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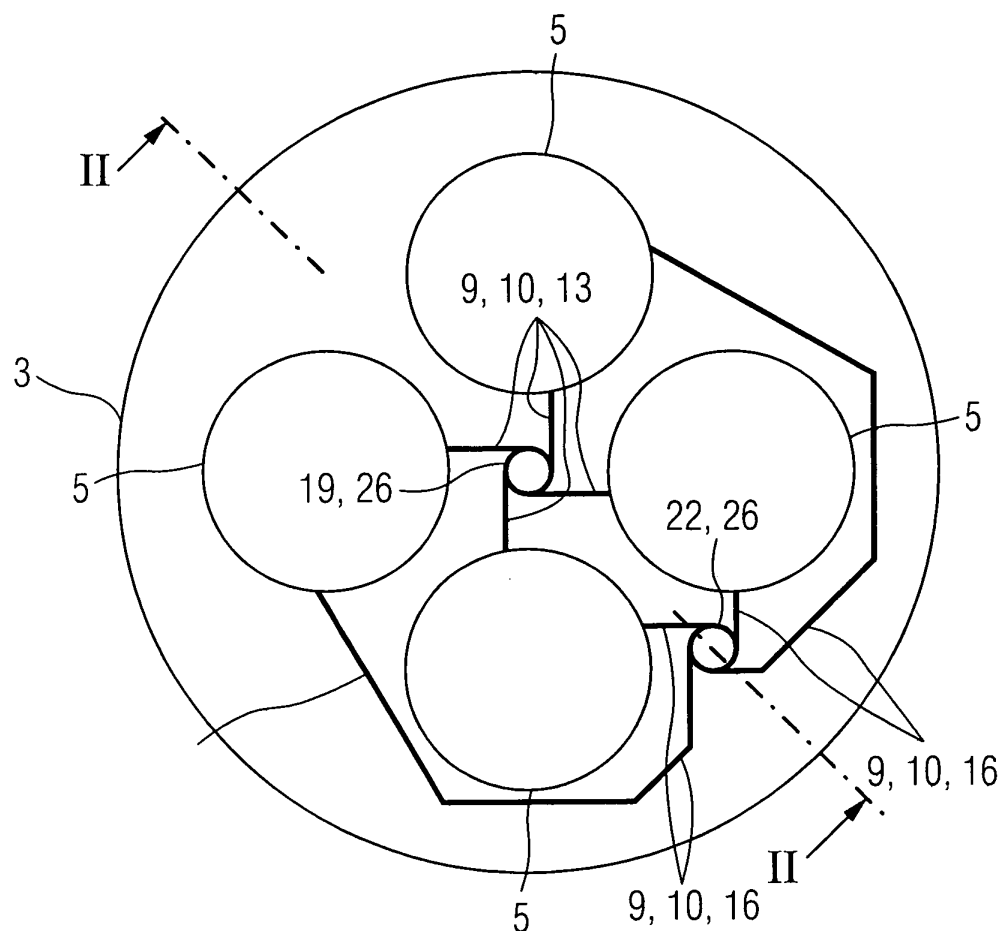
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(54) **Fuel supply module**

(57) Disclosed is a fuel supply module with a plurality of burner ports (7) for receiving respective burners (2) and a plurality of first fuel supply lines (15), each first fuel supply line (15) integrated into the fuel supply module (1)

and connected to one of the burner ports (7) and merging into a common first fuel injection entry (21) for supplying a fuel to the first fuel supply lines (15). Further disclosed is a method of manufacturing a fuel supply module.

FIG 1



Description

FIELD OF THE INVENTION

[0001] The present invention relates to a fuel supply module and a method of manufacturing a fuel supply module.

BACKGROUND OF THE INVENTION

[0002] In gas turbine combustors with multiple burners, it is well known that connection of multiple streams of gaseous fuel via conventional connection can be a source of mechanical complexity, long assembly and service times and lowered robustness to occasional leaks.

[0003] Furthermore, such systems have a tendency to "cross-talk" between different burners via fuel lines, which are not being used during particular phases of operation, due to differential pressures caused by normal part-to-part tolerances.

[0004] Where many burners and/or fuel streams are present on an engine, severe space problems may arise. The length and fluid resistance of such passages can require extra fuel compression and/or additional fuel pressure losses which constrain the design and performance of burner mixing passages and the engine itself.

[0005] The sealing problem is commonly addressed by special, high-cost connector designs, long lengths of piping to get the necessary flexibility and/or flexible pipes which are at risk of rupture and are very sensitive to hot cross-talk flows. The space issues have lead in some cases to routing extra piping well away from the combustor and compressor with extra costs and fitting time both during service and initial assembly.

[0006] Common solutions to the cross-talk problem are to use purging which involves extra components and control algorithms or non-return valves, in which the moving parts constitute a source of unreliability for industrial turbines which must work unattended and uninspected for long periods.

[0007] The cost of fuel compression is typically minimised by limiting the cycle pressure in small engines, but this clearly has a strong impact on achievable cycle efficiency.

SUMMARY OF THE INVENTION

[0008] An object of the invention is to provide a new robust, uncomplicated and reliable fuel supply module.

[0009] This objective is achieved by the claims. The dependent claims describe advantageous developments and modifications of the invention.

[0010] In the inventive fuel supply module most of the detailed distribution channels are placed within the burner flange to eliminate large numbers of joints. Therefore, a much smaller number of more robust seals are required and these do not have to be dismantled to inspect or

replace burner parts subject to limited life, which dramatically decreases downtime for maintenance or repair, a factor of great importance for the end-user.

[0011] Inventive fuel lines are formed by grooves arranged in burner flange parts placed on top of each other and brazed or welded together. Next to these fuel lines, burner flange parts form also connection points realized as fluidic valves which strongly restrict any flow not in the preferred (design) direction. Since such valves do not rely on moving parts, they are particularly robust. The large thermal mass of the parts in contact with any remnant cross-talk flows will tend to provide a heat extraction path which will render the flows cool enough not to cause problems with the external conventional connectors and pipes.

