US 20130269907A1

(19) **United States**

(12) **Patent Application Publication**

Fetcu

(10) **Pub. No.: US 2013/0269907 A1**

(43) **Pub. Date: Oct. 17, 2013**

(54) **STEAM-TO-GAS HEAT EXCHANGER**

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(21) Appl. No.: **13/831,905**

(22) Filed: **Mar. 15, 2013**

Related U.S. Application Data

(60) Provisional application No. 61/612,254, filed on Mar. 17, 2012.

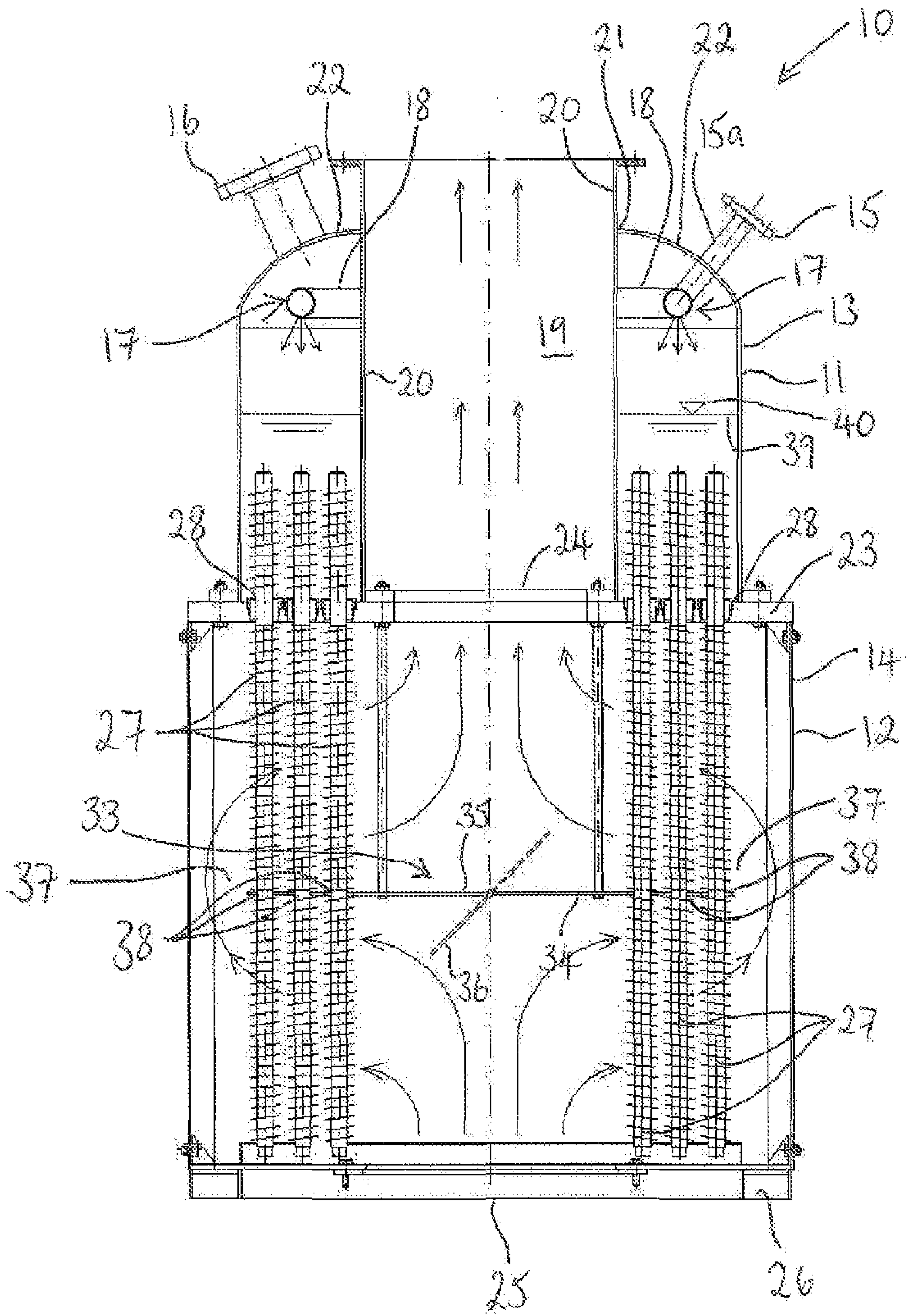
Publication Classification

(51) **Int. Cl.**
F28D 15/02 (2006.01)

(52) **U.S. Cl.**
CPC ***F28D 15/02*** (2013.01)
USPC **165/11.1**; 165/104.21; 165/96

(57) **ABSTRACT**

A heat exchanger for generating steam from water is disclosed. The exchanger comprises a first heat exchanging chamber, a second heat exchanging chamber and an array of heat pipes which are arranged to extend from within the first heat exchanging chamber to within the second heat exchanging chamber. The first heat exchanging chamber comprises a distributed inlet for passing the water into the first chamber from a distributed position around the chamber and an outlet through which the steam can exit the first chamber, the water being arranged to pass over the portion of the heat pipes which extend within the first chamber. The second heat exchanging chamber comprises an inlet for receiving a gas into the chamber and an outlet through which the gas can exit the second chamber, the gas being arranged to pass over the portion of the heat pipes which extend within the second chamber.



