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(54) Heat exchanging and liuid separation apparatus

(57) An apparatus for heat exchange and demoisturizing of hot compressed gas is described that can be operated at high pressures and dirty gases at elevated pressures of approximately 70 bar to 80 bar.

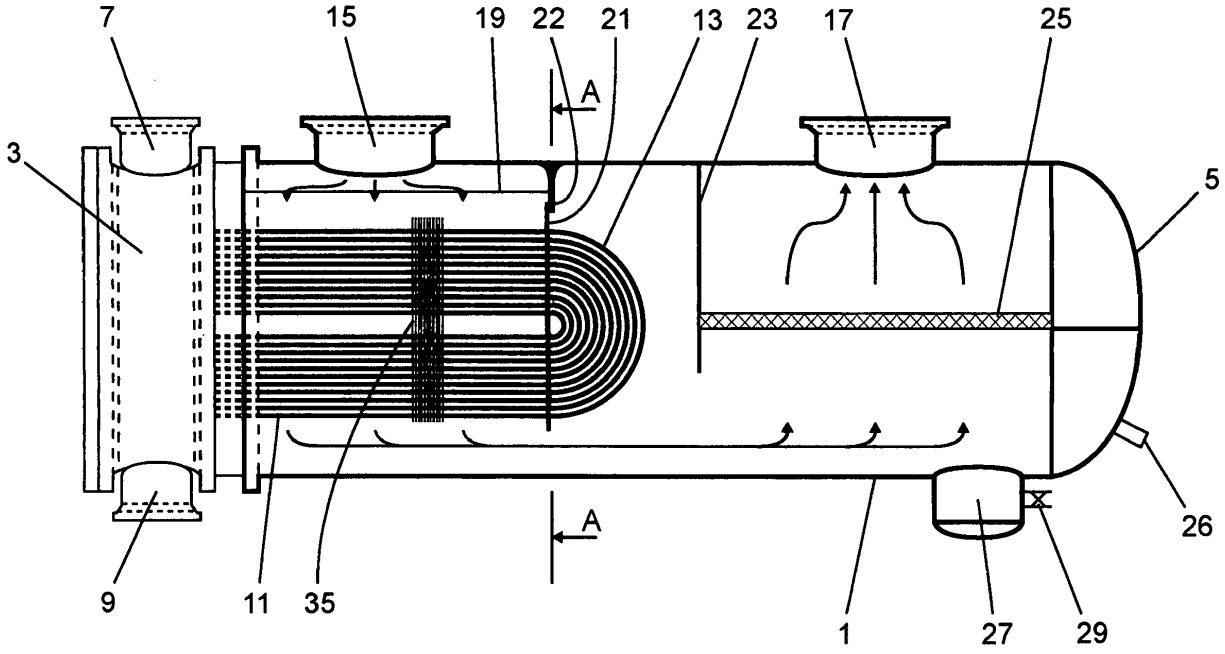

Fig.1

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Description

[0001] Heat exchanging apparatus are well known in the field of energy technology, namely power stations. With regard to different types of heat exchangers TEMA has classified several designs of the front-head, the shell and the rear-head of the heat exchanger.

[0002] One type is the so-called removable bundle tube heat exchanger. The bundle of tubes may be of the so-called U-tube-type or with a floating head type. For example the TEMA floating head types BET or AET are possible. Then the "T" head has to be elliptically shaped. This type includes BEU and AEU design according to the TEMA standard.

[0003] In all processes for CO_2 capture and storage the flue gas of the power station and/or CO_2 that has already been separated from the flue gas has to be compressed to achieve the conditions required for transport and/or storage. To minimize the energy consumption a multi stage compression with at least one cooling process is applied. In the course of multistage compression the interstage heat exchangers, liquid separators and piping are the major factor for total compression power requirements.

[0004] Currently there are two ways of approach to this matter:

A first alternative comprises the use of conventional heat exchangers followed by a liquid separation vessel. This conventional design leads to high interstage pressure drops due to the long piping runs required.

The second alternative comprises the use of continuous fin exchangers with integrated liquid separation. This design is mostly known in air separation applications. An example of such a compressed air aftercooler with integral moisture separator is known from WO 2006/065963 A2. This apparatus is usable only for clean gas flows and for low to medium pressures below 40 bar.