[0012] Since fuel lines and valves are comprised of two parts, access for accurate forming is particularly simple, permitting better tolerances thus reducing the part-to-part variability which leads to cross-talk in the first place. Eliminating such variability has other positive consequences for the engine performance such as more even hot part lives and avoidance of thermo-acoustically "forbidden" zones in burner operating maps.

[0013] The design is arranged so that the seal to the burners air passage parts can be made in a conventional way with gaskets or metal-to-metal contact (or other means), but also so that any leakage will emerge in a place where the incoming burner airflow will immediately entrain it into the burner (and mix with it) avoiding any issues of pre-ignition or burning outside the combustor and also minimising the emissions impact.

[0014] Because multiple burners can be mounted upon a single flange, the space requirement external to the engine pressure casing is much reduced, and the forces of relative thermal expansion are taken by a thick component (the flanges) capable of resisting them easily, rather than by the movement of small pipes and joints which may subsequently leak as a result. Furthermore those external pipes and joints which are necessary are correspondingly bigger and less prone to leaks caused by mechanical disturbance (for whatever reason this occurs).

[0015] The length and diameter of piping achievable in the new design also permits a reduction in fuel supply pressure losses and volumes, with benefits both for reduced energy content after the control valves for limiting turbine over-speed during load-drop events and also for compression cost and practicality on small engines as mentioned above.

[0016] Dismantling the combustor assembly is now much quicker than the conventional approach, since only a few large external joints need to be broken. This also allows rapid in-situ replacement with pre-prepared (and pre-tested) units, drastically reducing down-time experienced by the engine customer. Breaking these joints also effectively removes the "manifold" so that there is no longer hindered access for removal of combustors or transition ducts.

[0017] By such a design a robust and reliable fuel supply module is achieved.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] The invention will now be further described, with reference to the accompanying drawings in which:

- Figure 1 shows a main part of a flange with first parts of burner ports, grooves for fuel lines and parts of valves,
- Figure 2 shows first and second main parts of a flange with two vortex diodes along the line 2-2 of Figure 1,
- Figure 3 shows the fuel flow in a vortex diode seen from the side,
- Figure 4 shows the fuel flow in a vortex diode seen from the top in the forward (design) flow direction,
- Figure 5 shows a can-to-can cross-talk flow in a vortex diode in the reverse flow direction,
- Figure 6 shows a burner-to-burner cross-talk flow in a vortex diode in the reverse flow direction in one burner,
- Figure 7 shows the main fuel leakage paths,
- Figure 8 shows the pilot fuel leakage paths,
- Figure 9 shows an arrangement with inventive flanges for main and pilot fuel for a whole engine,
- Figure 10 shows the pigtail arrangement for the arrangement of Figure 9 seen from the side,
- Figure 11 shows a "daisy-chain" arrangement for the main fuel manifold for a whole engine,
- Figure 12 shows the cavities in a configuration with three main flange parts,
- Figure 13 shows the cavities in a configuration with two main flange parts,
- Figure 14 shows the cavities in another configuration with two main flange parts, and
- Figure 15 shows another arrangement for the main fuel manifold.

[0019] In the drawings like references identify like or equivalent parts.

DETAILED DESCRIPTION OF THE INVENTION

[0020] Referring to the drawings, Figure 1 shows a first main part 3 of the inventive fuel supply module 1, with four first parts of burner ports 5 and first parts of first and second fuel injection entries 19, 22 (one of each) formed as first parts of vortex diodes 26. Each first part of a vortex diode 26 connects to each first part of the burner ports 5 via first parts of fuel supply lines 10 formed as grooves 9 arranged in the first main part 3. First parts of the first fuel supply lines 13 interconnect first parts of burner ports 5 and first parts of the first fuel injection entry 19. First parts of the second fuel supply lines 16 interconnect first parts of burner ports 5 and first parts of the second fuel

injection entry 22.

[0021] Figure 2 is a view of an inventive fuel supply module 1 along the line II-II of Figure 1. The lower part of Figure 2 is the first main part 3 shown in Figure 1. This first main part 3 is covered by a second main part 4. A first part of a first fuel injection entry 19 in first main part 3 aligns with a second part of a first fuel injection entry 20 in the second main part 4 as well as a first part of a second fuel injection entry 22 in the first main part 3 aligns with a second part of a second fuel injection entry 23 in the second main part 4. First parts of first and second fuel injection entries 19, 22 are first parts of vortex diodes 26 and second parts of first and second fuel injection entries 20, 23 are second parts of vortex diodes 27. The first and second main parts 3, 4 are held together by a weld 42 around the rim 39 to form a flange 29, where first and second fuel injection entries 21, 24 form fluidic valves 25/vortex diodes 28.

[0022] Figures 3 to 6 show details and functionality of a vortex diode 28 as an example of one of the many types of fluidic valves 25 that might be used in this situation to restrict reverse flow. A vortex diode 28 as shown in Figure 3 with first and second parts 26, 27 of a vortex diode is a highly reliable check valve without moving parts that utilizes the properties of the fluid passage itself to generate a greater resistance to flow in one direction. The vortex diode 28 shown in Figures 3 to 6 comprises a vortex chamber 36, an axial port 37 and four tangential ports 38.

[0023] Figures 3 and 4 respectively show a top view and a side view of the forward fuel flow direction, where the fluid enters via the axial port 37 and encounters a minimum impedance with approximately one 90° bend before leaving the central vortex chamber 36 through the tangential ports 38.

[0024] In the reverse flow direction, the fluid enters the vortex chamber 36 via a tangential port 38 producing a vortex in the central vortex chamber 36. The high pressure drop associated with this vortex results in a high resistance to flow. Both can-to-can (Figure 5) and burner-to-burner (Figure 6) cross-talk flows must overcome their own angular or linear momentum, respectively, in order to flow in reverse. The burner-to-burner reverse flows experience less impedance than can-to-can reverse flows, but since burners 2 in the same can 8 have similar back-pressure, this is not a significant disadvantage.

