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(54) **Title**: VERTICAL SEPARATION STEAM GENERATOR

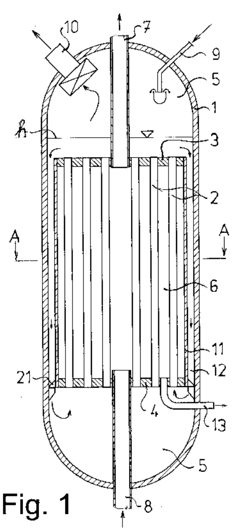

Fig. 1

(57) **Abstract**: System of heat exchange tubes (2) mounted in the upper and lower tube sheets (3,4) and jacketed with a cylindrical shell (11) is placed in the outer shell (1). Cavities (5) interconnected with tube space (6) are created in the outer shell (1) above and under tubes (2). Inter-tube space (6) enclosed circumferentially with cylindrical shell (11) and at the top and bottom with tube sheets (3,4) is located between tubes (2). Outer shell (1) is equipped with primary pipe sockets (7,8) and secondary pipe sockets (9,10) for media inlet and outlet. There is a gap (12) created between cylindrical shell (11) and outlet pressure shell (1). Inter-tube space (6) has inter-tube discharge (13) of condensate at the bottom. Cooler (14) with accessories is preferably above or below jacketed tubes (2). Systems of jacketed tubes (2) can be situated in multiplicity one above another. The media inlet and outlet elements should be matched adequately to the addition of cooler (14) and/or system of tubes (2).

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Vertical separation steam generator

Technical Field

The invention relates to the field of power engineering. It solved constructional arrangement of vertical separation steam generator intended for heat exchange between media during separation of carbon dioxide and production of superheated water steam for a low pressure steam turbine in power plants and heating plants.

Background Art

Separation steam generators are arranged as tubular heat exchangers in which heat-exchange surfaces are created allowing heat exchange between the media with phase change. The cooled medium, which is a mixture of gases, at least one of which condenses on cooling and the other does not condense during cooling, passes heat to the heated cooling medium, which is a liquid that evaporates on heating. In the case of circulation with steam-gas turbine, the cooled mixture is a steam-gas mixture based on water steam and gaseous carbon dioxide or other gases and the cooling mixture is usually the evaporated water.

At present, for heat exchange between media during separation and production of superheated steam for a low-pressure steam turbine, vertical separation steam generators in the form of heat exchangers are used, where a bundle of tubes is created inside a closed vessel consisting of a pressure outer shell, and the said tubes are mounted between tube sheets forming partitions in the inner space of the vessel. In the case of vertical steam generator, tubes are placed vertically in the vessel and one tube sheet is at the top and a second tube sheet is at the bottom on the tube ends. Cavities with a plenum for the cooling medium are made in the shell in the area near these tube sheets, above the top tube sheet and under the bottom tube sheet. The tubes are connected on both sides into the plenum cavities located above and under the tube sheets. Inlet and outlet of the cooling medium, usually the water inlet and outlet and the outlet of saturated steam, are connected inward the outer shell of the vessel into the plenums for the cooling medium. Inlet and outlet of the cooled medium, i.e. inlet and outlet of steam-gas mixture and outlet of condensate from condensing steam, are connected into the interspace between the tubes enclosed with the tube sheets. Connection of media, i.e. of the cooling medium in the form of water and of the cooled medium in the form of steam-gas mixture, from and into the heat exchanger is made using pipe sockets, which are usually in the form that is connectable to and disconnectable from the pipeline for the relevant medium.

The said arrangement of steam generator is described e.g. in the patent application CZ PV 2006-261. Here, a heat transformer in the form of exchanger is described having a tube bundle consisting of individual heat exchanger tubes located in the outer shell, and these tubes are mounted in the front tube sheet and the rear tube sheet, viewed in the direction of flow of the medium. Split or non-split helical baffle mounted on a central tube is located between the tube sheets in the tube interspace. Space between tubes is connected to the inlet hub of the cooled medium, i.e. of steam-gas mixture. The tube inner space is connected to the inlet or outlet hub of the cooling medium, usually water. This hub is connected into cavities above and under the tubes. During the steam generator operation, cooling of the steam-gas turbine exit steam-gas mixture using the cooling medium, usually evaporated water, is performed, while part of the water steam from the mixture condenses. In this way, carbon monoxide containing residual amount of water steam and possibly admixture of other gases is separated from the steam-gas mixture. According to the PV 2006-261, the space between tubes is delimitated with tubes, tube sheets, and the outer shell section between tube sheets. The space between tubes is designed for flowing of steam-gas mixture fed into it in the upper area through the input hub and drawn off in the lower area through the output hub or vice versa. The space inside the tubes and plenum cavities above and below the tubes is designed for circulation of cooling medium.

The disadvantage of present separation steam generators is especially the fact that they do not allow separation of carbon dioxide from the steam-gas mixture at sufficiently low temperature, so that the residual steam contents in carbon dioxide is relatively high. If also significant amount of steam leaves the steam generator together with non-liquefied gaseous fraction based on carbon dioxide, it results in energy losses decreasing the overall efficiency of the equipment.

Another disadvantage is also that separation steam generators do not have optionally variable construction and therefore usually they can not be constructed as needed in the optional variant according to the purpose and the effect attained. The existing arrangement usually does not allow utilising portion of the condensate sensible heat resulting from condensation of one component of cooled medium for preheating of the steam turbine condensate directly in the body of the separation steam generator. It also does not allow utilizing the condensate from the steam turbine for further cooling of the steam-gas mixture coming out of the inter-tube space. Another disadvantage is that the temperature of the inner surface of the outer shell of the separation steam generator varies along its height, which creates additional stress on the outer shell caused by temperature difference. Disadvantage is also that the present arrangement does not allow adapting the height of the heat exchange surface to the optimum course of temperatures of both media along its height.

The above-mentioned disadvantages of existing steam generators may result in decreased efficiency of steam-gas circulation with carbon dioxide separation and thereby also in limitation of their usability for developed advanced systems, and possibly even to inoperability of their engagement in these systems. This is the case for example of the circulation with a steam-gas turbine according to patent CZ 296199, where two turbines are used, a high pressure turbine and a low pressure turbine. The high-pressure turbine is used for expansion of the steam-gas mixture and it is designed as a back-pressure turbine with an output pressure of for example 4 bar. The low-pressure turbine is the output one, it is used to work with a slightly superheated water steam at a pressure lower than that of the steam-gas mixture leaving the high-pressure turbine and is designed as a condensing turbine.

