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(54) Title: SYSTEM FOR PRODUCING THERMAL ENERGY

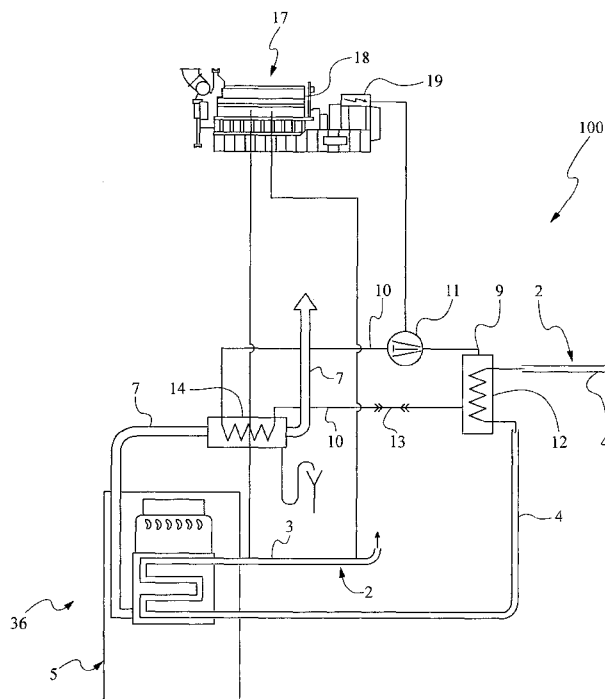


Fig. 1

(57) Abstract: System (100) for producing thermal energy comprising: - at least one heating network (2); - at least one boiler (5) connected with the said network (2) by means of at least one duct (3) for the delivery of a thermal fluid to the said network (2) and at least one duct (4) for the return the thermal fluid from the said network (2); said condensing boiler (5) comprising at least one combustion chamber fed with a fuel comprising hydrogen; - at least one duct (7) for discharging the flue gas coming from the said condensing boiler (5); characterized by comprising - at least one condenser (14) in which the flue gas is made to flow; - at least one unit (9) for heating the temperature of the thermal fluid at the return duct (4) for increasing the temperature of the thermal fluid entering the boiler.



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“System for producing thermal energy”

The present invention relates to a system for producing thermal energy.

In recent years considerable improvements have been achieved in hot
5 water production systems for space heating or sanitary water production.

For instance, condensing boilers have been introduced, which exploit the heat of condensation of water vapor contained in the flue gas for substantially increasing the amount of heat produced.

The fuels used in such boilers are substantially of three types:
10 methane or natural gas, fuel oil and liquefied petroleum gas, also called LPG.

These fuels comprise hydrogen in their molecule and thus water vapor is present in the flue gas.

The above is true for all the fuels, particularly for methane, chemical formula CH_4 , whose combustion produces one carbon dioxide molecule and
15 two water molecules.

WO 2006/111317 describes an heat exchange apparatus, particularly a condensing boiler, provided with an outer enclosure adapted to delimit a portion of space for containing the fluid to be heated, which is fed cold by means of a return duct located proximate to the base and flows out hot by
20 means of a delivery duct located proximate to the top of the enclosure. Such portion is crossed by flue gas conveyance tubes. The apparatus further has a bell-shaped element, which is located proximate the top of the abovementioned portion and is open at the lower end and closed at the top end. The bell-shaped element is provided with a thermostatic device adapted
25 to allow the fluid contained therein to flow out when a preset temperature is

reached.

The Applicant has noted that the condensation process is the more effective, the lower the temperature of the return water of the heating installation, which is the fluid used for cooling the condenser of the boiler.

5 In this way, the Higher Heating Value of the fuel is exploited rather than the Lower Heating Value, which is exploited in conventional boilers.

Energy saving installations require the lowest possible temperatures for the heating water.

Generally, the energy saving installation employs radiating panels, fan
10 coils or air treatment units, wherein the heating water temperature is in the first case about 35°C on the delivery side and 30°C on the return side, in the other cases 45°C on the delivery side and 40°C on the return side.

The lower the return temperature, the higher the amount of vapor contained in the flue gas which is condensed, resulting in a higher thermal
15 energy recovery.

In the abovementioned cases the temperature of the flue gas leaving the condenser is about 35-40°C for installations with panels, and 45-50°C in the other two cases considered above.

The saturation temperature of the flue gas or dewpoint temperature is
20 about 54°C and the humidity content is about 154 grams/m³.

The amount of water vapor which is condensed is about 60 grams/m³ if the temperature of the flue gas leaving the condenser is 40°C and about 40 grams/m³ if the flue gas temperature is 45-50°C.