[0025] Figures 7 and 8 show fuel leakage paths. Edge welds 42 around the rim 39 (see Figure 2) between the first and second main parts 3, 4 of the flange 29 constrain any leakage between the first and second main parts 3, 4 to flow towards the burner ports 7 and burners 2 arranged there-in. Further welds 42 around the burner ports 7 limit the leakage paths 34 to the pick-up points 45 between flange 29 and burner fuel passages 35 arranged in the main burner body 40 and the pilot burner body 41, respectively. The length of the leakage paths 34 should ensure that any leakage is minimal anyway. Figures 7 and 8 show details of a single burner 2 in a burner port 7 with leakage paths 34 at the pick-up points 45 between

flange 29 and burner fuel passage 35. It can be seen from Figure 7 that the main fuel path 30 comprises a fuel supply line 12 (in this case a first fuel supply line 15) in the flange 29 connecting to a burner fuel passage 35 arranged in the main burner body 40 and that any leaking gas fuel passing around the main burner body 40 automatically either enters the swirler 43 and mixes as intended with the incoming compressor air or is entrained into the swirler 43 into roughly the same position as if it had been introduced via main and pilot injection.

[0026] The real pilot fuel 32 path is shown in Figure 8. The pilot fuel 32 is provided by a second fuel supply line 18, traverses the main burner body 40 and enters the pilot burner body 41 before it is introduced into the burner 2. The pilot fuel 32 leaking paths are the same as for main fuel 30.

[0027] From Figures 7 and 8 it can also be seen that the burners 2 may be removed for inspection, etc. without touching the fuel supply connectors, since the fuel supply connects to the flange 29 and not to the burners 2.

[0028] Figure 9 shows the very compact arrangement of six cans 8 with four burners 2 per can 8, using the inventive fuel supply module 1. Fuel from the main fuel supply 31 is distributed via the main manifold 47 to the first fuel injection entries 21 of the inventive fuel supply modules 1. Fuel from the pilot fuel supply 33 is distributed via the pilot manifold 48 to the second fuel injection entries 24. Two flexible pigtailed 49 (see Figure 10) per can 8, i.e. one for the main fuel supply 31 and one for the pilot fuel supply 33, would be required in the third dimension (sticking into the page) to connect to the main manifold 47 and the pilot manifold 48, respectively.

[0029] Figure 10 shows main manifold 47 and pilot manifold 48 with pigtailed 49 of the arrangement shown in Figure 10 from a different perspective, as they would be used in this configuration. The access to burners 2 and cans 8 would not be restricted with suitable dimensioning and so removal of burners 2 and cans 8 would be possible without disturbing the manifolds 47,48.

[0030] Figure 11 shows a "daisy-chain" arrangement of the main manifold 47 with six fuel supply modules 1 (The arrangement for the pilot is not shown). External fuel pipes 44 always connect a fuel supply module 1 to its next neighbouring fuel supply modules 1 thus forming a "daisy-chain" main manifold 47. This arrangement requires additional passages in the flanges 29, referred to as first and second passages 51,52, respectively (see Figures 12 to 15), to allow for looping the main manifold 47 through the flanges 29.

[0031] Figure 12 shows schematically the cavities of the flanges 29 of the embodiment of Figure 11. In this embodiment, a flange 29 comprises three main parts 3,4,46. The interfaces of the main parts 3,4,46 are shown as split lanes 50. The second main part 4 comprises an axial port 37. First and second main parts 3,4 comprise tangential ports 38 with fuel supply lines 12 and a vortex chamber 36. The additional bifurcating passage consists of a first passage 51 and second passages 52 and is

arranged as adjoining grooves 9 (and holes) in the second main part 4 and a third main part 46 and is formed by assembling the second and third main parts 4,46. The external fuel pipes 44 (see Figure 11) interconnecting the flanges 29 would be attached to the second passages 52 of the third main part 46.

[0032] Figures 13 and 14 show the cavities of alternative first and second main parts 3,4 adapted to build a "daisy-chain" arrangement. Different from the embodiment shown in Figure 12, a first passage 51 is drilled through the second main part 4. One end of the first passage 51 connects to the axial port 37 of the vortex diode 28 and the other end is closed with a plug 53. Two second passages 52, arranged in the second main part 4, provide connection between the first passage 51 and external fuel pipes 44 (not shown). In Figure 13 the second passages 52 are perpendicular to the plane of the second main part 4 whereas in Figure 14 the second passages 52 lie in the plane of the second main part 4. It should be noted, that the orientation of the second passages 52 does not necessarily need to be as shown in Figures 13 and 14. Other orientations are also possible.

[0033] Concerning the cavities, the embodiments of Figures 14 and 15 are identical. But, unlike the embodiment shown in Figure 14, the fuel supply lines 12 in Figure 15 are formed by grooves 9 in the first main part 3 covered by the second main part 4 without grooves (see different location of the split lanes 50 in Figures 14 and 15).

[0034] Figure 16 shows cavities and external piping of another embodiment with six cans 8, and four burners 2 per can 8, using first and second main parts 3,4 (not explicitly indicated), where the first and second main parts 3,4 again comprise an axial port 37, tangential ports 38 and a vortex chamber 36. Similar to Figures 14 and 15, the first passage 51 would be arranged in the second main part 4 of the flange 29 and would lie in the plane of the second main part 4. It would traverse the second main part 4, not necessarily along the diameter of the second main part 4, and would connect the axial port 37 of the fluidic valves 25 (or vortex diodes 28) and to external fuel pipes 44.

[0035] A side effect of the presented embodiments is the much smaller volume of gas in the main manifold compared to prior art arrangements thus reducing over-speed problems on load drop.

[0036] In the presented embodiments, it is not essential that the depth of the grooves 9 forming fuel lines is equal in adjoining main parts 3,4,46. The number of main parts is also not restricted to two or three. In preferred embodiments fuel lines can be formed by grooves 9 arranged in one main part 3,4,46 of a flange 29 and covered by another main part 3,4,46 with a flat surface as shown in Figure 15. However, it is likely that the fluidic valves 25 would require structures on both sides of the main parts 3,4,46.

[0037] The cross-sectional shape of the fuel supply lines 12, passages 51 and grooves 9 does not need to be only circular or only rectangular.

[0038] All variations of assembling the main fuel supply 31 are also valid for the pilot fuel supply 33 or additional fuel streams. Combinations of different arrangements for main and pilot fuel supply 31,33 are possible.