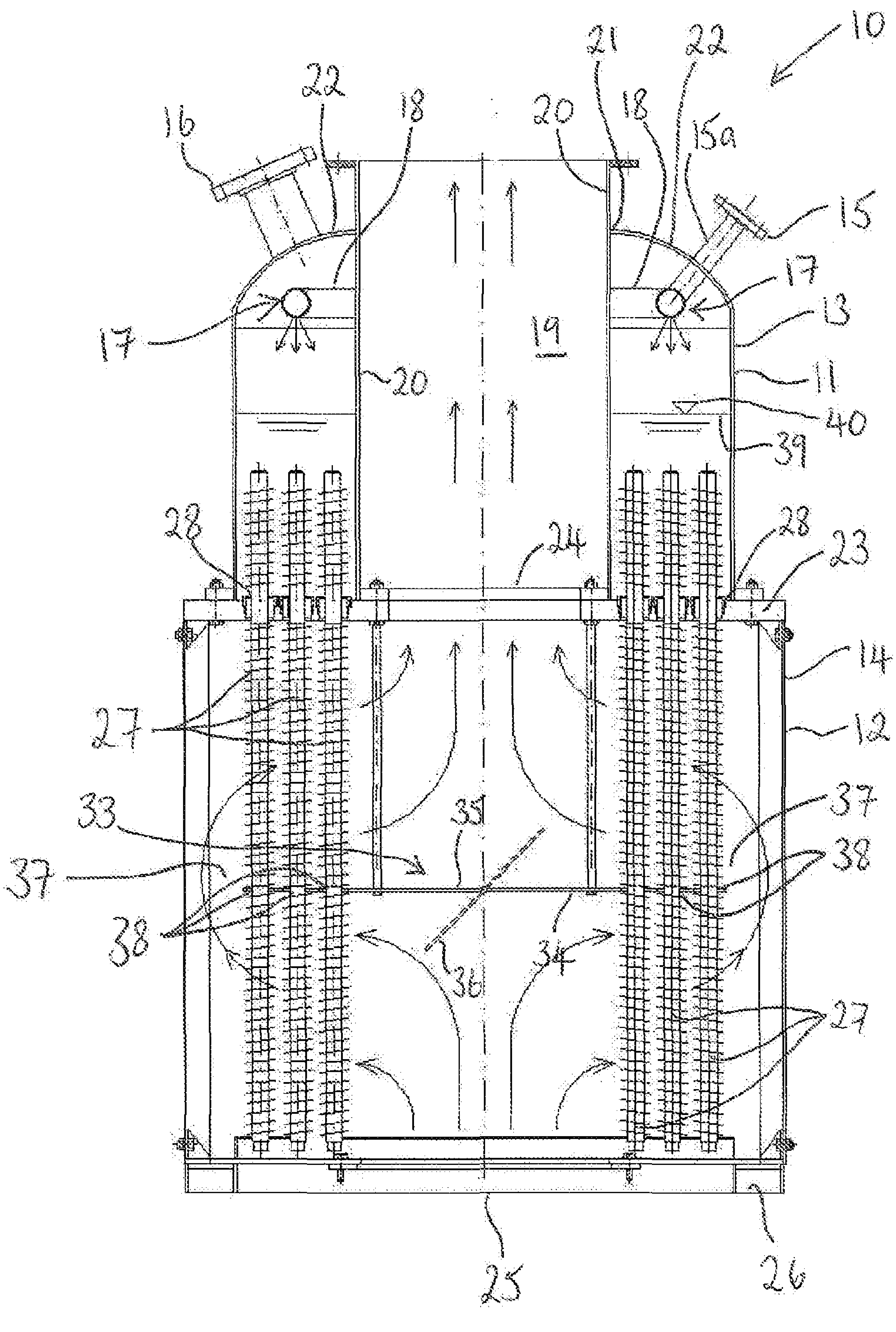

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Figure 1

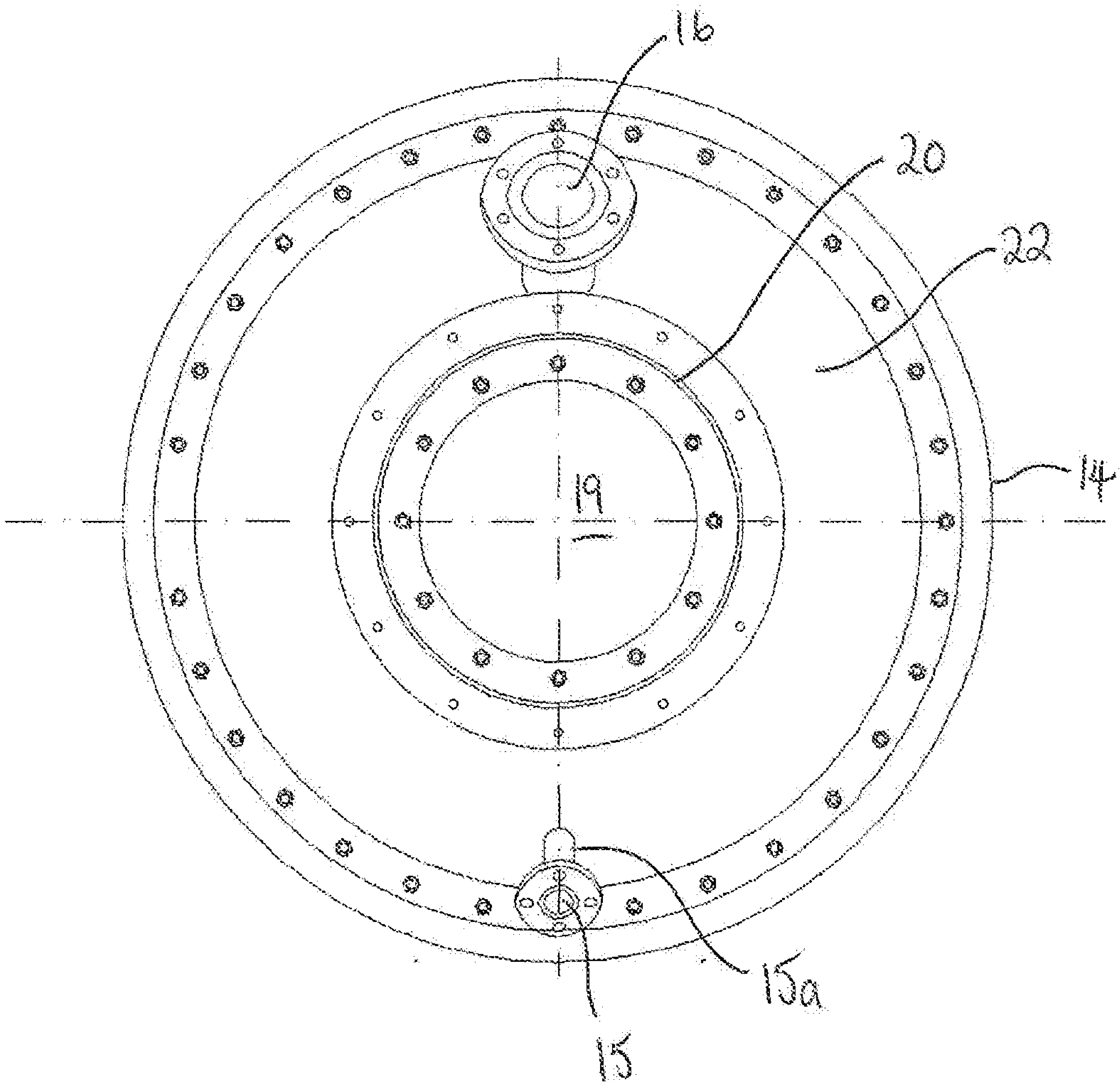

Figure 2

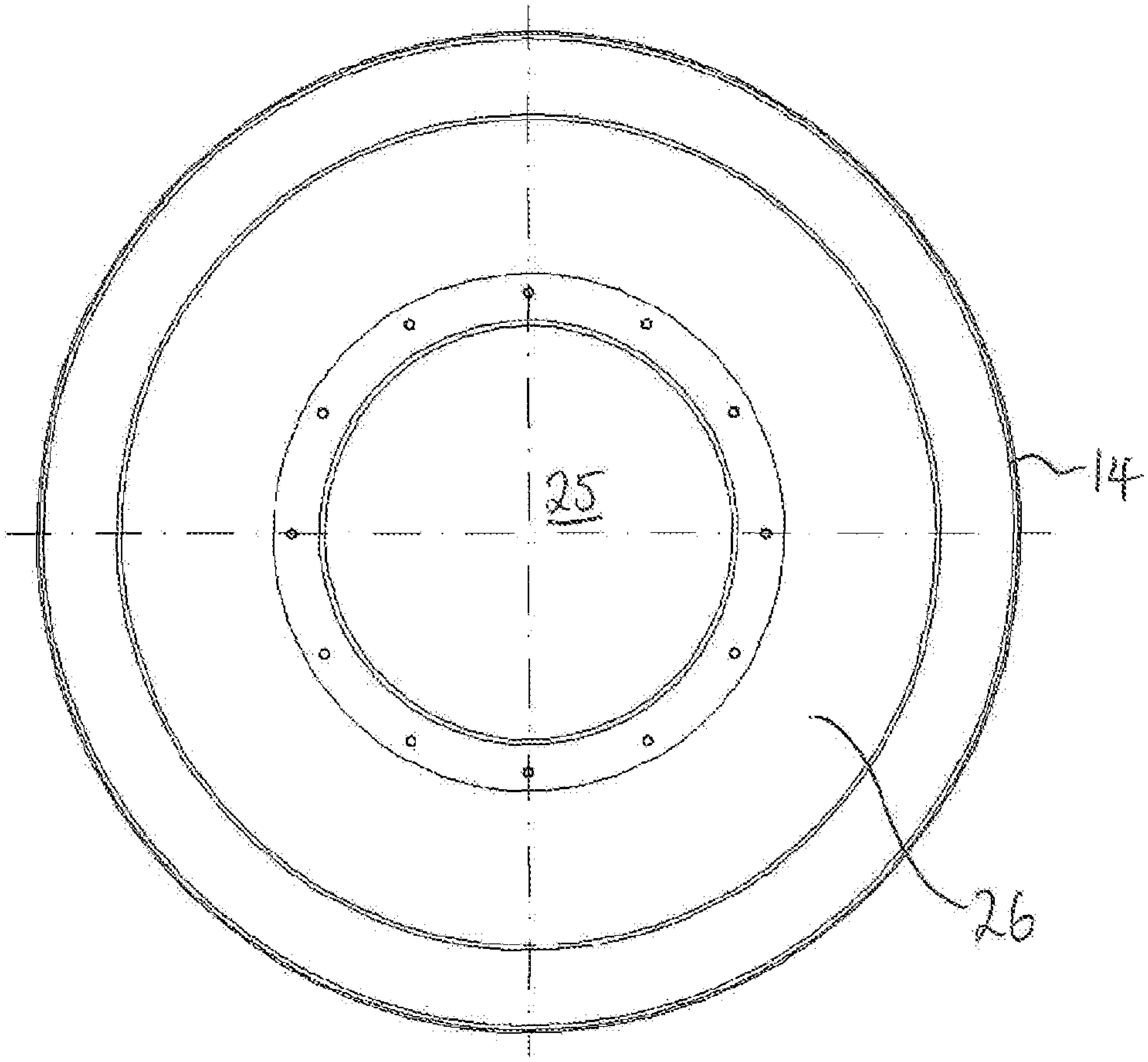

Figure 3

