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(54) Heat exchanger.

(57) A compact heat exchanger suitable for heat exchange between two fluids one of which is at a high pressure (e.g. above 50 atmospheres) incorporates a cylindrical former (14) supported by inlet and outlet ducts (28) for the low pressure fluid coaxially within a tubular cylindrical pressure vessel (12). The annular space between the former (14) and the vessel (12) is occupied by a plurality of radially-extending flow passages (20) for the low pressure fluid, between which are passages (18) for the high pressure fluid. Each low pressure fluid passage (20) is defined by a single sheet folded to form a pair of adjacent spaced-apart plates. A long sheet (22) may be folded into a zig-zag so as to form a plurality of such pairs of plates. The ends of the plates are welded to the ducts (28), and the pairs of adjacent plates are welded together to seal the ends of the passages (20).

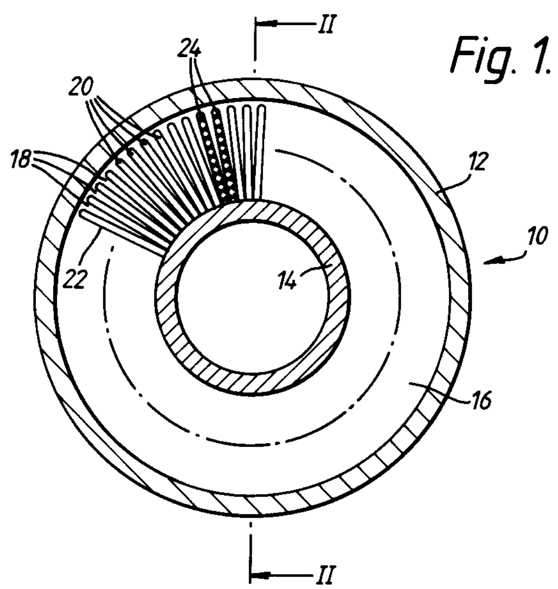

Fig. 1.

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This invention relates to a plate-type heat exchanger, and particularly, but not exclusively to a heat exchanger suitable for use where one fluid is at a high pressure.

Heat exchangers enable heat transfer to take place between two fluids by causing them to flow in adjacent ducts. In plate-type heat exchangers ducts are defined between parallel spaced-apart plates, and adjacent plates may be spaced apart for example by fins integral with one or other plate, or by a corrugated spacer. Where one or both fluids may be at a high pressure (e.g. between 10 and 300 atm.) the plates may be exposed to large forces; they may be held together by metallurgically bonding adjacent plates together so as to minimize the unsupported areas, for example by brazing the ends of the fins on one plate onto the adjacent plate, or they may be held together by bolts extending between thick end plates. Where corrosion is encountered it can be worsened by electrochemical differences between the metal of the braze and the plate, while the use of bolts puts the end plates under very large stresses if the fluid pressures are high.

According to the present invention there is provided a heat exchanger suitable for heat exchange between two fluids at least one of which is at a high pressure above 10 atmospheres comprising a hollow cylindrical pressure vessel through which a high pressure fluid may flow, an assembly comprising a plurality of spaced apart plates within the vessel defining passages between the plates for both the fluids, and ducts for flow of the lower pressure fluid to and from the assembly of plates, pairs of adjacent plates defining between them passages for the lower pressure fluid extending in respective substantially radial, angularly-spaced, planes within an annular region coaxial with the pressure vessel, and pairs of adjacent plates being defined by a folded sheet.

The plates may be flat and held apart by separators, or may be ridged to define fins, or may be corrugated. The separators, fins, or corrugations may be arranged to constrain the fluid flow into particular desired paths, for example to ensure two fluid flows on opposite sides of a plate are in countercurrent. The plates may be of any material which conducts heat sufficiently well, for example of metals such as titanium, or non-metals such as ceramics or plastics material. The material must be chosen in accordance with the pressures and temperature differences to which it will be subjected in use, and to the required heat flux.

Desirably a plurality of the plates, and more desirably all the plates, are defined by a single long sheet folded into a zig-zag. By using folded sheets the length of welded edges is reduced, and such a zig-zag sheet leads to a still greater reduction. The use of a circular geometry for the plates enables better use to be made of the volume of the pressure vessel compared to a conventional rectangular geometry. Preferably the radial planes defined by the passages between pairs of adjacent plates are at equally spaced angles around the longitudinal axis of the vessel.

