(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 141 411 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
06.01.2010 Bulletin 2010/01

(21) Application number: **08447033.5**

(22) Date of filing: **30.06.2008**

(51) Int Cl.:
F22B 37/22 *(2006.01)* ***F22B 29/06*** *(2006.01)*
F22B 37/14 *(2006.01)* ***F22B 37/74*** *(2006.01)*
F22B 1/18 *(2006.01)*

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MT NL NO PL PT RO SE SI SK TR
Designated Extension States:
AL BA MK RS

(71) Applicant: **Cockerill Maintenance & Ingenierie S.A.**
4100 Seraing (BE)

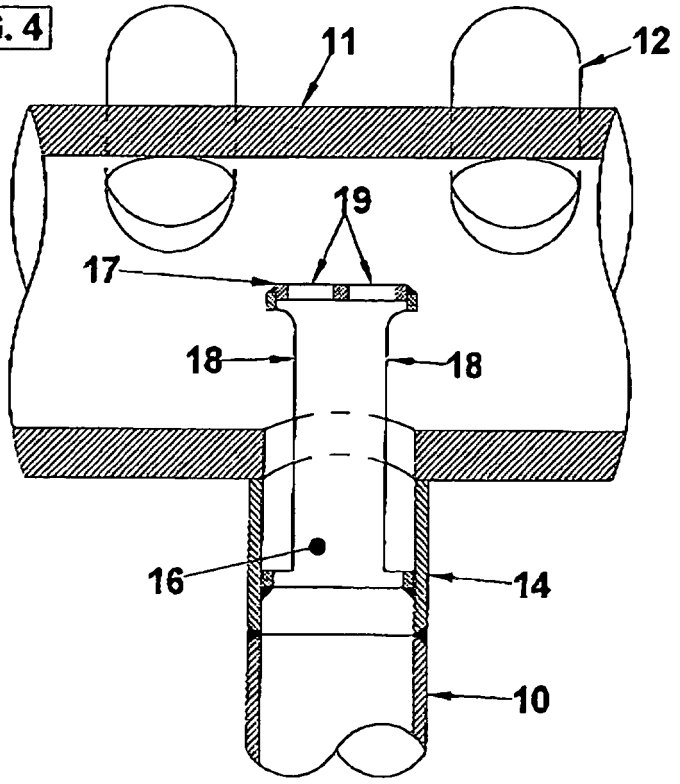
(72) Inventor: **Fraikin, Christian**
4053 Embourg (BE)

(74) Representative: **pronovem**
Office Van Malderen
Boulevard de la Sauvenière 85/043
4000 Liège (BE)

(54) Header distributor for two-phase flow in a single pass evaporator

(57) The present invention is related to an evaporator section (3) in a steam generator comprising an inlet header (11), an outlet header (13), a plurality of heating tubes (12) connected in parallel at a first end to said inlet header (11) and at a second end to said outlet header (13), at least a feeder pipe (10) terminated by a feeder nozzle (14) connected to said inlet header (11) and a header distributor (16, 20) for conveying a biphasic fluid through the inlet header (11) from the feeder pipe (10), **characterized in that** said header distributor (16, 20) comprises means (17, 18, 19, 21) to perform an equalization of the biphasic fluid distribution inside said plurality of heating tubes (12).

FIG. 4



EP 2 141 411 A1

Description

Field of the invention

[0001] The present invention is applicable to any steam generator, but more particularly to horizontal once-through heat recovery steam generators, where a two-phases flow has to be equally distributed inside all heating tubes through an inlet header.

Background art

[0002] In horizontal heat recovery steam generators, the evaporators bundles are usually formed with multiple parallel tubes arranged in successive rows perpendicular to the gas flow direction. Each row of tubes is connected at its lower side to an inlet header and at its upper side to an outlet header.

[0003] Horizontal heat recovery steam generators which are designed with a once-through evaporator may have this heat exchanger split in two sections in series.

[0004] In this case, the heating tubes of the first section once-through evaporator are fed with hot water coming from an economizer and discharge water-steam mixture with a partial steam fraction.

[0005] That fluid is transferred from the first to the second section by means of manifolds, pipes, distributors and feeders.

[0006] The heating tubes of the second section once-through evaporator are then fed with two-phases fluid and discharge superheated steam.

[0007] It is very important to assure that the feeding of the two-phases flow is equally distributed over all heating tubes of the second evaporator section in order to achieve an uniform temperature profile of the steam over all heating tubes outlets. If a particular tube receives more water than the average, the steam temperature at its outlet shall be lower than in the other tubes and its mean metal temperature shall also be lower inducing unexpected specific tensile thermal stress in said tube. The opposite behavior (so receiving less water than the average) also induces unexpected specific compressive thermal stress. Depending upon the tube configurations, those thermal stresses could also generate at the tubes-to-headers connections high bending stresses with detrimental effects in respect of lifetime.