Accordingly, the thermal recovery of a condensing boiler is limited by
25 the temperature of the return water in the installation and in many cases, such

as for example in installations with radiators, condensation is not possible or takes place only at the beginning and at the end of the season, when the heating needs are reduced and thus the heating water temperatures are relatively low.

5 The Applicant has thus noted that the use of condensing boilers often does not allow recovery of the latent heat of the water vapor contained in the flue gas, but in many cases just of the sensible heat, with short periods of time in which the latent heat recovery is possible.

10 The Applicant has found that by preheating the temperature of the thermal fluid entering the boiler and increasing the recovery of the heat of condensation of water vapor contained in the flue gas for achieving an average efficiency higher than 100% referred to the HHV (Higher Heating Value), it is possible to reduce fuel consumption keeping the heat produced by the system the same, or else to increase the heat produced by the system
15 keeping the fuel consumption the same.

In a first aspect thereof, the invention refers to a system for producing thermal energy comprising:

- at least one heating network;
- at least one heating device connected with the network by means of
20 at least one duct for the delivery of a thermal fluid to the said network and at least one duct for the return of the thermal fluid from the said network; the heating device comprising at least one combustion chamber fed with a fuel comprising hydrogen;
- at least one duct for discharging the flue gas coming from the said
25 heating device;

characterized by comprising

- at least one condenser in which the flue gas is made to flow;
- at least one unit for heating the temperature of the thermal fluid at the return duct for increasing the temperature of the thermal fluid entering the heating device.

Preferably, the heating device is a boiler.

According to an advantageous aspect, the thermal fluid is water.

Preferably, the heating unit comprises:

- a closed circuit in which a second thermal fluid flows;
- at least one compressor connected with the closed circuit and supplied with electrical energy for increasing the pressure of the second thermal fluid, flowing in the closed circuit;
- at least one heat exchanger connected with the closed circuit downstream the compressor for releasing heat to the return duct;
- at least one expansion device for lowering the pressure and, thus, the temperature of the second thermal fluid, said expansion device being connected with the closed circuit downstream the heat exchanger.

Advantageously, the expansion device comprises an expansion valve.

According to a preferred aspect, the expansion device is connected with the condenser.

Preferably, the system comprises a device for supplying electrical energy at least to the compressor.

Advantageously, the device for supplying electrical energy comprises a cogeneration device.

According to a preferred aspect, the cogeneration device comprises:

- at least one motor device;
 - at least one alternator for converting mechanical energy produced by the motor device into electrical energy;
 - at least one connection with the heating network for releasing to the
- 5 heating network heat produced by the cogeneration device.

Advantageously, the motor device is an explosion engine.

Preferably, the cogeneration device may be connected with the condenser for condensing the water vapor contained in the flue gas coming from the cogeneration device and recovering heat.

10 Preferably, the system may comprise a single enclosure for containing at least said boiler and said heating unit. This allows a reduction of the industrialization costs for the product, an increase in the overall reliability and easy installation.

Advantageously, the heating network may comprise at least one

15 radiating element.

Preferably, the heating network may comprise at least one fan coil.

Preferably, the heating network may comprise at least one air treatment unit.

Preferably, the heating network may comprise at least one radiator.

20 In order to increase efficiency, the system may suitably comprise a fin bank for allowing heat recovery from air outside the heating unit.

Alternatively, for the same purpose the system may comprise a fan.

Further features and advantages of the invention shall become clearer from the detailed description of some preferred but not exclusive

25 embodiments of a system for producing thermal energy according to the

present invention.

Such a description shall be presented hereafter with reference to the accompanying drawings, provided only for indicating, and thus non-limiting, purposes, wherein:

- 5 - figure 1 is a schematic view of a first embodiment of the system for producing thermal energy according to the present invention;
- figure 2 is a diagram representing a saturation line for methane; and
- figure 3 is a schematic view of a second embodiment of a system for producing thermal energy according to the present invention.

10 Referring to figure 1, a system for producing thermal energy according to the present invention is identified by reference numeral 100.

The system 100 comprises at least one heating network 2, in which a thermal fluid, preferably water, flows and provided with radiating panels and/or fan coils and/or air treatment units or radiators.

15 The heating network 2 is connected with at least one heating device, preferably a boiler 5, by means of at least one duct 3 for the delivery of the thermal fluid to the network 2 and at least one duct 4 for the return of the thermal fluid from the network 2.

