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(54) Title: HEAT EXCHANGING AND LIQUID SEPARATION APPARATUS

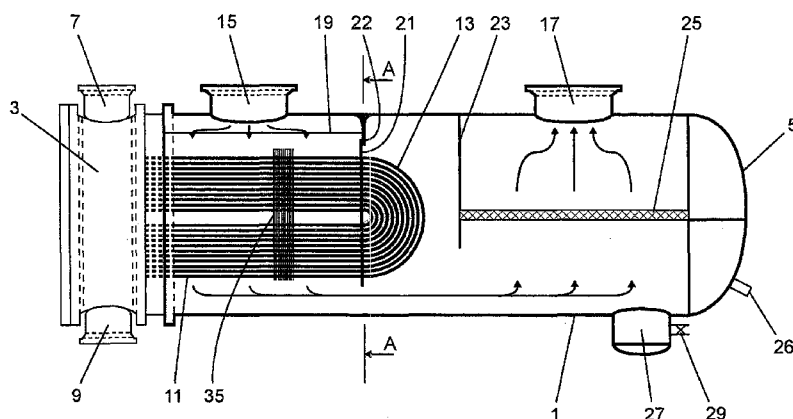


Fig.1

(57) Abstract: An apparatus for heat exchange and demisting 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.

HEAT EXCHANGING AND LIQUID SEPARATION APPARATUS

Background

The present disclosure relates to an apparatus for heat
5 exchanging and liquid separation.

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-
10 head of the heat exchanger.

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"
15 head has to be elliptically shaped. This type includes BEU
and AEU design according to the TEMA standard.

In all processes for CO₂ capture and storage the flue gas of
the power station and/or CO₂ that has already been separated
from the flue gas has to be compressed to achieve the
20 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
25 compression power requirements.

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
30 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
35 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.

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.

10

Summary

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.

This object is achieved by an apparatus for heat exchange and demisting 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.

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 condensed 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.

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
5 can be run at elevated pressures up to 80 bar or even more, although the shell has quite a large volume.

The U-tube design and the design with a floating end allows for differential thermal expansion between the shell and the tube bundle as well as for individual tubes. Other
10 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.

This design also provides a multipass tube circuit
15 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.

Furtheron, the separation of liquid and gas inside the shell
20 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.

To make sure that the compressed gas flows through the at
25 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
30 shell dividing the first section from the second section of the shell.

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,
35 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.

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.

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.

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.

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.

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.

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. Furthermore, 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.

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.

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.

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.

Brief Description of the Drawings

Further advantages and features are described based on the drawings, in which like items are numbered alike in the
5 various Figures.

The drawings show:

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

10 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.

15 Detailed Description

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
20 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
25 a floating end for the tubes (not shown).

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.

As can be clearly seen from figure 1, the tubes comprise a
30 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.

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.

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

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.

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.

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.

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.

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.

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.

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.

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
5 in an optional boot of the exchanger (not shown).

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
10 (not shown) in fig. 3) may be located for example centrally in the inlet 15.

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
15 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.

20 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.

High operating in design pressures possible, while keeping
25 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
30 arrangement.

While the invention has been described with reference to a number of preferred embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof
35 without departing from the scope of the invention. In

addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be
5 limited to the particular embodiments disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims. Moreover, the use of the terms first, second, etc. do not denote any order or
10 importance, but rather the terms first, second, etc. are used to distinguish one element from another.

Claims

What is claimed is:

- 5 1. An apparatus for heat exchange and demoinsturizing of hot compressed gas, the apparatus comprising:

 a cylindrical shell (1) including a front end (3) disposed at one end of the shell (1), a rear end (5) disposed at an opposite end of the shell, a gas inlet (15) proximate the front end (3), and a gas outlet (17) proximate the rear end (5);

 at least one bundle (11) of tubes disposed within the shell (1) at the front end (3), the at least one bundle (11) of tubes including a liquid inlet (7) and a liquid outlet (9), and the at least one bundle (11) of tubes defining a first section of the cylindrical shell through which the gas passes;

 a demister (25) disposed within the shell (1) proximate the rear end (5), the demister (25) defining a second section of the cylindrical shell through which the gas passes; and

 a liquid accumulator (27) disposed on the shell at a location lower than the demister (25).

- 25 2. The apparatus according to claim 1, wherein the first section and the second section are separated by a baffle plate (23) oriented perpendicular to a longitudinal axis of the shell (1).

- 30 3. The apparatus according to claim 2, wherein the demister (25) is disposed in a plane parallel to the longitudinal axis of the shell (1).

