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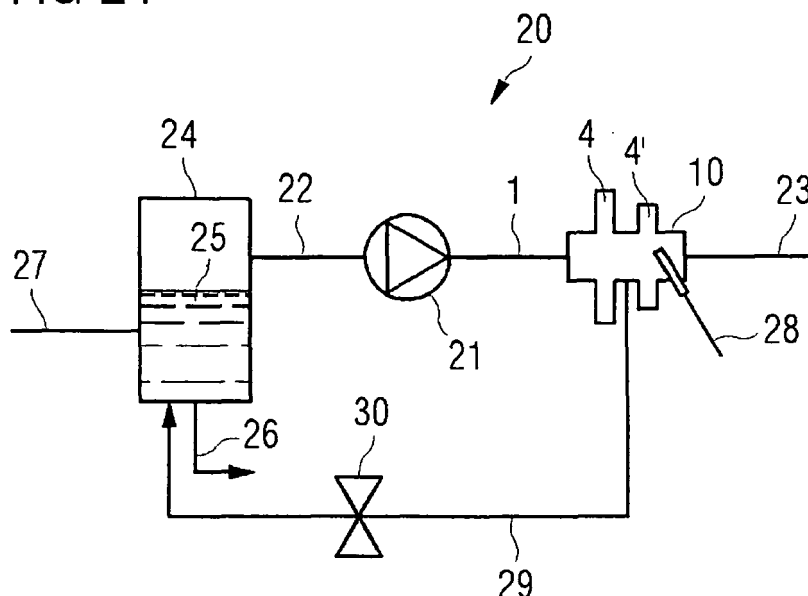
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(54) **Noise attenuation device for a centrifugal compressor discharge or suction nozzle**

(57) Noise damper for a radial (centrifugal) compressor, to be either integrally formed in the compressor housing or provided as a pipe section piece to be mounted on one of the housing nozzles. The damper consists of one or more side resonators, possibly of the Helmholtz-type. The side resonators may be arranged in series in the flow direction. A simple, modular and cost-effective construction of the damper consists in juxtaposing rings (diaphragms, discs) having concentric outer diameters but

inner contours that are not necessarily circular and that differ from each other. The resonator cavities then result from adjacent rings having different inner contours. These contours can be circles of different diameters, possibly eccentric, triangles, squares, or a circumferential array of radially staggered tubes. A self-cleaning mechanism by injection of liquid may be added to the damper. The cleaning liquid may be recuperated by a gas scrubber provided upstream of the compressor.

FIG 21



Description

[0001] The invention relates to a centrifugal compressor discharge or suction nozzle, a centrifugal compressor discharge or suction nozzle formed as a pipe section piece adapted to be mounted on a centrifugal compressor nozzle, a centrifugal compressor comprising the centrifugal compressor discharge or suction nozzle, and a centrifugal compressor arrangement comprising the centrifugal compressor.

[0002] In chemical and petrochemical plants a centrifugal compressor is commonly used for pressurising process gas. The centrifugal compressor comprises at least one suction nozzle and at least one discharge nozzle, wherein said nozzles are connected to plant piping. Through the suction nozzle process gas flows into the centrifugal compressor to be compressed therein. The compressed process gas exits the centrifugal compressor through the discharge nozzle to be delivered to downstream plant components.

[0003] The centrifugal compressor comprises at least one rotor with at least one impeller. Downstream of the impeller the centrifugal compressor comprises a diffuser. The impeller and the diffuser are aerodynamically effective to compress the process gas. During operation of the compressor the rotor rotates thereby generating noise. The noise is a combination of discrete frequency noise (tonal noise) related to the so-called blade passing frequency and its higher harmonics.

[0004] The noise generates a high noise exposure of the environment and can cause structural failures of the centrifugal compressor and the piping due to vibration cracking.

[0005] It is desirable to reduce the noise intensity level of the emitted noise spectrum at the blade passing frequency and its higher harmonics. Attenuation of the noise level upstream and downstream of the suction and discharge piping, respectively, will reduce the exposure to the environment and can reduce cyclic stresses in the structures upstream and downstream of the nozzles.

[0006] A remedy to reduce the noise intensity level of the centrifugal compressor is to cover the centrifugal compressor with a noise hood. The noise hood is able to reduce the noise exposure of the environment. However, the noise-hood is cost-intensive and needs to be taken into consideration with respect to space requirement being problematic in a plant with limited space.

[0007] Another remedy to reduce the noise intensity level of the centrifugal compressor is to provide the downstream piping of the centrifugal compressor with a piping silencer. However, the piping silencer is flown through by the process gas and therefore induces a high flow resistance resulting in an adverse pressure loss. Further, the piping silencer is costly in construction and large in geometrical dimensions.

[0008] Furthermore, another remedy to reduce the noise intensity level of the centrifugal compressor is to provide a Helmholtz array in the diffuser. The Helmholtz

array is installed on the diffuser wall resulting in a complicated and cost-intensive centrifugal compressor construction.

[0009] It is an object of the invention to provide a centrifugal compressor discharge or suction nozzle, a centrifugal compressor comprising the centrifugal compressor discharge or suction nozzle, and a centrifugal compressor arrangement comprising the centrifugal compressor, wherein the centrifugal compressor is effectively noise attenuated during operation and cost-effective in construction.