[0008] In steam generators as described in document WO-A-2006/107315, once-through evaporator sections are usually provided under the form of multiple single-row header-and-tube assemblies. As in such assemblies, each row of tubes is connected to a linear inlet header with a central water inlet tube, there is a risk that portions of the tubes where steam is created run dry. It may also occur in such a configuration that water is segregated in the outlet sections of the central tubes of the row, while steam is segregated in the outlet sections of the external tubes of the row. This produces higher temperatures in some tube walls and less efficient heat transfer. The higher temperatures require then the use of tubes made of expensive high alloy steels

[0009] In document WO-A-03/048638, heated water flows through the tubes of a once-through section at a rate sufficient to maintain the interiors of its tubes fully wetted while enabling steam to develop in that water. This is possible because the once-through section is followed by a circulation section delivering saturated steam to the superheater, while in a steam generator comprising only a once-through evaporator, no liquid water should leave the evaporator. In this case, as the fraction of steam remains always below 100%, the tubes of the once-through section remain fully wetted.

[0010] In document US-A-2004/0069244, a steam generator has a once-through evaporator which converts liquid water into steam in tubes over which hot gases flow. To overcome the drawback of tubes running dry, each tube contains a metal tape which is twisted into a helical configuration to induce turbulence in the mist produced by the boiling, and these turbulences insure that the mist wets the inside surfaces of the tubes, thus producing good heat transfer and moderate temperatures in the tubes.

[0011] Document JP-A-2007/298245 is related to an economizer designed to pass almost evenly liquid water, i.e. a monophasic fluid, through a row of heat transfer pipes.

[0012] Considering the properties of the two-phases flow, it is very difficult to easily achieve an equal distribution inside all the heating tubes because the water and the steam have highly different densities.

[0013] In that respect an appropriate distributor device should be installed in the interconnecting pipes in order to supply an identical steam fraction inside each feeder.

[0014] A feeder is connected on an inlet header for feeding several heating tubes. A specific distributor device must be installed either inside the inlet header or in each feeder nozzle to facilitate the equalization of the distribution.

Aims of the invention

[0015] The main object of the present invention is to drastically improve the distribution equalization of the water-steam flow inside all the heating tubes of the second evaporator section.

[0016] More particularly for a once-through evaporator, the invention intends to allow achieving a more uniform steam temperature profile at the outlet of the heating tubes and then to improve the lifetime of the components.

[0017] Among other objectives, the invention aims at accommodating with different geometries and dimensions of the heating tubes and the inlet headers.

[0018] The invention also intends to easily eliminate the stratification effect existing in the feeder nozzles due to water centrifugation induced by the feeder pipe routing.

[0019] A further goal of the invention is to permit its use as a retrofit in existing exchangers in order to restore

acceptable operating conditions.

Summary of the invention

[0020] A first object of the present invention is related, as indicated in Claim 1, to an evaporator sections in a steam generator comprising an inlet header, an outlet header, a plurality of heating tubes connected in parallel at a first end to said inlet header and at a second end to said outlet header, at least a feeder pipe terminated by a feeder nozzle connected to said inlet header and a header distributor for conveying a two-phases or biphasic fluid through the inlet header from the feeder pipe, characterized in that said header distributor comprises means to perform an equalization of the biphasic fluid distribution inside said plurality of heating tubes.

[0021] Preferred embodiments of the invention further contain, in combination with the features of Claim 1, one or several of the following features disclosed in the secondary claims :

- said header distributor is tubular, passing through the feeder nozzle at the connection of the feeder pipe to the inlet header, and having a protruding section inside said inlet header, said protruding section being provided with an end cap and having at least two diametrically-opposed main orifices located on the lateral surface of the distributor ;
- said main orifices are partly located in the protruding section of the distributor inside the inlet header and partly inside the feeder nozzle ;
- said end cap is provided with at least two secondary orifices aligned along the inlet header axis ;
- the size of the secondary orifices is smaller than the size of the main orifices ;
- the line joining the centres of the main orifices is perpendicular to the axis of the feeder pipe at the location the latter is entering the inlet header ;
- said header distributor is a conical or plug-like distributor, substantially comprising an inverted plug passing through the feeder nozzle connecting the feeder pipe and the inlet header and having a terminal part protruding into the inlet header ;
- said evaporator is a once-through evaporator ;
- the plurality of heating tubes is arranged along a single row of tubes connected to the inlet header and to the outlet header ;
- said biphasic fluid is a mixture of steam and water.

