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(54) Title: METHOD OF CONTROLLING DRUM TEMPERATURE TRANSIENTS

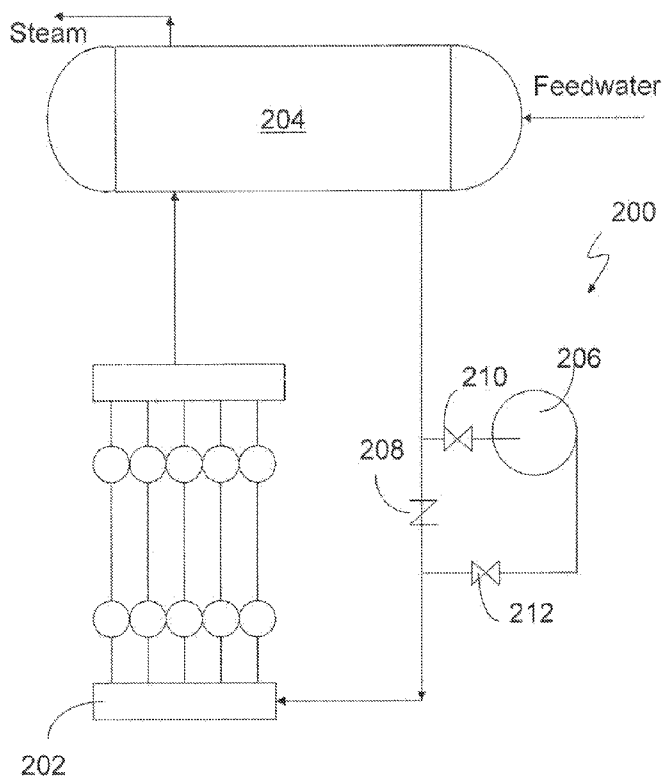


Figure 2

(57) Abstract: An evaporator system comprises an evaporator; a drum; and a pump that are in fluid communication with each other. The pump is operative to create a temporary pressure gradient during start-up of an evaporator system and transport a fluid from the evaporator to the drum prior to the fluid reaching its boiling point in the evaporator. Following the fluid reaching its boiling point in the evaporator, the fluid naturally circulates in the evaporator system.



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METHOD OF CONTROLLING DRUM TEMPERATURE TRANSIENTS

TECHNICAL FIELD

[0001] Disclosed herein is a method of controlling drum temperature transients in an evaporator system in a heat recovery steam generator. More specifically, disclosed herein is a method of using temporary forced circulation during startup to control drum temperature transients in a heat recovery steam generator.

BACKGROUND

[0002] Heat recovery steam generators generally comprise three major components: an evaporator, a superheater and an economizer. The different components are put together to meet the operating requirements of the unit. Some heat recovery steam generators may not have a superheater or may include additional components such as reheaters.

[0003] The Figure 1 is a depiction of an exemplary prior art evaporator system 100 of a heat recovery steam generator that comprises an evaporator 102 and a steam drum 104. The steam drum 104 is in fluid communication with the evaporator 102. In a natural circulation heat recovery steam generator, either no flow or minimal flow is established until boiling begins in the evaporator 102. This generally results in a very rapid rise in the steam drum 104 temperature.

[0004] For example, for a cold start the water temperature inside the steam drum 104 can rise from 15°C to 100°C in less than 10 minutes. This produces a large thermal gradient and hence compressive stress in the steam drum 104 wall. As the pressure in the steam drum 104 increases, the temperature gradient through the drum wall is reduced and consequently the stress due to pressure becomes the dominant stress in the drum. The stress due to pressure (with increased pressure in the steam drum 104) is a tensile stress. The stress range for the drum is determined by the difference between the final tensile stress at full load (pressure) and the initial compressive thermal stress. Boiler Design Codes (such as ASME and EN) impose limits on the stress at design pressure. Some codes, such as for example EN12952-3, also include limits on the permissible stress range for a startup-shutdown cycle. These limits are intended to protect against fatigue damage and phenomena such as cracking of the magnetite layer that forms on the surface of the steel at operating temperature.

[0005] As the pressure in the steam drum 104 increases, the wall thickness of the steam drum 104 is also increased to ensure that the tensile stress in the drum shell at design conditions does not exceed allowable stress limits specified in the design Codes. The thermal

stress however, becomes greater as steam drum 104 wall thickness increases. The maximum pressure that a drum can be designed for is thus limited by the initial thermal transient.

