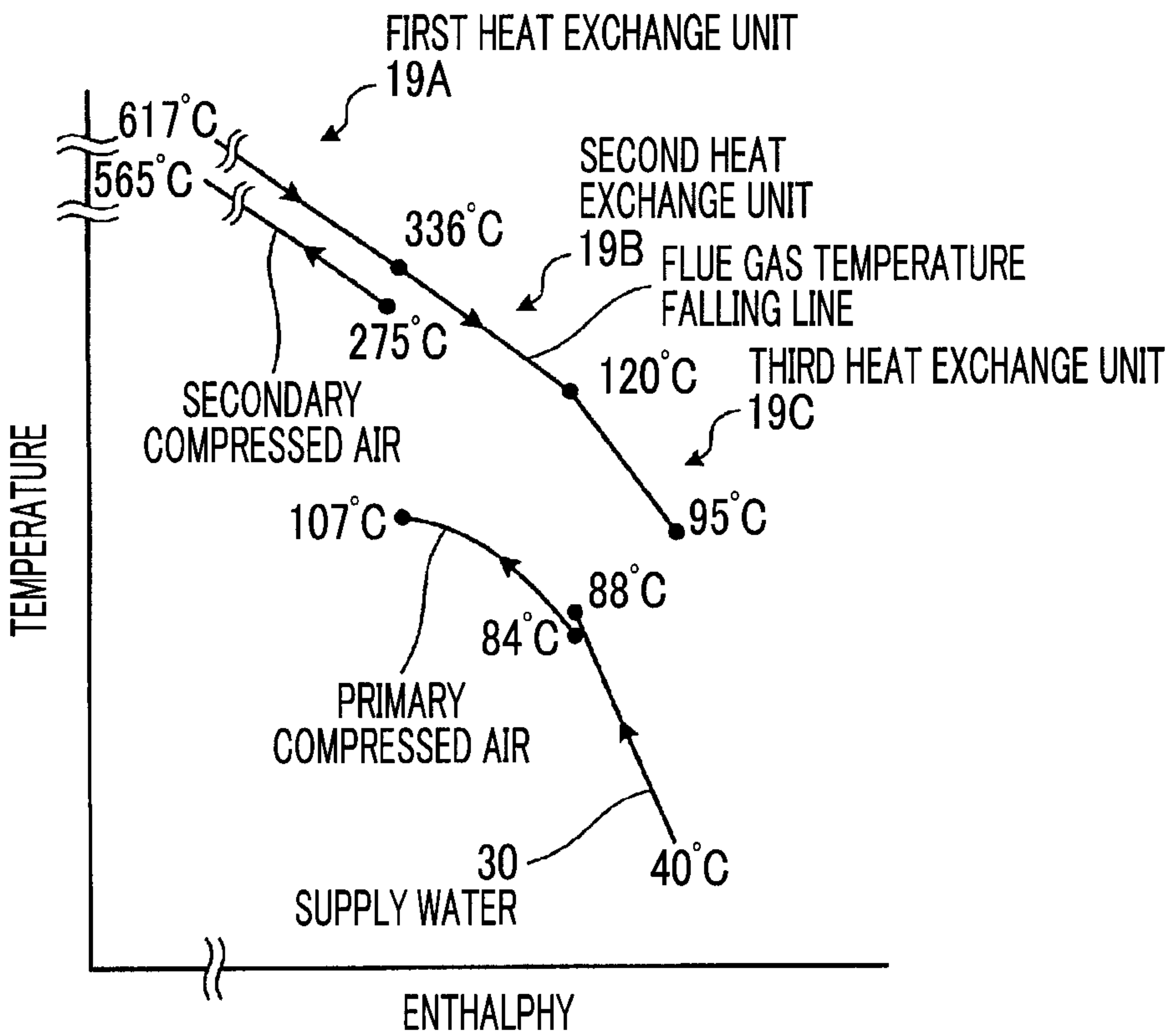

FIRST HEAT EXCHANGE UNIT
19A
617°C
565°C
336°C
SECOND HEAT
EXCHANGE UNIT
19B
FLUE GAS TEMPERATURE
FALLING LINE
275°C
120°C
THIRD HEAT EXCHANGE UNIT
19C
SECONDARY
COMPRESSED AIR
TEMPERATURE
107°C
95°C
88°C
84°C
PRIMARY
COMPRESSED AIR
30
SUPPLY WATER
40°C
ENTHALPHY