[0022] Still another objet of the present invention concerns, as indicated in Claim 11, concerns a heat recovery steam generator (HRSG) comprising an exhaust gas duct connected to a hot gas source, an economizer, a first section and a second section of a once-through evaporator and a superheater, means comprising manifolds, pipes, distributors and feeder pipes for transferring a water-steam mixture, i.e. a biphasic flow, from said first section to said second section of the evaporator, said distributors being configured for equally spreading the biphasic flow into the feeder pipes, characterized in that said second evaporator section is an evaporator section as in Claim 1.

Short description of the drawings

[0023] **FIG.1** is a schematic cross-sectional view of a horizontal once-through heat recovery steam generator (HRSG) constructed in accordance with and embodying the present invention.

[0024] **FIG.2** is a schematic perspective view of the second section of the evaporator with vertical heating tubes and embodying the present invention.

[0025] **FIG.3** is a schematic cross-sectional side view of the inlet header embodying the present invention.

[0026] **FIG.4** is a fragmentary schematic cross-sectional front view of the inlet header embodying a tubular distributor.

[0027] **FIG.5** is a fragmentary schematic cross-sectional plan view of the inlet header embodying a tubular distributor.

[0028] **FIG.6** is a fragmentary schematic cross-sectional plan view of the inlet header and the feeder pipe which could have a non-perpendicular orientation in regards of the inlet header axis.

[0029] **FIG.7** is a fragmentary schematic cross-sectional front view of the inlet header embodying a conical-type distributor.

Description of a preferred embodiment of the invention

[0030] Referring to FIG. 1, a steam generator according to a preferred embodiments of the present invention includes an exhaust gas duct 1 connected to a hot gas source such as a gas turbine. The hot gas flows in series respectively through a superheater 2, a second section 3 of a once-through evaporator, a first section 4 of said once-through evaporator and an economizer 5.

[0031] The water flows in the opposite direction and is forced by the feedwater pump 6 to the cold side of the economizer 5. The heat extracted from the hot gas elevates the temperature of the water which leaves the first exchanger hotter than when entering.

[0032] The liquid water then flows to the first section of the evaporator 4 which converts part of the water into steam at saturated conditions after further extraction of heat from the hot gas.

[0033] The water-steam mixture (i.e. a two-phases fluid) is transferred from said first section 4 to said second section 3 by means of manifolds 7, pipes 8, distributors 9 and feeders 10. The two-phases flow is equally spread into the feeders 10 by means of the distributors 9.

[0034] In the second section 3 of the evaporator, the extracted heat from the hot gas terminates the evaporation and slightly superheats the steam.

[0035] Finally the heat extracted inside the superheat-

er 2 raises the temperature of the superheated steam up to the live steam conditions needed for powering a steam turbine or any other process.

[0036] Referring to FIG.2, the second section 3 of the once-through evaporator includes a plurality of heating tubes 12 arranged along a single row - however a multiple tube rows arrangement is also possible - connected on the inlet header 11 at the lower side and on the outlet header 13 at the upper side.

[0037] The inlet header 11 has one or several feeder nozzles 14 onto which the feeders 10 are connected and receiving the two-phases flow from the distributors 9.

[0038] The outlet header 13 has one or several connector nozzles 15 for conveying the superheated steam to the superheater 2.

[0039] **FIG.3** to **FIG.7** illustrate preferred embodiments of the device of the invention which is called a "two-phases flow header distributor" for a tubular-type 16 or a conical-type distributor 20 respectively, where said two-phases flow is passing through the feeder nozzle 14 and entering partly inside the inlet header 11.

[0040] Referring to **FIG.3** to **FIG.5,** the tubular distributor is fitted with an end cap 17 in order to eliminate any water jet effect impacting the distribution equalization, especially in the nearby heating tubes 12 and more generally in all other heating tubes.

[0041] The distributor 16 is fitted in this example with two opposite main orifices or openings 18 located along the inlet header 11 axis. The purpose is to spread equally the water onto the sides of the inlet header 11 regardless of the possible water stratification in the feeder pipe 10 and feeder nozzle 14 sections. The type, number, dimensions and position of those openings 18 may vary according to the heating tubes-inlet header 11, 12 configuration, to the feeder pipe 10 routing and to the real operating conditions.

[0042] Moreover two small holes or orifices 19 are fitted on the distributor end cap 17 along the inlet header 11 axis. The purpose is to allow a direct and controlled water feeding of the nearby heating tubes 12 if they are partially hidden by the distributor according to the arrangement. The type, number, dimensions and position of those openings 19 may also vary according to the heating tubes-inlet header 11, 12 configuration, to the feeder pipe 10 routing and to the real operating conditions.