[0010] According to the invention, the centrifugal compressor discharge or suction nozzle comprises at least one side resonator integrally formed in the centrifugal compressor discharge or suction nozzle.

[0011] Alternatively, according to the invention, the centrifugal compressor discharge or suction nozzle is formed as a pipe section piece adapted to be mounted on a centrifugal compressor nozzle, comprising at least one side resonator integrated into the pipe section piece.

[0012] Further, according to the invention, between compressor nozzles and piping various stacked rings can be installed forming one or more side resonator(s).

[0013] Furthermore, according to the invention, the centrifugal compressor comprises the centrifugal compressor discharge or suction nozzle.

[0014] Additionally, according to the invention, the centrifugal compressor arrangement comprises the centrifugal compressor.

[0015] The process gas discharging the centrifugal compressor is interfered by tonal noise generated within the centrifugal compressor during its operation at a specific frequency band. The tonal noise is related to the so-called blade passing frequency and its higher harmonics.

The discharge or suction nozzle of the centrifugal compressor comprises the side resonator(s), whereby the side resonator(s) is (are) in direct cooperation with the discharge or inlet process gas. Since the side resonator(s) is (are) appropriate to reduce the tonal noise by the effects of acoustic impedance, the side resonator(s) act(s) like an acoustic mirror at the specific frequency band of the tonal noise. The geometrical dimensions of the side resonator(s) determine the frequency band in which the resonator(s) is (are) active. Therefore, it is possible to attenuate the frequency band in which the blade passing frequency is active. As a consequence of this, during operation of the centrifugal compressor, its noise emission level is lower.

[0016] Further, when the process gas flows through the discharge or suction nozzle, the process gas passes the side resonator without disturbing the process gas flow in the discharge or suction nozzle. Therefore, the side resonator includes very low or even less flow resistance to the process gas discharge or suction flow. Hence, a side resonator does not cause any significant pressure loss in the process gas discharge or suction flow. The process gas discharge or suction flow is noise attenuated by the side resonator(s). Consequently, the centrifugal

compressor comprising the side resonator has a high energy efficiency.

[0017] As an alternative, the side resonator(s) is (are) integrated in the pipe section piece, such that advantageously the centrifugal compressor can be equipped with the side resonator(s) subsequent to its assembly. Further, different types of side resonators can be provided for the centrifugal compressor in replacing the pipe section piece provided with different side resonators, and the pipe section piece can be designed as an universal section which can be mounted on any centrifugal compressor.

[0018] As an alternative various rings can be stacked in between the nozzle piping connection forming one or more resonators that can be fitted to any compressor.

[0019] Since the side resonator is integrally formed in the discharge or suction nozzle and in the pipe section piece, respectively, the centrifugal compressor has a compact design, which is easy and cost saving to be manufactured.

[0020] Preferably, the compressor discharge or suction nozzle comprises a plurality of side resonators located after each other. This enlarges the frequency band in which the noise is attenuated and makes the solution most robust.

[0021] Each side resonator is capable to reduce a specific frequency. Therefore, by providing a plurality of side resonators after each other, wherein each side resonator can be adapted to reduce another specific frequency, the frequency band in which the plurality of side resonators is effective to reduce the tonal noise, is broadened. This is the reason why the inventive centrifugal compressor is silenced in an effective way by means of the plurality of side resonators.

[0022] It is preferred that the pipe section piece comprises a plurality of ring elements having different inner diameters and concentrically adjoining each other, and at least one flange element facing the plurality of ring elements, wherein the plurality of ring elements form the side resonator(s).

[0023] The ring elements preferably can be formed by universal rings. Further, preferably standard flange elements can be used, such that manufacturing costs of the pipe section piece are low.

[0024] Preferably the side resonator consists of a single tube resonator.

[0025] Preferably, the side resonator comprises an array of single tube resonators circumferentially distributed.

[0026] Additionally preferred is that the side resonator comprises a circular resonator.

[0027] It is preferred that the side resonator comprises a cylindrical resonator.

[0028] Further, it is preferred that the side resonator comprises an eccentrically formed cylindrical resonator.

[0029] Alternatively, it is preferred that the side resonator is a Helmholtz resonator.

[0030] Further, preferably the side resonator consists

of a single Helmholtz resonator.

[0031] Additionally preferred is that the side resonator comprises an array of single Helmholtz resonators circumferentially distributed.

[0032] Further, it is preferred that the side resonator comprises a circular Helmholtz resonator.

[0033] Preferably, the side resonator is adapted to have self cleaning properties. The self cleaning properties can be generated either by using gravity or by having a secondary vortex flow.

[0034] It is preferred that the centrifugal compressor arrangement comprises the centrifugal compressor, wherein the side resonator comprises a liquid injection device for liquid injection into the side resonator for cleaning thereof.

[0035] Preferably, the centrifugal compressor arrangement comprises a gas scrubber provided upstream of the centrifugal compressor and a bypass line from the side resonator to the gas scrubber for bypassing the process gas or the liquid from the side resonator to the gas scrubber.

[0036] Further, it is preferred that the bypass line comprises a bypass valve.