Claims

1. A method of manufacturing a fuel supply module (1), the fuel supply module (1) configured to receive a plurality of burners (2), the method comprising:

providing a first main part (3) of the fuel supply module (1) ;
forming a first part of burner ports (5) for receiving the burners (2) on the first main part (3);
forming a first part of fuel supply lines (10) on the first main part (3) by introducing first grooves (9) into the first main part (3), wherein each first part of fuel supply lines (10) is connected to one first part of burner ports (5);
providing a second main part (4) of the fuel supply module (1);
forming a second part of burner ports (6) for receiving the burners (2) on the second main part (4);
forming a second part of fuel supply lines (11) on the second main part (4) by introducing second grooves (9) into the second main part (4), wherein each second part of fuel supply lines (11) is connected to one second part of burner ports (6); and
connecting the first and second main parts (3,4) to form the fuel supply module (1), wherein fuel supply lines (12) and burner ports (7) are formed in their entity by the aligned first and second grooves (9) of the first and second main parts (3,4).

2. A fuel supply module (1), comprising:

a plurality of burner ports (7) for receiving respective burners (2); and
a plurality of first fuel supply lines (15), each first fuel supply line (15) integrated into the fuel supply module (1) and connected to one of the burner ports (7) and merging into a common first fuel injection entry (21) for supplying a fuel to the first fuel supply lines (15).

3. The fuel supply module (1) according to claim 2, further comprising a plurality of second fuel supply lines (18), each second fuel supply line (18) integrated into the fuel supply module (1) and connected to one of the burner ports (7) and merging into a common second fuel injection entry (24) for supplying a pilot fuel (32) to the second fuel supply lines (18).

4. The fuel supply module (1) according to claim 2 or claim 3, wherein the first respectively the second fuel injection entry (21,24) is a fluidic valve (25).

5. The fuel supply module (1) according to claim 4, wherein the fluidic valve (25) is a vortex diode (26).

6. The fuel supply module (1) according to claim 2, wherein the fuel supply module (1) is a composite module consisting of at least first and second main parts (3,4).

7. The fuel supply module (1) according to claim 3, wherein the fuel supply module (1) is a composite module consisting of at least first and second main parts (3,4).

8. The fuel supply module (1) according to claim 6, wherein the first fuel supply lines (15) and/or the first fuel injection entry (21) are integrated into the at least first and second main parts (3,4) such that a first part of the first fuel supply lines (13) and/or a first part of the first fuel injection entry (19) is arranged in the first main part (3) and a second part of the first fuel supply lines (14) and/or a second part of the first fuel injection entry (20) is arranged in the second main part (4), wherein the first fuel supply lines (15) and/or the first fuel injection entry (21) are formed in their entity when the first and second main parts (3,4) are connected.

9. The fuel supply module (1) according to claim 7, wherein the second fuel supply lines (18) and/or the second fuel injection entry (24) are integrated into the at least first and second main parts (3,4) such that a first part of the second fuel supply lines (16) and/or the first part of the second fuel injection entry (22) is arranged in the first main part (3) and a second part of the second fuel supply lines (17) and/or the second part of the second fuel injection entry (23) is arranged in the second main part (4), wherein the second fuel supply lines (18) and/or the second fuel injection entry (24) are formed in their entity when the first and second main parts (3,4) are connected.

10. The fuel supply module (1) according to claim 6, wherein the first fuel supply lines (15) and/or the first fuel injection entry (21) are integrated into the at least first and second main parts (3,4) such that the first fuel supply lines (15) are arranged as grooves (9) in the first main part (3) and/or a first part of the first fuel injection entry (19) is arranged in the first main part (3) and a second part of the first fuel injection entry (20) is arranged in the second main part (4), wherein the first fuel supply lines (15) and/or the first fuel injection entry (21) are formed in their entirety when the first and second main parts (3,4) are connected.

11. The fuel supply module (1) according to claim 7, wherein the second fuel supply lines (18) and/or the second fuel injection entry (24) are integrated into the at least first and second main parts (3,4) such that the second fuel supply lines (18) are arranged as grooves (9) in the first main part (3) and/or a first part of the second fuel injection entry (22) is arranged in the first main part (3) and a second part of the second fuel injection entry (23) is arranged in the second main part (4), wherein the second fuel supply lines (18) and/or the second fuel injection entry (24) are formed in their entirety when the first and second main parts (3,4) are connected.
12. The fuel supply module (1) according to claim 6 or claim 7, wherein the at least two main parts are brazed or welded together.
13. A multi-combustor gas turbine engine, comprising a plurality of fuel supply modules (1) according to one of the preceding claims, wherein the first fuel injection entries of the respective fuel supply modules (1) are interconnected in a daisy chain.
14. A multi-combustor gas turbine engine, comprising a plurality of fuel supply modules (1) according to one of the preceding claims, wherein the second fuel injection entries of the respective fuel supply modules (1) are interconnected in a daisy chain.