20 The boiler 5 is provided with a combustion chamber fed with a fuel comprising hydrogen; in detail, the gaseous fuels fed to the boiler comprise hydrogen in their molecule and thus the flue gas deriving from their combustion contains water vapor.

 Preferably, the fuel fed to the combustion chamber is methane, chemical formula CH_4 , whose combustion produces one carbon dioxide
25 molecule and two water molecules.

The boiler is suitably dimensioned based on the thermal needs of the loads in the network 2.

At least one duct 7 for discharging the flue gas coming from the combustion chamber departs from the boiler.

5 According to a relevant aspect of the present invention the system 100 comprises:

- at least one condenser 14 in which the flue gas coming from the combustion chamber is made to flow, through the duct 7;
- at least one unit for heating the temperature of the thermal fluid at
10 the return duct 4, adapted to release heat to the said fluid for increasing the temperature of the thermal fluid entering the boiler 5.

The thermal fluid arriving from the network through the return duct 4 is thus brought by the heating unit 9 to a temperature of 60°C at the most, according to the kind of heating network.

15 Considering methane, as can be seen from figure 2, the saturation temperature of the flue gas or dewpoint temperature is about 54°C and the humidity content is about 154 grams/m³.

By increasing the temperature of the thermal fluid in the return duct 4 of the network it is possible to decrease the fuel consumption of the boiler 5, since through the heating group 9 it is possible to recover almost totally the
20 heat of condensation of water vapor contained in the flue gas of the boiler, reaching a coefficient of performance very close to 111%, that is the upper limit for methane.

The heating unit 9 comprises a closed circuit 10 in which a second
25 thermal fluid flows, said thermal fluid flowing through at least one compressor

11, at least one heat exchanger 12 for releasing heat to the return duct 4, at least one expansion device 13 for lowering the pressure and, thus, the temperature of the second thermal fluid flowing in the closed circuit 10. The condenser 14 is connected with the closed circuit 10 and the flue gas
5 discharge duct 7.

The compressor 11 is supplied with electrical energy and is the component which inputs energy into the heating unit 9. Inside the compressor 11 the pressure of the second thermal fluid, in the gas state, is increased.

Downstream the said compressor 11 at least one heat exchanger is
10 provided which releases heat to the return duct 4, for increasing the temperature thereof. In this exchanger the second thermal fluid changes its state, passing from the gas state to the liquid state.

An expansion device 13 is provided downstream the said exchanger 12. In the expansion device 13 the pressure of the second thermal fluid,
15 which is in the liquid state, and thus its temperature are considerably decreased.

Downstream the expansion device 13 and upstream the said compressor 11 there is provided the condenser 14, which absorbs heat from the flue gas discharge duct 7, for condensing the water vapor contained in the
20 flue gas and recovering heat.

The condenser 14, being crossed by the duct 7, acts as a condenser for the flue gas coming from the boiler 5 and as an evaporator for the closed circuit 10.

In the condenser 14, the second thermal fluid at low pressure and
25 temperature passes into the gas state by receiving heat from the flue gas

coming from the boiler. The second thermal fluid is now ready again to go through the cycle, passing through the compressor 11.

The compressor 11 of the heating unit 9 is supplied with electrical energy and has in turn a coefficient of performance varying from 5,5 to 4,5 (i.e., for each absorbed electric kilowatt, it delivers 5,5 to 4,5 thermal kilowatts) depending on the temperature of the return water of the heating installation, which cools down the condenser.

According to an advantageous aspect of the present invention the system can be contained within a single enclosure, not shown in the figure. This allows a reduction of the industrialization costs, an increase in the overall reliability and easy installation.

The heating network 2 of the system 100 may comprise radiating elements and/or panels and/or fan coils not explicitly shown.

In the case of radiating elements, the exchanger 12 heats the return water of the installation up to a temperature of 55-60°C and by means of the heating unit 9 the complete condensation of the flue gas during the entire heating season can be obtained.

In other words, by applying the teachings of the present invention, unlike what happens in current condensing boilers, coefficients of performance are reached that are close to the maximum theoretical value and condensation always takes place, during the entire heating season and not only when the external temperature is high enough to require low water temperatures in the heating installation, up to a return in the heating installation of 55/60°C.

As a device for supplying electrical energy to the compressor 11, the

system according to the present invention may comprise a cogeneration device 17.

The heating unit 9 according to the present invention is dimensioned for providing a refrigeration capacity which is sufficient for condensing the flue gas of the boiler 5 and of the cogeneration device 7 at a temperature close to 0°C or even lower, in any case such as to allow a wall temperature of the condenser 14 suitable for preventing frosting, so that the humidity contained in the flue gas deriving from methane or hydrocarbon combustion can be almost entirely condensed.

