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 (54) Title: HIGH EFFICIENCY FEEDWATER HEATER

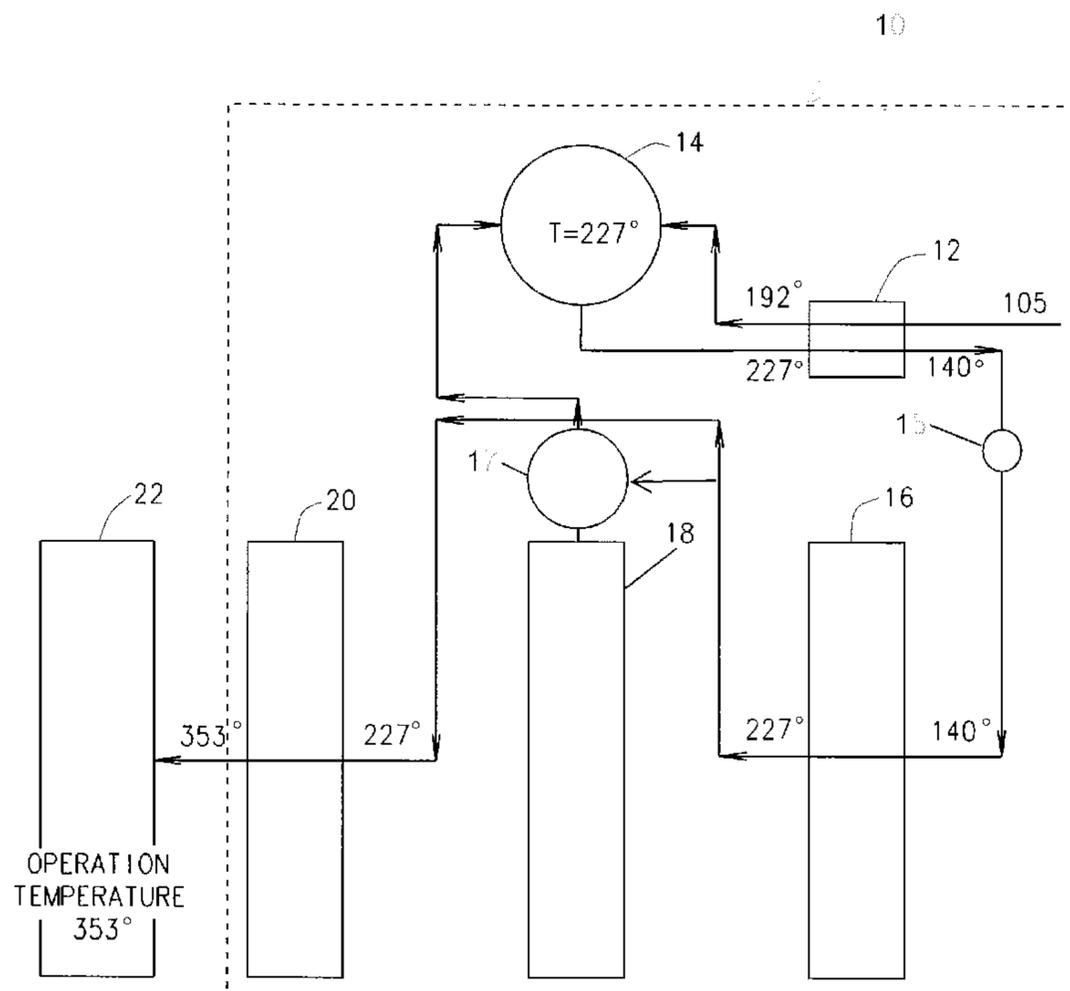


FIG. 2

(57) Abrégé/Abstract:

A feedwater heater (10) for a steam generator communicating feedwater through an external heat exchanger (12), a deaerator (14) that allows the use of carbon steel feedwater tubes, a first heater (16), an evaporator section (18) and steam drum (17) for communicating a portion of the feedwater in the form of steam to the deaerator (14), and a second heater (20).



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## HIGH EFFICIENCY FEEDWATER HEATER

### CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority to United States Provisional  
5 Application No. 60/895,437 filed March 22, 2007 entitled HIGH  
EFFICIENCY FEEDWATER HEATER and which is incorporated herein  
by reference.