[0005] Another restriction of the prior art heat exchangers for the intercooling or aftercooling of compressed flue gas and/or CO2 is that the materials of construction often do not allow an installation of the heat exchangers in corrosive environments, like in flue gas compression. This is due to the fact that the fins material is most commonly aluminium, copper or similar alloys.

[0006] Consequently, it is the object of the claimed invention to provide a new heat exchanger and liquid separation apparatus reflecting the needs for heat exchange and liquid separation in the course of clean or dirty gas compression up to elevated pressures above 40 bar.

[0007] This object is achieved by an apparatus for heat exchange and demoisturizing of hot compressed gas comprising a shell, a front end stationary head, a rear end stationary head and at least one bundle of tubes, the shell comprising an inlet and an outlet for the compressed gas, wherein the shell is divided into a first section and a second section and the at least one bundle of tubes is located in the first section and in the second section a liquid accumulator is installed.

[0008] This split design of the claimed apparatus allows an optimized heat exchange in the first section resulting in a partial condensation of the cooled compressed gas. The condensated gas in the form of a liquid is separated from the cooled gas in the second section of the inventive apparatus. Further on, this design allows the cleaning of the U-tubes during operation of the apparatus, leading to an improved availability and reduced stand still times. In this apparatus the hot gases for compression are handled on the shell-side, whereas the cooling medium is handled on the tube-side.

[0009] Since the heat exchanger as well as the liquid/gas separator are integrated in one shell, the piping can be simplified, the costs for manufacturing of the apparatus and the pressure drop during operation are reduced. Such a design can be run at elevated pressures up to 80 bar or even more, although the shell has quite a large volume.

[0010] The U-tube design and the design with a floating end llows for differential thermal expansion between the shell and the tube bundle as well as for individual tubes. Other advantages include a shell circuit that can be inspected and steam or mechanically cleaned. The bundle of tubes can be removed from the front end for cleaning and replacement, if required.

[0011] This design also provides a multipass tube circuit arrangement with more than one bundle of tubes. The bundle can be removed from one end for cleaning or replacement. Shortly said, the claimed apparatus can be designed as a BEU and/or AEU type according to the TEMA specifications.

[0012] Furtheron, the separation of liquid and gas inside the shell can be achieved by a liquid accumulator that is situated at the lower side of the shell in the second section. Consequently, easy separation from liquid and compressed gas is achieved.

[0013] To make sure that the compressed gas flows through the at least one bundle of tubes and subsequently flows through the second section of the shell to the outlet, the first section and the second section are separated by at least one baffle plate, wherein this at least one baffle plate is oriented more or less perpendicular to the longitudinal axis of the shell dividing the first section from the second section of the shell.

[0014] The claimed apparatus is characterized in that the inlet of the shell is located in the first section and the outlet is located in the second section, preferably at the upper side, of the shell. This arrangement allows an improved separation of liquid and gas and a good heat exchanging rate between the compressed gas and the tubes.

[0015] Preferably, the liquid accumulator is located at the lower side of the shell so that the liquid that has been separated from the gas can be extracted from the shell

supported by the gravity.

[0016] To make sure that no liquid leaves the shell through the outlet of the compressed gas, a demister is installed in the second section of the shell and this demister extends from a baffle plate to the rear end stationary head of the apparatus. This demister may consist of a woven cloth made of steel wires or other metallic steel wires. By the number of meshes per inch of this woven cloth, the maximum size of liquid particles that may enter the outlet of the shell can be limited.

[0017] To amend the liquid separation of condensate from the gas, it is a further advantageous feature of the claimed invention that the shell is inclined against the horizontal line at an angle between 1° and 5°, preferably between 2° and 3°. This allows that the liquid accumulator is situated at the lowest part point of the shell, thus allowing an easy and gravity-supported extraction of the liquid from the shell.

[0018] To further optimize the heat transfer between the compressed gas the at least one bundle of tubes is equipped with fin plates that are perpendicular to the longitudinal axis of the tubes. These fin plates are made of a sheet metal that is perforated so that several fin plates can be shifted into the at least one bundle of tubes. These fins improve the heat exchange and serve as a baffle for the compressed gas.