4. The apparatus according to claim 3, wherein the baffle plate (23) abuts an end of the demister (25).

5. The apparatus according to claim 1, wherein the at least one bundle (11) of tubes is supported by a baffle plate (21).

6. The apparatus according to claim 5, further comprising:

at least one sliding bar (24) disposed between the baffle plate (21) and the shell (1).

7. The apparatus according to claim 1, wherein the liquid accumulator (27) comprises an outlet pipe (29).

8. The apparatus according to claim 1, wherein the liquid accumulator (27) is disposed on the shell (1) proximate the rear end (5), and the shell (1) is inclined such that a longitudinal axis of the shell (1) forms an angle between 1° and 5° relative to a horizontal line, with the rear end (5) being lower than the front end (3).

9. The apparatus according to claim 1, wherein the at least one bundle (11) of tubes is equipped with fin plates (35) perpendicular to a longitudinal axis of the tubes.

10. The apparatus according to claim 1, further comprising:

a liquid distributor plate disposed within the shell (1) between the gas inlet (15) and the at least one bundle (11) of tubes.

11. The apparatus according to claim 1, further comprising:

a pipe disposed within the shell (1) between the inlet (15) and the at least one bundle (11) of tubes, the pipe including at least one of holes and nozzles for the application of a fluid to the gas.

12. The apparatus according to claim 1, wherein the at least one bundle (11) of tubes includes at least one of: a bundle of U-tubes and a bundle of tubes with a floating end.

13. The apparatus according to claim 1, wherein the front end (3) is of the TEMA-type BEU or AEU.

14. The apparatus of claim 1, wherein the at least one bundle (11) of tubes is affixed to a head that is removable
5 from the shell (1).