### BACKGROUND ART

The invention relates in general to steam generators or boilers  
10 and more particularly to a feedwater heater and feedwater heating  
process for a heat recovery steam generator.

Natural gas represents a significant fuel to produce of electrical  
energy in the United States. It burns with few emissions, and is  
available throughout much of the country. Moreover, the plants which  
15 convert it into electrical energy are efficient and, in comparison to  
hydroelectric projects and coal-fired plants, they are relatively easy and  
inexpensive to construct. In the typical plant, the natural gas burns in a  
gas turbine, causing the rotor of the turbine to revolve and power an  
electrical generator to which the rotor is connected. Turbine exhaust  
20 gases – essentially air, carbon dioxide and steam – leave the gas  
turbine at about 1200°F (649°C) and are a significant source of energy.  
To harness this energy, the typical combined cycle, gas-fired, power  
plant also has a heat recovery steam generator (HRSG) through which  
the hot exhaust gases pass to produce steam which powers a steam  
25 turbine which, in turn, powers another electrical generator. The exhaust  
gases leave the HRSG at temperatures as low as 150°F (66°C).

The steam turbine and the HRSG operate within a loop that also  
contains a condenser and a feedwater pump. The steam generated by

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the HRSG passes through the turbine and then into the condenser where it is condensed back into liquid water. The pump delivers that water to the HRSG at about 100°F (38°C) or perhaps a lower temperature. The water enters the HRSG at a feedwater heater or  
5 economizer which elevates its temperature for subsequent conversion into steam within an evaporator and superheater that are also part of the HRSG.

Often the feedwater requires deaeration with a deaerator to remove dissolved gases from the feedwater to prevent corrosion of the  
10 system. Feedwater entering a deaerator needs to be approximately 20°F below the deaerator operating temperature for proper operation. The temperatures shown in Fig.1 are merely illustrative as the temperatures can vary depending on the application.

Generally, feedwater heaters have tubes produced from costly  
15 high alloy material to withstand the dissolved gases in feedwater, such as a high oxygen concentration. Therefore, it would be advantageous to remove the dissolved gases from the feedwater so that feedwater heater tubes can be produced using more economical materials, such as carbon steel.

## 20 BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings which form part of the specification:

Figure 1 is a schematic of a prior art feedwater heater configuration for a heat recovery steam generator; and

25 Figure 2 is a schematic of a feedwater heater configuration for a heat recovery steam generator in accordance with the present invention.

Corresponding reference numerals indicate corresponding parts throughout the several figures of the drawings.

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BEST MODE FOR CARRYING OUT THE INVENTION

The following detailed description illustrates the invention by way of example and not by way of limitation. The description clearly enables one skilled in the art to make and use the invention, describes several  
5 embodiments, adaptations, variations, alternatives, and uses of the invention, including what is presently believed to be the best mode of carrying out the invention.

Figure 2 shows an embodiment of the present invention, generally referred to as a high efficiency feedwater heater 10 for a Heat  
10 Recovery Steam Generator (HRSG). An external heat exchanger 12 heats incoming feedwater, preferably from about 105°F to about 192°F, which then flows from the external heat exchanger 12 into a deaerator 14 for removing oxygen from the feedwater. From the deaerator 14, feedwater flows through the external exchanger 12 to cool the feedwater  
15 down, preferably from about 227°F to about 140°F. A pump 15 delivers feedwater to the a first stage heater 16 which heats the feedwater from about 140°F to about 227°F. A designated portion of the feedwater from the first stage heater 16 flows to a steam drum 17 and feedwater evaporator 18, which communicates the feedwater in the form of steam  
20 to the deaerator 14. The balance of the feedwater from the first stage heater 16 flows through a second stage heater 20, which heats the feedwater from about 227°F to about 353°F, to an LP evaporator 22.

With this approach, only deaerated water flows through the feedwater heater sections. Thus, the feedwater heater tubes can  
25 comprise carbon steel, or other suitable material, rather than higher cost high alloy material. The savings of using carbon steel tubes instead of high alloy tubes in the heater coils offsets the cost of adding the feedwater evaporator, pump, and external exchanger to the HRSG. It also avoids stress corrosion cracking associated with some high alloy  
30 heater tubes.