For this purpose, a mixture of water and antifreeze flows in the closed circuit 10 of the heating unit 9 as the second thermal fluid.

Preferably the antifreeze is glycol.

Alternatively, in the heat exchanger 14 flows water alone.

The dimensioning of the heating unit 9 is such that a refrigeration capacity can be generated which is sufficient for condensing the flue gas of the boiler and of the cogeneration device 17 to a temperature close to 0°C.

Such dimensioning allows also heat recovery from the air of the external environment, when the temperature thereof is higher than 0°C, by using the second thermal fluid (mixture of water and antifreeze) which prevents frost formation on the bank, thus making defrosting operations unnecessary.

The mixture of water and antifreeze, preferably glycol, is stored in a storage reservoir 40 of suitable volume, not shown in figure 1, so as to allow proper operation of the heating unit also in the presence of thermal load variations or when the boiler 5 is switched off because the desired

temperature has been reached.

The cogeneration device 17 is dimensioned for providing the electrical energy required for the operation of the heating unit 9 and of possible auxiliary appliances (such as for example pumps, etc.), but it can also be
5 suitably over-dimensioned to meet possible electric power needs of the final user.

Suitably, the cogeneration device 17 has an electric power lower than 50 kW, preferably lower than 40 kW, for example 30 kW.

Advantageously, the cogeneration device 17 has a thermal power
10 lower than 90 kW, preferably lower than 80 kW.

The cogeneration device 17 comprises at least one motor device 18, such as for example an internal-combustion engine, and at least one alternator 19 mechanically coupled with the motor device 18 for converting mechanical energy produced by the motor device into electrical energy.

15 Alternatively, the cogeneration device 17 might comprise a gas turbine or fuel cells.

Advantageously, in the embodiment show in figure 1 the motor device 18 is an explosion engine.

The heat generated by the motor device 18, contained in the flue gas, in the lubricating oil, and in the cooling water, is than released to the heating
20 network 2.

According to an advantageous aspect of the present invention, the flue gas produced by the motor device 18 flows through the condenser 14, by means of a duct not shown in the figure, for releasing heat to the heating
25 network 2.

While keeping the heat generated the same, it is thus possible a smaller dimensioning for the boiler 5. In this case, the following advantages are achieved. The boiler 5 operates with a coefficient of performance close to 111% referred to the lower heating value, thanks to the heating unit 9 which
5 produces thermal energy usable for condensing humidity contained in the flue gas coming from the combustion chamber.

The heating unit 9, in fact, releases the heat of condensation to the thermal fluid, preferably water, arriving from the return duct 4, while the cogeneration device 17, besides generating thermal energy usable by the
10 heating network 2, generates the electrical energy required for the operation of the heating unit 9.

According to an advantageous aspect of the present invention, it is further possible to connect the alternator 19 of the cogeneration device 17 also with an electric network, not shown in the figure, so that the electrical
15 energy produced by the cogeneration device 17 and not used by the compressor 11 can be supplied to said network.

According to another advantageous aspect, the system 100 comprises means for partializing the said boiler.

Preferably, for this purpose the system 100 comprises at least one
20 valve and control elements of the said valve. Accordingly, the heat pump, represented by the heating unit 9 and by the condenser 14, can recover heat from the air of the outside environment, while the cogeneration device 17 continues to operate at full regime.

The dewpoint temperature of the flue gas deriving from methane
25 combustion is about 54°C with a water vapor content of 154 grams per m³ of

flue gas.

Considering a flue gas temperature of 40°C, a sensible heat recovery and a latent heat recovery can be obtained as calculated below:

Temperature of the flue gas leaving the cogeneration device: 120°C

5 Flue gas specific heat: 0,29 kcal/m³

Latent heat of condensation: 573, 5 kcal/kg

Recovered sensible heat:

$$(120 - 40) \times 0,29 = 23,2 \text{ kcal/m}^3$$

$$0,054 \times 573,5 = 30,97 \text{ kcal/m}^3$$

10 Water content in the flue gas at 40°C:

$$100 \text{ grams/m}^3$$

$$\text{Total heat recovered: } 23,2 + 30,97 = 54,17 \text{ kcal/m}^3$$

The head loss on the flue gas side due to condensation will be compensated by means of a fan, not shown in the figure.

15 In the case of the present invention a further condensation will be performed by means of the expansion of a refrigerating gas at a temperature suitable for producing a mixture of water and glycol at a temperature of about 0°C, by means of the heating unit 9 with a temperature of the flue gas of about 4-5°C.