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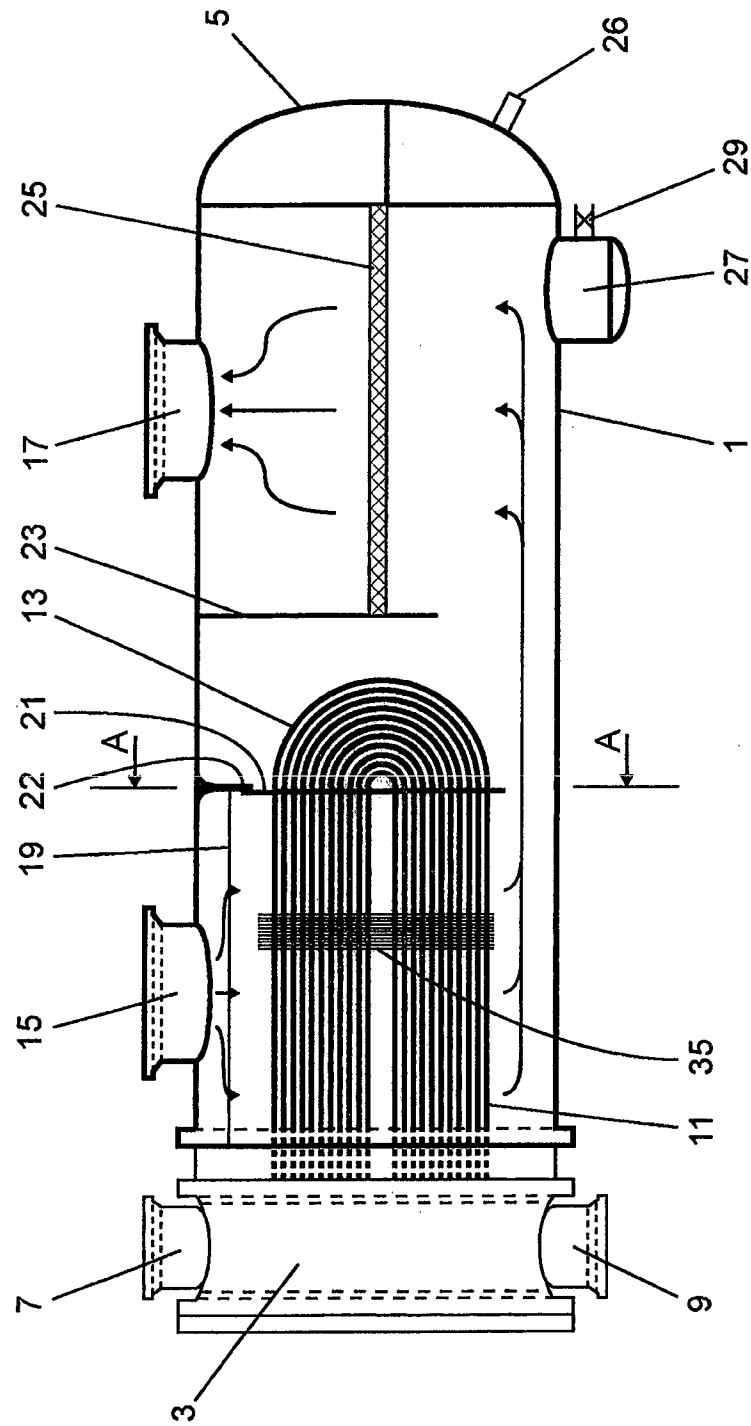
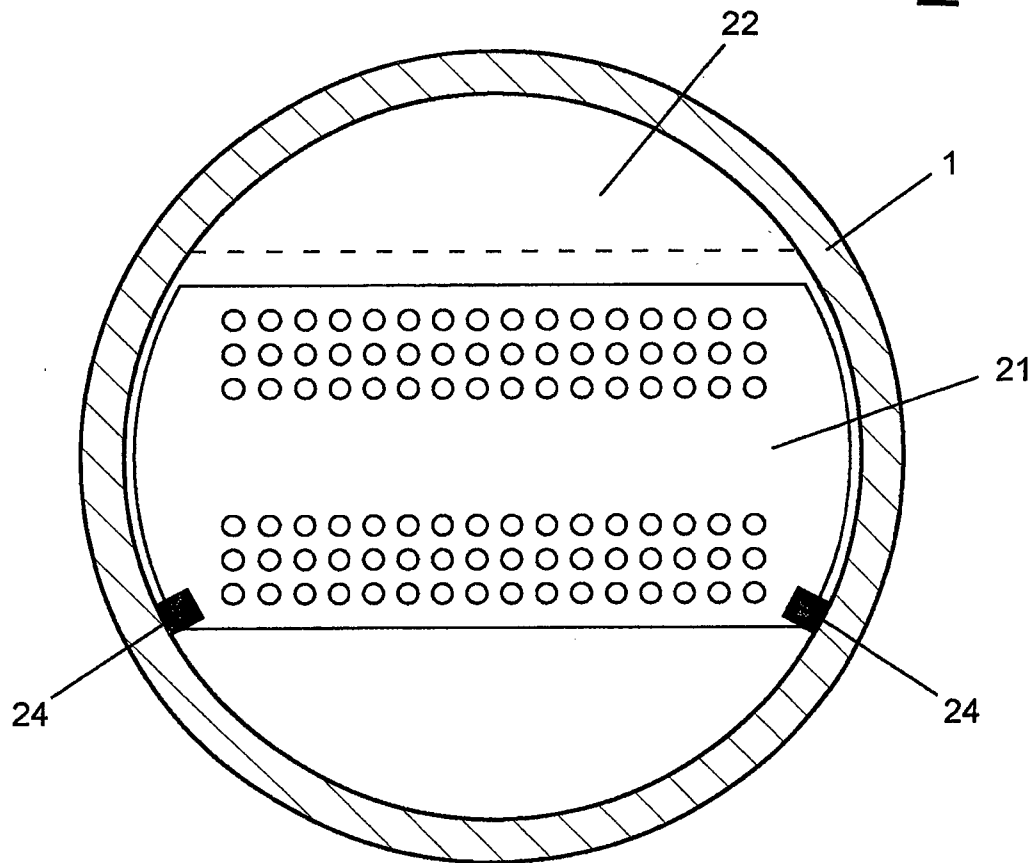


Fig.1

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Fig. 1a



Section A-A
(enlarged)