[0043] Referring to **FIG.6**, the orientation of the feeder pipe 10 has a direct impact on the water stratification inside the pipe due to the centrifugation effect taking place in the last pipe elbow. The header distributor 16 shall be preferably oriented for having the lateral openings 18 perpendicular to the last elbow in order to force the water film present on the extrados side of the upstream elbow to remix in the pipe end cap before being equally spread through the openings. The type, number, dimensions and position of those openings 18 may also vary according to the heating tubes-inlet header 11, 12 configuration and to the real operating conditions.

[0044] Referring to **FIG.7,** a conical-type distributor 20 is an alternate design for the same purpose. It consists substantially in an inverted cone 21 passing through the feeder nozzle 14.

Claims

1. Evaporator section (3) in a steam generator comprising an inlet header (11), an outlet header (13), a plurality of heating tubes (12) connected in parallel at a first end to said inlet header (11) and at a second end to said outlet header (13), at least a feeder pipe (10) terminated by a feeder nozzle (14) connected to said inlet header (11) and a header distributor (16, 20) for conveying a biphasic fluid through the inlet header (11) from the feeder pipe (10), **characterized in that** said header distributor (16, 20) comprises means (17, 18, 19, 21) to perform an equalization of the biphasic fluid distribution inside said plurality of heating tubes (12).

2. Evaporator section (3) according to Claim 1, **characterized in that** said header distributor (16) is tubular, passing through the feeder nozzle (14) at the connection of the feeder pipe (10) to the inlet header (11), and having a protruding section inside said inlet header (11), said protruding section being provided with an end cap (17) and having at least two diametrically-opposed main orifices (18) located on the lateral surface of the distributor (16).

3. Evaporator section (3) according to Claim 2, **characterized in that** said main orifices (18) are partly located in the protruding section of the distributor (16) inside the inlet header (11) and partly inside the feeder nozzle (14).

4. Evaporator section (3) according to Claim 2, **characterized in that** said end cap is provided with at least two secondary orifices (19) aligned along the inlet header axis.

5. Evaporator section (3) according to Claim 4, **characterized in that** the size of the secondary orifices (19) is smaller than the size of the main orifices (18).

6. Evaporator section (3) according to Claim 2, **characterized in that** the line joining the centres of the main orifices (18) is perpendicular to the axis of the feeder pipe (10) at the location the latter is entering the inlet header (11).

7. Evaporator section (3) according to Claim 1, **characterized in that** said header distributor (20) is a conical or plug-like distributor, substantially comprising an inverted plug (21) passing through the feeder nozzle (14) connecting the feeder pipe (10) and the inlet header (11) and having a terminal part protrud-

ing into the inlet header (11).

8. Evaporator section (3) according to Claim 1, **characterized in that** said evaporator is a once-through evaporator.

9. Evaporator section (3) according to Claim 1, **characterized in that** the plurality of heating tubes (12) is arranged along a single row of tubes connected to the inlet header (11) and to the outlet header (13).

10. Evaporator section (3) according to Claim 1, **characterized in that** said biphasic fluid is a mixture of steam and water.

11. Heat recovery steam generator comprising an exhaust gas duct (1) connected to a hot gas source, an economizer (5), a first section (4) and a second section (3) of a once-through evaporator and a superheater (2), means comprising manifolds (7), pipes (8), distributors (9) and feeder pipes (10) for transferring a water-steam mixture, i.e. a biphasic flow, from said first section (4) to said second section (3) of the evaporator, said distributors (9) being configured for equally spreading the biphasic flow into the feeder pipes (10), **characterized in that** said second evaporator section (3) is an evaporator section (3) as in Claim 1.