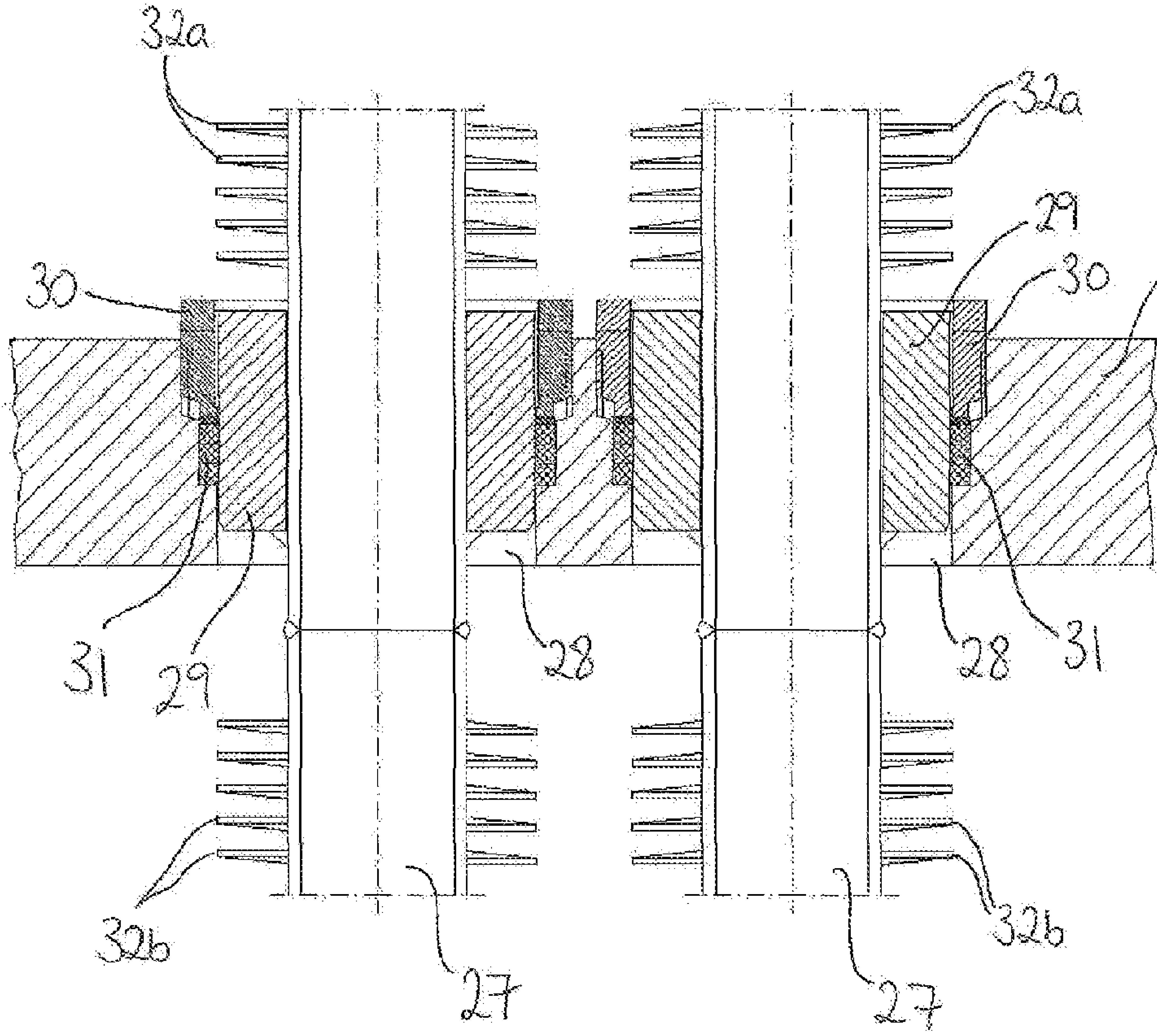

Figure 4

STEAM-TO-GAS HEAT EXCHANGER

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This non-provisional application claims the benefit of provisional application No. 61/612,254 filed on Mar. 17, 2012, entitled "Steam-to-Gas Heat Exchanger", including Appendix A, which application and appendix are incorporated herein in their entirety by this reference.