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Moreover, the steam drum 17 and feedwater evaporator 18 can be chemically treated with solid alkalis such as phosphates or caustic, thereby, reducing the possibility of flow accelerated corrosion. Flow accelerated corrosion is a major problem in low pressure evaporators without solid alkali chemical treatment. The Electric Power Research Institute (EPRI), an independent, nonprofit center for public interest energy and environmental research, recommends the use of solid alkalis in its most recent HRSG water chemistry guidelines. If there is no concern of chemically treating the feedwater evaporator 18 with solid alkalis, the feedwater evaporator circulation can be through the deaerator 14 and a separate steam drum 17 can be omitted.

In the embodiment of Fig. 2, the deaerator 14 and external heat exchanger 12 do not need to be located on top of the HRSG. Even though relocating the deaerator 14 and exchanger 12 takes more plant plot space, this can result in savings in comparison to a conventional integral deaerator.

While Figure 2 shows a feedwater heater 10 with a first heater 16 and a second heater 20, those skilled in the art will recognize that other configurations can be used. For example, the feedwater heater 10 can include only the first stage heater 16 or only the second stage heater 20.

In contrast to the prior art shown in Fig. 1, The HRSG of the present invention does not require a temperature difference between the incoming feedwater and the evaporator operating temperature because the feedwater has already been deaerated within the deaerator 14. Therefore, the previously required 20°F approach may be reduced to 0°F approach. Moreover, the evaporator 22 may produce more low-pressure steam than was ever possible before by preheating low pressure feedwater to saturation with the feedwater heater 10 before entering the evaporator 22 downstream.

In some steam generators the feedwater heater is referred to as an "economizer" or "feedwater preheater", and in some instances the

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use of “feedwater heater” or “feedwater preheater” or “economizer” depends on the location of the device in relation to the pump. Here the expression “feedwater heater” not only identifies a device of that name, but also a feedwater preheater and an economizer located downstream  
5 in the direction of gas flow from the last boiler or evaporator in a steam generator.

The feedwater heater 10 has utility beyond HRSGs used to extract heat from the gases discharged by gas turbines. Indeed, it may be used with steam generators in a wide variety of applications,  
10 including those that extract heat from the combustion of about any type of fossil fuel and with those that extract heat from the gases derived from the incineration of waste.

Changes can be made in the above constructions without departing from the scope of the invention, it is intended that all matter  
15 contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

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CLAIMS:

1. A feedwater heater, comprising:
  - an external heat exchanger having an inlet for receiving feedwater and an outlet;
  - a deaerator having at least one outlet and having an inlet for receiving feedwater discharged from the outlet of the external exchanger;
  - a first heater having an outlet and having an inlet for receiving feedwater discharged from the outlet of the deaerator and communicated through the external heat exchanger and;
  - an evaporator section having an outlet and having an inlet for receiving a portion of the feedwater discharged from the outlet of the first heater, and an outlet for communicating steam to the deaerator; and
  - a second heater having an outlet and having an inlet for receiving a remaining portion of the feedwater discharged from the outlet of the first heater.
2. The feedwater heater of claim 1, further comprising:
  - an evaporator having an inlet for receiving feedwater discharged from the outlet of the second heater.
3. The feedwater heater of claim 2, wherein the temperature of the feedwater discharged from second heater is about the same as the operating temperature of the evaporator.
4. The feedwater heater of claim 1, further comprising, feedwater tubes of carbon steel.
5. A feedwater heater for a steam generator, comprising
  - an external heat exchanger having an outlet and having an inlet for receiving feedwater, the external exchanger configured to elevate the temperature of the incoming feedwater;

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a deaerator having at least one outlet and having an inlet for receiving feedwater discharged from the outlet of the external exchanger;

a first heater having an outlet and having an inlet for receiving feedwater discharged from the outlet of the deaerator and communicated through the external heat exchanger, the first heater elevating the temperature of the feedwater;

an evaporator section having an inlet for receiving a portion of the feedwater from the outlet of the heater, and an outlet for communicating steam and water to the deaerator; and

a second heater having an outlet and having an inlet for receiving a remaining portion of the feedwater discharge from the outlet of the first heater, the second heater configured to elevate the temperature of the feedwater.

6. The feedwater heater of claim 5, further comprising:

an evaporator having an inlet for receiving feedwater discharged from the outlet of the second heater.