The present invention provides a heat exchanger in which the pressure forces are primarily taken by the cylindrical pressure vessel, which may form a part of a high pressure pipeline, and may be the same diameter as the pipeline. It enables a simple compact heat exchanger to be made of corrosion-resistant materials such as titanium and its alloys, and enables wastage of such material during construction to be minimized. The heat exchanger can provide more than 100 m^2/m^3 of heat transfer surfaces, preferably more than 200 m^2/m^3, for example 250 m^2/m^3. Such a compact heat exchanger would be suitable for use for example on a production platform in an off-shore gas-field, where the fluids would be high pressure natural gas (principally methane, along with carbon dioxide and water vapour) at a temperature between about 150° and 250°C, and low pressure sea-water or fresh water/glycol mixture. Since the heat exchanger is smaller and lighter than heat exchangers used hitherto it enables consequential space and weight reductions to be made in other aspects of the platform.

The pressure vessel might be of diameter between about 0.1m and 1.5m, a diameter of about 1.0m being suitable for the off-shore use mentioned above. The annular region occupied by the plates is preferably of inner diameter about half that of the pressure vessel, and may be of outer diameter just less than that of the vessel. The plates might be of length between about half and about five times the diameter of the pressure vessel; for the off-shore use described, the plates might be between about 1m and 4m or even 5m long, the preferred length being about 3m. The folded sheet might be of stainless steel or of titanium alloy, and of thickness between about 0.3 and 1.2mm, preferably about 0.5mm. The gap between the pairs of adjacent plates, which define a passage for the low pressure fluid, might be between 2mm and 10mm, preferably between 2mm and 6mm, most preferably about 3mm.

The lower pressure fluid ducts may provide support for the assembly of the plates within the vessel. Strains due to thermal expansion and contraction of the heat exchanger have to be withstood by these ducts, one or both of which may incorporate for example strain-accommodating bends. The ducts may be connected to opposite ends of the plate assembly, or alternatively may both be connected to the same end of the assembly (for example with the ducts being coaxial). If the cylindrical pressure vessel is vertical the latter arrangement of the ducts enables the plate assembly to be withdrawn easily from the pressure vessel, for example for cleaning.

The invention will now be further and more particularly described, by way of example only, and with reference to the accompanying drawings in which:

Figure 1 shows a transverse sectional view of a heat exchanger (on the line I-I of Figure 2);

Figure 2 shows a longitudinal sectional view of the heat exchanger of Figure 1, on the line II-II of Figure 1, but to a smaller scale;

Figure 3 shows to a larger scale than Figure 1, a transverse sectional view partly broken away of a modification to the heat exchanger of Figure 1;

Figure 4 shows a longitudinal sectional view of an alternative heat exchanger;

Figure 5 shows a transverse sectional view partly broken away of another alternative heat exchanger; and

Figure 6 shows a longitudinal sectional view of another modification to the heat exchanger of Figure 1.

Referring to Figure 1 there is shown a transverse sectional view of a compact heat exchanger 10 for use on an off-shore gas production platform, for bringing about heat transfer between a stream of natural gas at a pressure of 200 atmospheres and a temperature usually about 150°C (but which may be as high as 250°C), and a stream of coolant water. The heat exchanger 10 incorporates a cylindrical tubular titanium alloy pressure vessel 12 of external diameter 0.50m, which is installed as part of a pipeline of the same diameter which carries the gas stream.

A cylindrical former 14, of external diameter 0.25m, is supported coaxially within the vessel 12, so an annular space 16 is defined between the former 14 and the vessel 12. Within the space 16 passages 18 and 20 are defined, for the gas and for the water respectively, by a long rectangular sheet 22 of 0.5mm thick titanium alloy folded into a zig-zag to form almost four hundred flat plates, the ends of the sheet 22 being welded together; this zig-zag extends throughout the space 16 as indicated by the chain-dotted line, each plate of the zig-zag extending from the former 14 to within 1mm of the inner surface of the vessel 12.