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FIG 1

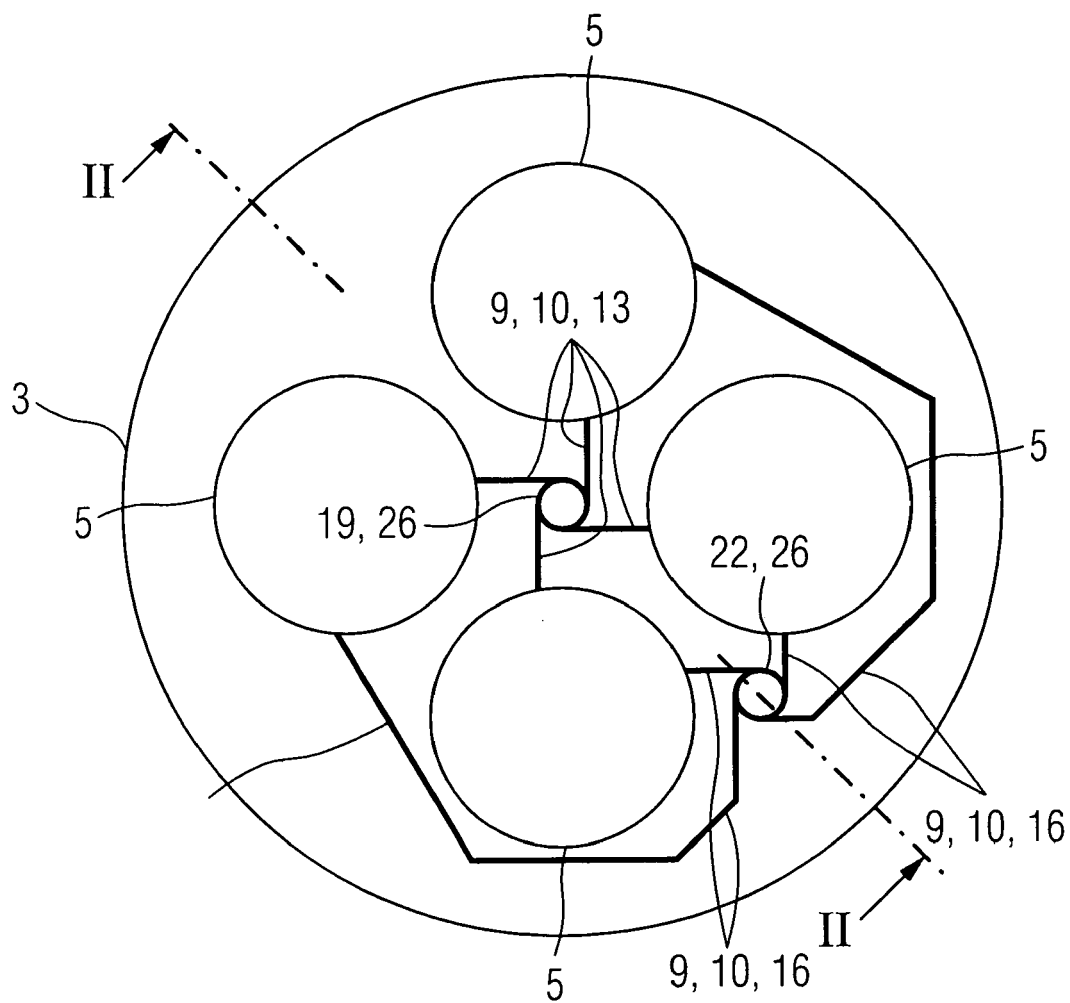


FIG 2

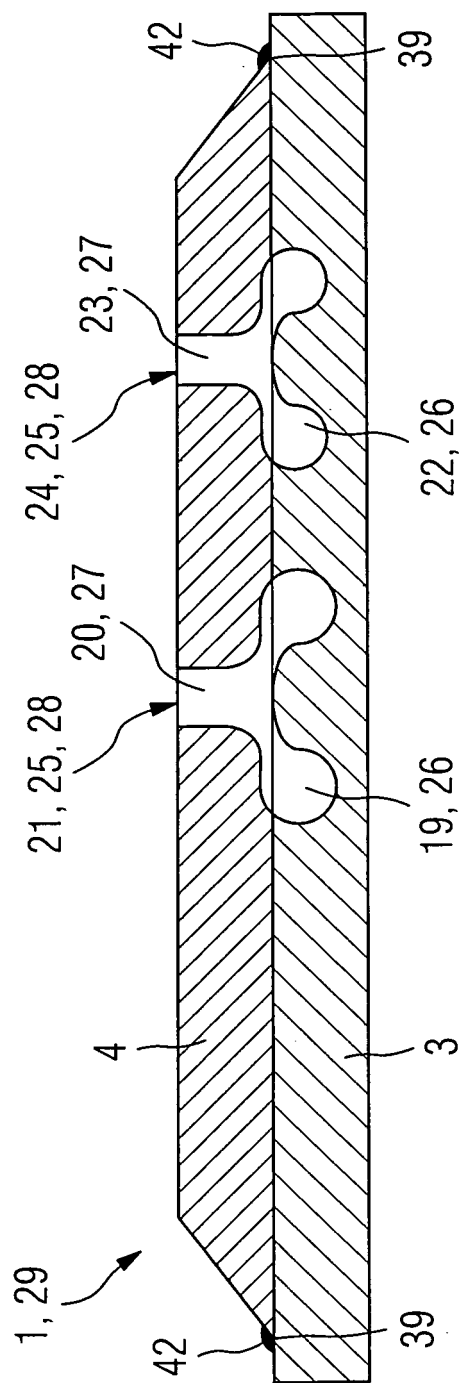


FIG 3