Disclosure of Invention:

The above-mentioned disadvantages are eliminated to a considerable extent by the invention. New layout of the separation steam generator arranged on the principle of heat exchanger is solved. The invented vertical separation steam generator for heat exchange between media includes the outer shell in which at least one system of heat exchange tubes mounted in upper and lower tube sheets is placed, where cavities allowing circulation of cooling medium are created above the upper tube sheet and below the lower tube sheet in the inner space of the outer shell. The space of these plenum cavities is interconnected with the space in tubes, while an inter-tube space, which is enclosed with tube sheets at the top and at the bottom, is located between tubes. The outer shell is in the form of closed pressure vessel equipped with at least one pair of pipe sockets containing channels for input and output of the cooled medium and called hereinafter as primary pipe sockets, and furthermore, the outer shell is also equipped with at least one pair of other pipe sockets containing channels for input and output of the cooling medium and called hereinafter as secondary pipe sockets. Primary pipe sockets are led into the inter-tube space whereas secondary pipe sockets are led into the space interconnected with the tube space. The essence of the invention is that the system of heat exchange tubes contained in the steam generator is jacketed with a cylindrical shell that is closed with tube sheets at the top and at the bottom, and in this way a unit is created allowing with its dimensions placing inside the outer shell so that a through gap is created outwards around the circumference of the cylindrical shell between the cylindrical shell and the outer pressure shell of the steam generator. Size of this gap is such that it allows circulation of cooling medium, and the inter-tube space is equipped at the lower end with at least one inter-tube condensate discharge allowing by its shape and dimensions draining of condensate that is separated from the steam-gas mixture in the course of the equipment operation. The inter-tube condensate discharge is led outside the inter-tube space. This means that depending on the particular embodiment, it is led either outside from the outer shell, or into the space inside the outer shell, but out of the inter-tube space, as will be shown hereinafter.

Vertical separation steam generator according to the invention has preferably at least one cooler placed under the evaporator consisting of cylindrical shell with tubes and tube sheets, and the said cooler is equipped with elements for input as well as output of cooling medium. The space located between the evaporator and the cooler is preferably divided with at least one partition called hereinafter the lower partition for the sake of distinguishing it from other partitions mentioned herein. In the layout mentioned above, the space under the cooler is equipped with at least one supplementary discharge of condensate, called hereinafter condensate discharge, allowing with its shape and dimensions draining of condensate. The lower supplementary condensate discharge is led out of the outer shell.

The inter-tube space is preferably interconnected with the space located under the lower partition, which is done by means of at least one lower connecting channel. This channel is denoted herein as the lower channel because of its location under the lower partition and to distinguish it from other channels mentioned hereinafter.

At least one cooler can be preferably placed above the evaporator comprised of cylindrical shell with tubes and tube sheets. Said cooler must be equipped with elements for input and, as the case may be, also for output of cooling medium. The space between evaporator and cooler is divided using at least one upper partition. The space located above the upper partition is in its lower part equipped with at least one supplementary condensate discharge of such size and dimensions to allow draining of condensate separated from the steam-gas mixture and, as the case may be, also of drawn-off cooling medium.

The upper primary pipe socket can be preferably embodied as at least two-piece body containing at least two parts that are separated from one another. In such case the upper piece of the primary pipe socket is located in the wall of the outer shell and is led outwards of the outer shell on one side and into the space above the upper partition on the other side. Lower piece of the primary pipe socket is led into the space above the upper partition on one side and into the inter-tube space on the other side. The lower piece can be done as a direct connection of the said spaces, but it can also go as bypass, e.g. through the outer shell.

Other possible preferred variant of the steam generator embodiment is such that at least two evaporators comprised of cylindrical shell with tubes and tube sheets are placed one above the other in one common outer shell of the steam generator, while a space allowing by its shape and size movement of cooling medium is created between these evaporators, and this space is divided with at least one dividing wall. Each of the included evaporators is equipped with its own secondary pipe sockets for input and output of cooling medium and with its own inter-tube condensate discharge. The secondary pipe sockets are also preferably interconnected in parallel.

In case of steam generator with two or more evaporators according to the previous paragraph, it is optimal that the inter-tube spaces of said evaporators are interconnected with each other. The adjacent evaporators that are located one above the other are preferably interconnected with at least one connecting tube. In such case the whole steam generator has preferably only one pair of primary pipe sockets. Evaporators are interconnected one above the other in series using the connecting tube. The connecting tube can be a direct one, but it can also go from the inter-tube space of one evaporator into the inter-tube space of other evaporator in detour, e.g. through the outer shell. This solution is the most advantageous from the point of view of function as well as purposefulness.

Alternatively, it is possible not to connect the inter-tube spaces of evaporators using connecting tube, but to leave them separated. In such case, each evaporator has its own primary pipe sockets.

The invention allows running carbon dioxide separation at as low as possible temperature and with as low as possible residual steam content in the carbon dioxide. Separation steam generator according to the invention can be designed as needed in chosen variant according to the purpose and attained effect. Design with only a single internal evaporator is possible for production of saturated steam from evaporated medium. In this case the output temperature of cooled medium cannot be reduced below the boiling point of evaporated medium, but the separation steam generator will be simpler and cheaper. When choosing the invention variant where the evaporator is supplemented with cooler, cooling with a steam turbine condensate is achieved and the cooled medium temperature can be reached that is lower than the boiling point of evaporated medium, but higher than the output temperature of heated steam condensate. However this variant of design will be more complicated and more expensive. The arrangement according to the invention allows utilising portion of the condensate sensible heat resulting from condensation of one component of cooled medium for preheating of the steam turbine condensate directly in the body of the separation steam generator. It is also advantageous that the temperature of the inner surface of the body of the separation steam generator practically does not change along its height, so that additional stress on the outer shell caused by temperature differences is minimal. Another advantage of the invention is that it is possible to improve achieved results by making the steam generator variant in the arrangement with suggested cooler, which allows reaching lower temperature of the cooled medium. Cooler can be located in the very body of the steam generator. With high steam generator height, the invention embodiment variant with evaporators situated one above the other is advantageous. With this variant, division of the separator inner space to multiple parts with lower height is reached, where two or more evaporators are included, which allows decreasing the boiling point of evaporated medium at the input into each of the evaporators. In this way, reduction of necessary difference in pressures of both media at the inlet into the evaporator is reached.

The invented vertical separation steam generator can be used for the most advanced systems intended for power plants and heating plants. It is utilizable even in such systems that could not be used so far in practice because of problems with existing steam generators. It can be made in the embodiment variant that will be the most suitable for the given system arrangement and fully functional in it, which will make commercial implementation of these advanced systems possible.

Description of Drawings

The invention is illustrated using drawings, where Fig. 1 represents vertical separation steam generator according to the invention in the basic arrangement in the front view on longitudinal section, Fig. 2 shows cross-sectional view of this separation steam generator when section is drawn along the line A-A indicated on previous figure, Fig. 3 shows diagram of exemplary circulation with connected steam generator according to previous figures, Fig. 4 shows example of separation steam generator with cooler under the system of tubes, Fig. 5 shows example of separation steam generator with cooler above the system of tubes, Fig. 6 shows example of separation steam generator with two tube systems one above the other and with connecting tube, and Fig. 7 shows example of separation steam generator with two tube systems one above the other and with their own primary pipe sockets.

Best Mode for Carying Out the Invention

Example 1

Example of embodiment of the invention in the simplest form is the vertical separation steam generator according to Figs. 1 and 2.