7. The feedwater heater of claim 6, wherein the temperature of the feedwater discharged from second heater is about the same as the operating temperature of the evaporator.

8. The feedwater heater of claim 5, further comprising, feedwater tubes of carbon steel.

9. A process for heating feedwater for a steam generator, comprising:

directing the feedwater into a first portion of an external heat exchanger to elevate the temperature of the incoming feedwater;

directing the feedwater into a deaerator to remove gases from the feedwater;

directing the feedwater to a second portion of the external exchanger to elevate the temperature of the feedwater within the first portion of the external exchanger;

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directing the feedwater to a first heater to elevate the temperature;

directing a portion of the feedwater to a feedwater evaporator;  
and

directing a remaining portion of the feedwater to a second heater to elevate the temperature of the feedwater.

10. The feedwater heater of claim 8, further comprising:

directing the feedwater to an evaporator having an inlet for receiving feedwater discharged from the outlet of the second heater wherein the temperature of the feedwater discharged from second heater is about the same as the operating temperature of the evaporator.

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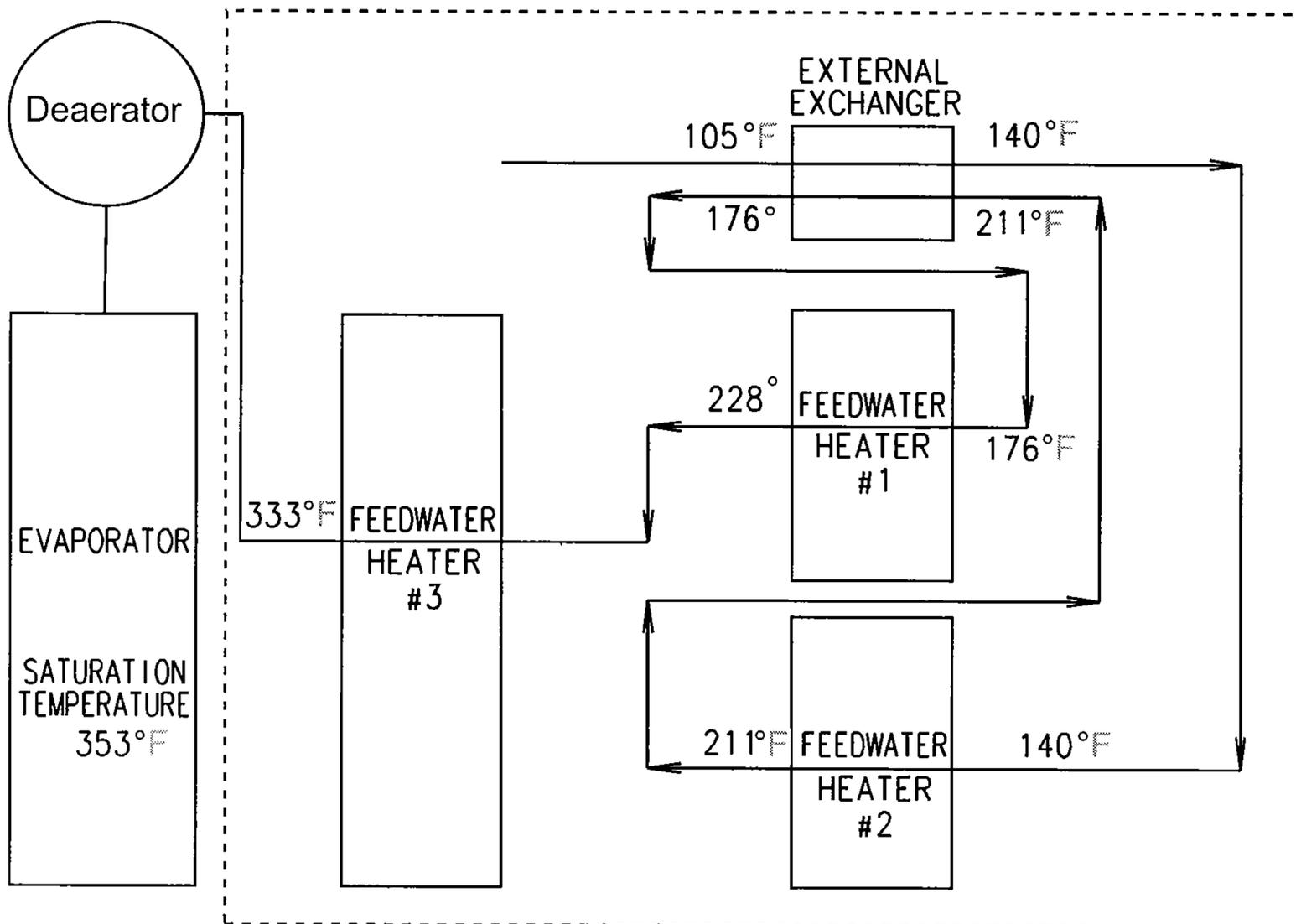