BACKGROUND

[0002] The present invention relates to a heat exchanger and particularly, but not exclusively to a heat exchanger comprising heat pipes.

[0003] A heat pipe is a hermetically sealed evacuated tube typically comprising a mesh or sintered powder wick and a working fluid in both the liquid and vapor phase. When one end of the tube is heated the liquid turns to vapor upon absorbing the latent heat of vaporization. The hot vapor subsequently passes to the cooler end of the tube where it condenses and gives out the latent heat to the tube. The condensed liquid then flows back to the hot end of the tube and the vaporization-condensation cycle repeats. Since the latent heat of vaporization is usually very large, considerable quantities of heat can be transported along the tube and a substantially uniform temperature distribution can be achieved along the heat pipe.

[0004] It is known to utilize a heat exchanger comprising separated chambers and a plurality of heat pipes which extend between the chambers, such that heat can become transferred from one chamber to the other. In this respect, by passing a heated fluid through one chamber, the heat pipes can transfer the heat absorbed from the heated fluid to the other chamber wherein a cooled fluid may pass to subsequently absorb the heat from the heat pipes.

[0005] Heat exchangers are known for recovering heat from exhaust gases generated by industrial processes, and this heat is typically used to generate steam for driving a steam turbine, for example. In this respect, the heat pipes are arranged to extend from a position within an exhaust gas outlet to within a water chamber, such that the heat transferred along the heat pipes can be used to produce steam in the water chamber. It is found however that the heat extracted from the heat pipes within the chamber varies between heat pipes which can thus reduce the efficiency of the heat exchanger and cause an early failure of one or more of the heat pipes. Moreover, it is found that the variation in heat extraction between heat pipes can lead to a dangerous build up of heat within the heat exchanger.

SUMMARY

[0006] We have now devised an improved heat exchanger which alleviates the above-mentioned problem.

[0007] In accordance with the present invention, there is provided a heat exchanger for generating steam from water, the exchanger comprising a first heat exchanging chamber, a second heat exchanging chamber and an array of heat pipes which are arranged to extend from within the first heat exchanging chamber to within the second heat exchanging chamber;

[0008] the first heat exchanging chamber comprising an inlet for receiving the water into the chamber and an outlet through which the steam can exit the first chamber, the water being arranged to pass over the portion of the heat pipes which extend within the first chamber;

[0009] the second heat exchanging chamber comprising an inlet for receiving a gas into the chamber and an outlet through which the gas can exit the second chamber, the gas being arranged to pass over the portion of the heat pipes which extend within the second chamber;

[0010] wherein the inlet to the first chamber comprises a distributed inlet for passing the water into the first chamber from a distributed position around the first chamber.

[0011] The distributed inlet ensures a uniform cooling of the portion of the heat pipes within the first chamber and thus a uniform extraction of heat from the heat pipes. The distributed inlet minimizes any localized heating within the first chamber, which is typically associated with a localized inlet for the water.

[0012] The distributed inlet preferably comprises a distributed nozzle arrangement and is preferably arranged to extend above the portion of heat pipes which extend within the first chamber. The distributed nozzle arrangement preferably comprises a tube which extends around the first chamber and which comprises a plurality of apertures formed therein though which the water can pass.

[0013] The first heat exchanging chamber preferably further comprises a sensor for monitoring the level of water therein.

[0014] Preferably, the portion of at least one of the heat pipes within the first heat exchanging chamber comprises a fin arranged in contact therewith which is arranged to increase thermal transfer between said portion of the heat pipe and the water. The provision of at least one fin increases thermal transfer between said portion of the heat pipe and the water to provide for a more efficient heat transfer.

[0015] The portion of each of the heat pipes within the first heat exchanging chamber comprises a fin. Preferably, the or each fin is arranged to extend in a substantially helical path around the portion of the at least one or each heat pipe within the second heat exchanging chamber.

[0016] The portion of at least one of the heat pipes within the second heat exchanging chamber comprises a fin arranged in contact therewith, which is arranged to increase thermal transfer between said portion of heat pipe and the gas. Alternatively, each of the heat pipes within the second heat exchanging chamber comprises a fin arranged in contact therewith which is arranged to increase thermal transfer between said portion of the heat pipe and the gas. Preferably, the or each fin is arranged to extend in a substantially helical path around the portion of the at least one or each heat pipe within the second heat exchanging chamber.