Separation steam generator has outer shell 1 created by closed pressure vessel situated vertically. Inside of it, there is a system of heat exchange tubes 2, created from parallel vertically situated tubes and the tube ends are mounted in tube sheets 3, 4. The heat exchange tubes 2 are through, open-ended tubes, and cavities 5 are created above the upper tube sheet 3 and below the lower tube sheet 4 in the inner space of the outer shell 1. The heat exchange tubes 2 are not adjacent, but they are placed in a certain distance from each other. Inter-tube space 6 is located between tubes 2, which is enclosed at the top and at the bottom with tube sheets 3, 4. Outer shell 1 is equipped with a pair of primary pipe sockets 7, 8 led out in the upper part and in the lower part, which have inside channels for inlet and outlet of cooled medium. Outer shell 1 is further equipped with a pair of secondary pipe sockets 9, 10 having channels inside for inlet and outlet of cooling medium. Both primary pipe sockets 7, 8 are led into the inter-tube space 6. Secondary pipe sockets 9, 10 are led into the cavity 5 above the upper tube sheet 3, i.e. into the space interconnected with the tube 2 space. The system of heat exchange tubes 2 is equipped with a cylindrical shell 11 that is enclosed at the top and at the bottom with tube sheets 3, 4. All around the circumference of the cylindrical shell 11, between the cylindrical shell 11 and the outer shell 1 of the steam generator, there is a gap 12, which is through in the direction from the top towards the bottom and its size allows circulation of cooling medium. The assembly of heat exchange tubes 2, cylindrical shell 11 and tube sheets 3, 4 represents evaporator. The inter-tube space 6 is equipped in the lower area with inter-tube discharge 13 with inner channel for draining of condensate separated from steam-gas mixture. In this example of embodiment, the inter-tube discharge 13 of condensate has the shape of a tube with one end mounted in the lower tube sheet 4 from where this tube goes out and is led out of the outer shell 1. Mounting of the inter-tube discharge 13 in the lower tube sheet 4 is advantageous, but it is not a requirement.

During operation of this steam generator, the generated steam-gas mixture can be formed as a mixture of non-condensing gas such as for instance carbon dioxide and a condensing gas, for instance water steam. The steam-gas mixture represents the cooled medium. The heated, i.e. cooling, medium is the evaporated liquid, for instance water, steam of which is further superheated to the low-pressure turbine operating temperature before entering the low-pressure turbine. The lower cavity 5, heat exchange tubes 2, gap 12, and part of the upper cavity 5 plenum above the upper tube sheet 3 of the evaporator are inundated up to the working height *h* during operation of the separation steam generator. The inlet secondary pipe socket 9 serves for inundation with water as the cooling medium. The lower primary pipe socket 8 serves for input of the steam-gas mixture into the inter-tube space 6. Pressure of the steam-gas mixture as the cooled medium at the input to the inter-tube space 6 is higher than pressure of saturated steam as the cooling medium located above the liquid level of the cooling medium at the working height *h*, so that the cooling medium above the level at the working height *h* has temperature lower than that of the cooled medium in the inter-tube space 6. Cooling medium in the input part of heat exchange tubes 2 will have, due to superelevation of level at the working height h, higher boiling point than that at the level *h*, so that it will be first heated to the temperature corresponding to the boiling point at higher pressure and it will start to evaporate only after reaching that temperature. Heat exchange tubes 2 are thus divided longitudinally to heating part and evaporating part. Coefficient of heat-transfer from the medium to the tube 2 wall in the heating part of heat exchange tubes 2 will be different from that in the evaporating part of tubes 2. Because of higher boiling point, the temperature gradient between the steam-gas mixture and the cooling medium will be lower in the input part of heat exchange tubes 2, both of which influences the amount of heat transferred in the evaporator. Hence the cooling medium pressure and superelevation of its level h must be determined depending on the required temperature difference between both media. It holds true that higher temperature difference is reached with higher difference between input pressures of both media in the input part of heat exchange tubes 2, which leads to reduction of heat exchange area of evaporator or to increase of its output of heat, but at the same time, higher difference between pressures of both media results in reduction of the circulation efficiency. Condensate that is led out via inter-tube discharge 13 segregates from the steam-gas mixture flowing upwards into the inter-tube space 6. Residual steam-gas mixture containing carbon dioxide with admixture of water steam is carried away from the steam generator at the top through the upper primary pipe socket 7. Saturated water steam released from heated water, i.e. from cooling medium, is drawn off from the steam generator through the output secondary pipe socket 10. In consequence of the designed layout according to the invention, the cooling medium effectively circulates in the equipment. Natural circulation is reached. The gap 12 between the cylindrical shell 11 of evaporator and the outer shell 1 of steam generator functions as flood system for heat exchange tubes 2. Mounting of evaporator inside the outer shell 1 is done using suitable connecting means that will not result in impassability of the gap 12, e.g. using local supports 21.

With the steam generator layout demonstrated herein, the whole inner surface of the outer shell 1 is in contact with the cooling medium of the same temperature corresponding to the boiling point of cooling medium at given pressure. This beneficially influences strength stress in the cylindrical section of the outer shell 1, because there is practically no additional stress in it due to temperature differences in a vertical direction.

Vertical steam generator according to this example of embodiment can be utilised for example for connection into circulation with a generator 111, a high-pressure turbine 112, and a low-pressure turbine 113, as shown in diagram on Fig. 3. Fuel, e.g. natural gas oxidised with introduced oxygen, is combusted in generator 111, which can be for instance modified rocket engine. Combustion gives rise to the steam-gas mixture based on water steam and carbon dioxide that is maintained at a desired temperature by cooling with injected water. In the circulation shown, saturated steam superheater 114 with output to the low-pressure turbine 113 as well as to the lower primary pipe socket 8 of steam generator is connected to the output of a high-pressure turbine 112 , while the superheater 114 is further connected to the secondary pipe socket 10 of the steam generator. Furthermore, expander 115, feed tank 116, condenser 117, pumps 118, cooling unit 119 etc. are located here. The diagram is shown to demonstrate how it is possible, using the invented steam generator in the cycle, efficiently utilise the heat of cooled steam-gas mixture. To be descriptive, directions of media flow in the cycle are also indicated with arrows. The steam-gas mixture of suitable temperature, e.g. 600 °C, and pressure, e.g. 150 bar, is introduced into the high-pressure turbine 112 and after expansion, e.g. to pressure of 5 bar, it continues to the saturated steam superheater 114, in which the temperature of the steam-gas mixture is lowered approximately to a temperature corresponding to the saturation temperature at the given partial pressure of water vapour in the steam-gas mixture. The steam-gas mixture cooled in this way flows into steam generator through the lower primary pipe socket 8, where it is cooled down in the inter-tube space 6 below the saturation temperature, so that part of the water steam from the steam-gas mixture condenses. Condensate separated from the steam-gas mixture is drained out of the steam generator through inter-tube discharge 13, from where it is introduced to expander 115 and subsequently utilised for generator 111, and partially utilised also as a cooling medium introduced to steam generator via the inlet secondary pipe socket 9 through a feed tank 116. Residual steam-gas mixture containing carbon dioxide with residual admixture of water steam is carried away from the system through the upper primary pipe socket 7 as utilisable product. The heat released in the steam generator by cooling down the steam-gas mixture and condensation of part of steam is utilised for production of saturated steam from cooling medium, for instance with pressure of 3bar. The saturated steam produced is directed from the steam generator through the outlet secondary pipe socket 10 to the saturated steam superheater 114 in which it is superheated to the desired temperature utilising the heat of cooled medium, i.e. the steam-gas mixture, and in a superheated state, it is further utilised for the low-pressure turbine 113.