[0019] These fins can be made of any appropriate material, such as all grades of steel, including stainless steel, or titanium-based material. By using an appropriate material for the shell, the tubes, the baffle plates and the fins, it is possible to make the claimed apparatus resistant to even corrosive compressed gas for a long operating time.

[0020] In most cases it is not necessary to braze the fin plates to the tubes, because a great number of contact points between the fins and tubes exists, so that the heat transfer from the tubes to the fin plates is sufficient. Furtheron, not brazing or welding the fin plates to the tubes leads to reduced tensile stress that is induced by different temperatures and temperature gradients, so that the danger of ruptures of one or more of the tubes is reduced.

[0021] A further embodiment of the claimed invention provides a feed distributor between the inlet and the at least one bundle of tubes to make sure that the compressed gas is diverted over the whole length of the bundle of tubes, so that an optimized heat transfer and reduced pressure drops are achieved.

[0022] In case of high fouling tendencies or to solute certain gas components, a pipe for liquid distribution with perforations and/or spray nozzles is installed between the inlet and the at least one bundle of tubes. Due to the inlet distribution due to this arrangement at the inlet of the compressed gas, a good gas-liquid mixing can be ensured.

[0023] The liquid and the gas are pressed through the holes together. After having cleaned the tube bundle the liquid is separated from the gas by condensation and collected in the optional boot of the exchanger. This means that during operation of the claimed apparatus cleaning of the tubes can be executed without any interruption. If the pipe for liquid distribution serves to condition the gas, the gas components go into solution with the liquid and then the solution is collected in the optional boot of the exchanger.

[0024] Further advantages and features are described based on the drawings.

[0025] The drawings show:

Figure 1 a first embodiment of the claimed apparatus with one bundle of U-tubes,

Figure 2 a second embodiment of the claimed apparatus with two bundles of U-tubes and

Figure 3 a third embodiment showing a pipe for liquid distribution between inlet and the bundle of U-tubes.

Description of the drawings

[0026] Figure 1 shows a longitudinal section of a first embodiment of the claimed apparatus comprising a shell 1, a removable front end 3 and a rear end 5. The rear end 5 may be removable, but can also be welded to the shell 1. The front end 3 comprises an inlet 7 and an outlet 9 for a liquid, for example cooling water. The inlet 7 and the outlet 9 are hydraulically connected to a bundle 11 of U-tubes. The tubes themselves do not have a reference number in the drawings. Instead of the U-tube design it is also possible to install a floating end for the tubes (not shown).

[0027] As can be seen from figure 1, the claimed apparatus has a AEU-type front head 3, but also many other TEMA-front head types are possible.

[0028] As can be clearly seen from figure 1, the tubes comprise a U-bend 13. The front end 3 as well as the hydraulic connection between the front end 3 and the bundle 11 of U-tubes are state of the art and may be designed according to the TEMA Standards. The U-tubes are supported by conventional sliding bars or skid bars (not shown) that transfer the weight of the U-tubes to the shell. Consequently, these details are part of the knowledge of a person skilled in the art and therefore are not described in connection with the claimed invention. For further details we refer to the TEMA Guidelines.

[0029] The shell 1 comprises an inlet 15 for compressed and hot gas as well as an outlet 17 for compressed and cooled gas. Between the inlet 15 and the bundle 11 of U-tubes a feed distributor plate 19 is installed. This feed distributor plate 19 may be a perforated sheet metal plate or the like.

[0030] The distributor plate 19 is attached to a wall 22, the latter being for example welded to the shell 1.

[0031] To make sure that the hot compressed gas that enters the inlet 15 flows through the bundle 11 of U-tubes, a baffle plate 21 is installed. This baffle plate 21 is in

sealing contact with the the wall 22. The baffle plate 21 is perforated so that it can be shifted in the bundle 11 of U-tubes thus stabilizing and supporting the tubes. The baffle plate 21 comprises at its lower end two sliding bars 24 or skid bars that are in contact with the shell 1. Consequently the bundle 11 of U-tubes is supported by the baffle plate 21 and the bending forces that apply to the tubes are minimized. For further details see Ssection A-A of fig. 1.

[0032] The baffle plate 21 does not extend to the lower side of the shell 1, thus allowing the gas that enters the shell at the inlet 15 to flow through the bundle 11 of U-tubes to the outlet 17 of the shell 1.