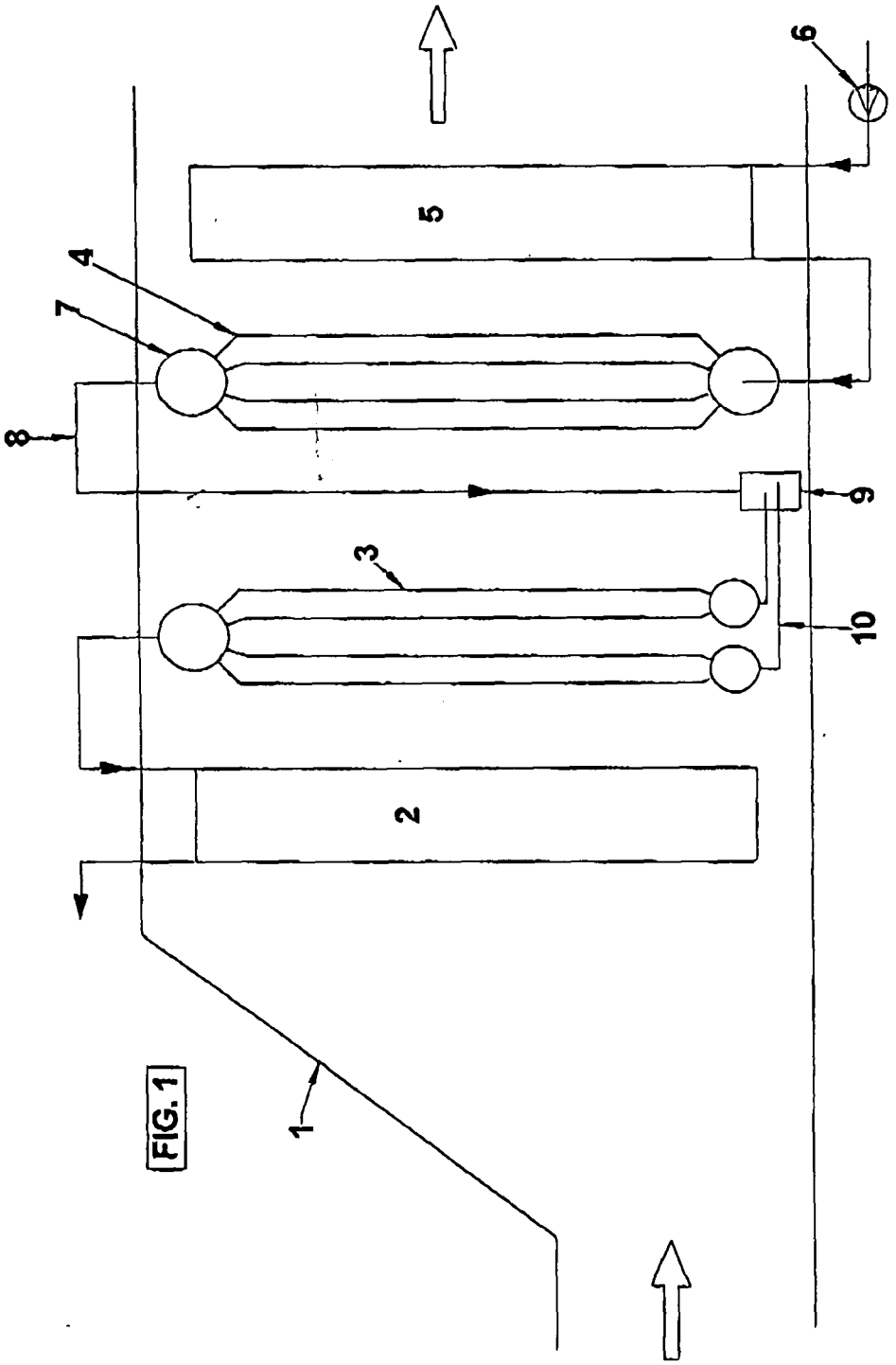