Each passage 18 is of triangular cross-section tapering towards zero width nearest the former 14, and of width 4mm at its radially outermost part. Each passage 20 is of uniform width 3mm and lies in a respective radial plane, and the plates on either side of a passage 20 are held apart by a rectangular sheet of coarse woven wire mesh 24 (two wire mesh sheets 24 are indicated diagrammatically in Figure 1). The sheet 22 is thus folded into a sharp fold adjacent to the former 14, and a rounded fold enclosing the mesh 24 remote from the former 14.

Referring now to Figure 2, the former 14 is closed at each end and is supported by coaxial perforated tubes 26, one at each end, which extend from the mouths of tubes 28; the tubes 28 are of the same diameter as, and coaxial with, the former 14. There is a gap 30 of width 0.1m bridged by the perforated tube 26 at each end between the mouth of the tube 28 and the former 14. The zig-zag plates defined by the sheet 22 extend beyond the former 14 at each end and are welded to the outer surface of the tube 28, and the ends of the plates on either side of each passage 20 are bent towards each other and welded together, so as to seal the ends of each passage 20. The tubes 28 support the assembly of the former 14 and the zig-zag sheet 22 within the pressure vessel 12, each tube 28 tapering to a diameter of 0.15m and turning through a right angle to protrude through the wall of the pressure vessel 12, to which it is welded; one of the tubes 28 is bent to form an S-bend 32, in order to accommodate any thermal strains.

In use coolant water is caused to flow to and from the heat exchanger 10 through the tubes 28, as the hot high pressure gas flows along the pipeline and along the pressure vessel 12. The gas flows through the passages 18, while the water flows through one gap 30 into and along the passages 20 to emerge through the other gap 30. The pressure of the gas is contained by the vessel 12, and the mesh sheets 24 prevent the passages 20 from being crushed. The former 14 helps to support the zig-zag sheet 22 against the radial inward forces due to gas pressure. The heat exchanger 10 provides a heat exchange area of about 250 m^2/m^3, and so may be referred to as compact.

The heat exchanger 10 may be modified in a variety of ways. For example each passage 20 might contain, instead of a mesh sheet 24, a corrugated titanium plate (not shown), the orientation of the corrugations being arranged to ensure the low pressure fluid follows a particular route through the passage 20, and ensuring adequate fluid flow at all parts of the passage. Such a corrugated plate might be slitted with the corrugations oriented approximately transverse to each slit, but with the peaks on one side aligning with the troughs on the other side of that slit, so the fluid may flow alternately on one side and then the other of the corrugated plate. In another modification the ends of the passages 20 might be sealed by welding the adjacent plate edges to a titanium strip (not shown), the strip either occupying the entire thickness (3mm) of the gap between the plates, or being thinner in which case some bending of the ends of the plates would again be necessary. Furthermore such strips might extend radially inwards beyond the inside of the zig-zag sheet 22 and be welded to each other to define a ring to which the mouth of the tube 28 is connected.

Referring to Figure 3, two modifications to the heat exchanger 10 are illustrated. To ensure the passages 20 remain in their radial planes and so to ensure the passages 18 are not distorted, one or more spacer wires 36 or strips may be provided in each passage 18 extending parallel to the longitudinal axis of the assembly from one end of the passage 18 to the other. At the ends of the assembly all the spacer wires 36 at a particular radius from the axis might be fixed to a ring (not shown) or be welded to one or other of the adjacent plates to ensure they cannot be displaced during operation. Alternatively or additionally the radially outermost parts 38 of the sheet 22 might be bent over so as to touch the adjacent plate on the opposite side of the passage 18.

Referring now to Figure 4 there is shown an alternative heat exchanger 40 with most of its features in common with the heat exchanger 10, identical components being referred to by the same reference numbers. The water flow tubes 28 and flow passages 20 are substantially the same as in the heat exchanger 10. However the ends of the plates defined by the zig-zag sheet 22, at each end of the assembly, are all welded to an annular end plate 42, so this plate 42 seals the ends of the passages 20. There is a radial gap 43 of width 50mm between the radially outermost folds of the zig-zag sheet 22 and the inner surface of the pressure vessel 12, so although the ends of the gas passages 18 are closed by the end plates 42 the gas can flow into the passages 18 via the radial gap 43 between the outer edge of the end plate 42 and the vessel 12. Flow along the gap 43 is prevented by a tubular member 44 fixed to the inner surface of the vessel 12, which extends along the entire length of the assembly apart from 0.1m at each end. The gas flow is hence as indicated by the broken line arrow. It will be appreciated that the heat exchanger 40 may have the modifications to the gas flow passage 18 shown in Figure 3 (spacer wires 36 and bent over outer parts 38) but that these features must not extend to the ends of the passages 18, and if provided preferably terminate at least 0.1m from each end.