[0033] To further optimize the heat transfer between the compressed gas the at least one bundle of U-tubes is equipped with fin plates 35 that are perpendicular to the longitudinal axis of the tubes. These fin plates 35 are made of a sheet metal that is perforated so that several fin plates can be shifted into the at least one bundle 11 of U-tubes. These fins improve the heat exchange and serve as a baffle for the compressed gas.

[0034] The inlet 15 of the shell 1 is located at a first section (without reference number) of the shell 1 and the outlet 17 is located at a second section (without reference number) of the shell 1. The first section is limited by the first baffle plate 21 and the front end 3 in the longitudinal direction. Similarly the second section is limited by a second baffle plate 23 and the rear end 5 of the apparatus. Staring at the inlet 15 the compressed gas flows through the diverter plate 19, the bundle 11 of tubes, a high-capacity demister 25 and finally exits the shell 1 via the outlet 17 as is shown by arrows (without reference numbers) in figure 1.

[0035] At the lower side of the second section of the shell 1 a liquid accumulator 27 is installed. When the liquid accumulator 27 is filled with liquid, the liquid can be extracted from the shell via an outlet pipe 29. If necessary the bottom of the liquid accumulator 27 can be bolted to the liquid accumulator 27 itself, thus allowing to open the liquid accumulator 27.

[0036] Further on, it may be helpful to install a level sensor 26 in the shell 1 to avoid liquid pass the demistior plate 25. In case the level exceeds a predetermined level the outlet pipe 29 of the liquid accumulator 27 can be opened.

[0037] In figure 2 a second embodiment is shown with two bundles 11 of U-tubes. This arrangement enables full cross-flow behaviour of the exchanger leading to the possibility of temperature crosses between the hot and the cold side of the exchanger.

[0038] In figure 3 a third embodiment is shown with a pipe 31 for liquid distribution between the inlet 15 and the bundle 11 of U-tubes. At the lower side of this pipe 31 several spray nozzles 33 are arranged. This arrangement allos to spray a liquid into the hot compressed gas that comes from the inlet 15 before entering the feed distributor plate 19, allowing a good mixing of the gas and the liquid. Together with the gas the liquid is pressed through the holes of the distributor plate 19 washing the tubes of the bundle 11 and is collected in an optional boot of the exchanger (not shown).

[0039] When the pipe 31 for liquid distribution is used for gas conditioning, the gas components go into solution with the liquid and then the solution is collected in the optional boot of the exchanger. Alternatively a single spray nozzle (not shown) in fig. 3) may be located for example centrally in the inlet 15.

[0040] To sum up, the claimed invention combines the heat exchange and liquid separation in one shell 1 for dirty gases and/or high pressures. The claimed arrangement allows crossflow conditions in the heat exchanger. An intrinsic safe design is possible even at high pressures. Furtheron, an advanced online cleaning option is given and the possibility of gas enrichment with liquid or removal of gas components is available.

[0041] The resulting advantages of the claimed apparatus are shortly spoken a smaller plot space compared to conventional designs, robustness compared to conventional design having material or fouling problems.

[0042] High operating in design pressures possible, while keeping intrinsic safety. Online cleaning and/or gas enrichment with liquid and/or removal of gas components is also possible. Finally, low pressure drop of the claimed apparatus saves compression energy costs and leads to a reduction of the power requirements of about -9% compared to a conventional arrangement.

Claims

1. Apparatus for heat exchange (aftercooling) and demoisturizing of hot compressed gas comprising a shell (1) and a front end (3) and an rear end (5) stationary head, at least one bundle (11) of tubes, the shell (1) comprising an inlet (15) and an outlet (17) for the hot compressed gas, **characterized in, that** the shell (1) is divided into a first section and a second section, that the at least on bundle (11) of tubes is located in the first section and that in the second section a liquid accumulator (27) is installed.

2. Apparatus according to claim 1, **characterized in, that** the first section and the second section are separated by at least one baffle plate (21, 23), that the at least one baffle plate (21, 23) is oriented perpendicular to the longitudinal axis of the shell (1) and/or that the at least one baffle plate (21, 23) extends from the lower end of a wall (22) downwards and does not extend to the lower side of the shell (1) .

3. Apparatus according to claim 1 or 2, **characterized in, that** the inlet (15) of the shell (1) is located in the first section and the outlet (17) is located in the second section, preferably at the upper side, of the shell (1).