[0037] In the following the invention is explained on the basis of preferred embodiments with reference to the drawings. In the drawings:

Fig. 1 is a longitudinal section of a first embodiment of a compressor nozzle according to the invention,

Fig. 2 is a cross section of the first embodiment in Fig. 1,

Fig. 3 is a longitudinal section of a second embodiment of a compressor nozzle according to the invention,

Fig. 4 is a longitudinal section of a third embodiment of a centrifugal compressor nozzle according to the invention,

Fig. 5, 6 are longitudinal sections of variations of a fourth embodiment of a centrifugal compressor nozzle according to the invention,

Fig. 7 to 14 are cross sections and longitudinal sections of variations of a fifth embodiment of a centrifugal compressor nozzle according to the invention,

Fig. 15 is a longitudinal section of a seventh embodiment of a centrifugal compressor nozzle according to the invention,

Fig. 16 is a longitudinal section of a seventh embodiment of a centrifugal compressor nozzle according to the invention,

Fig. 17 is a longitudinal section of a eighth embodi-

ment of a centrifugal compressor nozzle according to the invention,

Fig. 18 is a longitudinal section of a ninth embodiment of a centrifugal compressor nozzle according to the invention,

Fig. 19 is a longitudinal section of a tenth embodiment of a centrifugal compressor nozzle according to the invention,

Fig. 20 is a longitudinal section of a eleventh embodiment of a centrifugal compressor nozzle according to the invention,

Fig. 21 is a schematic view of a centrifugal compressor arrangement according to the invention, and

Fig. 22, 23 are views of the first embodiment in Fig. 1, 2 having self cleaning properties.

[0038] In Fig. 1 to 17, eight embodiments of centrifugal compressor nozzles 1 are shown, wherein each centrifugal compressor nozzle comprises a side resonator 2 to 9 which is integrally formed in the centrifugal compressor nozzle 1.

[0039] The side resonator according to Fig. 1, 2 consists of a single tube resonator 2. The single tube resonator 2 is comprised by a cylindrical cavity. The cavity is formed by a hollow cylinder body perpendicularly protruding from the compressor nozzle 1 and being delimited by a bottom of the cylinder body at its end opposing the centrifugal compressor nozzle, wherein the cavity is in communication with the interior of the compressor nozzle 1.

[0040] The side resonator according to Fig. 3 is an array 3 of the single tube resonators 2 which are circumferentially distributed at the centrifugal compressor nozzle 1. The single tube resonators 2 forming the array side resonator 3 are arranged equally spaced such that the acoustic effect of the array side resonator 3 is circumferentially uniform.

[0041] Further, the side resonator according to Fig. 4 comprises a circular resonator 4. The circular resonator 4 is a disc-shaped cavity encompassing the centrifugal compressor nozzle 1.

[0042] Furthermore, the side resonator according to Fig. 5, 6 comprises a cylindrical resonator 5. The cylindrical resonator 5 is formed like the circular resonator 4, but with an L-shaped cross section in longitudinal direction of the centrifugal compressor nozzle 1.

[0043] For the side resonator any shape is possible provided its -effective length is such that the desired noise attenuation is possible. Therefore, the side resonator do not need to be rotation symmetric but can comprise an eccentrically formed cylindrical resonator 6. Examples of the eccentrically formed cylindrical resonator 6 are shown in Fig. 7 to 14. The eccentrically formed cylindrical

resonator 6 according to Fig. 7, 8 is formed like the circular resonator 4, but with a varying inner diameter over the circumference of the centrifugal compressor nozzle 1. The eccentrically formed cylindrical resonator 6 according to Fig. 1, 10 has a square cross section. The eccentrically formed cylindrical resonator 6 according to Fig. 11, 12 has a cross section formed as an equilateral triangle. The eccentrically formed cylindrical resonator 6 according to Fig. 13, 14 has a cross section elliptically formed.

[0044] According to Fig. 15 to 17, the side resonators 7 to 9 are of Helmholtz side resonator type.

[0045] The side resonator according to Fig. 15 consists of a single Helmholtz resonator 7. The single Helmholtz resonator 7 is comprised by a cylindrical cavity. The cavity is in communication with the interior of the compressor nozzle 1 and comprises an enlargement opposing the centrifugal compressor nozzle 1.

[0046] Further, the side resonator according to Fig. 16 comprises an array 8 of the single Helmholtz resonators 7 provided circumferentially distributed. The single Helmholtz resonators 7 are arranged equally spaced such that the acoustic effect of the array Helmholtz resonator 8 is circumferentially uniform.

[0047] Furthermore, the side resonator according to Fig. 17 comprises a circular Helmholtz resonator 9. The circular Helmholtz resonator 9 is a disc-shaped cavity encompassing the centrifugal compressor nozzle 1, wherein the cavity comprises an enlargement opposing the centrifugal compressor nozzle 1.

[0048] Fig. 18 to 20 show a pipe section piece 10. The pipe section piece 10 is adapted to be mounted on a centrifugal compressor nozzle. Therefore, when the pipe section piece is mounted on the centrifugal compressor nozzle, process gas entering or discharging the centrifugal compressor passes through the pipe section piece 10. Fig. 18 to 20 show one of many possible variants of the pipe section piece 10.

[0049] The pipe piece section 10 according to Fig. 18 and 20 is integrally formed and comprises a pipe 11 and two flanges 12 provided on the longitudinal ends of the pipe 11. The flanges 12 are adapted to be fitted to the centrifugal compressor nozzle. The pipe 11 has an inner diameter 15.