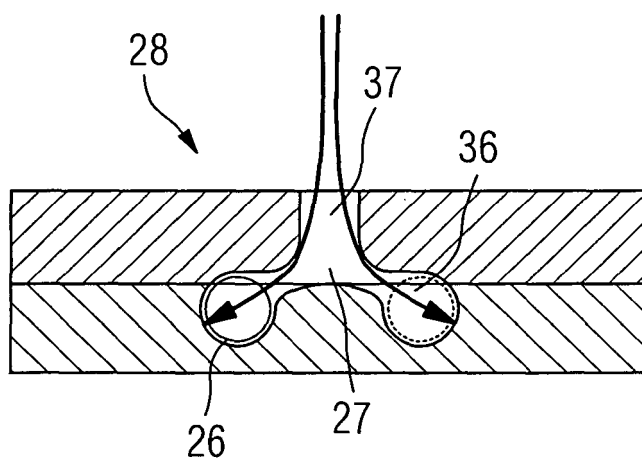


FIG 4

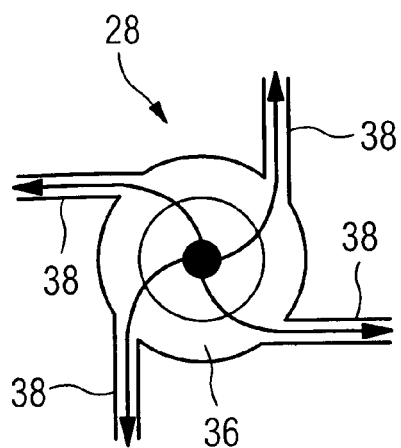


FIG 5

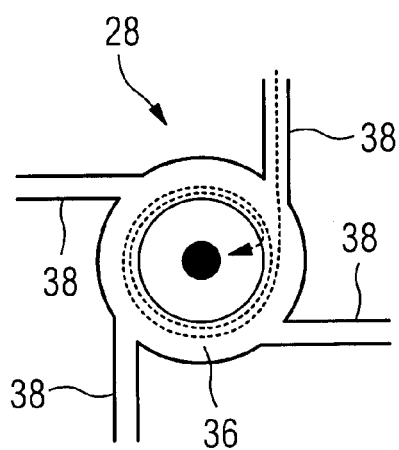


FIG 6

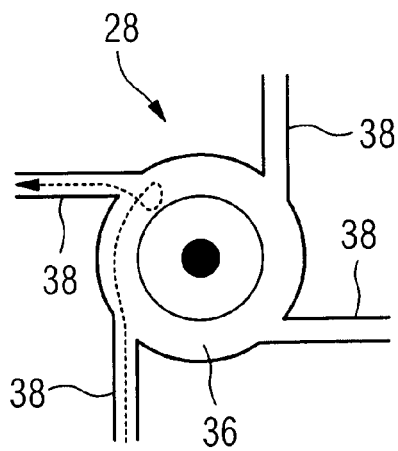