20 In this case the water content in the flues gas will be 10 grams/m³.

Recovered sensible heat, in addition to the amount indicated above:

$$(40 - 7) \times 0,29 = 9,57 \text{ kcal/m}^3$$

Recovered latent heat, in addition to the amount indicated above:

$$0,09 \times 590,5 = 53,14 \text{ kcal/m}^3$$

25 Total heat recovered, in addition to the amount indicated above:

$$9,57 + 53,14 = 62,71 \text{ kcal/m}^3$$

An example can be useful for making clearer what stated above.

As an example, the manufacturer's data of a cogeneration device with 25 kW of electric power are reported:

- 5 Electric power 25 kW
- Thermal power 47 kW
- Methane consumption 8,4 m³/h
- Power of the inlet fuels 79,5 kW
- Electric efficiency 31,4%
- 10 Thermal efficiency 59,1%
- Total efficiency 90,5%
- Exhaust gas temperature 120°C
- Exhaust gas volume 84 Nm³/h.

Furthermore, by means of a fan the device disperses 6,5 kW deriving
15 from the cooling of the alternator and the radiation heat of the internal combustion engine.

This heat shall be released at low temperature so that the inlet air, at the soundproof enclosure of the device, has a temperature not higher than 40°C.

20 This thermal energy can be removed from the heating unit 9.

Total heat recovered from condensation with return water at 30°C:

54,17 kcal/m³ (see line 14 page 13) corresponding to $54,17 \times 84 \text{ Nm}^3 =$
4550,28 kcal/h

$$4550,28 / 860 = 5,29 \text{ kW}.$$

25 Heat recovered from condensation with heat pump:

62,71 kcal/m³ corresponding to $62,71 \times 84 \text{ Nm}^3 = 5267,64 \text{ kcal/h}$.

$$5267,64 / 860 = 6,12 \text{ kW}$$

Total heat recovered:

$$6,5 + 5,29 + 6,12 = 17,91 \text{ kW}$$

- 5 The thermal power generated by the cogeneration device changes from 47 kW to $47 + 17,91 = 64,91$.

Total power, electrical + thermal, generated by the cogeneration device:

$$25 + 64,91 = 89,91$$

- 10 Thermal power generated by the methane combustion 79,5 kW.

Coefficient of performance C.O.P.

$$88,91 / 79,5 = 1,131$$

$$113,1 - 90,5 = 22,59\%$$

- 15 The value slightly higher than the theoretical one is due to approximations.

This %-value represents the increase in the total efficiency of the device, obtained through the condensation at low temperature, made possible by the use of the heat pump.

- 20 Actually, considering the C.O.P. of the heating unit equal to 5,3, for producing the thermal energy from condensation (excluding the amount produced from condensation by means of the return water of the heating installation) the following electric power, produced by the cogeneration device, must be spent: $6,12 + 6,5 = 12,62$

$$12,62 / 5,3 = 2,38 \text{ kW}.$$

- 25 Total thermal power available to the installation:

$$64,91 + 2,38 = 67,29 \text{ kW.}$$

The electric power is released to the heating water in form of heat.

In order to increase efficiency, the system may suitably comprise a fin bank for allowing heat recovery from air outside the heating unit.

5 Alternatively, for the same purpose the system may comprise a fan.

In figure 3 an alternative embodiment of the system 100 for producing thermal energy according to the present invention is shown which is totally similar to that shown in figure 1, apart from the presence of a first exchanger 14' intended for the condensation of the flue gas coming from the boiler 5 and
10 a second exchanger 14" intended for the condensation of the flue gas coming from the cogeneration device 17.

In figure 3 a circulation pump 21 and a storage reservoir 40 are further shown.

Furthermore, in such an embodiment a circulation pump in the return
15 duct of the network 2 and a gate valve 23 are included in a known manner.

The present invention has been described with reference to some embodiments thereof. Many modifications can be introduced in the embodiments described in detail, falling anyhow within the scope of protection of the invention, which is defined by the following claims.