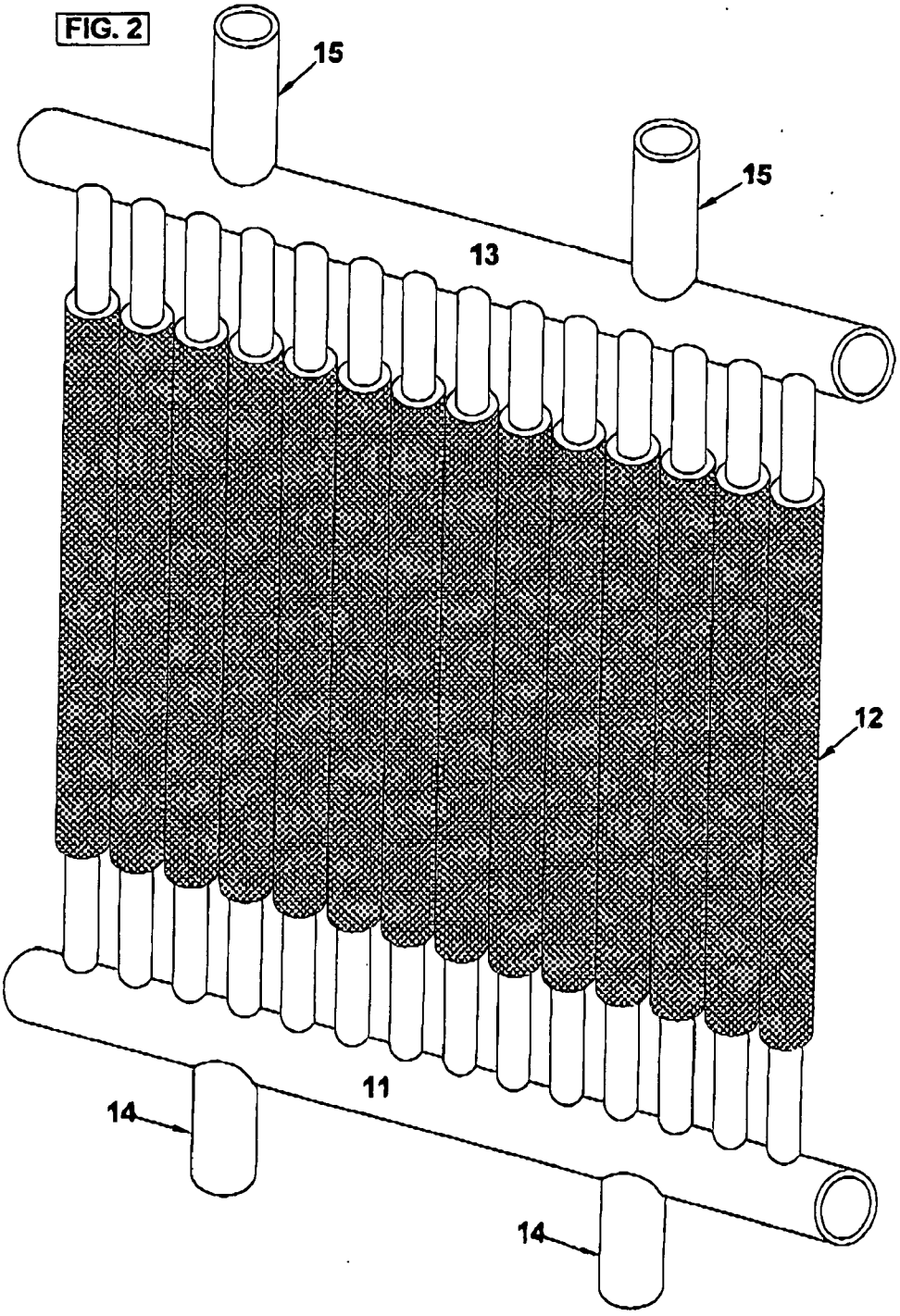