FIG 7

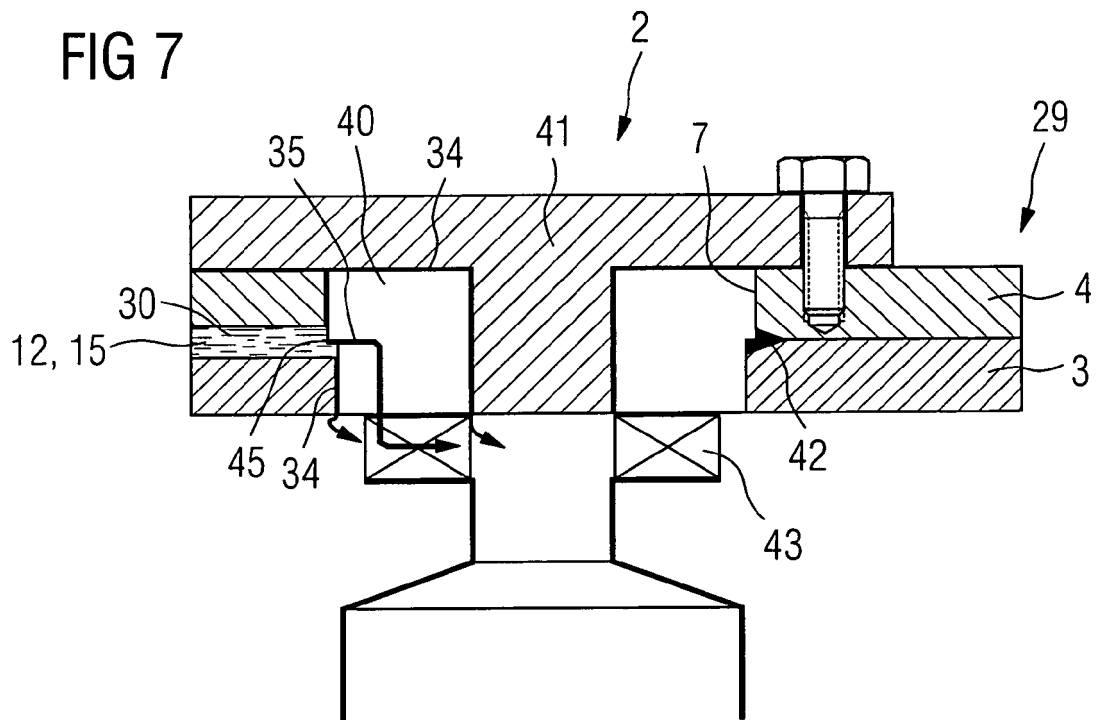


FIG 8

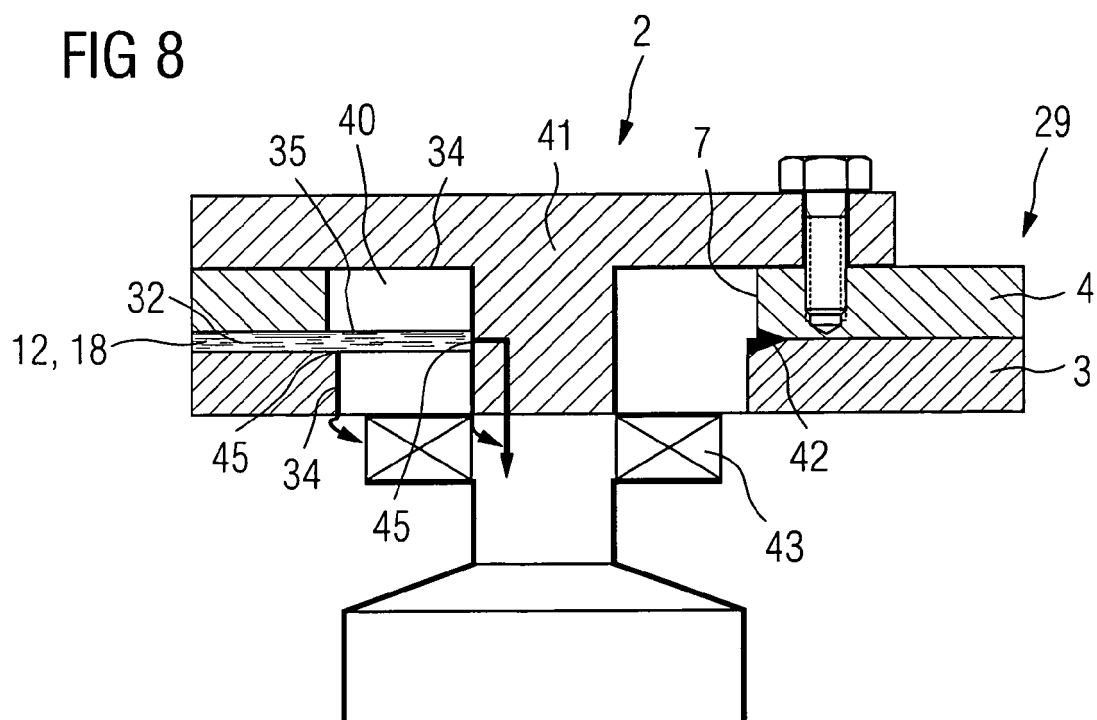


FIG 9

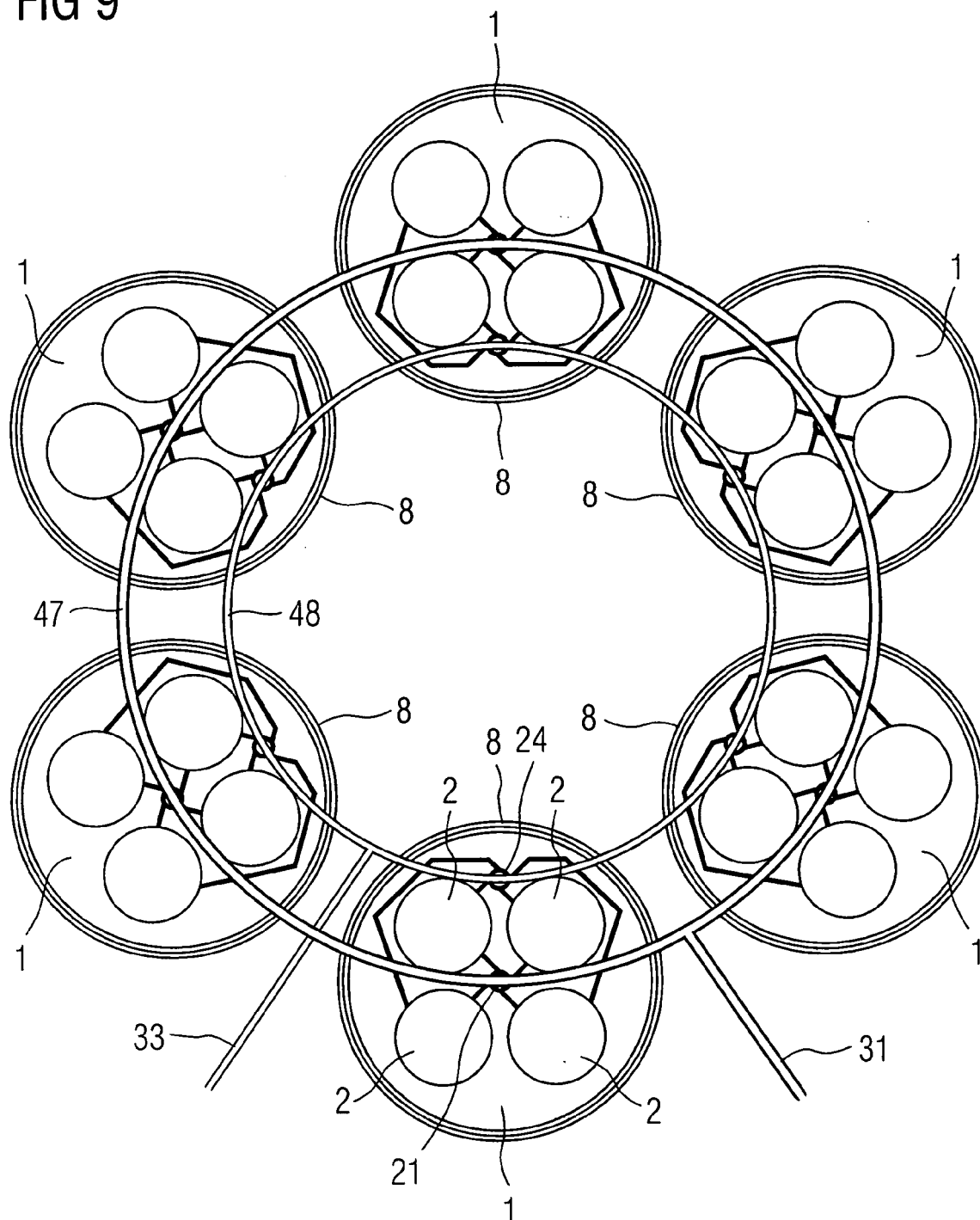