Example 2

Other example embodiment of the invention demonstrates the vertical separation steam generator according to Fig. 4.

The upper part of the tube steam generator is arranged in the same way as in the previous example. Also this separation steam generator has outer shell 1 created by closed pressure vessel situated vertically. Inside of it, there is a system of heat exchange tubes 2, consisting of parallel tubes with their ends mounted in tube sheets 3, 4. The heat exchange tubes 2 are through tubes, have open ends, and cavities 5 for flow of cooling medium through the tubes 2 are created above the upper tube sheet 3 and below the lower tube sheet 4 in the inner space of the outer shell 1. Inter-tube space 6 is located between the heat exchange tubes 2, which is enclosed at the top and at the bottom with tube sheets 3, 4. Outer shell 1 is equipped with a pair of primary pipe sockets 7, 8 led out outwards for inlet and outlet of cooled medium, i.e. the steam-gas mixture. Outer shell 1 is equipped with a pair of secondary pipe sockets 9, 10 for input and output of cooling medium. Both primary pipe sockets 7, 8 are led with their other end into the inter-tube space 6. Secondary pipe sockets 9, 10 are led into the cavity 5 above the upper tube sheet 3, i.e. into the space interconnected with the space in tubes 2. The system of heat exchange tubes 2 is jacketed all around with a cylindrical shell 11 that is enclosed at the top and at the bottom with tube sheets 3, 4. In the annular area outside the circumference of the cylindrical shell 11, between the cylindrical shell 11 and the outer shell 1 of the steam generator, there is a gap 12, which is through in the direction from the top towards the bottom and its size allows cooling medium to circulate through the gap 12. The inter-tube space 6 is equipped in the lower area with inter-tube discharge 13 for draining of condensate separated from steam-gas mixture. This condensate flows through the annular space between the inter-tube discharge 13 and the lower primary pipe socket 8.

Also in this example of embodiment, the upper primary pipe socket 7 has a one-piece form, one of its ends is led into the inter-tube space 6 and the other end is led out of the outer shell 1.

The lower part of the steam generator has different arrangement. Cooler 14 with elements 15 for input as well as output of cooling medium is placed under the evaporator consisting of a cylindrical shell 11 with tubes 2 and tube sheets 3, 4. This cooler 14 allows for efficient after-cooling of condensate separated from the steam-gas mixture. The lower cavity 5 of steam generator is between evaporator and cooler 14 divided with lower partition 16, where the term lower means location under the lower tube sheet 4 of the evaporator. With the help of this lower partition 16, separation of the steam-gas mixture condensate in the cooler 14 space from the inundated space of the cooling medium circulation circuit in the evaporator with working level h is reached. In this way, this lower partition 16 efficiently modifies media flow and circulation inside the steam generator and prevents unwanted mixing of condensate from the steam-gas mixture with the cooling medium directed into the steam generator through the input secondary pipe socket 9. The space under the cooler 14 is equipped with a supplementary condensate discharge 17 for draining of condensate separated from the steam-gas mixture and after-cooled with the cooler 14. This supplementary condensate discharge 17 is led out of the outer shell 1 at the bottom.

In the demonstrated variant of the invention embodiment, the inter-tube discharge 13 from the evaporator is advantageously solved so that it is realized as a connecting channel through which the inter-tube space 6 is interconnected with part of the lower cavity 5 located under the lower partition 16.

This alternative embodiment allows after-cooling of condensate separated from the steam-gas mixture during its cooling in the evaporator. Cooling medium can be used for the cooler 14 that is different from the cooling medium for evaporator. The cooler 14 can be utilised as a device for preheating the cooling medium used in it.

Example 3

Another example embodiment of the invention demonstrates the vertical separation steam generator according to Fig. 5.

The lower part of the tube steam generator is arranged in the same way as in the first example. Also this separation steam generator has outer shell 1 created by closed pressure vessel situated vertically. Inside of it, there is a system of heat exchange tubes 2, created from tubes whose ends are mounted in tube sheets 3, 4. The heat exchange tubes 2 are through and have open ends, and cavities 5 for flow of cooling medium through the tubes 2 are created above the upper tube sheet 3 and below the lower tube sheet 4 in the inner space of the outer shell 1. Inter-tube space 6 is located between the heat exchange tubes 2, which is enclosed at the top and at the bottom with tube sheets 3, 4. Outer shell 1 is equipped with primary pipe sockets 7, 8 for input and output of cooled medium, which are led outwards. The outer shell 1 is further equipped with a pair of secondary pipe sockets 9, 10 for input and output of cooling medium. The lower primary pipe socket 8 is with its upper end led into the inter-tube space 6. The upper primary pipe socket 7 is a two-piece, i.e. split, pipe socket, as will be clarified hereinafter.

The system of heat exchange tubes 2 is equipped with a cylindrical shell 11 that is enclosed at the top and at the bottom with tube sheets 3, 4. All around the circumference of the cylindrical shell 11, in the annular space between the cylindrical shell 11 and the outer shell 1, there is a gap 12, which is through in the direction from the top towards the bottom and its size allows circulation of cooling medium. The inter-tube space 6 is equipped in the lower area with an inter-tube discharge 13 for outlet of condensate separated from steam-gas mixture, which is led out of the outer shell 1. In this example embodiment, the lower primary pipe socket 8 has one of its ends led out of the outer shell 1 and the other end is led into the inter-tube space 6.

The upper part of the steam generator has different arrangement. Cooler 14 embodied as a tubular heat exchange surface with elements 15 for input as well as output of cooling medium is placed above the evaporator consisting of a cylindrical shell 11 with tubes 2 and tube sheets 3, 4. This cooler 14 allows for efficient after-cooling of residual cooled medium exiting from the evaporator before the cooled medium is leaving the steam generator. The upper cavity 5 of the steam generator is between evaporator and cooler 14 divided with an upper partition 18, where the term upper is used because of its location above the evaporator, above its upper tube sheet 3. This upper partition 18 efficiently modifies media circulation inside the steam generator and prevents unwanted mixing of condensate from cooler 14 with the cooling medium directed into the steam generator through the input secondary pipe socket 9. The space located under the cooler 14 is equipped with a condensate discharge 17 for draining of condensate formed during after-cooling of residual steam-gas mixture in the cooler 14. The condensate discharge 17 has one orifice in the lower part of the space above the upper partition 18 and the other orifice outwards of the outer shell 1.