Referring now to Figure 5 there is shown another alternative heat exchanger 50, for heat exchange amongst three fluids. Many of its features are substantially identical to those of heat exchanger 10, identical components being referred to by the same reference numbers. Between a cylindrical former 14 and a concentric cylindrical pressure vessel 12 a first long titanium sheet 52 is folded into a zig-zag to define passages 54 of constant width 4mm for a first low-pressure fluid (for example coolant water), each passage 54 enclosing a coarse mesh sheet 24 as a separator. Each passage 54 lies in a respective radial plane, and between one and the next the sheet 52 is folded round a 5mm wide spacer bar 56. A second long titanium sheet 58 is folded into a zig-zag to define passages 60 of constant width 3mm for a second low-pressure fluid (for example a second, low pressure gas or water), each passage 60 also enclosing a coarse mesh sheet 24 as a separator. Each passage 60 lies in a respective radial plane midway between planes in which adjacent passages 54 lie and between one passage 60 and the next the sheet 58 defines an arcuate portion 62 which lies on the inner surface of the pressure vessel 12. The high pressure gas can flow along the gaps 64 between the interleaved zig-zag sheets 52 and 58.

At the ends of the assembly the passages 54 and 60 are sealed, as described in relation to heat exchanger 10. The first low-pressure fluid is supplied to, and issues from, the passages 54 via tubes supporting the ends of the former 14, as described in relation to heat exchanger 10. The second low-pressure fluid is supplied to, and issues from, the passages 60, via respective headers (not shown) on the outside of the pressure vessel 12 and slots or perforations (not shown) through the wall of the pressure vessel 12, at each end of the assembly.

In a modification (not shown), the pressure vessel 12 is provided with a sleeve spaced apart from its inner surface over a length slightly greater than that of the heat exchange assembly, the sleeve being welded to the vessel 12 around each end, and the central portion of the annular space between the sleeve and the vessel 12 being occupied by a tubular member. The arcuate portions 62 of the sheet 58 lie on the inner surface of the sleeve, and the ends of the passages 60 are sealed by welding adjacent plates to each other and to the sleeve. The unobstructed portions at each end of the annular space between the sleeve and the vessel 12 act as headers, to which a fluid may be supplied through ports in the vessel 12.

In a further modification (not shown) to the heat exchanger 50 there are half as many of the outer passages 60 as of the inner passages 54, the arcuate portions 62 of the sheet 58 being long enough that a pair of adjacent passages 54 fit between one passage 60 and the next. Between each such pair of passages 54 the sheet 52 is folded into a sharp fold, the spacer bar 56 being omitted.

Referring now to Figure 6 there is shown a longitudinal sectional view of a modified version of the compact heat exchanger 10 of Figure 1, the same components being referred to by the same reference numerals. A heat exchanger 66 comprises a zig-zag sheet 22 defining passages for gas and for a liquid, as described previously, the sheet 22 occupying the annular space between the inner surface of a tubular pressure vessel 12 and a cylindrical former 68. The longitudinal axes of the vessel 12 and of the heat exchanger 66 are vertical. The former 68 is supported at both ends by coaxial perforated tubes 26. At the lower end the tube 26 bridges the gap between the former 68 and an end cap 70 of the same diameter as the former 68, while at the top end the tube 26 bridges the gap between the former 68 and a support tube 72. An outlet tube 74 communicates with the space between the lower end of the former 68 and the cap 70, and extends upwardly through the former 68 and coaxially along the support tube 72.

Above the heat exchanger 66 the tubular pressure vessel 12 is closed by an end plate 75 secured to the vessel 12 by bolts 76 (only two are shown), below which a high pressure duct 78 branches off the vessel 12. The support tube 72 is fixed to the plate 75, through which it extends. Above the plate 75 the tube 72 is closed at its top end, and to it is fixed a lifting ring 80. A duct 82 branches off from the tube 72, and the tube 74 emerges through the wall of the tube 72. Hence in use a high pressure gas flows through the pressure vessel 12 and the high pressure duct 78, while a coolant liquid can be passed via the duct 82 and the tube 72 into and through the heat exchanger 66, to emerge through the coaxial tube 74. This arrangement enables the heat exchanger 66 to be removed from the vessel 12, for example for cleaning.