CLAIMS

1. System (100) for producing thermal energy comprising:
 - at least one heating network (2);
 - at least one heating device (36) connected with the said network (2)
- 5 by means of at least one duct (3) for the delivery of a thermal fluid to the said network (2) and at least one duct (4) for the return of the thermal fluid from the said network (2);
 - at least one heating device (36); said heating device (36) being a boiler (5) comprising at least one combustion chamber fed with a fuel
- 10 comprising hydrogen;
 - at least one duct (7) for discharging the flue gas coming from the said heating device (36);
- characterized by comprising
 - at least one condenser (14,14',14'') in which the flue gas is made to
- 15 flow;
 - at least one unit (9) for heating the temperature of the thermal fluid at the return duct (4) for increasing the temperature of the thermal fluid entering the heating device (36);
 - at least one cogeneration device (17) for supplying electrical energy
- 20 to the said heating unit (9).
2. System (100) according to claim 1, characterized in that said fuel is methane.
3. System (100) according to anyone of the previous claims, characterized in that said thermal fluid is water.
- 25 4. System (100) according to anyone of the previous claims,

characterized in that said heating unit (9) comprises:

- a closed circuit (10) in which a second thermal fluid flows;
- at least one compressor (11) connected with the said closed circuit (10) and supplied with electrical energy for increasing the pressure of the second thermal fluid, flowing in the said closed circuit (10);
- at least one heat exchanger (12) connected with the said closed circuit (10) downstream said compressor (11) for releasing heat to the return duct (4);
- at least one expansion device (13) for lowering the pressure and, thus, the temperature of the second thermal fluid, said expansion device (13) being connected with the said closed circuit (10) downstream the said heat exchanger (12).

5. System according to anyone of the previous claims, characterized in that said expansion device (13) comprises an expansion valve.

15 6. System according to anyone of the previous claims 4 to 5, characterized in that said expansion device (13) is connected with said condenser (14).

7. System (100) according to anyone of the previous claims, characterized in that said cogeneration device (17) supplies electrical energy to the said compressor (11).

8. System according to claim 1, characterized in that said cogeneration device (17) comprises:

- at least one motor device (18);
- at least one alternator (19) for converting mechanical energy produced by the motor device into electrical energy;

- at least one connection with the heating network for releasing to the said heating network (2) heat produced by the said cogeneration device (17).

9. System according to claim 8, characterized in that said motor device (18) is an explosion engine.

5 10. System according to anyone of claims 7 to 10, characterized in that said cogeneration device (17) is connected with the said condenser (14) for condensing the water vapor contained in the flue gas coming from the said cogeneration device (17) and recovering heat.

10 11. System according to anyone of the previous claims, characterized by comprising a single enclosure for containing at least said boiler (5) and said heating unit (9).

12. System according to anyone of the previous claims, characterized in that said heating network (2) comprises at least one radiating element.

15 13. System according to anyone of the previous claims, characterized in that said heating network (2) comprises at least one air treatment unit.

14. System according to anyone of the previous claims, characterized in that said heating network (2) comprises at least one radiator.

15 15. System according to anyone of the previous claims, characterized by comprising means for partializing the said boiler.