[0017] Preferably, the number of turns of the or each fin per unit length around the or each heat pipe in the first heat exchanging chamber is greater than number of turns of the or each fin per unit length around the or each heat pipe in the second heat exchanging chamber.

[0018] The first and second heat exchanging chambers are preferably separated by a separation plate. The plurality of heat pipes are preferably supported within the heat exchanger by the separation plate which is coupled to the heat pipes at a position intermediate opposite ends of the heat pipes. Accordingly, the separation plate obviates the requirement to support the heat pipes at their free end and as such the free ends of the heat pipes can be left uncoupled. This therefore enables the heat pipes to expand and contract along their length during use thereby minimizing thermal stresses upon the heat pipes.

[0019] The second heat exchanging chamber preferably further comprises at least one baffle for directing the flow of gas over the respective portions of the heat pipes. The baffle preferably further comprises a valve to control the passage of gas direct from the inlet to the outlet of the second chamber. The baffle preferably comprises a butterfly valve.

[0020] Note that the various features of the present invention described above may be practiced alone or in combination. These and other features of the present invention will be described in more detail below in the detailed description of the invention and in conjunction with the following figures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] In order that the present invention may be more clearly ascertained, some embodiments will now be described, by way of example, with reference to the accompanying drawings, in which:

[0022] FIG. **1** is a longitudinal sectional view through a heat exchanger according to an embodiment of the present invention;

[0023] FIG. **2** is a top view of the heat exchanger illustrated in FIG. **1**;

[0024] FIG. **3** is a view from the underside of the heat exchanger illustrated in FIG. **1**; and

[0025] FIG. **4** is a magnified longitudinal sectional view of a heat pipe disposed within a separation plate.

DETAILED DESCRIPTION

[0026] The present invention will now be described in detail with reference to several embodiments thereof as illustrated in the accompanying drawings. In the following description, numerous specific details are set forth in order to provide a thorough understanding of embodiments of the present invention. It will be apparent, however, to one skilled in the art, that embodiments may be practiced without some or all of these specific details. In other instances, well known process steps and/or structures have not been described in detail in order to not unnecessarily obscure the present invention. The features and advantages of embodiments may be better understood with reference to the drawings and discussions that follow.

[0027] Referring to FIGS. **1** to **3** of the drawings, there is illustrated a heat exchanger **10** according to an embodiment of the present invention for generating steam from water. The heat exchanger **10** comprises a first heat exchanging chamber **11** and a second heat exchanging chamber **12**. Each chamber **11**, **12** comprises a substantially cylindrical housing **13**, **14**, which are mounted one on top of the other such that a longitudinal axis of the first chamber **11** extends in a substantially collinear relationship with a longitudinal axis of the second chamber **12** and thus the heat exchanger **10**. The housing of the first and second chambers **11**, **12** further comprises removable side panels (not shown) which enable the interior of the respective chambers **11**, **12** to be accessed for cleaning and maintenance, for example.

[0028] The first chamber **11** of the heat exchanger **10** is disposed above the second chamber **12** and comprises an inlet **15** for passing water into the first chamber **11**, and an outlet **16** through which the steam, which is generated from the heating of the water, can pass out from the first chamber **11**. The inlet **15** comprises a duct **15*a*** having a proximal end disposed outside of the chamber **11** for coupling with a source of water (not shown), and a distal end disposed within the chamber **11**, which is arranged to couple with a distributed nozzle arrangement **17**. The nozzle arrangement **17** comprises a substantially circular tube **18** which extends around an upper region of the first chamber **11**, and comprises a plurality of apertures or nozzles (not shown) disposed therein which are arranged to spray water into the chamber **11** from a distributed position around the tube **18**.

[0029] The first chamber **11** further comprises a passage **19** which extends along the first chamber **11** substantially along the longitudinal axis thereof. The passage **19** is defined by a substantially cylindrical wall **20** which seals the interior of the first chamber **11** from the passage **19**, and extends from an opening **21** disposed in an upper end wall **22** of the first chamber **11** to an upper region of a separation plate **23**.

[0030] The separation plate **23** comprises a first aperture **24** disposed substantially at the centre thereof which is arranged to align with the cylindrical wall **20** defining the passage **19**, such that the wall **20** extends substantially around a periphery of the first aperture **24**. The second chamber **12** is secured to the underside of the separation plate **23** and thus the first chamber **11**, and comprises an inlet **25** disposed substantially upon the longitudinal axis of the chamber **12**, within a lower end wall **26** thereof. The first aperture **24** disposed within the separation plate **23** serves as an outlet from the second chamber **12**, such that heated gas from an industrial process (not shown) for example, can pass into the second chamber **12** through the inlet **25** disposed in the lower end wall **26** of the second chamber **12**, through the first aperture **24** in the separation plate, namely the outlet to the second chamber **12**, into the passage **19** and out from the heat exchanger **10** via the opening **21** disposed in the upper end wall **22** of the first chamber **11**.