In the demonstrated variant of the invention embodiment, the upper primary pipe socket 7 is advantageously resolved. It consists of two pieces 71, 72 separated from each other. The upper piece 71 of the primary pipe socket 7 is located in the wall of the outer shell 1 and it is led outwards of the outer shell 1 on one side, and into a part of the cavity 5 located above the upper partition 18 on the other side. The lower piece 72 of the primary pipe socket 7 is led into a part of the cavity 5 located above the upper partition 18 on one side, and into the inter-tube space 6 on the other side.

This alternative embodiment allows after-cooling of residual steam-gas mixture to a lower temperature with utilisation of the cooled medium heat and separation of the additional unwanted steam amount from residual steam-gas mixture. Different cooling medium and of different temperature can be used for the cooler 14, compared to the cooling medium for evaporator.

Cooler 14 can be, as the case may be, realized as a mixing heat exchanger with suitably arranged internals. In such case, the cooler 14 is equipped with elements 15 only for input of cooling medium. In the case of this alternative, cooling medium is sprayed in the cooler 14 and directed out through the condensate discharge 17 together with condensate formed from steam-gas mixture. Elements 15 for input of cooling medium are selected in the form that allows spraying of cooling medium.

Example 4

Another example embodiment of the invention demonstrates the vertical separation steam generator according to Fig. 6.

Separation steam generator has outer shell 1 created by closed pressure vessel situated vertically. There are two evaporators inside, situated one above the other. Each of them is created as a jacketed system of heat exchange tubes 2 with their ends mounted in tube sheets 3, 4. The heat exchange tubes 2 are through, they have open ends, and cavities 5 for flowing of cooling medium from the space of cavities 5 through the tubes 2 are created above the upper tube sheet 3 and below the lower tube sheet 4 in the inner space of the outer shell 1. Inter-tube space 6 is located between the heat exchange tubes 2, which is enclosed at the top and at the bottom with tube sheets 3, 4. Each system of heat exchange tubes 2 is equipped with a cylindrical shell 11 that is enclosed at the top and at the bottom with tube sheets 3, 4. All around the circumference of the cylindrical shell 11, between the cylindrical shell 11 and the outer shell 1 of the steam generator, there is a gap 12, which is through in the direction from the top towards the bottom and its size allows circulation of cooling medium. The inter-tube space 6 of each evaporator is equipped in the lower area with an inter-tube discharge 13 for draining of condensate separated from steam-gas mixture, which is led out of the outer shell 1.

Outer shell 1 is equipped with a pair of primary pipe sockets 7, 8 for input and output of cooled medium, which are led outwards. The outer shell 1 is further equipped for each evaporator with one pair of secondary pipe sockets 9, 10 for input and output of cooling medium. The upper primary pipe socket 7 has its upper end led out of the outer shell 1 and its lower end is led into the inter-tube space 6 of the upper evaporator. The lower primary pipe socket 8 is with its upper end led into the inter-tube space 6 of the lower evaporator, and with its lower end it is led of the outer shell 1.

The space located between evaporators is divided using partition wall 19. The inter-tube spaces 6 of these evaporators are interconnected to one another, which is in this demonstrational case done using connecting tube 20. Each evaporator is equipped with its own inter-tube discharge 13 of condensate.

By dividing heat exchange tubes 2 and inter-tube space 6 by means of creation of at least two evaporators one above the other, the working height *h* of circulation circuits will be lowered compared to undivided arrangement, which leads to reduction of pressure of the evaporated cooling medium, i.e. water, on the input to the heat exchange tubes 2. Fig. 6 shows embodiment where evaporators have parallel input secondary pipe sockets 9, parallel output secondary pipe sockets 10, and parallel inter-tube discharges 13. Interconnection of inter-tube spaces 6 of evaporators is serial. This example embodiment is the most advantageous one because of its simplicity for connection in circulation.

Example 5

Another example embodiment of the invention demonstrates the vertical separation steam generator according to Fig. 7.

Arrangement of the steam generator is similar to that one described in the previous example. However, evaporators have parallel input secondary pipe sockets 9, parallel output secondary pipe sockets 10, parallel inter-tube discharges 13, parallel upper primary pipe sockets 7, and parallel lower primary pipe sockets 8.

All the embodiment variants demonstrated herein can be mutually combined as needed and according to the intended achieved effect. Heat from media can be utilised to modify temperature conditions for surrounding and/or connected equipment.

Claims

1. Vertical separation steam generator including outer shell (1) in which at least one system of heat exchange tubes (2) is placed having open ends that are mounted in upper and lower tube sheets (3,4), where cavities (5) with a space interconnected with the space in tubes (2) are located above the upper tube sheet (3) and under the lower tube sheet (4) in the inner space of the outer shell (1), while inter-tube space (6) enclosed at the top and at the bottom with tube sheets (3,4) is located between tubes (2), and where the outer shell (1) is in the form of closed pressure vessel equipped with at least one pair of primary pipe sockets (7,8) for input and output of cooled medium based on steam-gas mixture and at least one pair of secondary pipe sockets (9,10) for input and output of cooling medium, where the primary pipe sockets (7,8) are led into the inter-tube space (6) and secondary pipe sockets (9,10) are led into the space interconnected with the space of tubes (2), **characterized by that** the system of heat exchange tubes (2) is equipped with a cylindrical shell (11) closed with tube sheets (3,4) at the top and at the bottom, while a circumferential, in vertical direction open, gap (12) of a size allowing circulation of cooling medium is created outwards around the circumference of the cylindrical shell (11) between the cylindrical shell (11) and the outer shell (1) of the steam generator, while the inter-tube space (6) located in the cylindrical shell (11) is equipped at the lower end with at least one inter-tube discharge (13) of condensate for draining of the condensate separated from the steam-gas mixture out of the inter-tube space (6).

2. Vertical separation steam generator according to the claim 1 **characterized by that** at least one cooler (14) equipped with elements (15) for input and output of cooling medium is placed under the evaporator consisting of cylindrical shell (11) with tubes (2) and tube sheets (3, 4), and the space between the evaporator and the cooler (14) is divided with at least one lower partition (16), while the space located under the cooler (14) is equipped with at least one supplementary condensate discharge (17) for draining of condensate separated from the steam-gas mixture and the said supplementary condensate discharge (17) is led out of the of the outer shell (1).

3. Vertical separation steam generator according to the claim 2 **characterized by that** at least one inter-tube discharge (13) is embodied as a connecting channel through which the inter-tube space (6) is interconnected with the space under the lower partition (16).

4. Vertical separation steam generator according to the claims 1 to 3 **characterized by that** at least one cooler (14) equipped with elements (15) for input and possibly output of cooling medium is placed above the evaporator consisting of cylindrical shell (11) with tubes (2) and tube sheets (3, 4), and the space between the evaporator and the cooler (14) is divided by means of at least one upper partition (18), while the space located above the upper partition (18) is in its lower part equipped with at least one supplementary condensate discharge (17) for draining of condensate separated from the steam-gas mixture and, as the case may be, also of a drawn-off cooling medium.