4. Apparatus according to one of the foregoing claims, **characterized in, that** in the liquid accumulator (27) is located at the lower side of the shell (1).

5. Apparatus according to one of the foregoing claims, **characterized in, that** the at least one bundle (11) of tubes is supported by a first baffle plate (21).

6. Apparatus according to claim 5, **characterized in, that** the first baffle plate (21) comprises at least one sliding bar (24).

7. Apparatus according to one of the foregoing claims, **characterized in, that** in the second section a demister (25) is installed.

8. Apparatus according to claim 6, **characterized in, that** in the demister (25) extends between a second baffle plate (23) and the rear end (5) stationary head.

9. Apparatus according to one of the foregoing claims, **characterized in, that** the liquid accumulator (27) comprises an outlet pipe (29).

10. Apparatus according to one of the foregoing claims, **characterized in, that** the shell (1) is inclined against a horizontal line at an angle between 1° and 5°, preferably between 2° and 3°.

11. Apparatus according to one of the foregoing claims, **characterized in, that** the at least one bundle (11) of tubes are equipped with fin plates (35) perpendicular to the longitudinal axis of the tubes.

12. Apparatus according to one of the foregoing claims, **characterized in, that** between the inlet (15) and the at least one bundle (11) of tubes a feed distributor plate (19) is installed.

13. Apparatus according to one of the foregoing claims, **characterized in, that** between the inlet (15) and the at least one bundle (11) of tubes a pipe (31) for liquid distribution with perforation and/or spray nozzles (33) is installed.

14. Apparatus according to one of the foregoing claims, **characterized in, that** the at least one bundle (11) of tubes is a bundle of U-tubes or a bundle of tubes with a floating end and/or is of the TEMA-type BEU or AEU.

15. Apparatus according to one of the foregoing claims, **characterized in, that** the at least one bundle (11) of tubes is removable.