FIG. 1  
PRIOR ART

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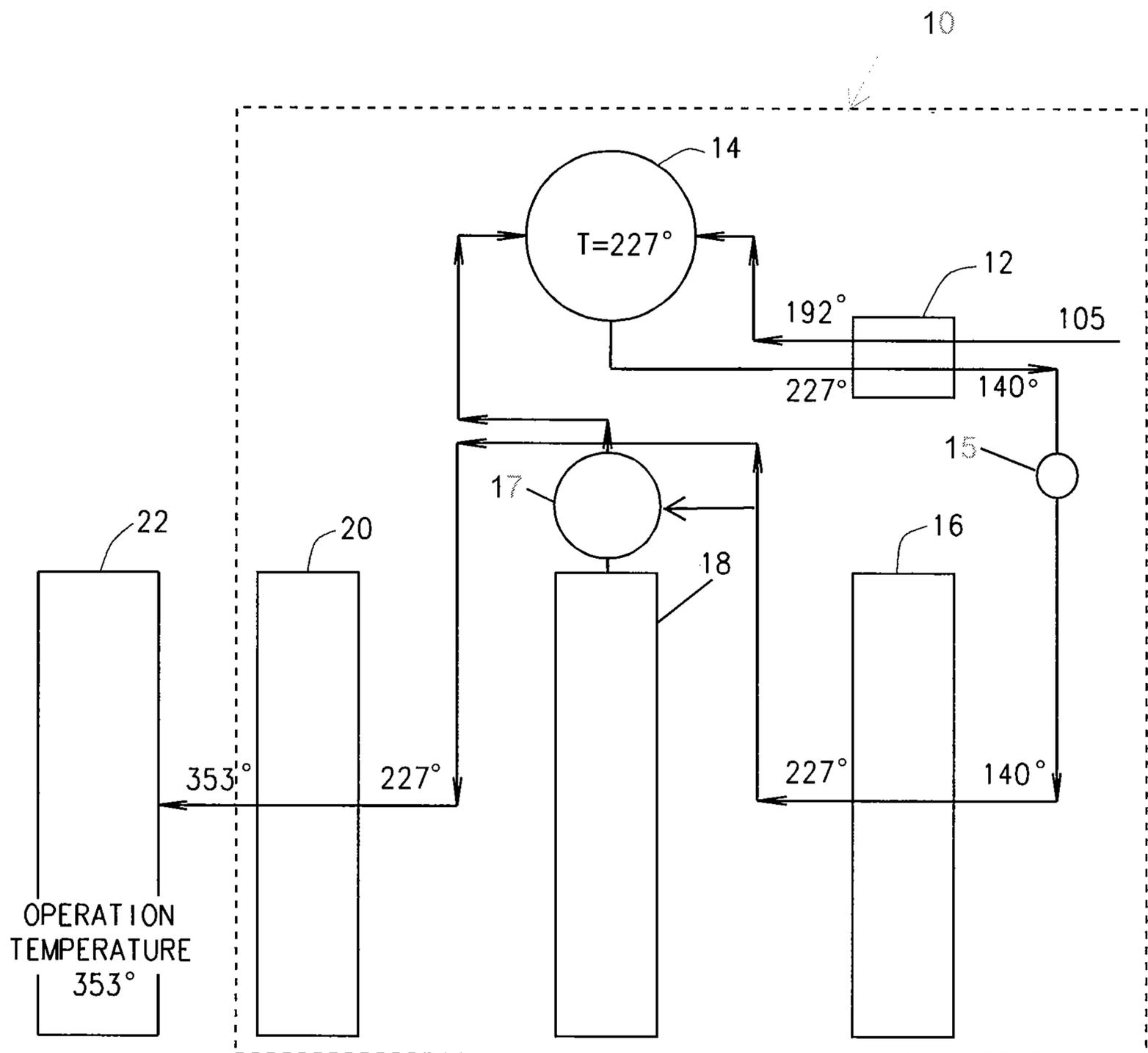