[0031] The heat exchanger **10** further comprises a plurality of substantially linear heat pipes **27** which extend from within the first chamber **11**, through an array of second apertures **28** disposed within the plate **23** around the first aperture **24**, and terminate in the second chamber **12** so as to enable heat to be transferred between the chambers **11**, **12**. The heat pipes **27** extend substantially parallel to the longitudinal axis of the first and second chambers **11**, **12** and are configured in a substantially arcuate arrangement of rows of heat pipes **27**, the radius of curvature of each arcuate row being centered substantially on the longitudinal axis. In this manner each chamber **11**, **12** comprises a plurality of arcuate rows of heat pipes **27**, having different radii of curvature.

[0032] Referring to FIG. **4** of the drawings, the heat pipes **27** are supported within the heat exchanger **10** by the separation plate **23** by a series of collars **29** which separately extend within each of the second apertures **28** and which further serve to seal the heat pipes **27** to the separation plate **23**. The collars **29** are bonded to the heat pipes **27**, for example by a weld, and a nut **30** is then screwed upon the collar **29** to compress a sealing ring **31** to the separation plate **23** and thus ensure that the interior of the first and second chambers **11**, **12** remain isolated from each other. The longitudinal ends of the heat pipes **27** are uncoupled and spaced from the upper end wall **22** of the first chamber **11** and the lower end wall **26** of the second chamber **12**, such that the heat pipes **27** are free to expand and contract and thus relieve any thermal stresses which would otherwise develop during use of the heat exchanger **10**.

[0033] The portion of each of the heat pipes **27** which extend in the first chamber **11** comprise a helical fin **32*a*** disposed around the outer surface thereof which extend substantially along the length of the portion of the respective heat pipe **27** within the first chamber **11**. The fins **32***a* comprise a metallic strip which extends away from the outer surface of the respective heat pipe **27**, in direction which is substantially perpendicular to the longitudinal axis of the respective heat pipe **25**. The fins **32***a* are found to increase the transfer of heat between said portion of the heat pipes **27** and the water to provide for a more efficient heating of the water within the first chamber **11**.

[0034] The portion of each of the heat pipes **27** which extend in the second chamber **12** similarly comprise a helical fin **32***b* disposed around the outer surface thereof which extend substantially along the length of the portion of the respective heat pipe **27** within the second chamber **12**. The fins **32***b* similarly comprises a metallic strip which extends away from the outer surface of the respective heat pipe **27**, in direction which is substantially perpendicular to the longitudinal axis of the respective heat pipe **27**.

[0035] The second chamber **12** of the heat exchanger **10** further comprises a baffle **33** which extends across the second chamber **12**, substantially transverse to the longitudinal axis of the heat exchanger **10**, and serves to direct the flow of gas from an industrial process for example, across the portion of the heat pipes **27** within the second chamber **12**, to ensure that the heat associated with the gas is given up to the portion of the heat pipes **27** within the second chamber **12**. The baffle **33** comprises an annular disc **34** centered substantially upon a longitudinal axis of the heat exchanger **10**, having an aperture **35** disposed substantially centrally thereof. The baffle **33** further comprises a closure **36** which is sized to substantially match the aperture **35** within the annular disc **34**, and which is rotatable about a diameter thereof, to open and close the aperture **35** within the annular disc **34**.

[0036] The outer periphery of the annular disc **34** is spaced from the housing **14** of the second chamber **12** to define an annular passage **37**. The heat pipes **27** are arranged to extend through apertures **38** in the annular disc **34** in sealing relation therewith, such that the gas is arranged to pass across the heat pipes **27**, through the annular passage **37**, and back across the heat pipes **27**, in moving from the inlet **25** to the outlet **24** of the second chamber **12**.

[0037] The annular disc **34** and closure **36** cooperatively define a valve, such as a butterfly valve, which can be configured between a fully open state in which the gas is arranged to pass direct from the inlet **25** to the outlet **24** without substantially passing through the annular passage **37**, a closed state in which the majority of the gas is arranged to pass through the annular passage **37** in passing from the inlet **25** to the outlet **24** of the second chamber **12**, and various intermediate states in which a portion of the gas is arranged to pass through the aperture **35** and a portion of the gas is arranged to pass through the annular passage **37**.

[0038] In use, hot gas from an industrial process (not shown) for example, is passed into the second chamber **12** through the inlet **25**, and caused to pass radially outwardly across the heat pipes **27** due to the baffle **33** and through the annular passage **37**. The gas is then caused to pass radially inwardly of the second chamber **12**, back across the heat pipes **27** toward the outlet **24** thereof. As the gas passes across the heat pipes **27**, the heat associated with the gas becomes transferred to the heat pipes **27**, causing the gas to become cooled. The heat transferred to the heat pipes **27** is then communicated along the heat pipes **27** to the first chamber **11** and becomes extracted therefrom by the water within the first chamber **11**.

[0039] The heat extracted by the water causes the water temperature to increase and this heat is allowed to increase to convert the water into steam in the first chamber **11**. The steam generated is then passed out from the outlet **16** of the first chamber **11** and may be used to drive a steam turbine (not shown) for example. The distributed nozzle arrangement **17** in the first chamber **11** ensures that each heat pipe portion within the first chamber **11** receives a uniform cooling and thus minimizes any localized heating of the heat pipes **27**.