[0006] It is also desirable to have as much operational flexibility as is desirable for combined cycle power plants because these power plants are often shut down and restarted as electrical power demand varies. The addition of renewable energy sources such as solar and wind increases the need to shut down and restart combined cycle power plants due to the variation in power output from such renewable resources. Stresses in the drum during these start ups due to thermal transients can also limit the total number of times the heat recovery steam generators can be shut down and started over its operational life.

[0007] It is therefore desirable to reduce the temperature transient in the drum. This will allow the use of drum type boilers at higher pressures than can be achieved with conventional natural circulation and/or allow greater numbers of start up cycles.

SUMMARY

[0008] Disclosed herein is a method comprising creating a temporary pressure gradient during start-up of an evaporator system, where the evaporator system comprises an evaporator; a drum; and a pump; where the evaporator, the drum and the pump are in fluid communication with each other; transporting a fluid from the evaporator to the drum prior to the fluid reaching its boiling point in the evaporator; and circulating the fluid through the evaporator system via natural circulation after the fluid has reached its boiling point in the evaporator.

BRIEF DESCRIPTION OF THE FIGURES

[0009] Figure 1 is a prior art depiction of the evaporator system;

[0010] Figure 2 is a depiction of an exemplary embodiment of the evaporator system of the present invention; and

[0011] Figure 3 is another depiction of an exemplary embodiment of the evaporator system of the present invention.

DETAILED DESCRIPTION

[0012] The invention now will be described more fully hereinafter with reference to the accompanying drawings, in which various embodiments are shown. This invention may, however, be embodied in many different forms, and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure

will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like reference numerals refer to like elements throughout.

[0013] It will be understood that when an element is referred to as being “on” another element, it can be directly on the other element or intervening elements may be present therebetween. In contrast, when an element is referred to as being “directly on” another element, there are no intervening elements present. As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items.

[0014] It will be understood that, although the terms first, second, third etc. may be used herein to describe various elements, components, regions, layers and/or sections, these elements, components, regions, layers and/or sections should not be limited by these terms. These terms are only used to distinguish one element, component, region, layer or section from another element, component, region, layer or section. Thus, a first element, component, region, layer or section discussed below could be termed a second element, component, region, layer or section without departing from the teachings of the present invention.

[0015] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting. As used herein, the singular forms “a,” “an” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “comprises” and/or “comprising,” or “includes” and/or “including” when used in this specification, specify the presence of stated features, regions, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, regions, integers, steps, operations, elements, components, and/or groups thereof.

[0016] Furthermore, relative terms, such as “lower” or “bottom” and “upper” or “top,” may be used herein to describe one element's relationship to another element as illustrated in the Figures. It will be understood that relative terms are intended to encompass different orientations of the device in addition to the orientation depicted in the Figures. For example, if the device in one of the figures is turned over, elements described as being on the “lower” side of other elements would then be oriented on “upper” sides of the other elements. The exemplary term “lower,” can therefore, encompasses both an orientation of “lower” and “upper,” depending on the particular orientation of the figure. Similarly, if the device in one of the figures is turned over, elements described as “below” or “beneath” other elements would then be oriented “above” the other elements. The exemplary terms “below” or “beneath” can, therefore, encompass both an orientation of above and below.

[0017] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and the present disclosure, and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

[0018] Exemplary embodiments are described herein with reference to cross sectional illustrations that are schematic illustrations of idealized embodiments. As such, variations from the shapes of the illustrations as a result, for example, of manufacturing techniques and/or tolerances, are to be expected. Thus, embodiments described herein should not be construed as limited to the particular shapes of regions as illustrated herein but are to include deviations in shapes that result, for example, from manufacturing. For example, a region illustrated or described as flat may, typically, have rough and/or nonlinear features. Moreover, sharp angles that are illustrated may be rounded. Thus, the regions illustrated in the figures are schematic in nature and their shapes are not intended to illustrate the precise shape of a region and are not intended to limit the scope of the present claims.

[0019] Disclosed herein is an evaporator system that comprises a pump for circulating heated fluid from the evaporator to the steam drum. The pump provides circulation during start-up to initiate heating of the steam drum, which reduces the rate of temperature change in the drum. This reduction in the rate of temperature change in the steam drum causes reduced thermal stresses in the drum. In an exemplary embodiment, the fluid is water.