[0050] Further, in the pipe 11 three circumferentially extending ring grooves are provided thereby forming three circular resonators 4 to 4" integrated into the pipe section piece 10, respectively. Each circular resonator 4 to 4" has an inner diameter 13 to 13", respectively, being greater than the inner diameter 15 of the pipe 11, wherein the inner diameter 13 is smaller than the inner diameter 13', and the inner diameter 13' is smaller than the inner diameter 13". The circular resonators 4 to 4" are arranged side by side such that the pipe piece section is acoustically effective for a broad frequency band.

[0051] The body of the pipe section piece 10 according to Fig. 18 is formed as a hollow cylinder. The pipe section piece 10 according to Fig. 20 is flexible and formed like

a bellow or a diaphragm coupling. Therefore, the pipe section piece 10 can reduce compressor casing / piping forces and moments. Hence, allowable nozzle movements are larger.

[0052] The number and shape of the resonators 4 to 4'' can be varied depending on the desired acoustic characteristic of the pipe section piece 10. In Fig. 18 and 19 i designates the number of resonators, 0 designates the diameter of the resonator i , t_i designates the width of the resonator i , and L_i designates the distance between the resonator i and the resonator $i+1$.

[0053] The pipe piece section 10 according to Fig. 19 is similar to the pipe piece section 10 according to Fig. 18 and 20, but comprises seven individual ring elements 14, 14', 14'', 14''', 14^{IV}, 14^V, 14^{VI}. The inner diameter of the ring elements 14, 14', 14'', 14''' equals the inner diameter 15 of the pipe 11. The ring elements 14', 14'', 14^V have different inner diameters 13 to 13'' and are concentrically adjoined together. Further, the pipe piece section 10 according to Fig. 19 comprises two flange elements 12 facing the ring elements 14, 14', 14'', 14''', 14^{IV}, 14^V, 14^{VI} for being adapted to be mountable to a centrifugal compressor nozzle. The seven ring elements 14, 14', 14'', 14''', 14^{IV}, 14^V, 14^{VI} are stacked and form the circular resonators 4, 4', 4''. Any other number of ring elements 14, 14', 14'', 14''', 14^{IV}, 14^V, 14^{VI} is possible.

[0054] Fig. 20 shows a centrifugal compressor arrangement comprising a centrifugal compressor 21 comprising the centrifugal compressor nozzle 1. The centrifugal compressor nozzle 1 comprises the circular resonators 4 and 4'.

[0055] As a further option, the centrifugal compressor nozzle 1 comprises a wash water injection device 28 for wash water injection into the side resonators 4 and 4' for cleaning thereof. Further, the centrifugal compressor arrangement 20 comprises a gas scrubber 24 provided upstream of the centrifugal compressor 21 and a bypass line 29 from the centrifugal compressor nozzle 1 to the gas scrubber 24. By means of the bypass line 29 a gas flow can be forced through the pipe section piece 10 to the gas scrubber 24. Further, the bypass line 29 comprises a bypass valve 30 for controlling the bypassed gas flow. Additionally, wash water is fed back to the scrubber 24 via the bypass line 29.

[0056] Fig. 22, 23 show views of the first embodiment according to Fig. 1, 2 having self cleaning properties. The single tube resonator 2 is thread-like arranged on the compressor nozzle

1. Therefore, a part of the process gas flows through the cavity.

Claims

1. Centrifugal compressor discharge or suction nozzle comprising at least one side resonator (2-9) integrally formed in the centrifugal compressor discharge or

suction nozzle (1).

2. Centrifugal compressor discharge or suction nozzle formed as a pipe section piece (10) adapted to be mounted on a centrifugal compressor (21), comprising at least one side resonator (2-9) integrated into the pipe section piece (10).
3. Centrifugal compressor discharge or suction nozzle according to claim 2, wherein the side resonator (2-9) is integrally formed in the pipe section piece (10).
4. Centrifugal compressor discharge or suction nozzle according to claim 2 or 3, wherein the compressor discharge or suction nozzle (1) comprises a plurality of side resonators (2-9) located after each other.
5. Centrifugal compressor discharge or suction nozzle according to claim 4, wherein the pipe section piece (10) comprises one or a plurality of ring elements (14-14^{IV}) having different inner diameters (13-13'') and concentrically adjoining each other, and at least one flange element (12) facing the plurality of ring elements (14-14^{VI}), wherein the plurality of ring elements (14-14^{VI}) form the side resonator (4-4'').
6. Centrifugal compressor discharge or suction nozzle according to claim 5, wherein the side resonator consists of a single tube resonator (2).
7. Centrifugal compressor discharge or suction nozzle according to claim 5 or 6, wherein the side resonator comprises an array of single tube resonators (3) circumferentially distributed.
8. Centrifugal compressor discharge or suction nozzle according to any of claims 5 to 7, wherein the side resonator comprises a circular resonator (4).
9. Centrifugal compressor discharge or suction nozzle according to any of claims 5 to 8, wherein the side resonator comprises a cylindrical resonator (5).
10. Centrifugal compressor discharge or suction nozzle according to any of claims 5 to 9, wherein the side resonator comprises an eccentrically formed cylindrical resonator (6).
11. Centrifugal compressor discharge or suction nozzle according to any of claims 1 to 5, wherein the side resonator is a Helmholtz resonator (7-9).
12. Centrifugal compressor discharge or suction nozzle according to claim 11, wherein the side resonator consists of a single Helmholtz resonator (7).
13. Centrifugal compressor discharge or suction nozzle according to claim 11 or 12, wherein the side reso-

nator comprises an array of single Helmholtz resonators (8) provided circumferentially distributed.