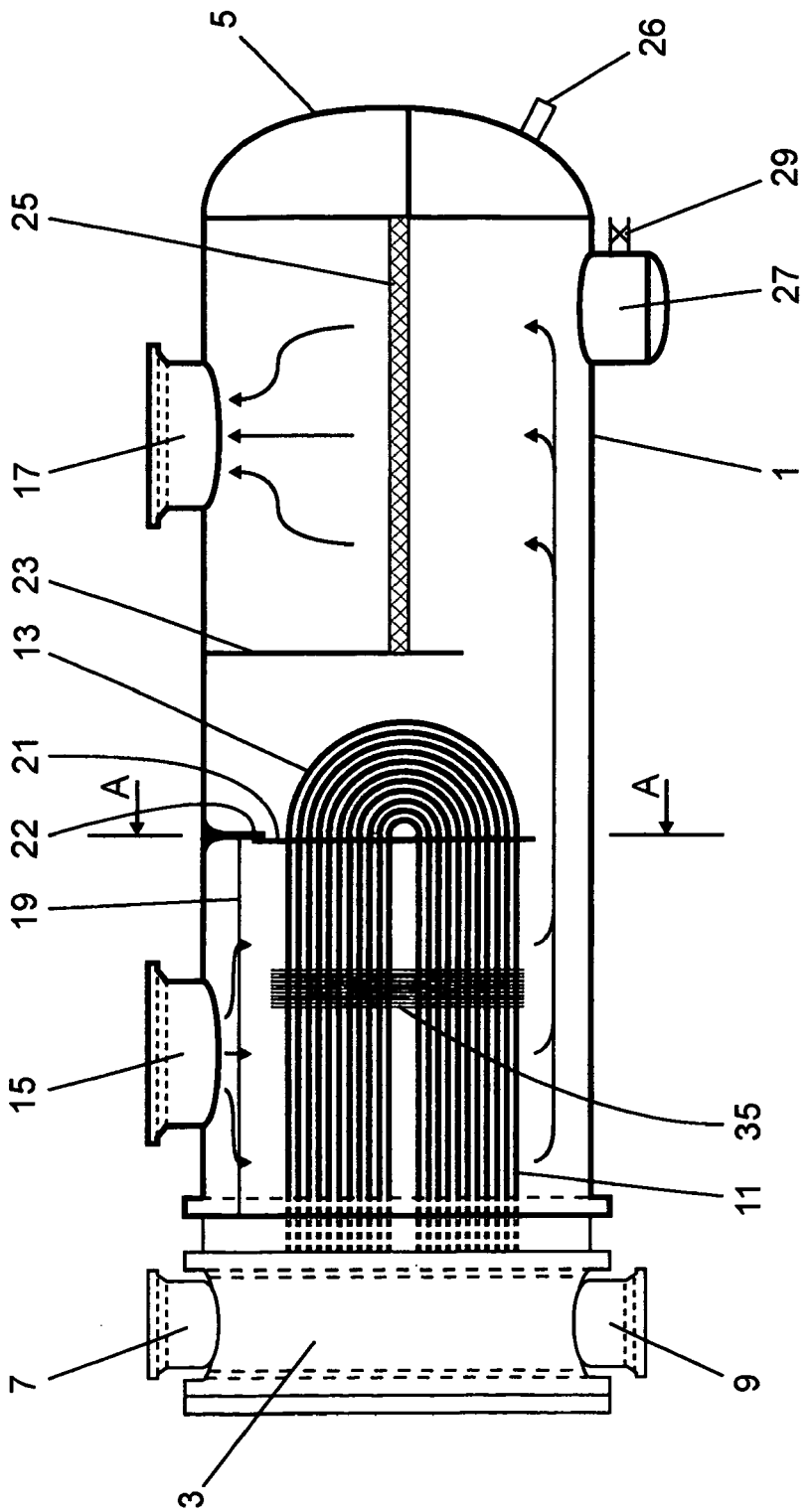
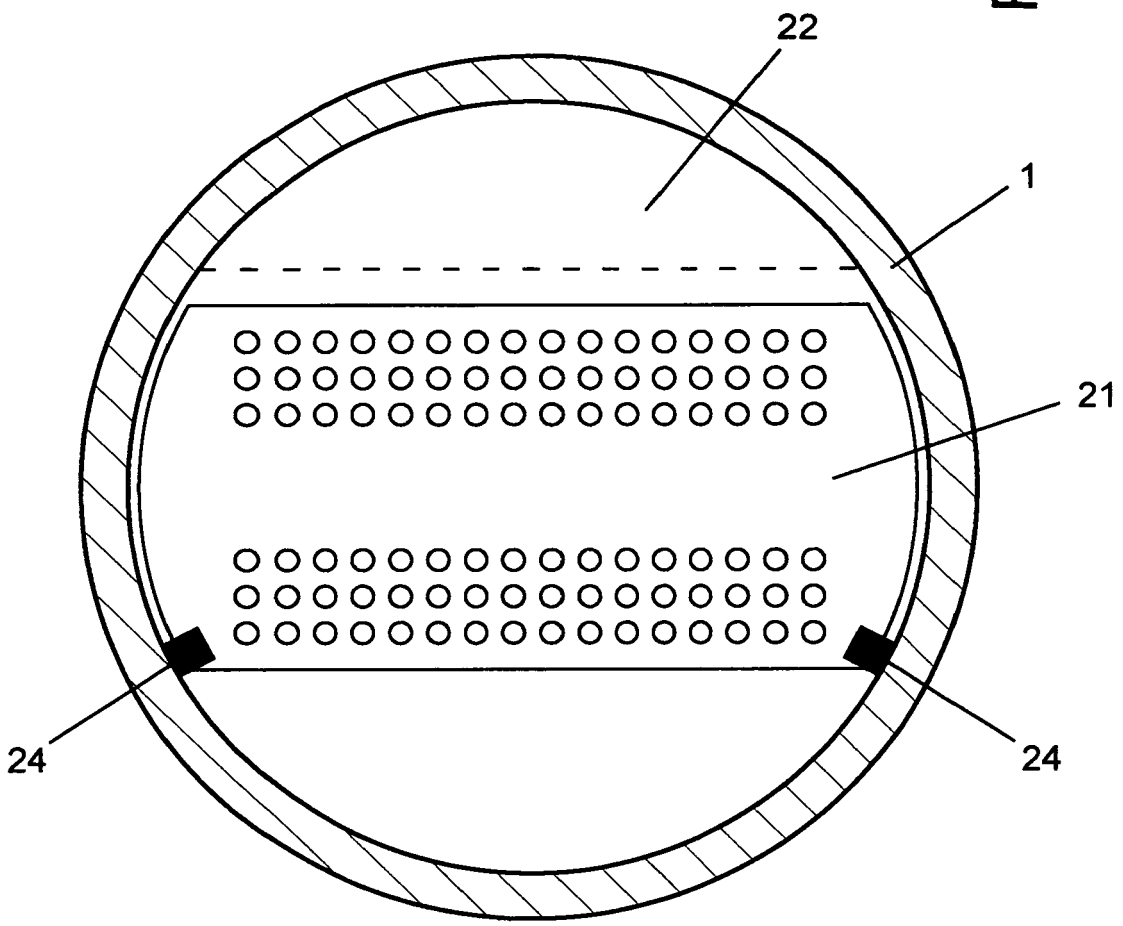