FIG. 1

FIG. 2



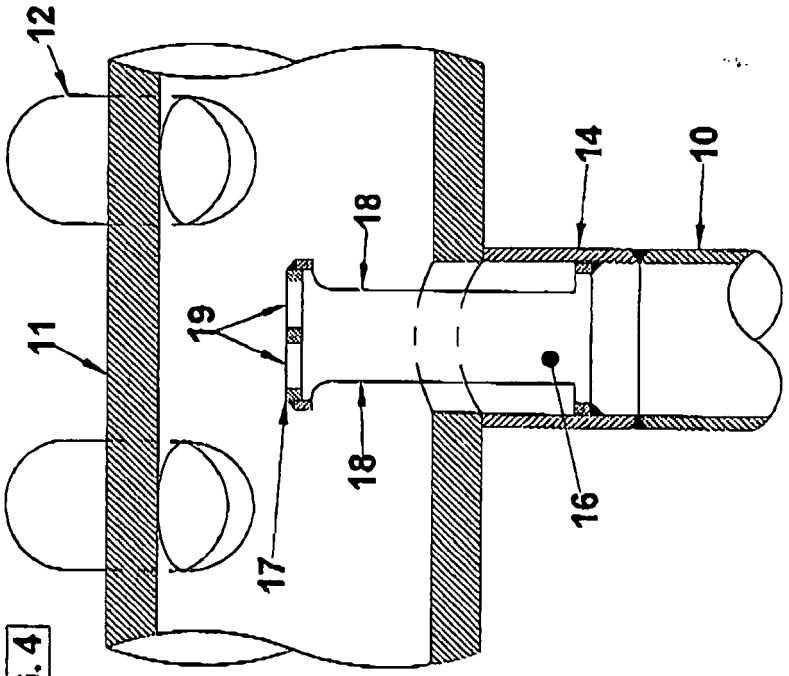


FIG. 4

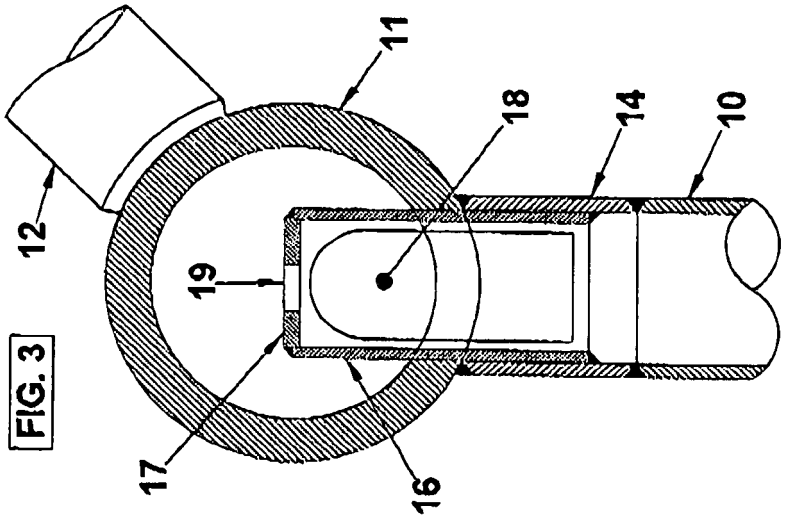


FIG. 3

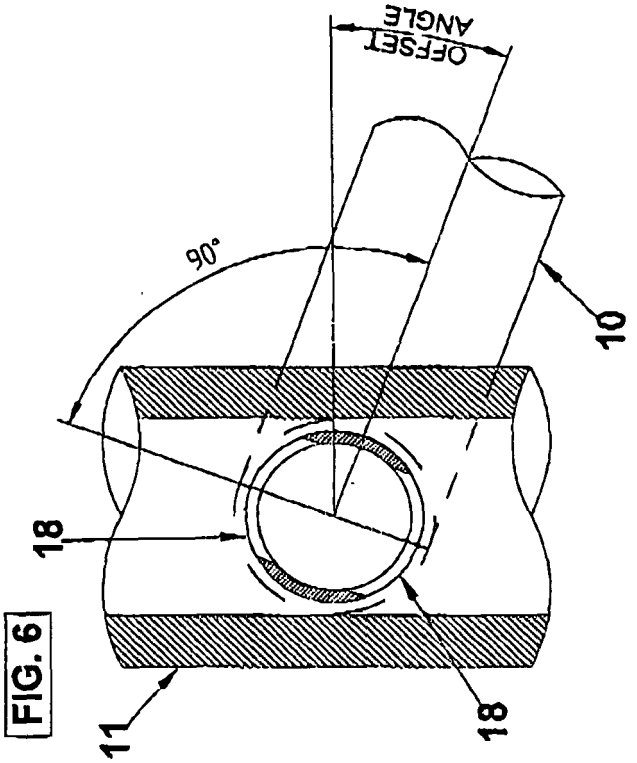


FIG. 6

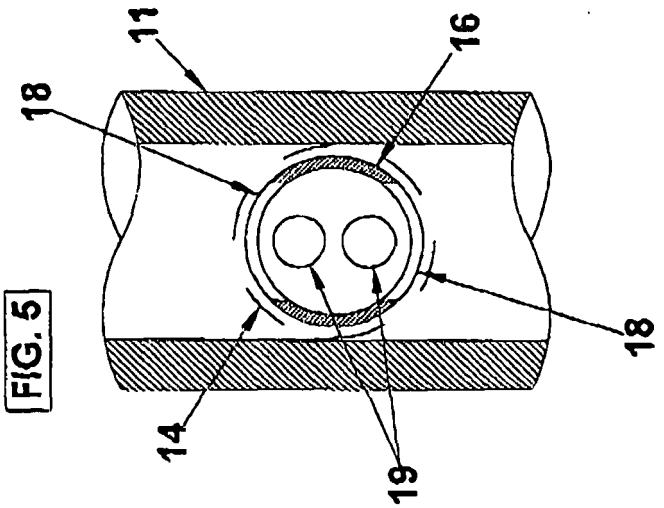
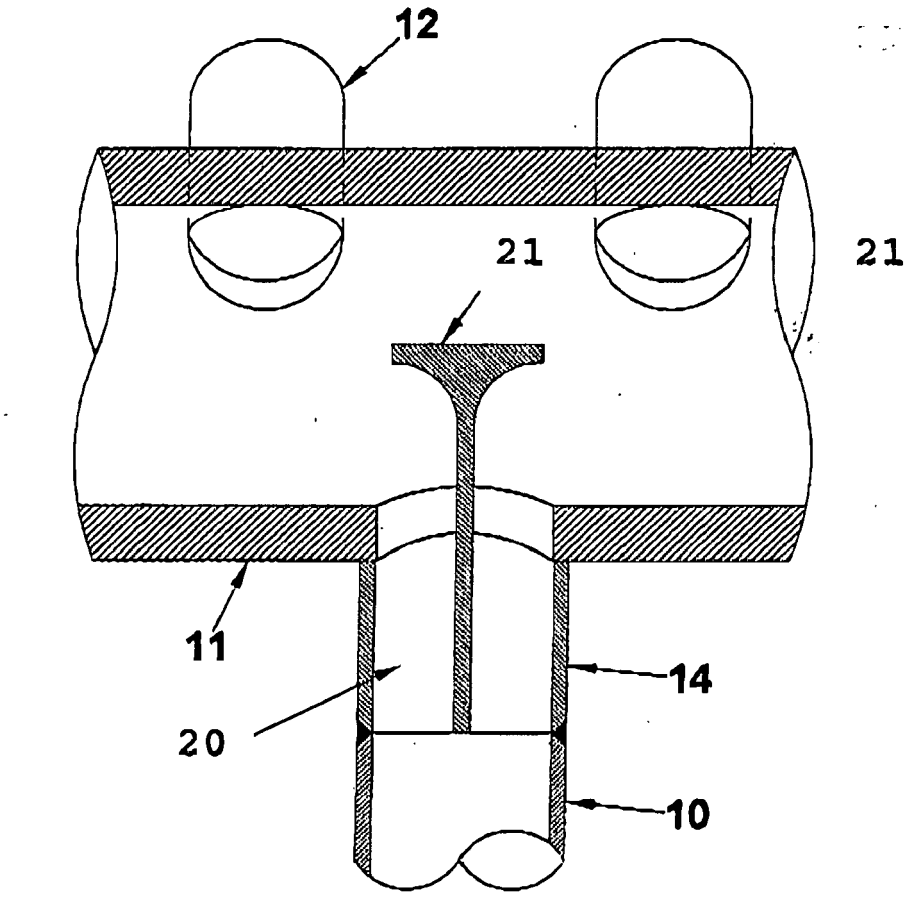


FIG. 5

FIG. 7



Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 08 44 7033

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	US 5 806 586 A (OSTHUES JOSEF [DE] ET AL) 15 September 1998 (1998-09-15) * figures 2,3 *	1-3,6-9 4,5,10, 11	INV. F22B37/22 F22B29/06 F22B37/14 F22B37/74 F22B1/18
X	FR 1 549 058 A (ELECTRODYNE RESEARCH CORP.) 6 December 1968 (1968-12-06) * figures 2A,2B *	1,2,9	
X	GB 949 027 A (VORKAUF HEINRICH; MONT INTERNAT ASS LTD) 5 February 1964 (1964-02-05) * page 1, line 13 - page 2, line 60 * * figures 1-6 *	1	
X Y	JP 58 173393 A (MITSUBISHI HEAVY IND LTD) 12 October 1983 (1983-10-12) * figures 1,3 *	1 10,11	
Y	JP 57 101296 A (MITSUBISHI HEAVY IND LTD) 23 June 1982 (1982-06-23) * figures 5,6 *	4,5,10	TECHNICAL FIELDS SEARCHED (IPC) F22B F28F
Y,D	US 6 957 630 B1 (MASTRONARDE THOMAS P [US]) 25 October 2005 (2005-10-25) * figure 3 *	10,11	