[0020] The pump may be a centrifugal pump, a jet-pump pump, or the like, and its purpose is to provide a pressure gradient in the evaporator system that promotes fluid circulation from the evaporator to the steam drum before fluid (e.g., water) present in the evaporator begins to boil. In one embodiment, the pump produces a lower pressure in the steam drum in relation to the evaporator before fluid present in the evaporator begins to boil. Upon generating a lower pressure in the steam drum, fluid from the evaporator is drawn into the steam drum causing the drum to heat up gradually. The gradual heating takes place until the fluid in the evaporator reaches the boiling point, at which point the pump may be shut off or isolated. After the pump is shut off, natural circulation promotes circulation of the fluid in the evaporator system.

[0021] The pump therefore operates for a short period of time, until the steam drum reaches the temperature of the boiling fluid. This allows for a pump that is smaller in size

than other comparative pumps that are normally used. It also reduces stress in the wall of the steam drum.

[0022] With reference to the Figure 2, an evaporator system 200 of the present invention comprises an evaporator 202, a steam drum 204 and a pump 206. The pump 206 is in fluid communication with the steam drum 204 and the evaporator 202. In one embodiment, the pump 206 lies downstream of the steam drum 204. The steam drum lies downstream of the evaporator 202.

[0023] Disposed across the inlet and outlet to the pump 206 is a one-way check valve 208. The check valve 208 permits only fluid flow from the steam drum 204 downstream to the evaporator 202 via the pump 206. The check valve further permits only fluid flow from the evaporator 202 downstream to the steam drum 204. The pump 206 has a first valve 210 and a second valve 212 disposed upstream and downstream of it respectively. The first valve 210 and the second valve 212 can isolate the pump 206 from the evaporator system 200 when desired. The first valve 210 and the second valve 212 can be electrically, pneumatically or manually activated.

[0024] In one embodiment, in one method of operation of the evaporator system 200, the pump 206 is used to circulate fluid from the evaporator 202 to the steam drum 204 during start up of the heat recovery steam generator to eliminate the rapid drum temperature rise that would normally occur in a natural circulation heat recovery steam generator. Once the steam drum 204 temperature reaches a predetermined value, the pump 206 is isolated and the evaporator 202 runs under natural circulation. As the pump 206 can be isolated after start-up, it does not have to be sized for full flow load, pressure and temperature. This reduces the cost of the pump 206 when compared with comparative pumps that are used for full time circulation.

[0025] In another embodiment, depicted in the Figure 3, the evaporator system 200 comprises a jet-pump 306 (eductor) that creates a pressure gradient in the evaporator system that promotes fluid circulation from the evaporator 202 to the steam drum 204 before fluid (e.g., water) present in the evaporator 202 begins to boil. In one embodiment, the jet-pump 306 produces a lower pressure in the steam drum in relation to the evaporator before the fluid present in the evaporator begins to boil.

[0026] The jet-pump 306 creates low pressure in a downcomer 308 that is in fluid communication with the steam drum 204 as a result of which fluid is drawn into the steam drum 204 from the evaporator 202. High velocity fluid flow in the narrow downcomer 308 induces a low pressure in the downcomer 308 relative to the steam drum 204, which in turn

causes flow in the downcomer 308. When the low pressure is created in the downcomer 308, the steam drum 204 is at a lower pressure than the evaporator, which causes the fluid to flow from the evaporator 202 to the steam drum 204. In one embodiment, low pressure created in the downcomer 308 by the operation of the jet-pump 306 drives the circulation of fluid from the evaporator 202 to the steam drum 204.

[0027] The jet-pump 306 is in fluid communication with a first valve 310 and a second valve 312. The first valve 310 is used to control the flow of feed water into the steam drum 204, while the second valve 312 is used to isolate the jet-pump 306 from the downcomer.

[0028] The jet-pump 306 of the Figure 3 functions in a manner similar to the pump 206 of the Figure 2 in that it permits a temporary fluid flow from the evaporator 202 to the steam drum 204 before the fluid present in the evaporator 202 begins to boil.

[0029] As noted above, the use of a pump for temporary circulation of fluid to the steam drum has a number of advantages. These include using a pump that is smaller in size than other comparative pumps that are normally used. It also reduces stress in the wall of the steam drum and permits the use of steam drums with larger wall thickness than those that are currently used in evaporator systems that do not employ temporary circulation. This in turn allows operation of the steam drum at higher pressures or greater numbers of stop-start cycles.