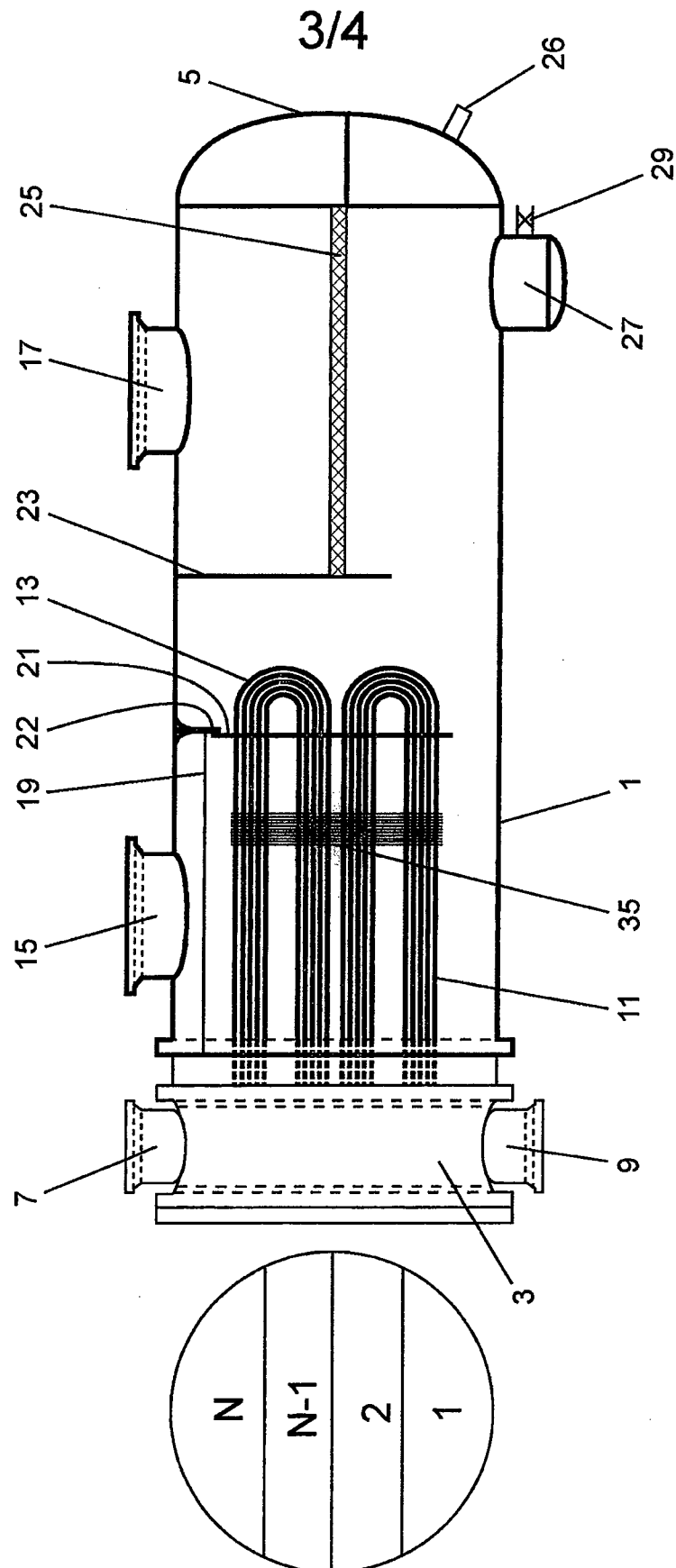


Fig.2

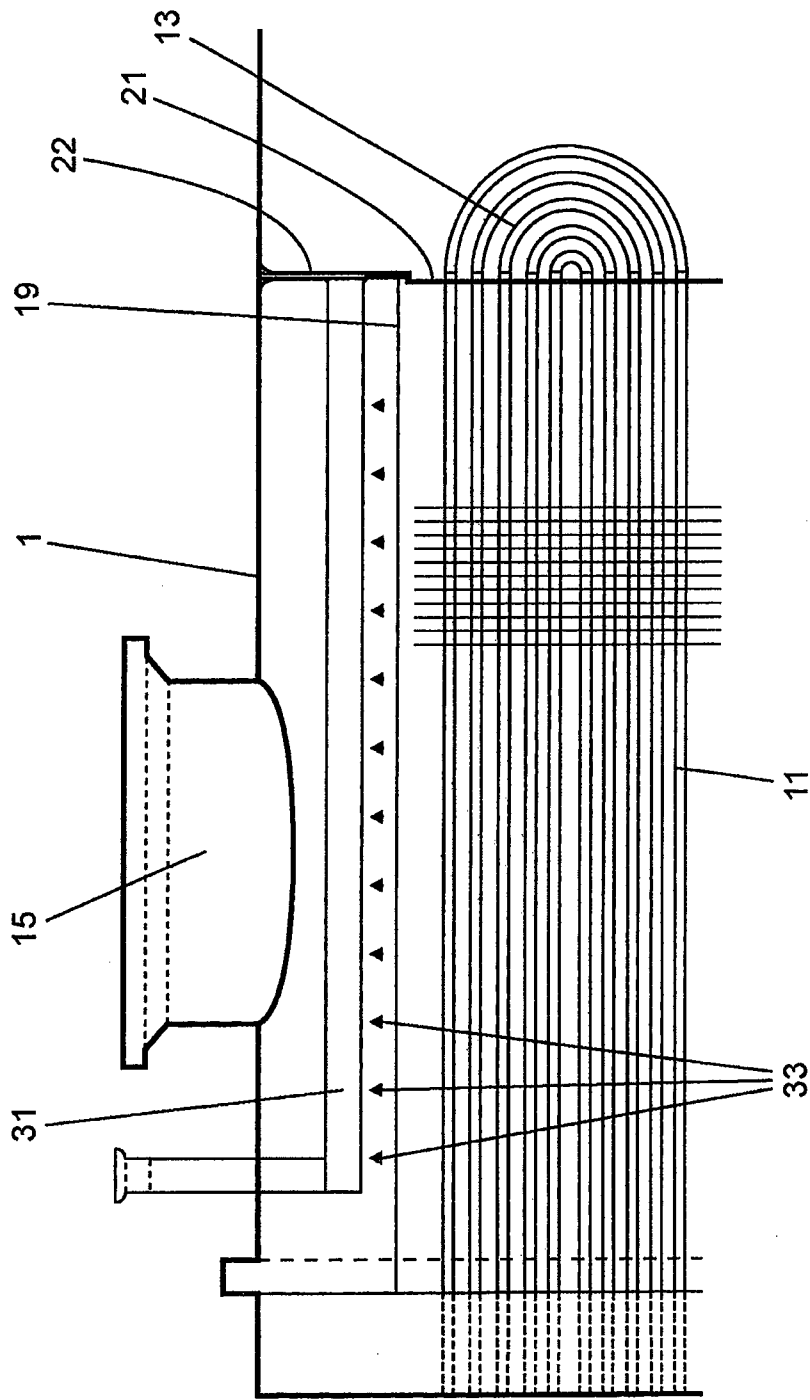


Fig.3

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2011/000268

A. CLASSIFICATION OF SUBJECT MATTER
INV. F28D7/06 F28F9/00 F28F9/22 F28F17/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F28D F28F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 960 638 C (SULZER AG) 28 March 1957 (1957-03-28)	1,5-9, 12-14
Y	figure 1	10
X	----- US 4 431 049 A (ZAMMA JUN [JP] ET AL) 14 February 1984 (1984-02-14)	1,12,14
X	----- US 3 503 440 A (ROMANOS NICHOLAS D) 31 March 1970 (1970-03-31)	1,2, 11-13
X	----- US 4 174 273 A (CROS PIERRE [FR] ET AL) 13 November 1979 (1979-11-13)	1-5,7,14
	----- -/-	

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"&" document member of the same patent family

Date of the actual completion of the international search

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25/07/2011

Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2011/000268

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4 671 082 A (MAEDA KENSAKU [JP] ET AL) 9 June 1987 (1987-06-09) figure 2 -----	10
A	US 4 193 443 A (BABA KOJI [JP] ET AL) 18 March 1980 (1980-03-18) figure 1 -----	1,2,4,5, 7
A	GB 2 193 299 A (WESTINGHOUSE ELECTRIC CORP WESTINGHOUSE ELECTRIC CORP [US]) 3 February 1988 (1988-02-03) figure 1 -----	1