[0040] The water level **39** within the first chamber is maintained above an upper region of the portion of heat pipes **27** therein to maximize the heat transfer area between the portion of the heat pipes **27** and the water. This water level is maintained by a sensor **40**, the output from which is arranged to selectively open and close the water supply into the first chamber **11**. In this manner, as the water becomes converted to steam, the water level **39** within the first chamber **11** will fall. This change in water level **39** will become sensed by the sensor **40**, which in turn will open the inlet **15** to the first chamber **11** causing water to become sprayed into the chamber **11** until the desired water level **39** is achieved.

[0041] The intimate contact and increased surface area of the portion of the heat pipes **27** in the first chamber **11**, due to the presence of the fins **32***a*, provides an efficient removal of heat from the heat pipes **27**, such that the portion of the heat pipes **27** in the second chamber **12** can further absorb the heat from the gas and thus cool the gas. This increased surface area provides for an increased effective thermal coefficient and thus a reduced length of the portion of the heat pipe **25** in the first chamber **11** compared with conventional heat exchangers. Moreover, in the event that a condensate (not shown) of the industrial gas forms in the second chamber **12**, then the fins **32***b* associated with the portion of the heat pipes **27** in the second chamber **12**, enable the condensate (not shown) to develop thereon as opposed to the pipe itself, which would otherwise insulate pipe from cooling further industrial gas.

[0042] For further details of the present invention, please see attached Appendix A.

[0043] While this invention has been described in terms of several embodiments, there are alterations, modifications, permutations, and substitute equivalents, which fall within the scope of this invention. It should also be noted that there are many alternative ways of implementing the methods and apparatuses of the present invention. It is therefore intended that the following appended claims be interpreted as including all such alterations, modifications, permutations, and substitute equivalents as fall within the true spirit and scope of the present invention.

What is claimed is:

1. A heat exchanger for generating steam from water, the exchanger comprising a first heat exchanging chamber, a second heat exchanging chamber and an array of heat pipes which are arranged to extend from within the first heat exchanging chamber to within the second heat exchanging chamber;

the first heat exchanging chamber comprising an inlet for receiving water into the chamber and an outlet through which the steam can exit the first chamber, the water being arranged to pass over the portion of the heat pipes which extend within the first chamber;

the second heat exchanging chamber comprising an inlet for receiving a gas into the chamber and an outlet through which the gas can exit the second chamber, the gas being arranged to pass over the portion of the heat pipes which extend within the second chamber;

wherein the inlet to the first chamber comprises a distributed inlet for passing the water into the first chamber from a distributed position around the first chamber.

2. A heat exchanger according to claim **1**, wherein the distributed inlet is arranged to extend above the portion of heat pipes which extend within the first chamber.

3. A heat exchanger according to claim **1**, wherein the distributed inlet comprises a distributed nozzle arrangement.

4. A heat exchanger according to claim **3**, wherein the distributed nozzle arrangement comprises a tube which extends around the first chamber and which comprises a plurality of apertures formed therein though which the water can pass.

5. A heat exchanger according to claim **1**, wherein the first heat exchanging chamber further comprises a sensor for monitoring the level of water therein.

6. A heat exchanger according to claim **1**, wherein the portion of at least one of the heat pipes within the first heat exchanging chamber comprises a fin arranged in contact therewith which is arranged to increase thermal transfer between said portion of the heat pipe and the water.

7. A heat exchanger according to claim **1**, wherein the portion of each of the heat pipes within the first heat exchanging chamber comprises a fin.

8. A heat exchanger according to claim **6**, wherein the or each fin is arranged to extend in a substantially helical path around the portion of the at least one or each heat pipe within the second heat exchanging chamber.

9. A heat exchanger according to claim **1** wherein the portion of at least one of the heat pipes within the second heat exchanging chamber comprises a fin arranged in contact therewith, which is arranged to increase thermal transfer between said portion of heat pipe and the gas.

10. A heat exchanger according to claim **1**, wherein the portion of each of the heat pipes within the second heat exchanging chamber comprises a fin arranged in contact therewith which is arranged to increase thermal transfer between said portion of the heat pipe and the gas.

11. A heat exchanger according to claim **9**, wherein the or each fin is arranged to extend in a substantially helical path around the portion of the at least one or each heat pipe within the second heat exchanging chamber.

12. A heat exchanger according to claim **8**, wherein the number of turns of the or each fin per unit length around the or each heat pipe in the first heat exchanging chamber is greater than number of turns of the or each fin per unit length around the or each heat pipe in the second heat exchanging chamber.

13. A heat exchanger according to claim **1** wherein the first and second heat exchanging chambers are separated by a separation plate.

14. A heat exchanger according to claim **13**, wherein the plurality of heat pipes are supported within the heat exchanger by the separation plate which is coupled to the heat pipes at a position intermediate opposite ends of the heat pipes.

15. A heat exchanger according to claim **1**, wherein the second heat exchanging chamber further comprises at least one baffle for directing the flow of gas over the portion of the heat pipes within the second chamber.

16. A heat exchanger according to claim **15**, wherein the at least one baffle comprises a valve to control the passage of gas direct from the inlet to the outlet of the second chamber.

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