A	GB 770 589 A (SIEMENS AG) 20 March 1957 (1957-03-20) * the whole document *		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	2 March 2009	Lepers, Joachim

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 08 44 7033

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

02-03-2009

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5806586 A	15-09-1998	AT 163224 T	15-02-1998
		CA 2166395 A1	19-01-1995
		DE 4422178 A1	12-01-1995
		DK 706633 T3	28-09-1998
		WO 9502159 A1	19-01-1995
		EP 0706633 A1	17-04-1996
		ES 2115242 T3	16-06-1998
FR 1549058 A	06-12-1968	CH 497664 A	15-10-1970
		DE 1601788 A1	23-12-1971
		GB 1143509 A	26-02-1969
		US 3399656 A	03-09-1968
GB 949027 A	05-02-1964	AT 252959 B	10-03-1967
		DE 1401366 A1	17-10-1968
JP 58173393 A	12-10-1983	NONE	
JP 57101296 A	23-06-1982	NONE	
US 6957630 B1	25-10-2005	EP 1869367 A1	26-12-2007
		WO 2006107315 A1	12-10-2006
GB 770589 A	20-03-1957	NONE	

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- WO 2006107315 A **[0008]**
- WO 03048638 A **[0009]**
- US 20040069244 A **[0010]**
- JP 2007298245 A **[0011]**