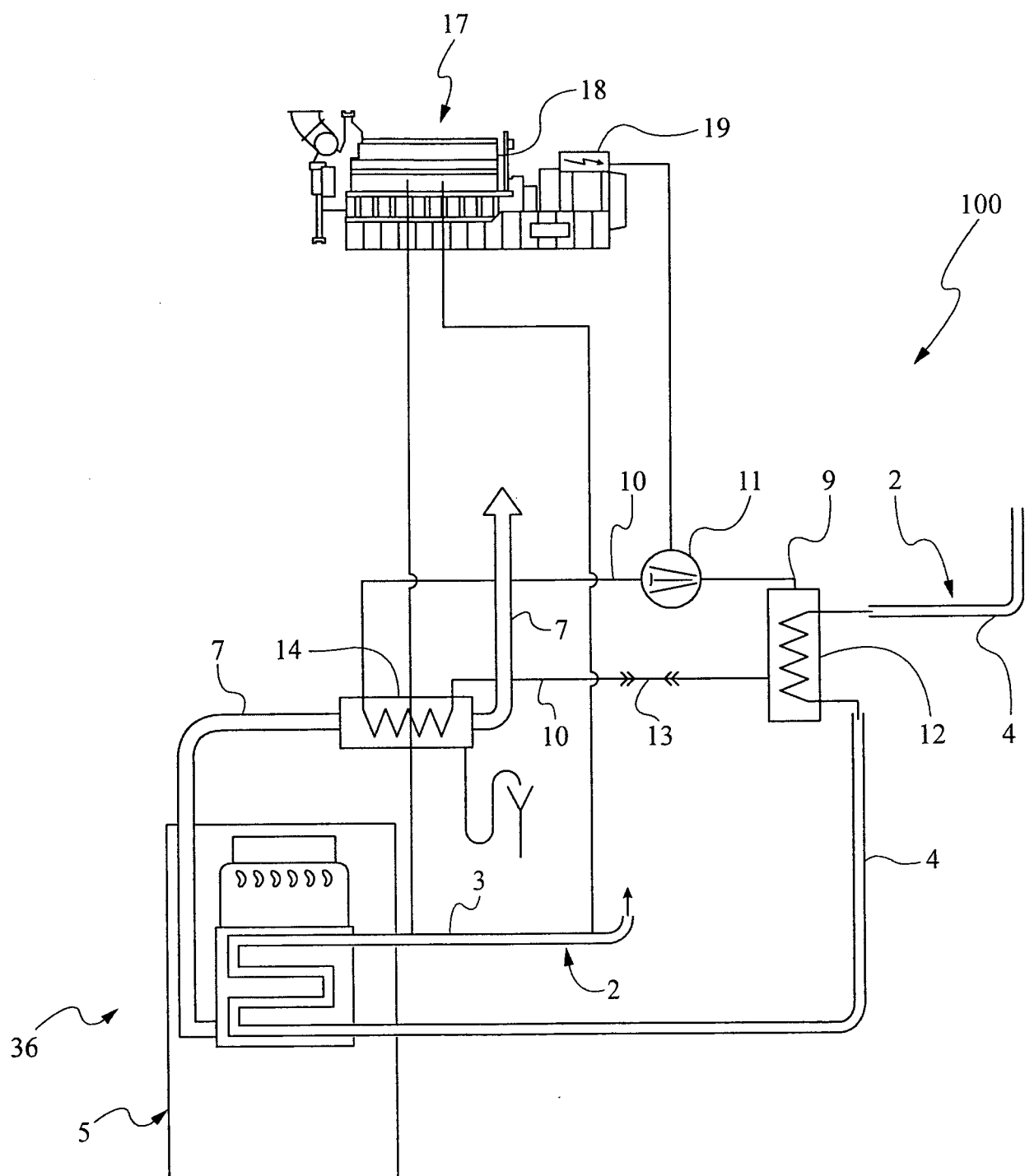


Fig. 1

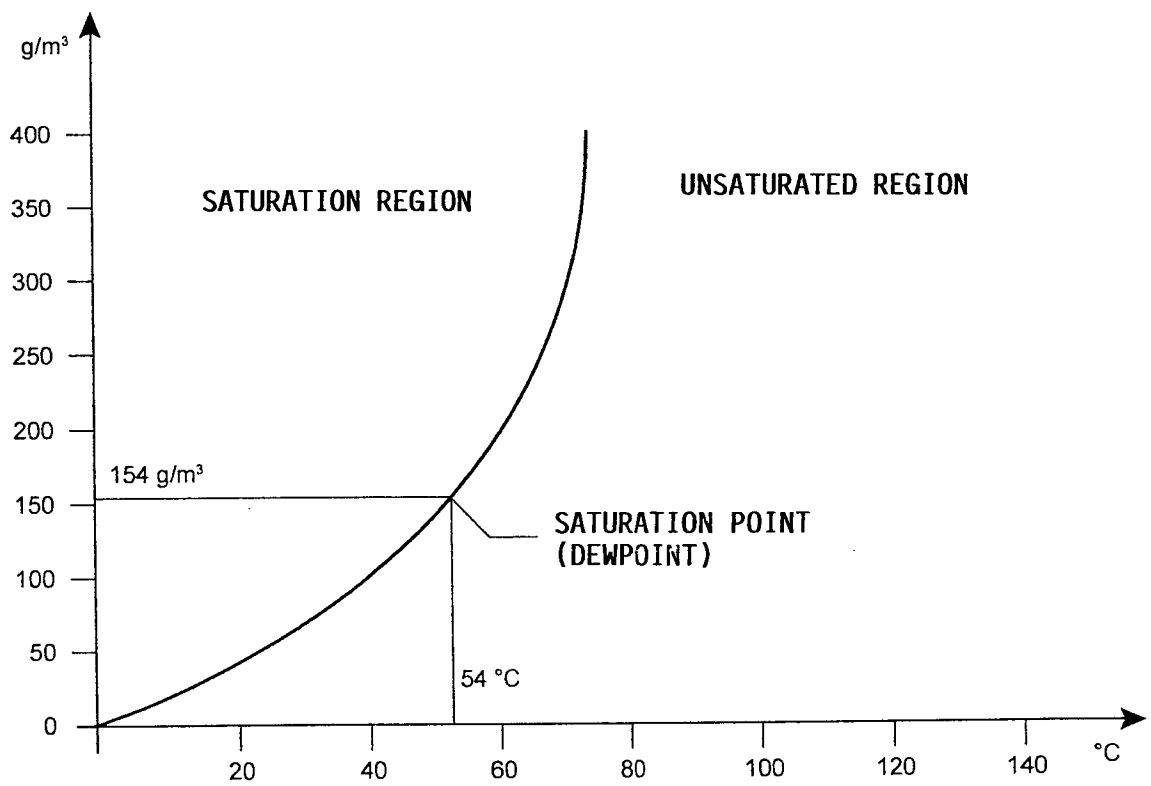