Claims

1. A heat exchanger suitable for heat exchange between two fluids at least one of which is at a high pressure above 10 atmospheres comprising a hollow cylindrical pressure vessel (12) through which a high pressure fluid may flow, characterised by an assembly comprising a plurality of spaced apart plates within the vessel defining passages (18, 20) between the plates for both the fluids, and ducts (28) for flow of the lower pressure fluid to and from the assembly of plates, pairs of adjacent plates defining between them passages (20) for the lower pressure fluid extending in respective substantially radial, angularly-spaced, planes within an annular region (16) coaxial with the pressure vessel (12), and pairs of adjacent plates being defined by a folded sheet (22).

2. A heat exchanger as claimed in Claim 1 wherein a plurality of the plates are defined by a single long sheet (22) folded into a zig-zag.

3. A heat exchanger as claimed in Claim 2 wherein all the plates are defined by a single long sheet (22) folded into a zig-zag.

4. A heat exchanger as claimed in any one of the preceding Claims wherein the said radial planes are at equally spaced angles around the longitudinal axis of the vessel (12).

5. A heat exchanger as claimed in any one of the preceding Claims wherein the radial width of the annular region (16) is about half the radius of the plate assembly (14, 22).

6. A heat exchanger as claimed in any one of the preceding Claims wherein the heat transfer surface area within the heat exchanger (10) is more than 100 m^2/m^3.

7. A heat exchanger as claimed in Claim 6 wherein the heat transfer surface area is more than 200 m^2/m^3.

8. A heat exchanger as claimed in any one of the preceding Claims wherein the ducts (28) support the plate assembly (14, 22) within the pressure vessel (12).

9. A heat exchanger as claimed in Claim 8 wherein the ducts (72, 74) are both connected to the same end of the plate assembly (68, 22).

10. A heat exchanger as claimed in any one of the preceding Claims including pairs of plates (58) interleaved between the aforementioned pairs of plates (52) and arranged to define passages (60) for a third fluid, the passages (60) for the third fluid extending in radial planes and communicating at their radially outermost parts with headers for the third fluid.

Fig. 1.

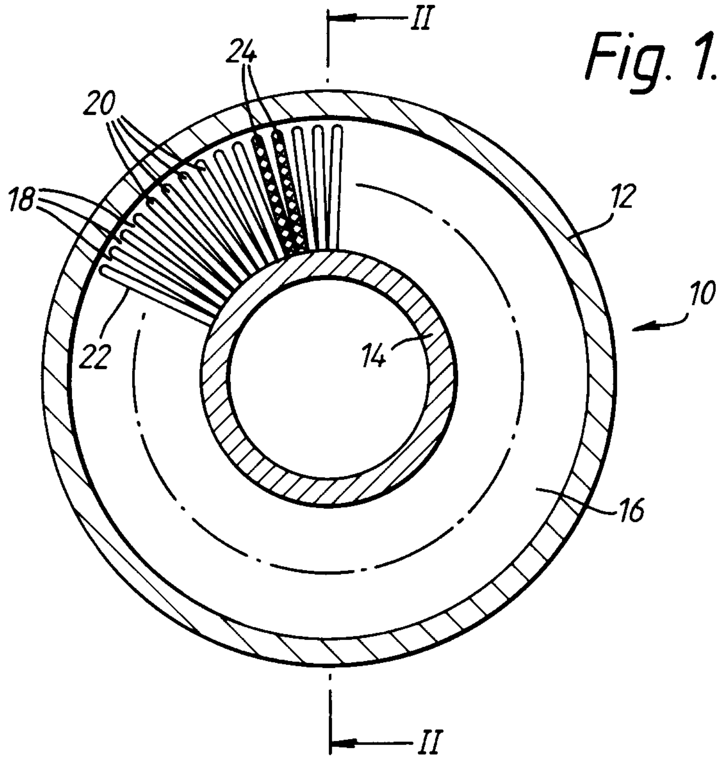


Fig. 2.