14. Centrifugal compressor discharge or suction nozzle according to any of claims 11 to 13, wherein the side resonator comprises a circular Helmholtz resonator (9). 5
15. Centrifugal compressor discharge or suction nozzle according to any of claims 1 to 14, wherein the side resonator is a resonator adapted to have self cleaning properties. 10
16. Centrifugal compressor comprising a centrifugal compressor discharge or suction nozzle according to claim 1 to 15. 15
17. Centrifugal compressor arrangement comprising a centrifugal compressor (21) according to claim 16, wherein the side resonator (2-10) comprises liquid injection device (28) for liquid injection into the side resonator (2-10) for cleaning thereof. 20
18. Centrifugal compressor arrangement according to claim 17, wherein the centrifugal compressor arrangement (20) comprises a gas scrubber (24) provided upstream of the centrifugal compressor (21) and a bypass line (29) from the side resonator (2-10) to the gas scrubber (24) for bypassing the liquid from the side resonator (2-10) to the gas scrubber (24). 25
30
19. Centrifugal compressor arrangement according to claim 18, wherein the bypass line (29) comprises a bypass valve (30). 35
20. Centrifugal compressor arrangement according to claims 18 or 19, wherein the centrifugal compressor arrangement (20) comprises an additional gas scrubber (24) provided upstream of the centrifugal compressor (21). 40