A	DE 100 01 112 A1 (ALSTOM POWER SCHWEIZ AG BADEN [CH]) 19 July 2001 (2001-07-19) figure 1 -----	1
A	EP 0 881 451 A2 (BAYER AG [DE] BAYER MATERIALSCIENCE AG [DE]) 2 December 1998 (1998-12-02) figure 3 -----	1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IB2011/000268

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
DE 960638	C	28-03-1957	CH 309301 A	31-08-1955
US 4431049	A	14-02-1984	DE 3039787 A1	04-06-1981
			GB 2064091 A	10-06-1981
			IN 153892 A1	25-08-1984
			JP 56077692 A	26-06-1981
US 3503440	A	31-03-1970	BE 743535 A	28-05-1970
			CH 499747 A	30-11-1970
			DE 1961150 A1	02-07-1970
			FR 2030101 A1	30-10-1970
			NL 6919192 A	25-06-1970
US 4174273	A	13-11-1979	NONE	
US 4671082	A	09-06-1987	JP 1763451 C	28-05-1993
			JP 4054868 B	01-09-1992
			JP 61262567 A	20-11-1986
US 4193443	A	18-03-1980	DE 2861322 D1	14-01-1982
			EP 0002325 A1	13-06-1979
GB 2193299	A	03-02-1988	FR 2583502 A1	19-12-1986
			JP 2015589 C	19-02-1996
			JP 6084803 B	26-10-1994
			JP 61291801 A	22-12-1986
DE 10001112	A1	19-07-2001	GB 2362452 A	21-11-2001
			US 2001015059 A1	23-08-2001
EP 0881451	A2	02-12-1998	CN 1200479 A	02-12-1998
			DE 19722360 A1	03-12-1998
			ES 2226030 T3	16-03-2005
			US 6178293 B1	23-01-2001