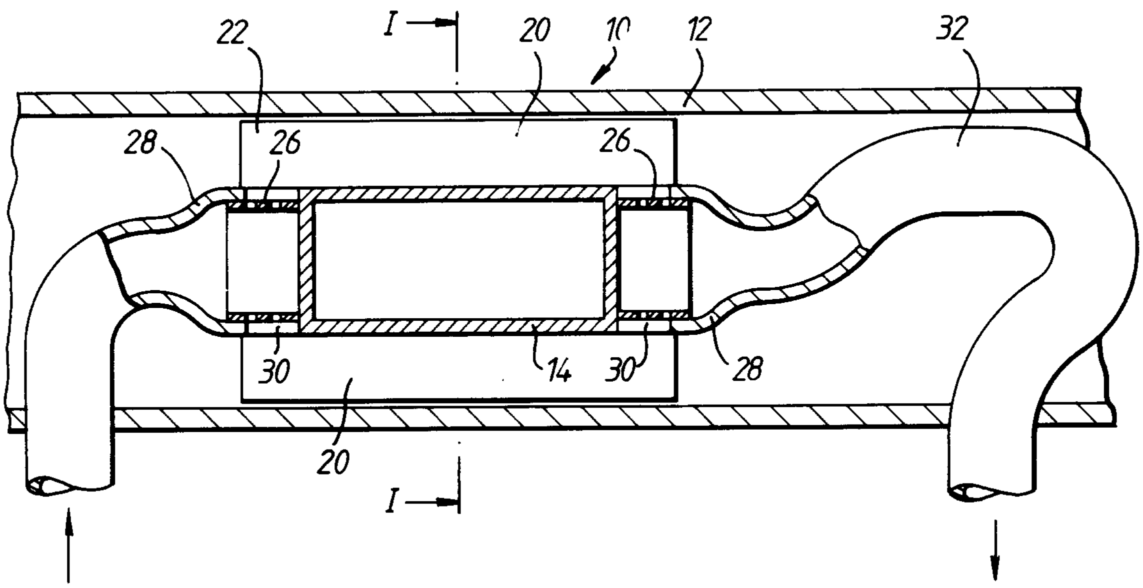


Fig. 3.

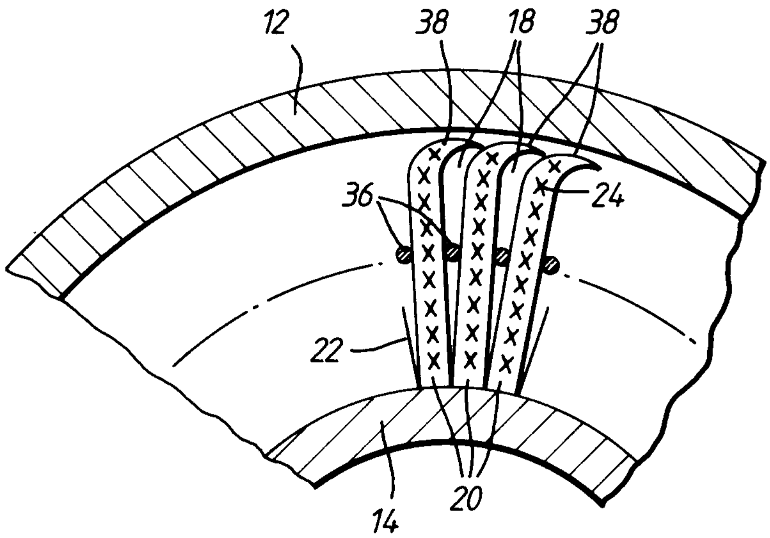


Fig. 4.