5. Vertical separation steam generator according to the claim 4 **characterized by that** the upper primary pipe socket (7) consists of two pieces (71, 72) separated from each other, from which the upper piece (71) of the primary pipe socket (7) is located in the wall of the outer shell (1) and is led outwards of the outer shell (1) on one side and into the space above the upper partition (18) on the other side, and the lower piece (72) of the primary pipe socket (7) is led into the space above the upper partition (18) on one side, and into the inter-tube space (6) on the other side.

6. Vertical separation steam generator according to the claims 1 to 5 **characterized by that** at least two evaporators comprised of cylindrical shell (11) with tubes (2) and tube sheets (3, 4) are placed one above the other in one outer shell (1) where the space between these evaporators is divided with at least one dividing wall (19), while each of these evaporators has its own secondary pipe sockets (9,10) for input and output of cooling medium and its own inter-tube discharge (13) of condensate, and these secondary pipe sockets (9,10) are interconnected in parallel.

7. Vertical separation steam generator according to the claim 6 **characterized by that** the inter-tube spaces (6) of these evaporators are mutually interconnected using at least one connecting tube (20) and the steam generator has only one pair of primary pipe sockets (7, 8).

8. Vertical separation steam generator for heat exchange between media according to the claim 6 **characterized by that** the inter-tube spaces (6) of these evaporators are separated and each evaporator has its own primary pipe sockets (7, 8).