[0030] While the invention has been described with reference to various exemplary embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

What is claimed is:

1. A method comprising:
creating a temporary pressure gradient during start-up of an evaporator system, where the evaporator system comprises:
an evaporator;
a drum; and
a pump; where the evaporator, the drum and the pump are in fluid communication with each other;
transporting a fluid from the evaporator to the drum prior to the fluid reaching its boiling point in the evaporator; and
circulating the fluid through the evaporator system via natural circulation after the fluid has reached its boiling point in the evaporator.
2. The method of Claim 1, where the pump is a centrifugal pump or a jet pump.
3. The method of Claim 1, where the fluid is water.
4. The method of Claim 1, where the fluid is steam.
5. The method of Claim 1, where the evaporator system further comprises valves for isolating the pump from the evaporator system.
6. The method of Claim 1, where the evaporator system further comprises a downcomer; the pressure gradient being created in the downcomer from a region of lower pressure in the steam drum to a region of higher pressure in the evaporator.
7. The method of Claim 1, where the pump is downstream of the steam drum and upstream of the evaporator.
8. The method of Claim 2, where the jet pump is downstream of the steam drum and in fluid communication with a downcomer that is in fluid communication with the steam drum.

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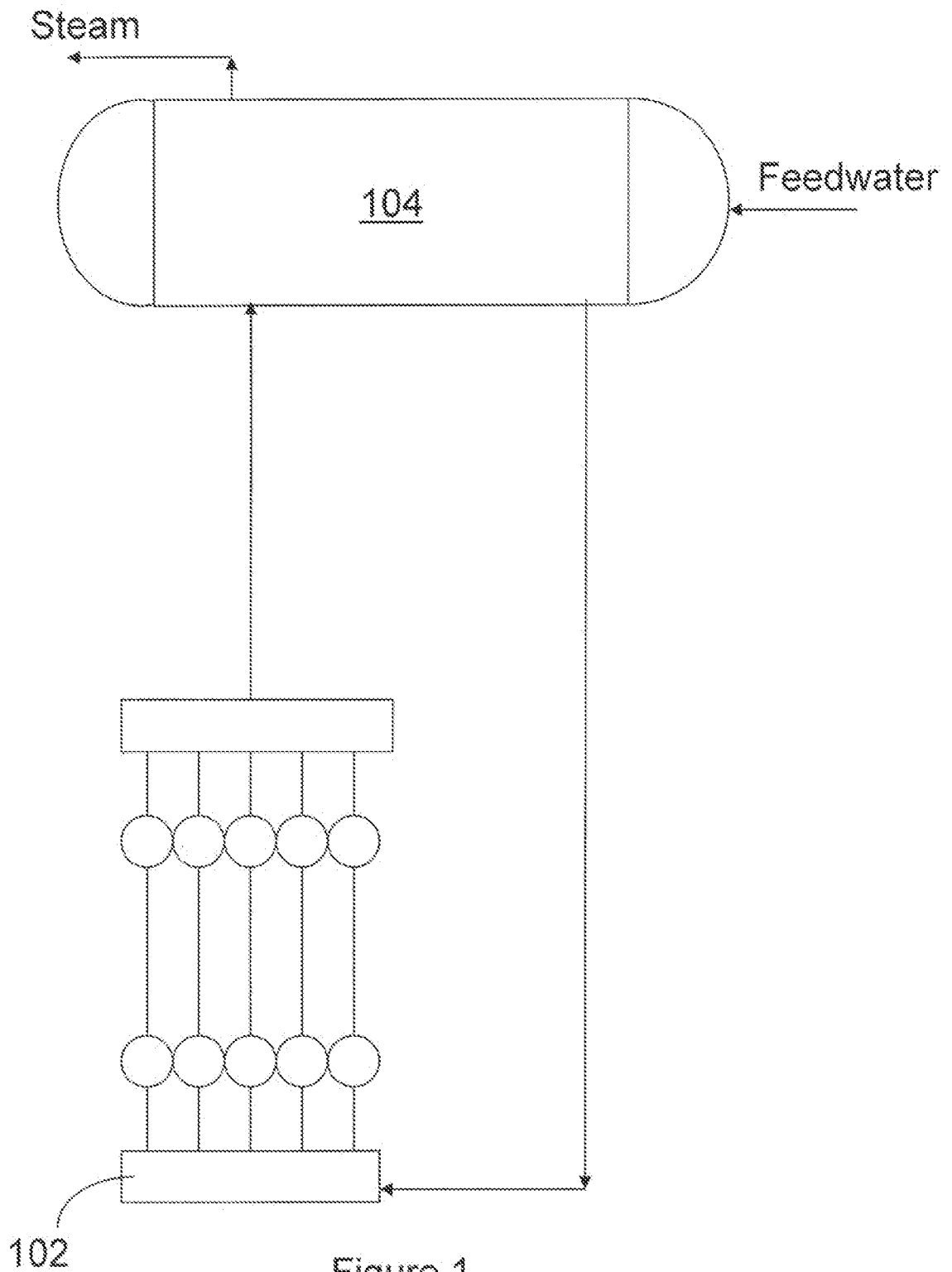