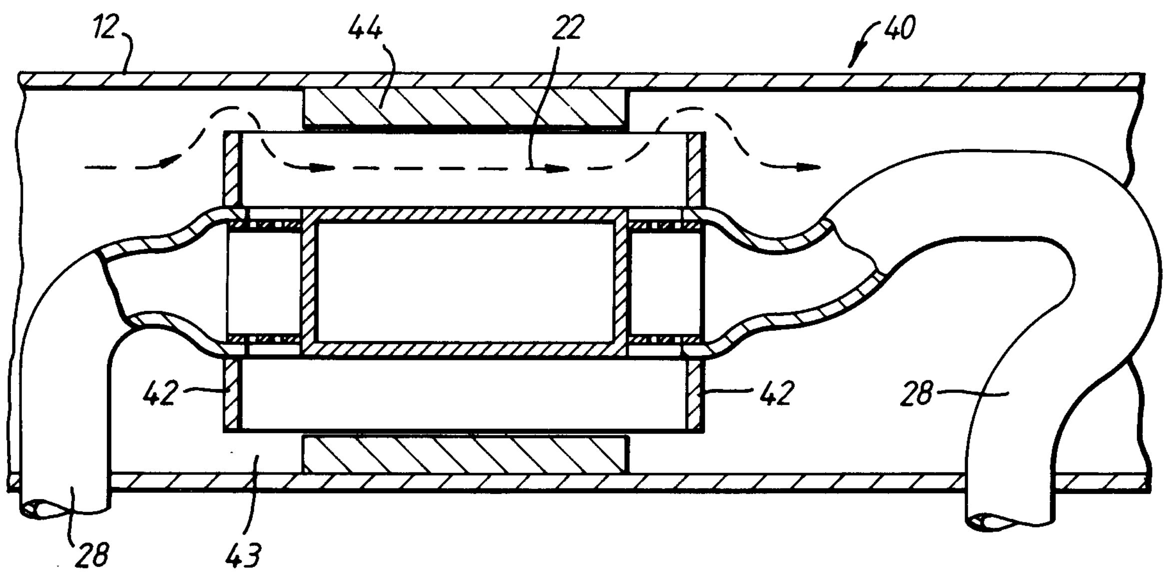


Fig. 5.

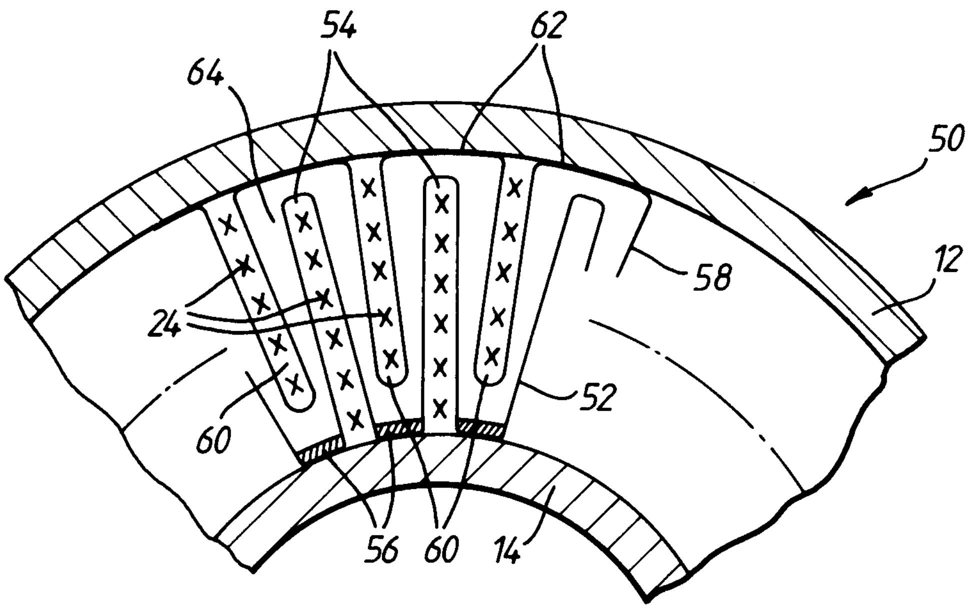
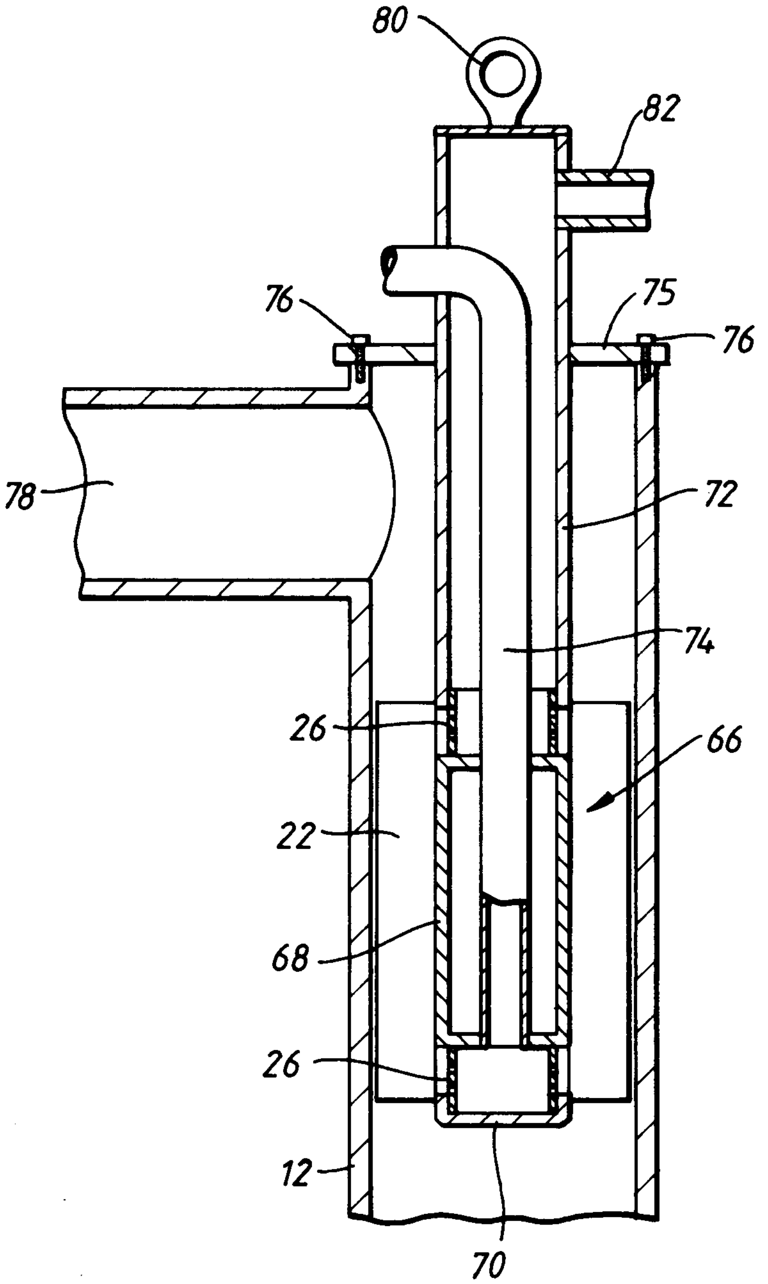