Fig.1

Fig.1a



Section A-A
(enlarged)

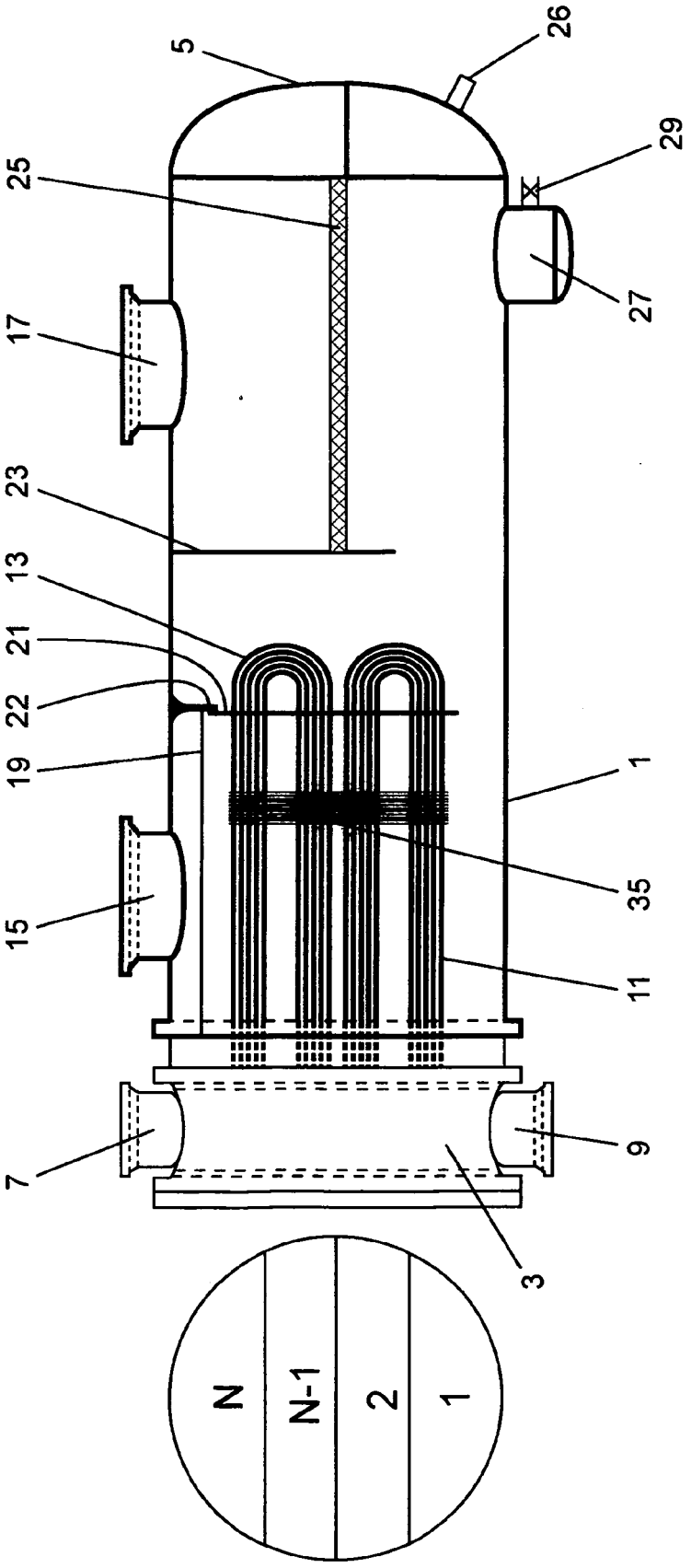


Fig.2

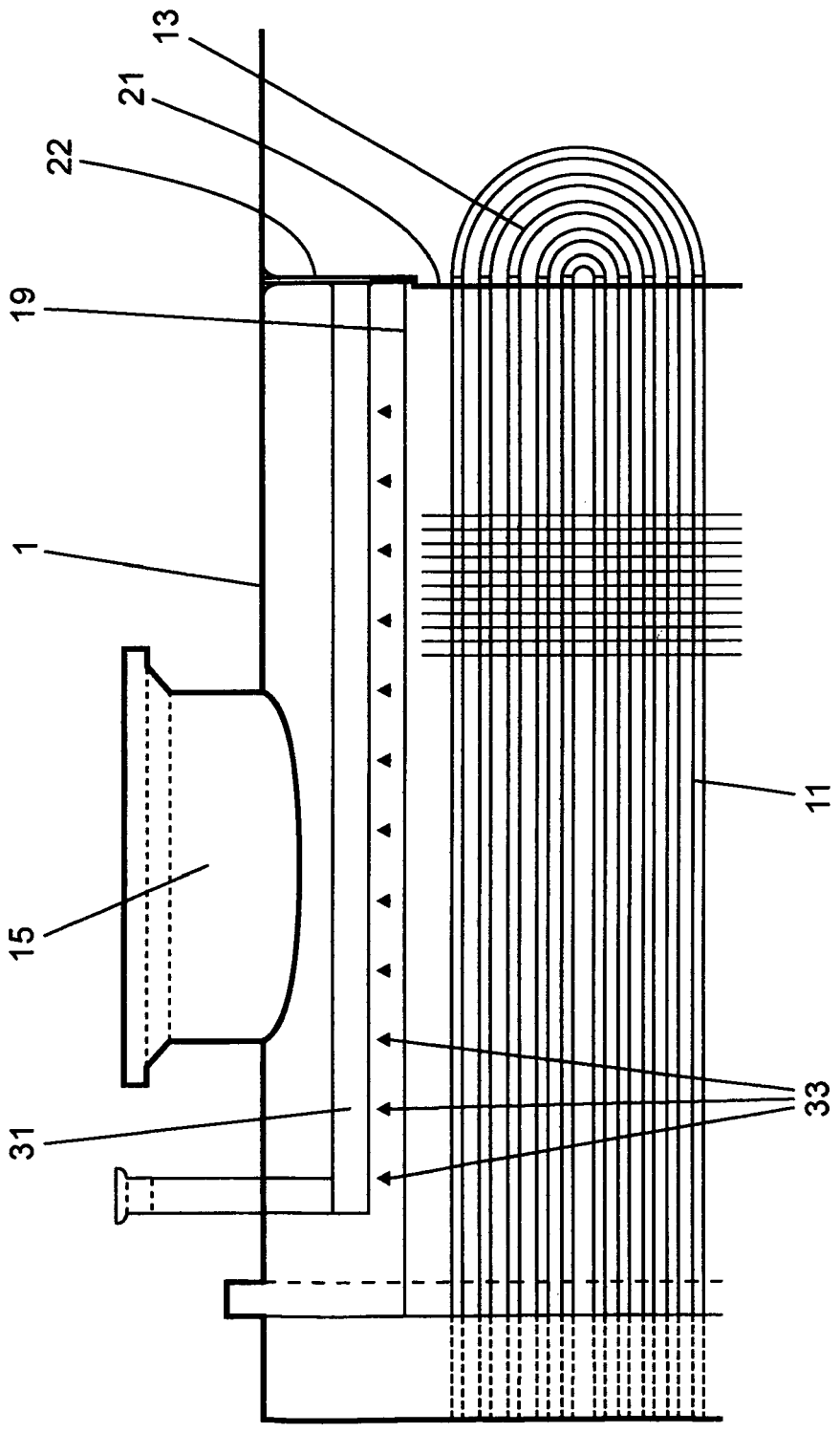


Fig.3

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EUROPEAN SEARCH REPORT

Application Number
EP 10 00 2157

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	16 September 2010	Vassoille, Bruno

CATEGORY OF CITED DOCUMENTS

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