Figure 1
(Prior Art)

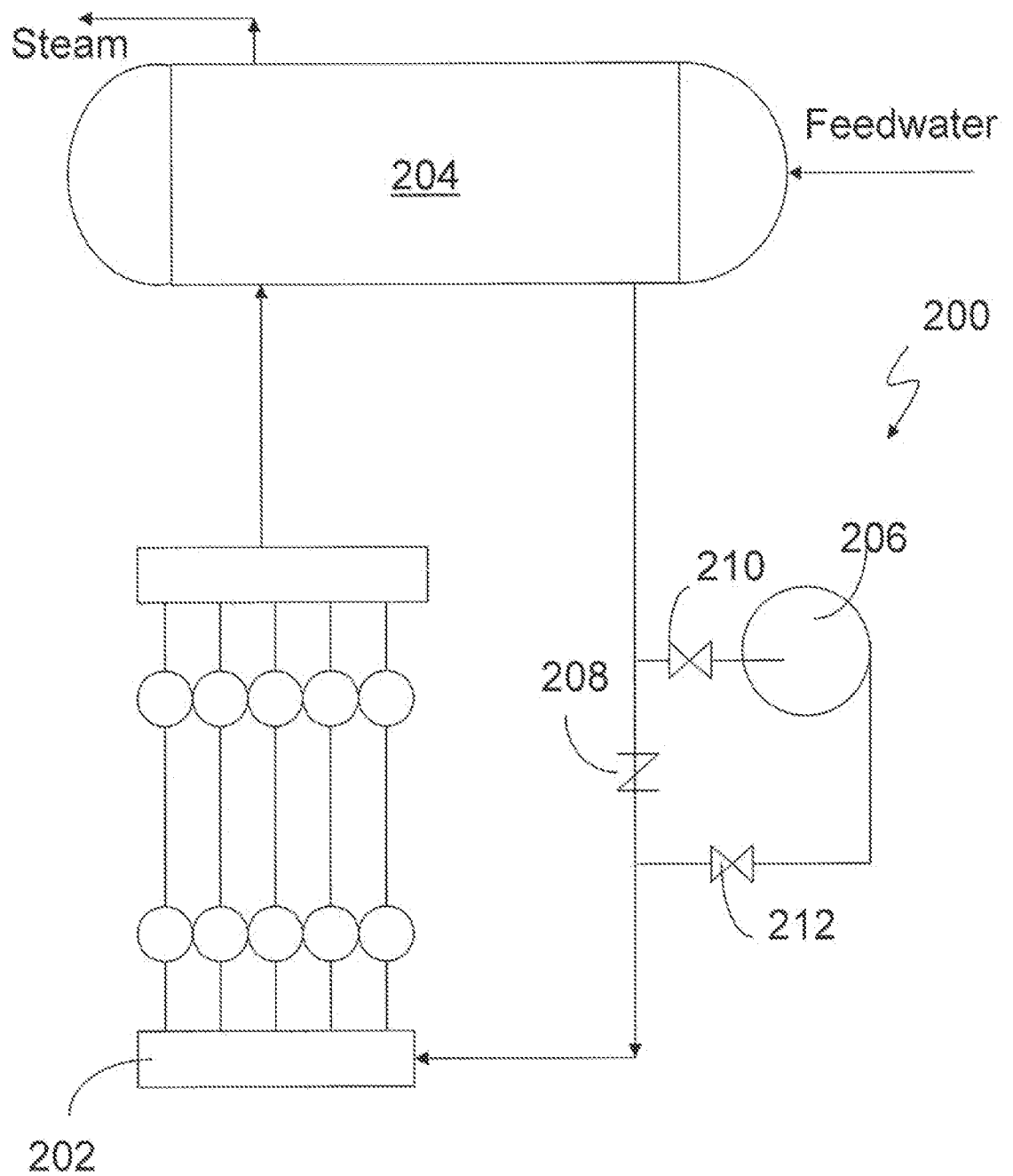