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FIG 1

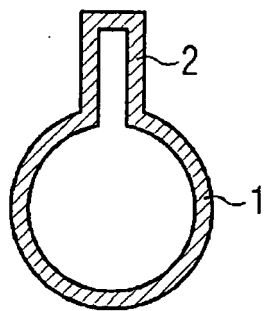


FIG 2

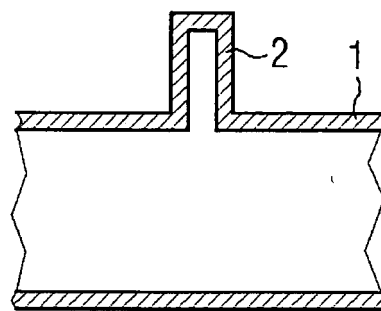


FIG 3

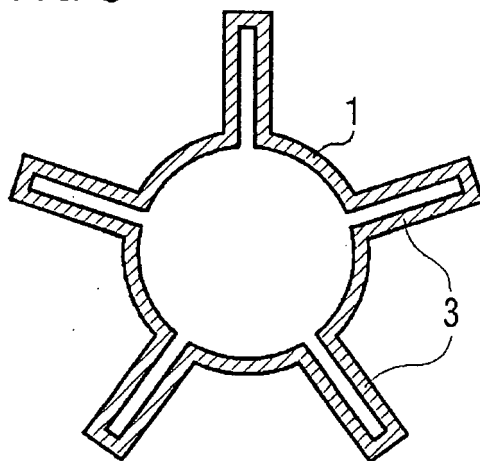


FIG 4

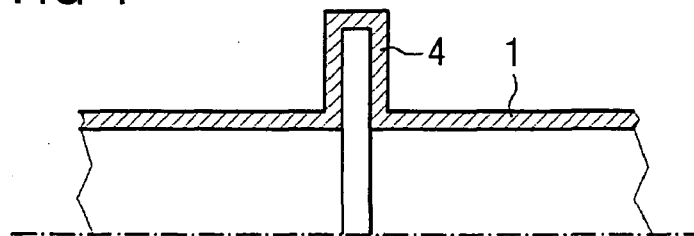


FIG 5

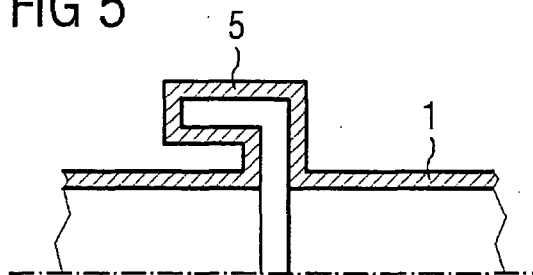


FIG 6

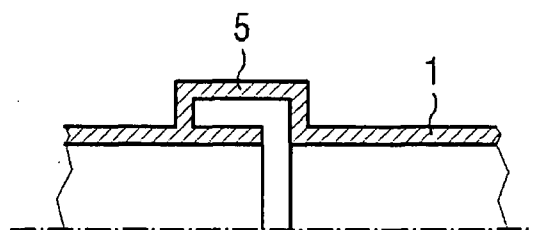


FIG 7

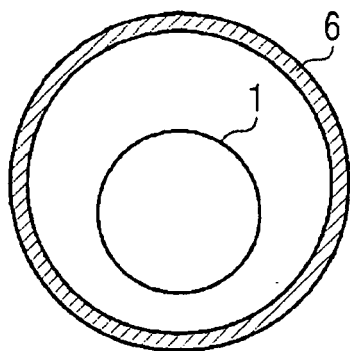


FIG 8

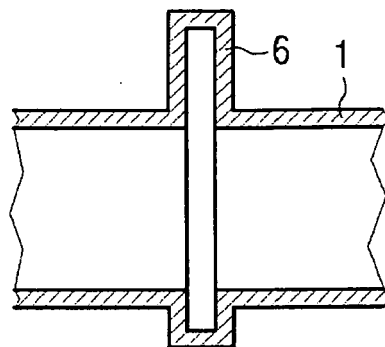


FIG 9

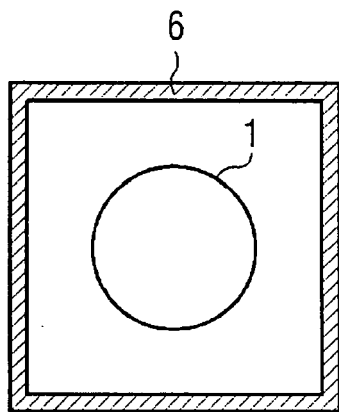


FIG 10

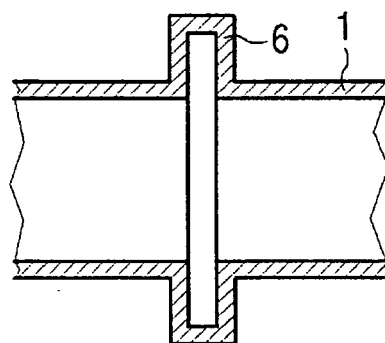


FIG 11

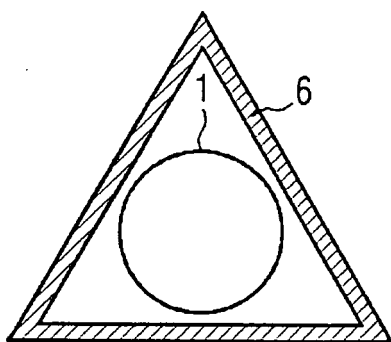


FIG 12

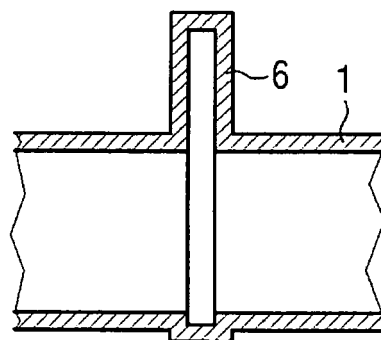


FIG 13

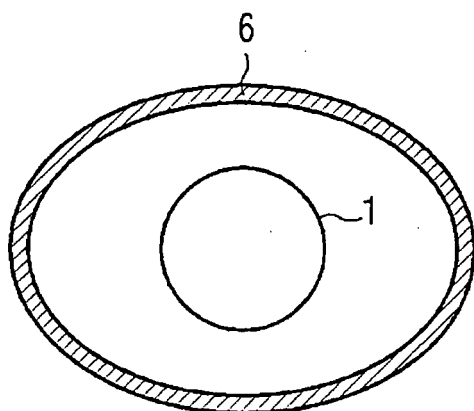


FIG 14

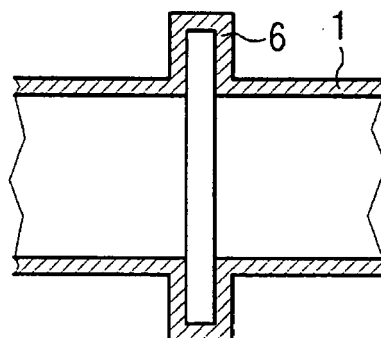


FIG 15