Fig. 1

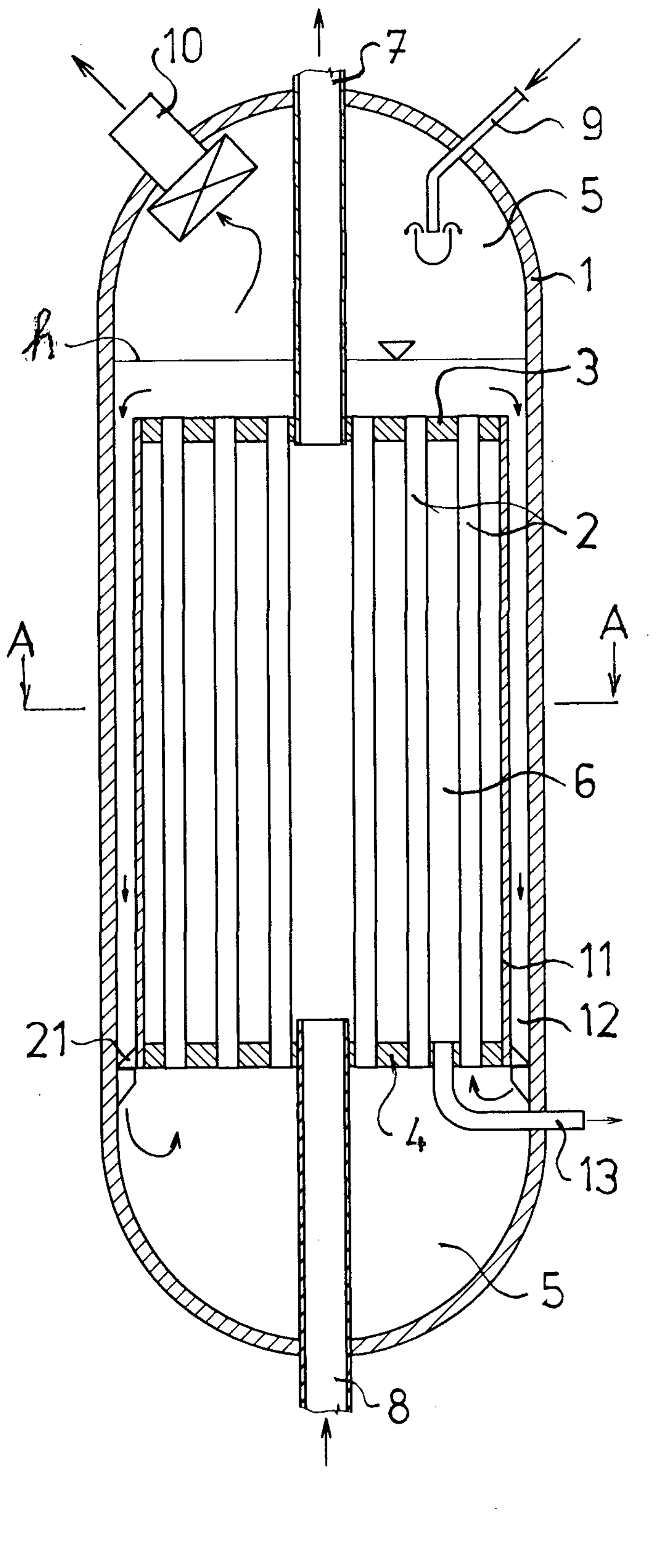

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Fig. 2

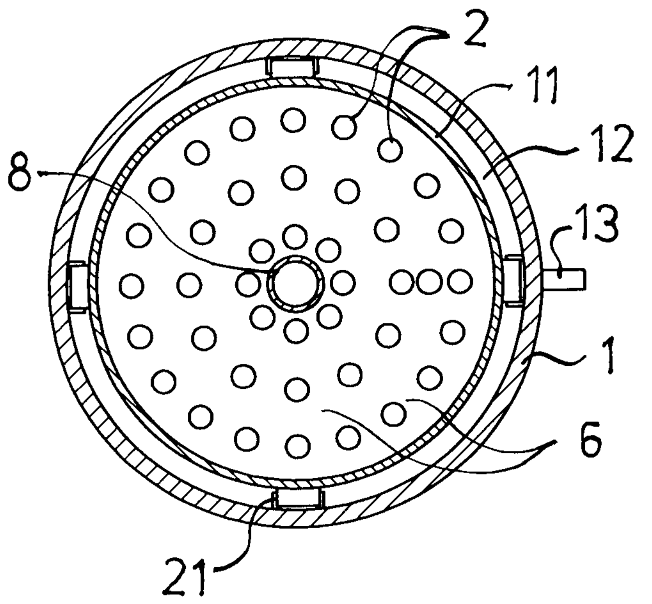

Fig. 3

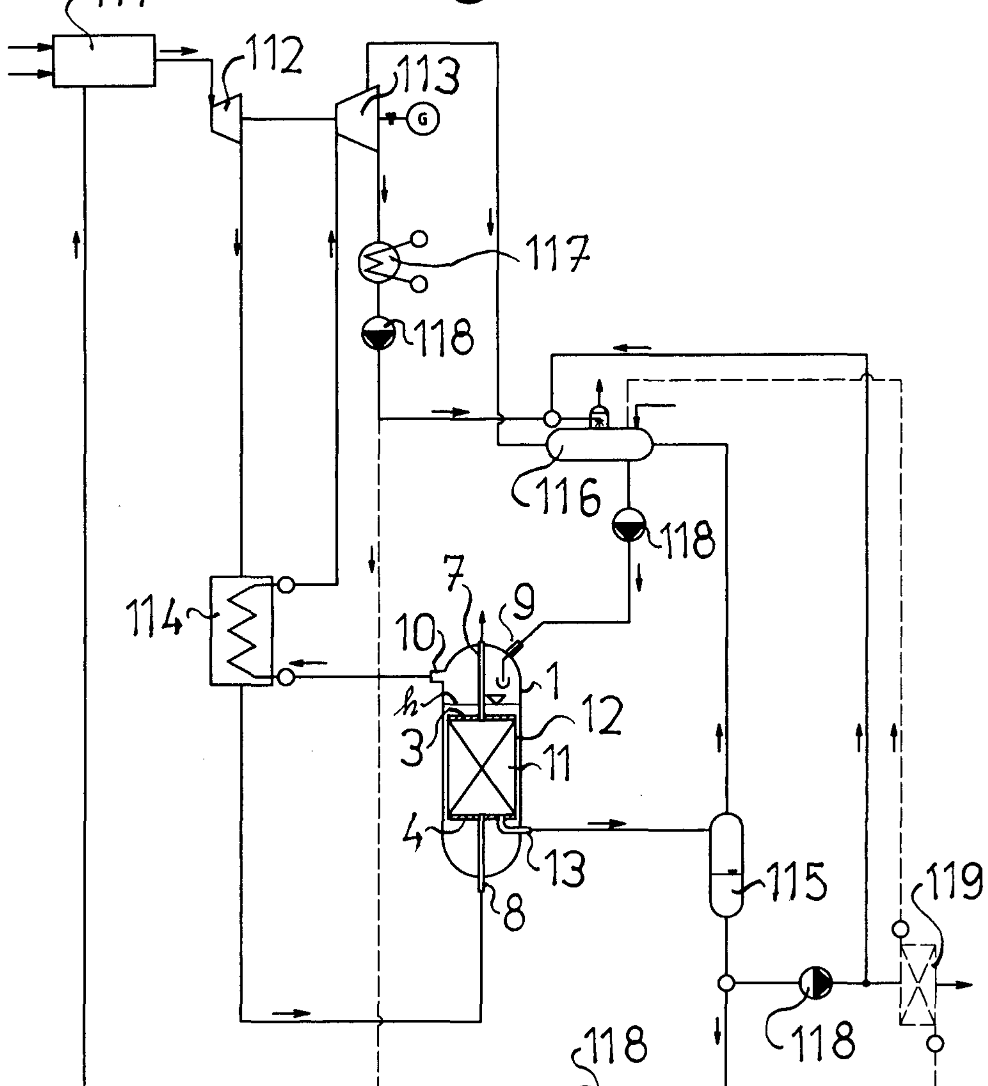
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Fig. 4