Figure 2

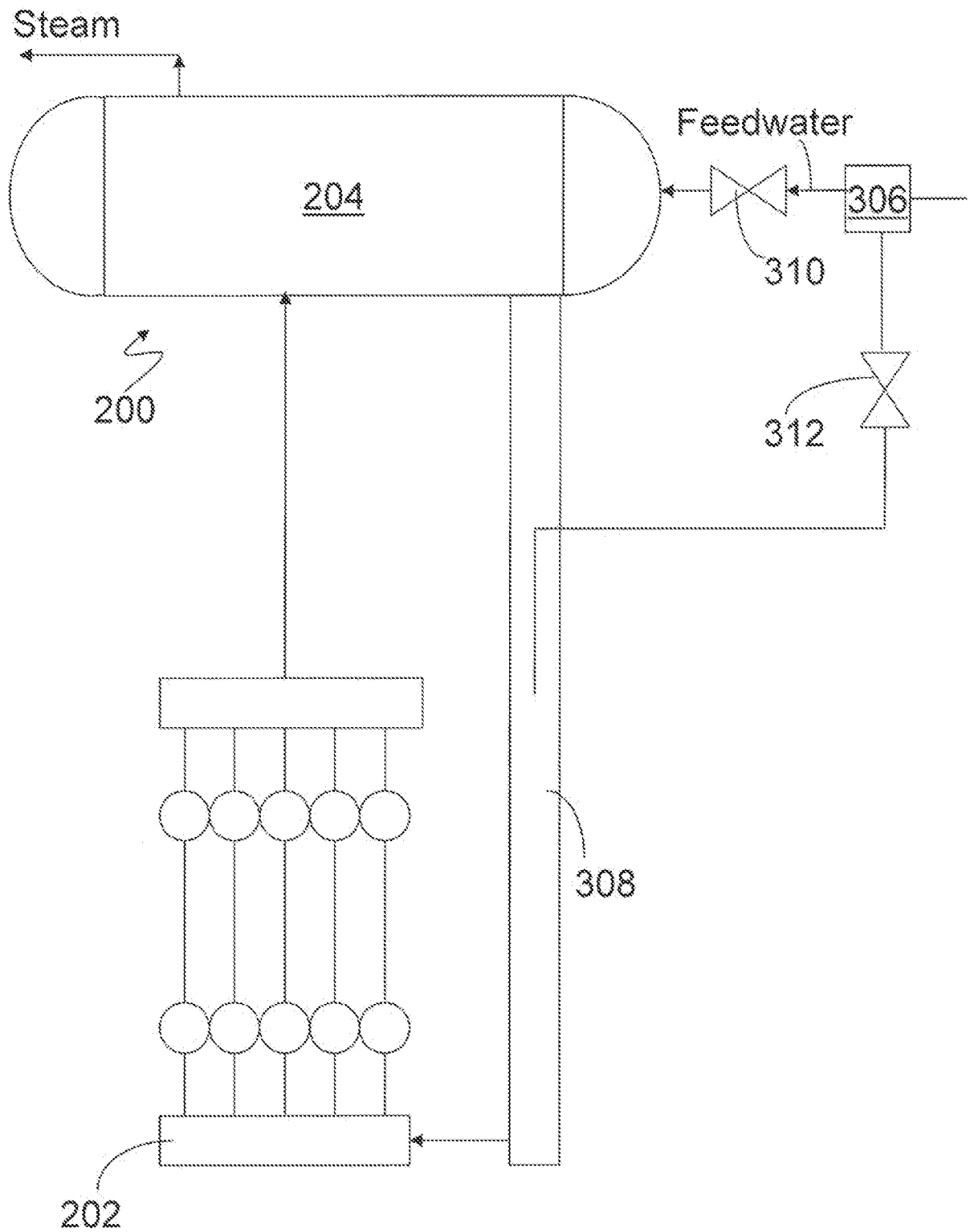


Figure 3