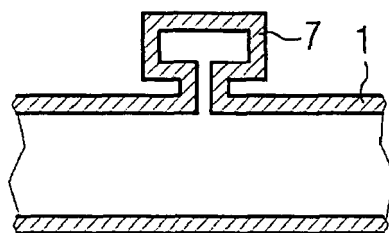


FIG 16

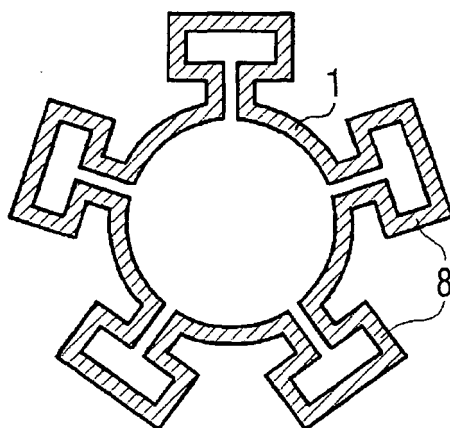


FIG 17

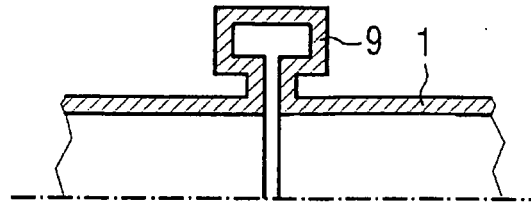


FIG 18

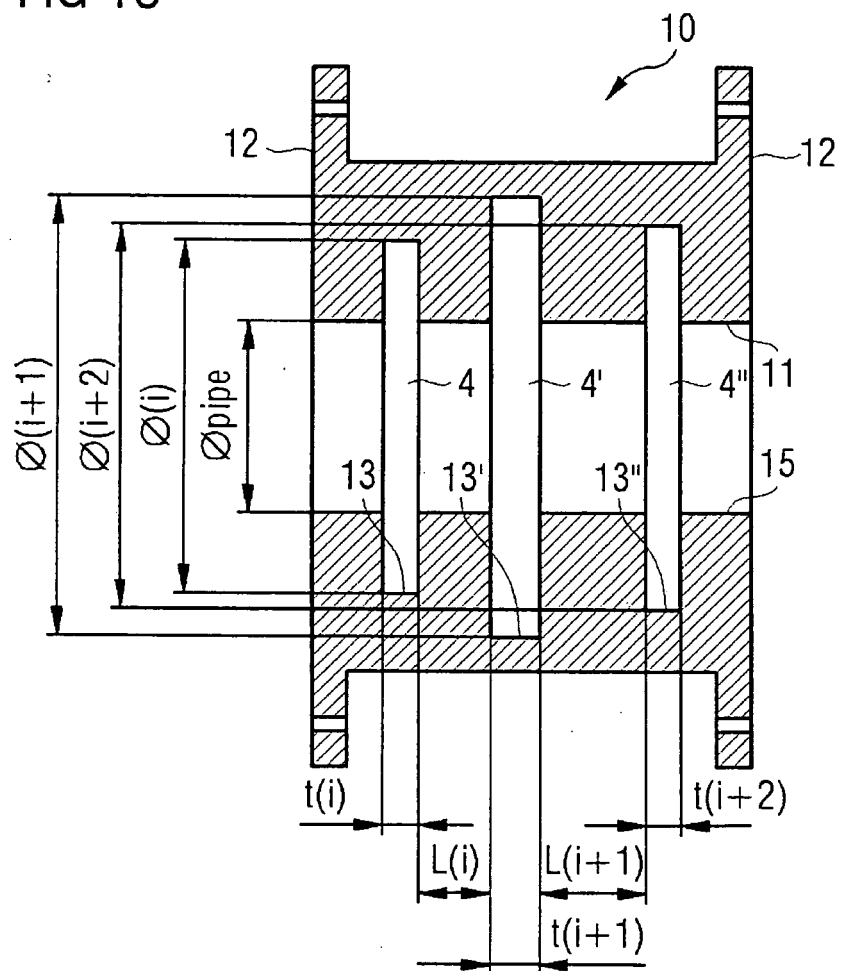


FIG 19

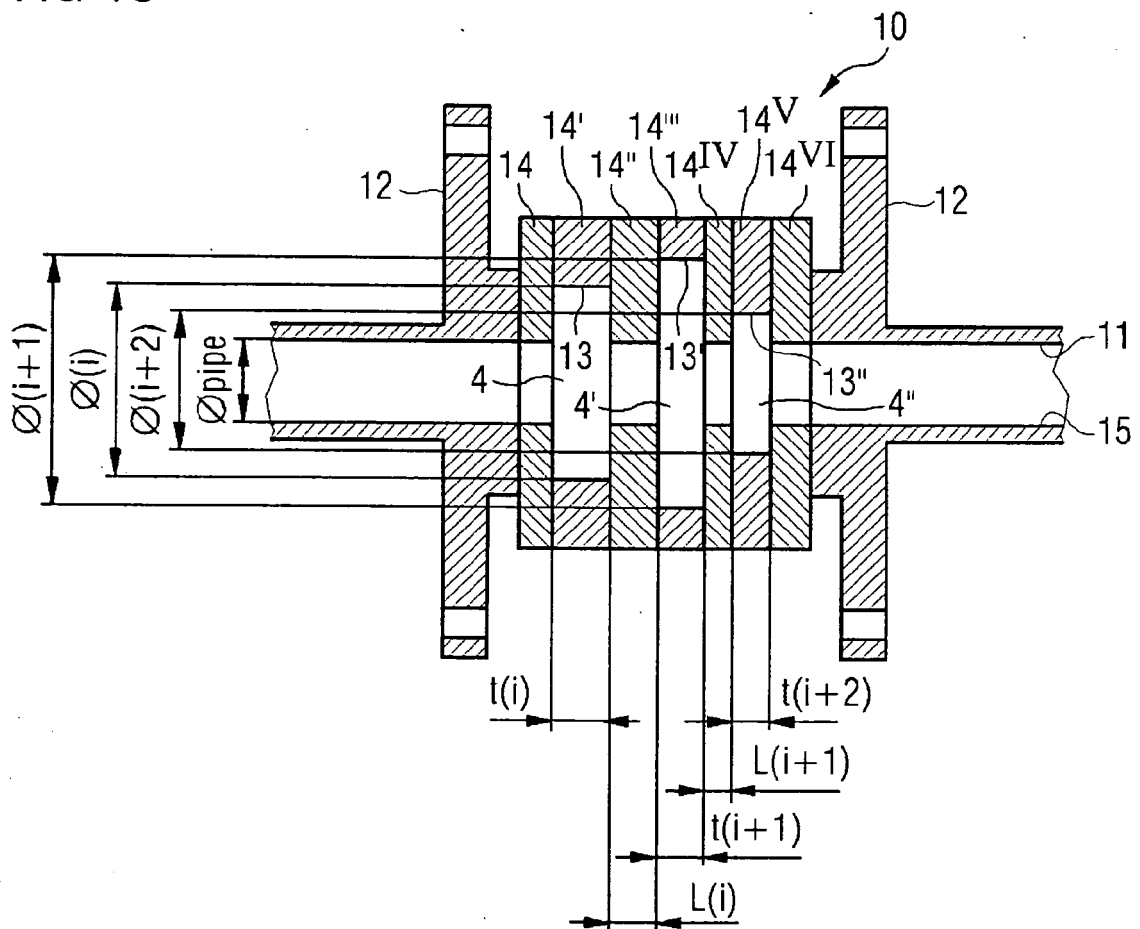


FIG 20

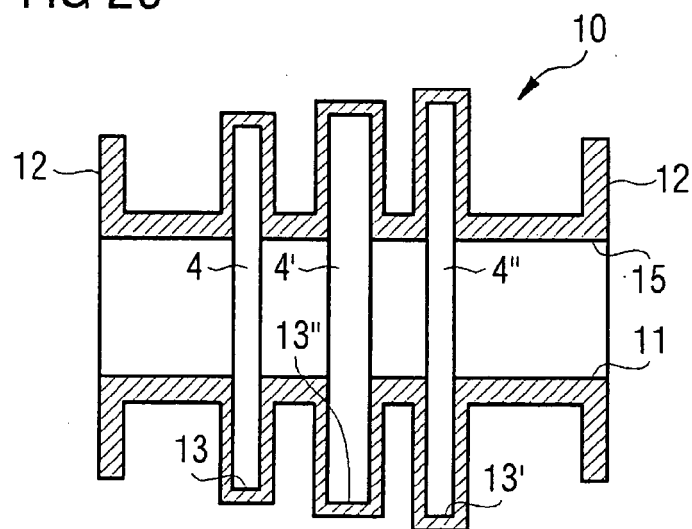


FIG 21

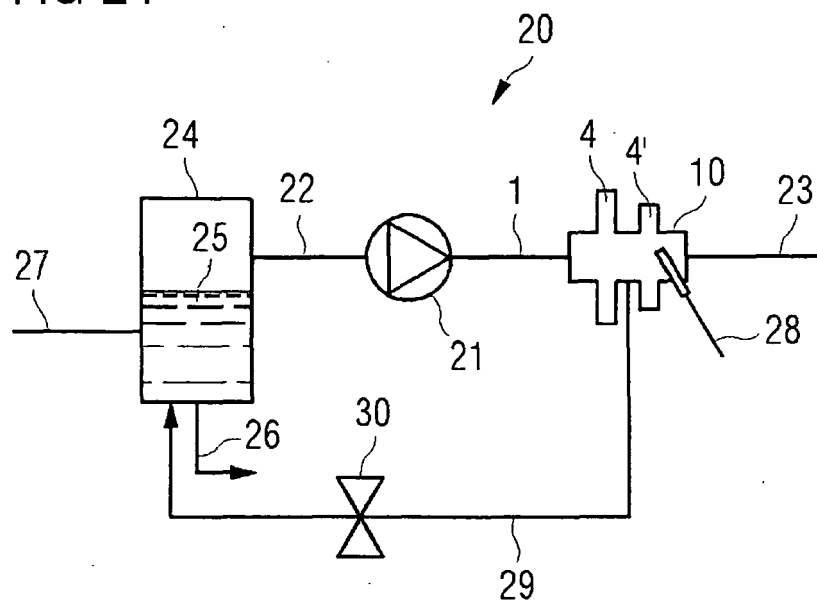


FIG 22

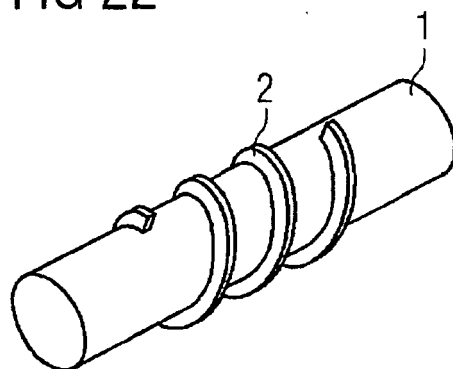
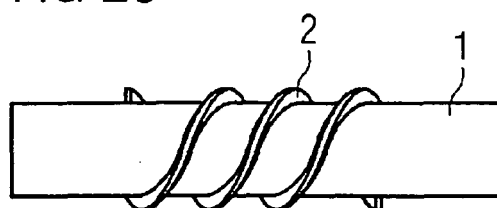


FIG 23





European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 07 02 2502

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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3 X	DE 18 14 146 A1 (TEEM INC AB) 10 July 1969 (1969-07-10) * the whole document * * figures 2,7,8 *	2,4,5,8,9	
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4 X	DE 10 2004 057413 A1 (MAHLE FILTERSYSTEME GMBH [DE]) 29 June 2006 (2006-06-29) * the whole document * * paragraph [0002] * * figures 3-5,9,10 * * paragraphs [0033] - [0037] *	2,11-13,16	TECHNICAL FIELDS SEARCHED (IPC) F04D F16L F01N F02M G10K
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7	The present search report has been drawn up for all claims		
Place of search The Hague		Date of completion of the search 16 SEP 2008	Examiner Brouillet, Bernard
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)



European Patent
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Application Number
EP 07 02 2502

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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