Fig. 2

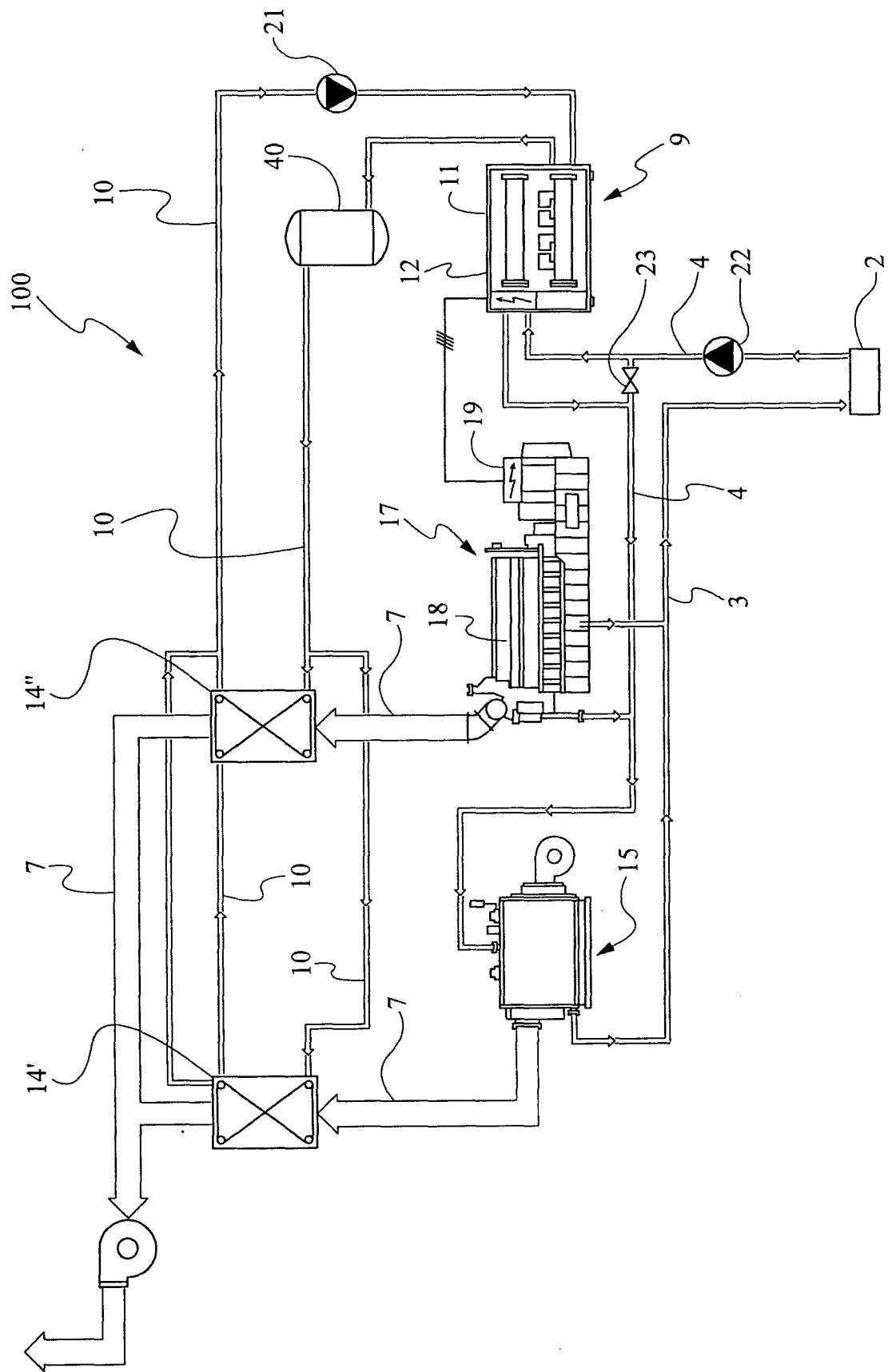


Fig. 3