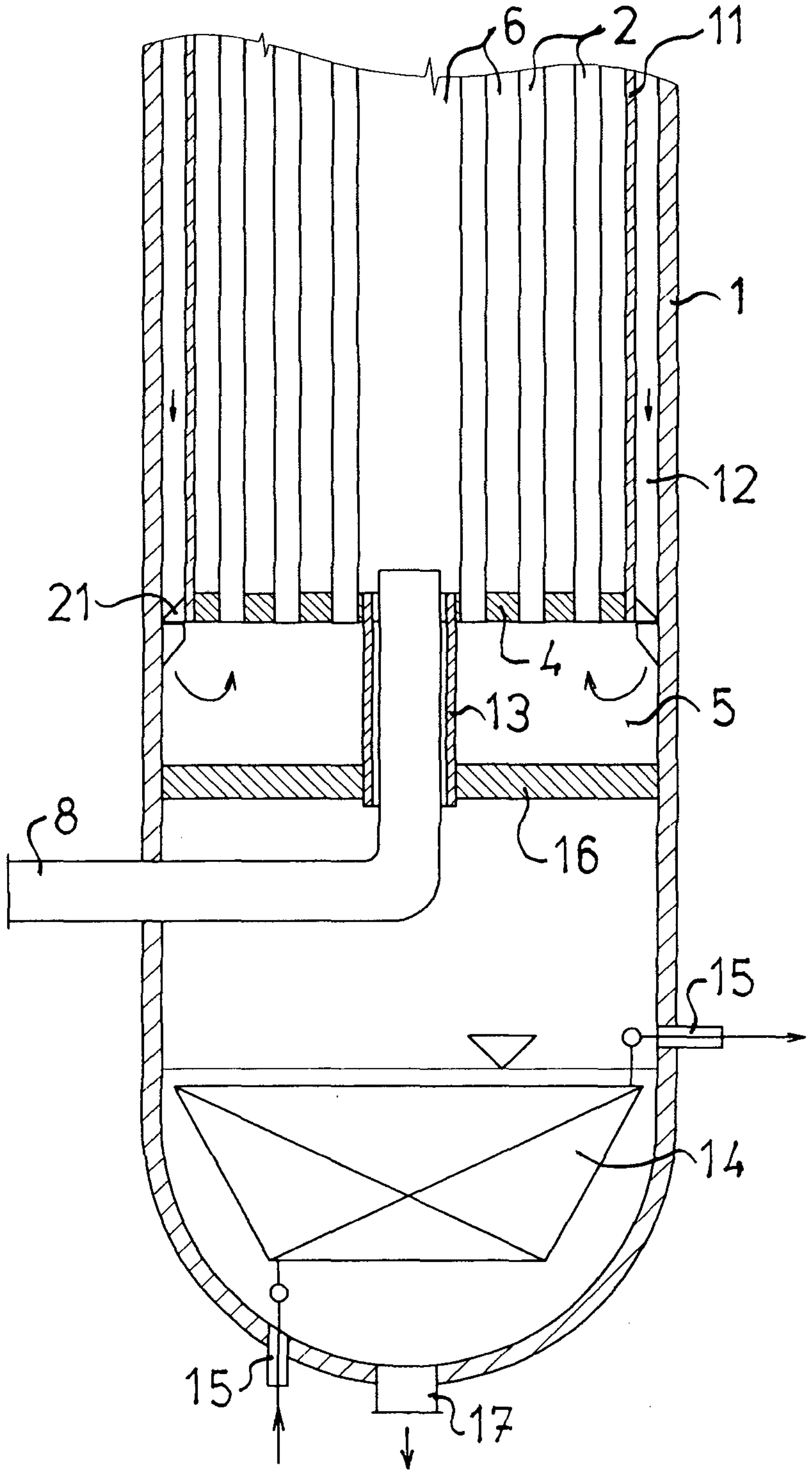

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Fig. 5

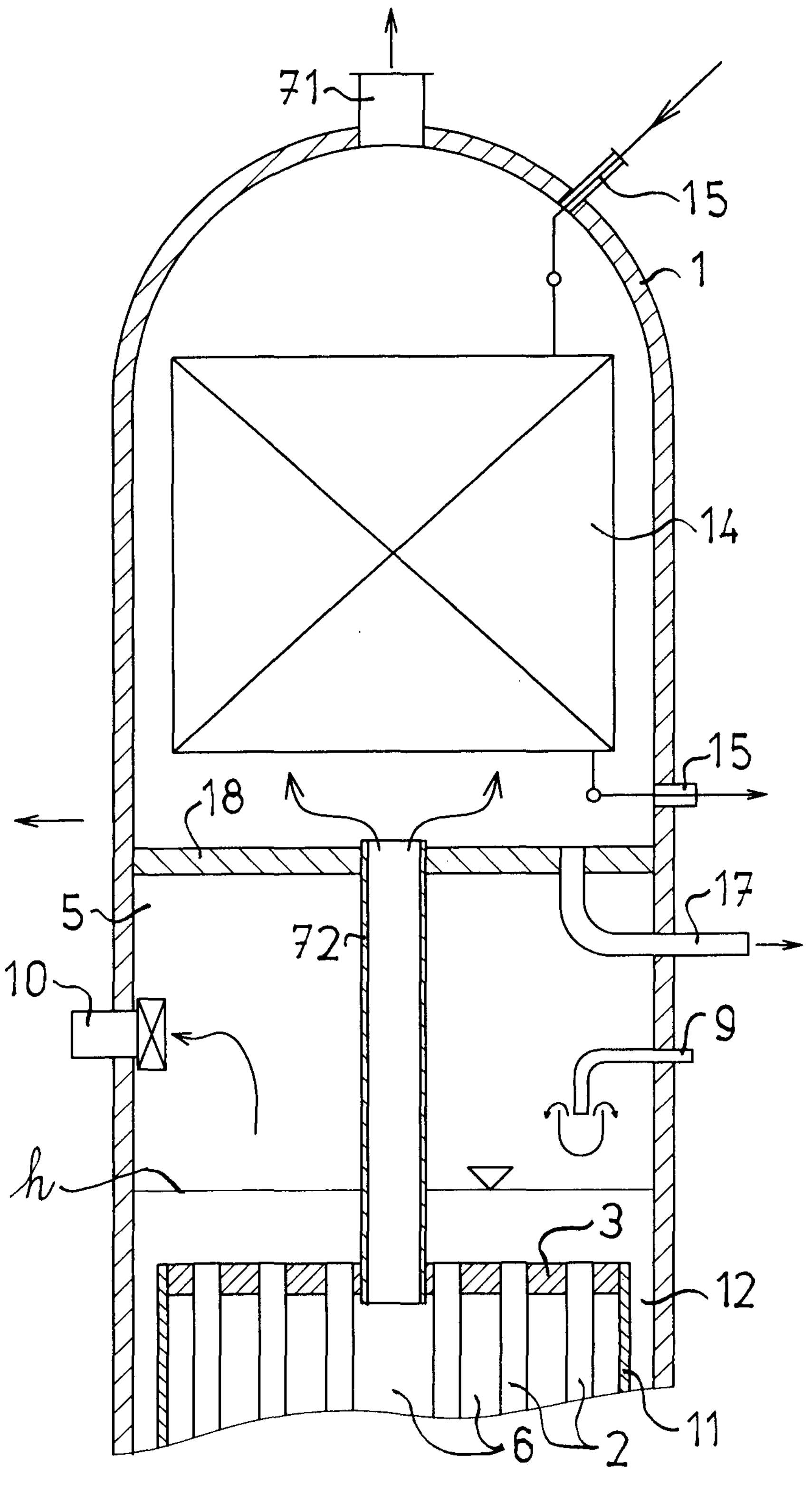

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Fig. 6

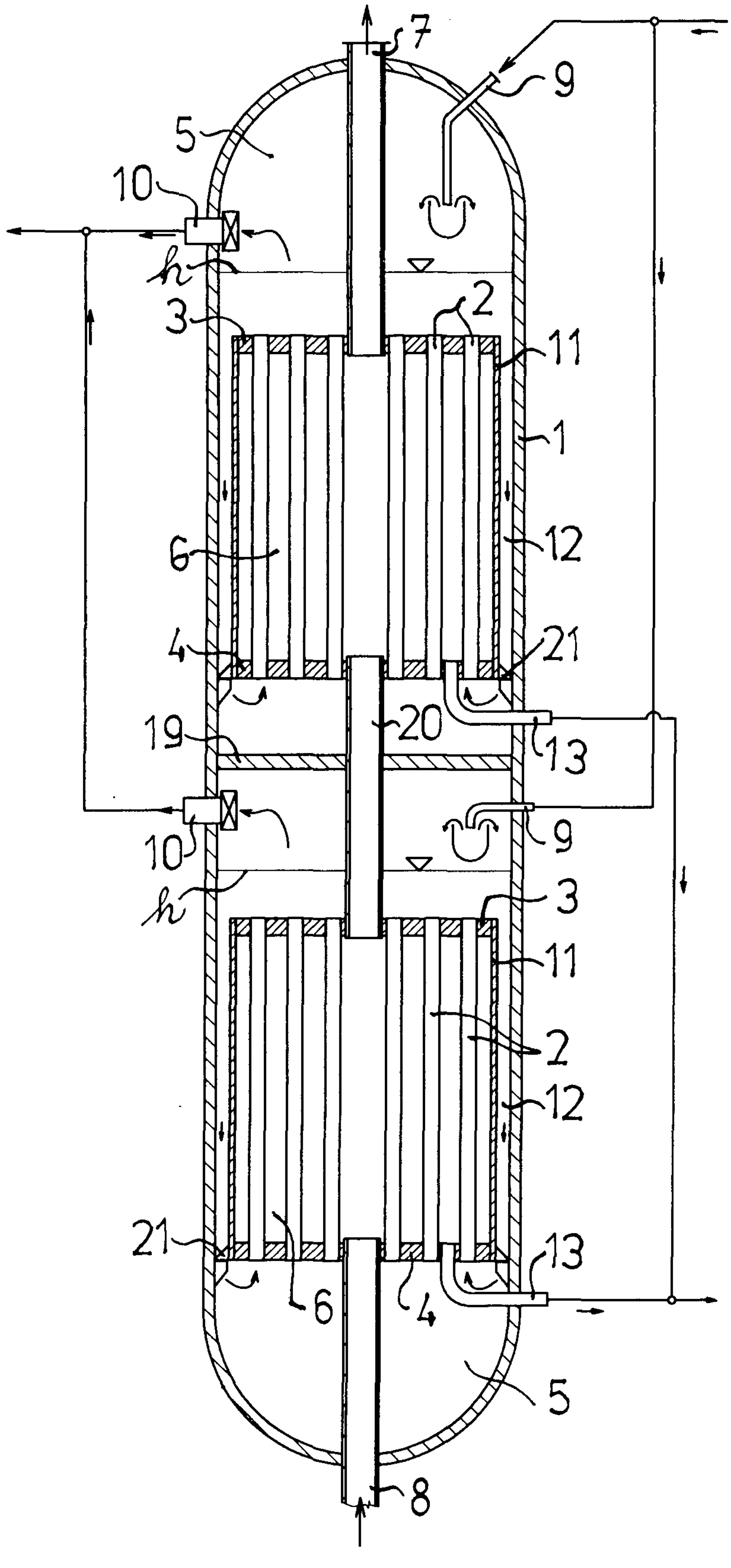

Fig. 7