Fig.6.



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DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X A	US-A-2 616 530 (HOROWITZ) * column 3, line 28 - column 3, line 52 * * column 4, line 59 - column 4, line 70 * * column 6, line 7 - column 7, line 32; figures 1,2,13-15 *	1-4 5	F28D9/00
X	FR-A-2 269 694 (DESCHAMPS LABORATORIES INC.) * page 12, line 31 - page 14, line 20; figures 2D,3C,9E-11 *	1-4	
A	US-A-4 109 710 (FÖRSTER ET AL) * column 2, line 59 - column 2, line 65 * * column 3, line 39 - column 4, line 42 * * column 4, line 67 - column 5, line 6 * * column 5, line 15 - column 5, line 16; figures 1-5 *	1	
A	DE-C-729 339 (KRUPP AG) * page 2, line 73 - page 3, line 122; figures 1-4 *	1	**TECHNICAL FIELDS SEARCHED (Int. Cl.5)**
A	DE-C-887 951 (GOEBELS) * page 2, line 35 - page 2, line 92; figures 1,2 *	1	F28D
A	US-A-2 953 110 (ETHERIDGE) * column 3, line 27 - column 4, line 68 * * column 5, line 29 - column 5, line 47; figures 4,8-10,12 *	1	
A	US-A-3 983 933 (FLETCHER ET AL) * column 2, line 48 - column 4, line 41; figures 1-6 *	1	
A	FR-A-2 134 639 (NV PHILIPS GLOEILAMPENFABRIKEN) * page 3, line 16 - page 5, line 22; figures 1-3 *	1	
A	US-A-4 267 882 (GRALTON)		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	18 MARCH 1992	BELTZUNG F.C.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
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DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)

A	FR-A-2 647 198 (PACKINOX SA)		

			TECHNICAL FIELDS SEARCHED (Int. Cl.5)

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THE HAGUE	18 MARCH 1992	BELTZUNG F.C.

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