FIG. 2

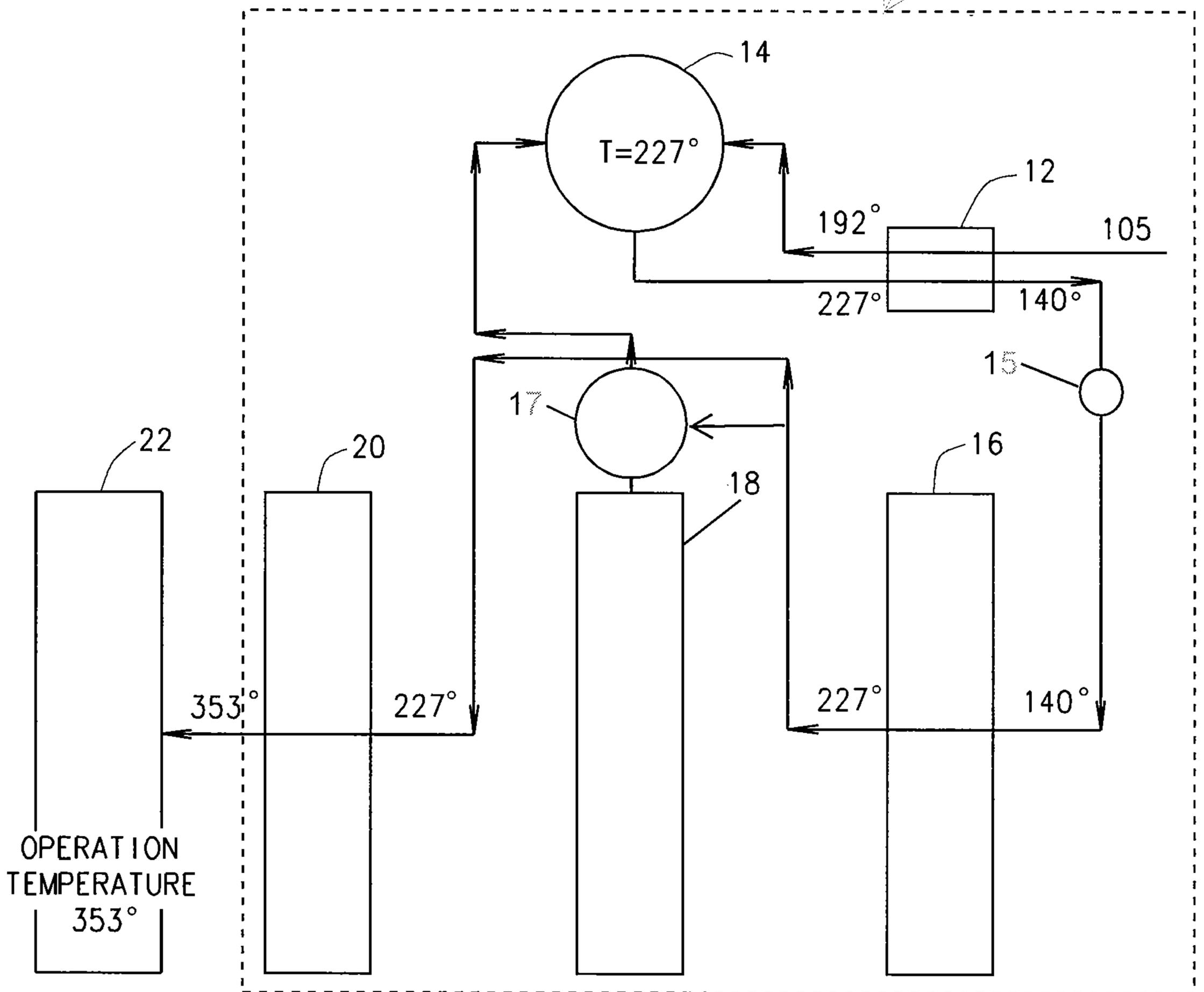


FIG. 2