FIG. 7

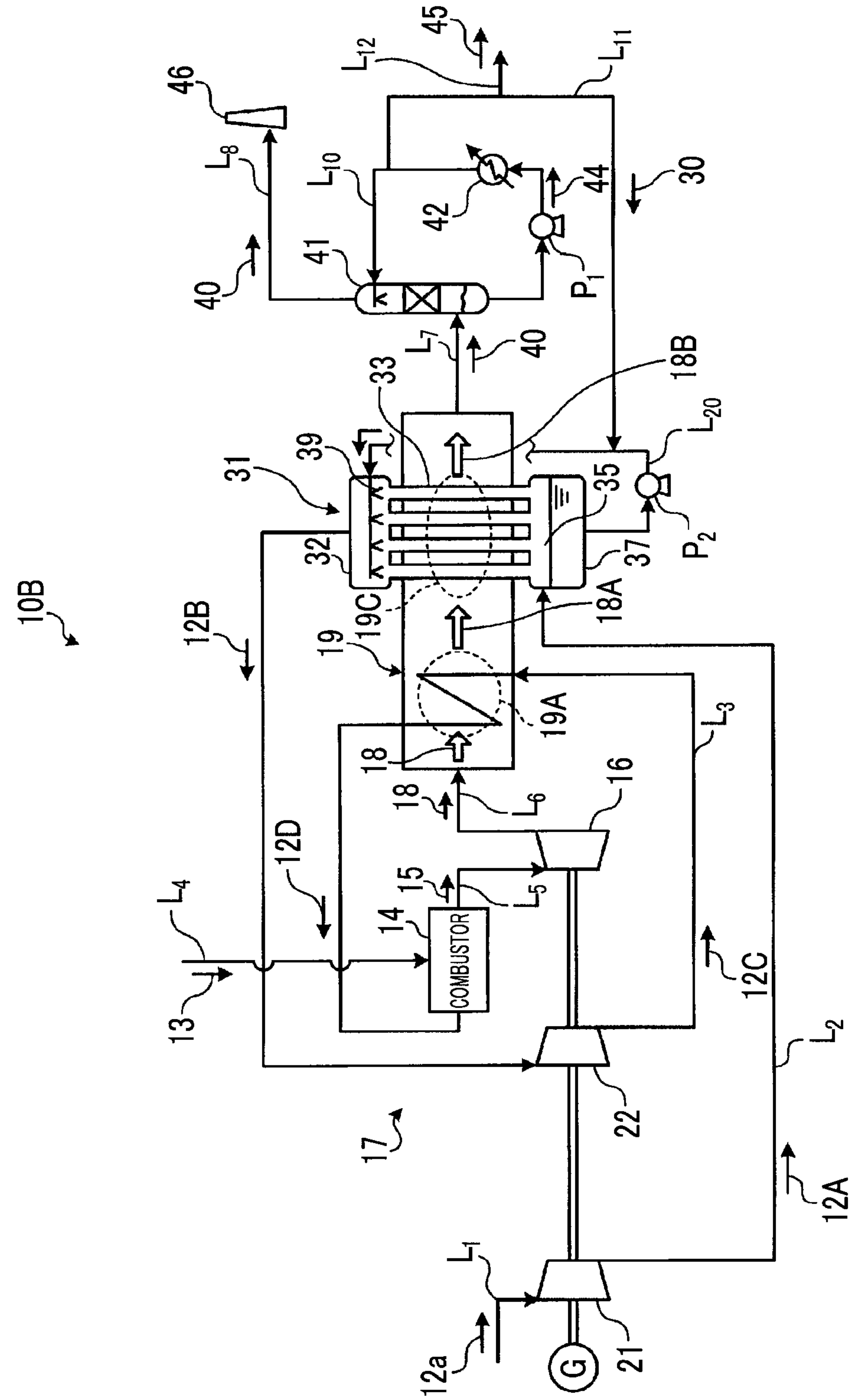
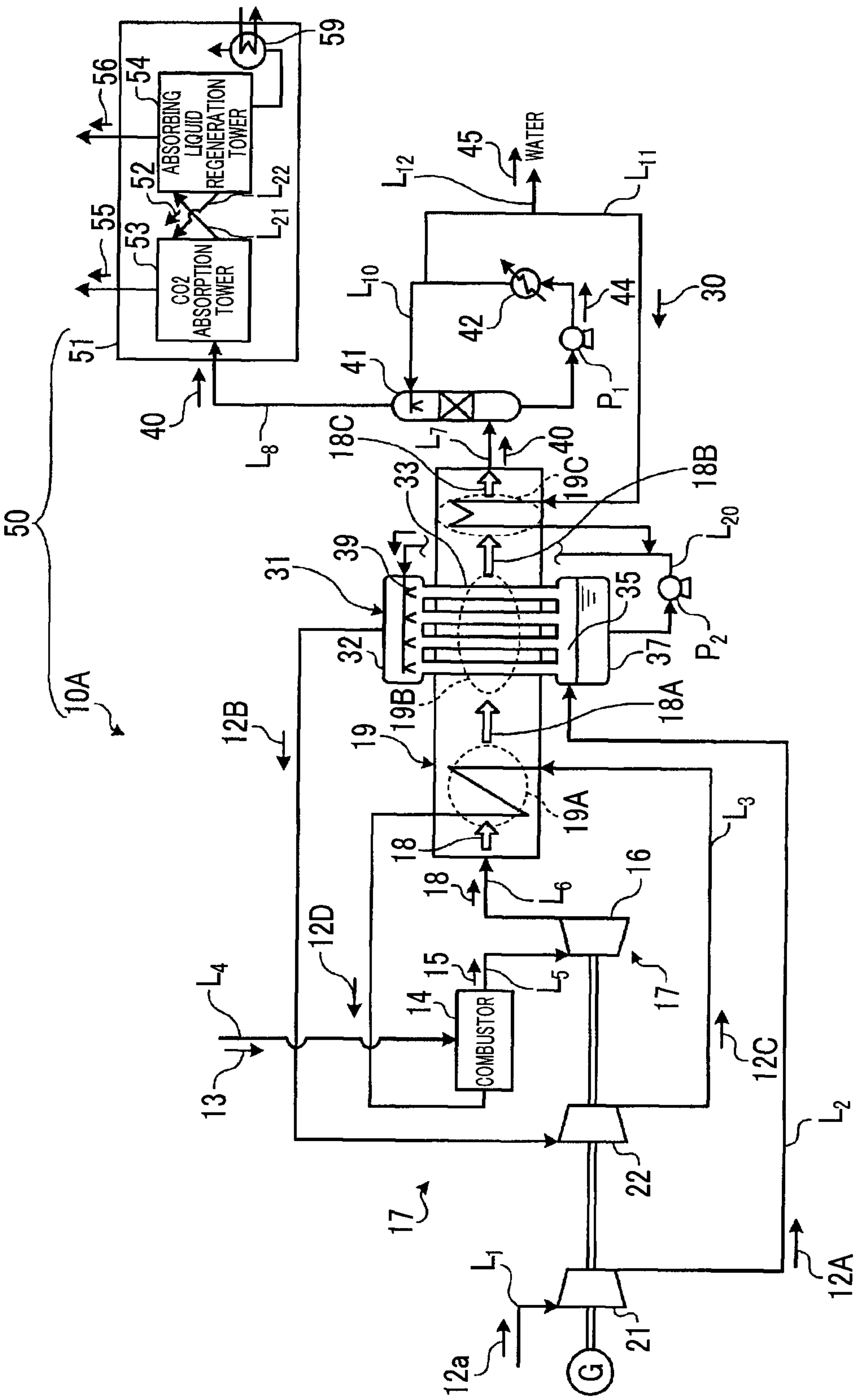

10B
COMBUSTOR
G
12a
21
L1
12A
L2
17
22
13
L4
14
15
L5
16
L6
18
12C
L3
12D
12B
19
19A
19C
18A
31
32
39
33
35
37
P2
L20
18B
L7
40
41
L8
46
L10
42
P1
44
L11
L12
45
30

FIG. 8


ABSORBING LIQUID REGENERATION TOWER
CO2 ABSORPTION TOWER
WATER
COMBUSTOR

14 Combustor

42 Cooler