FIG 10

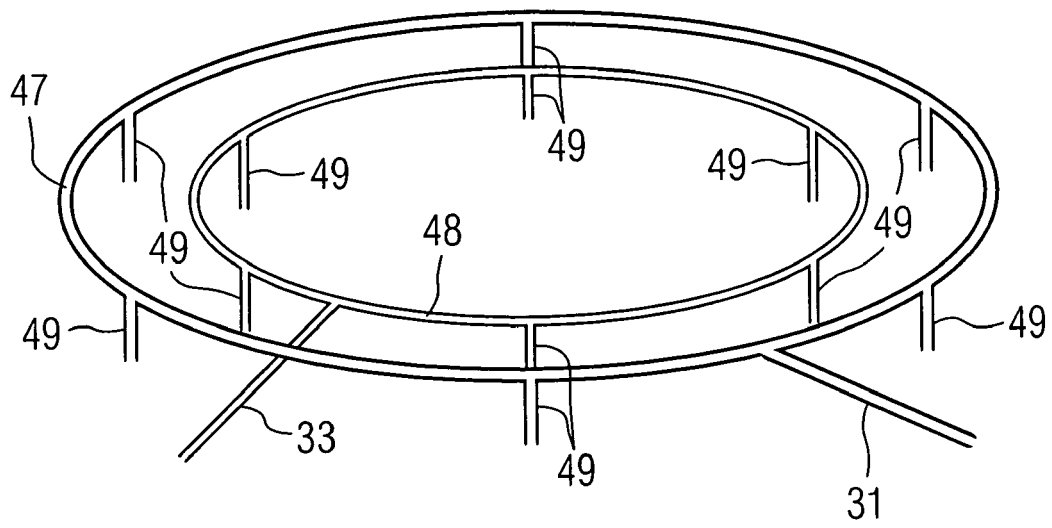


FIG 11

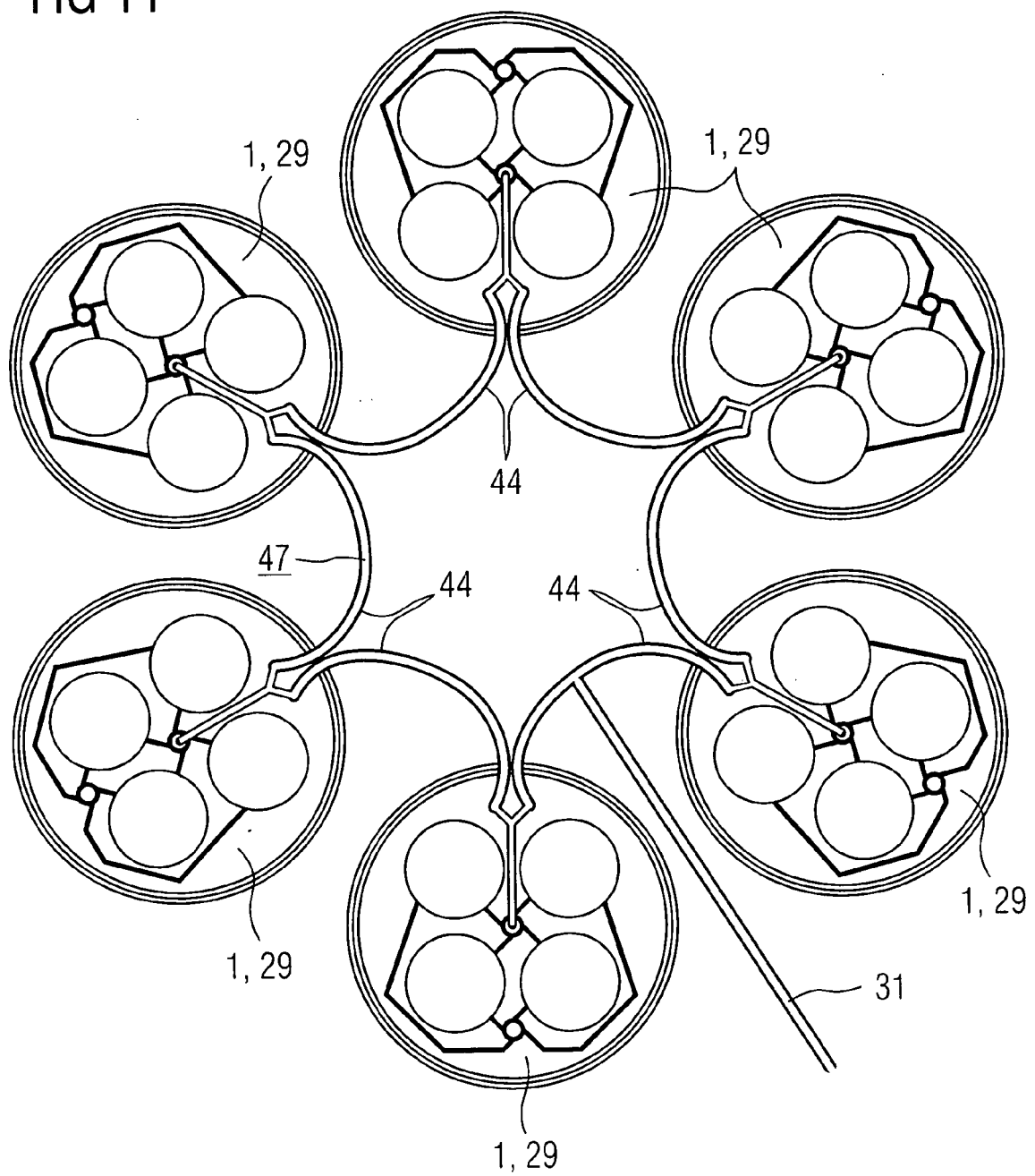


FIG 12

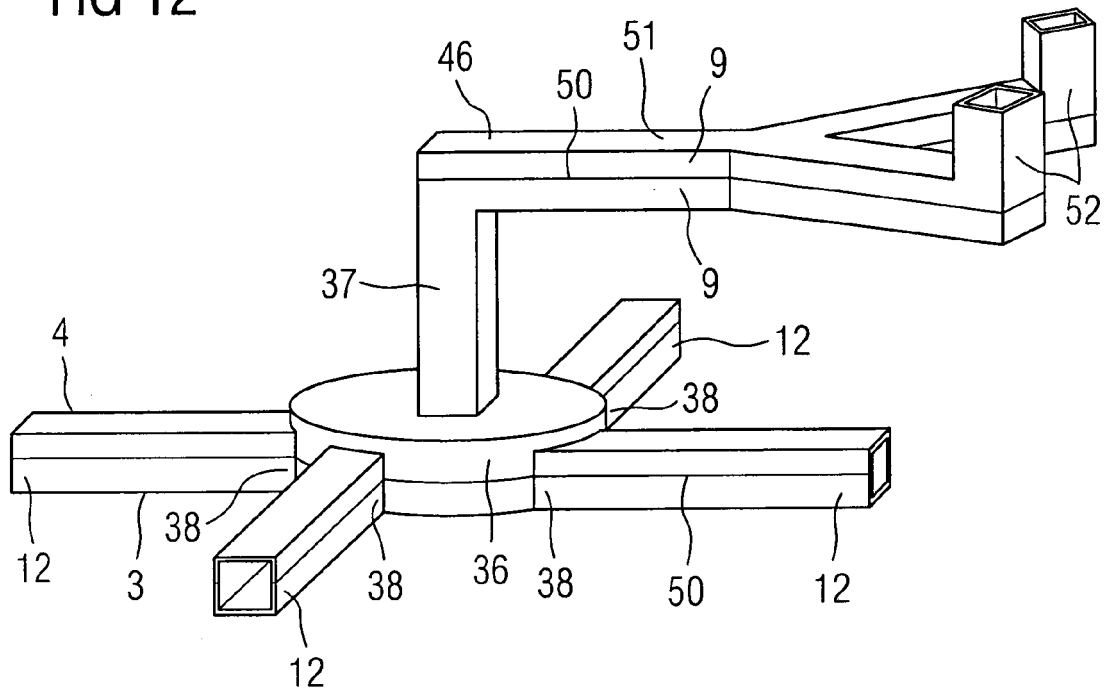


FIG 13

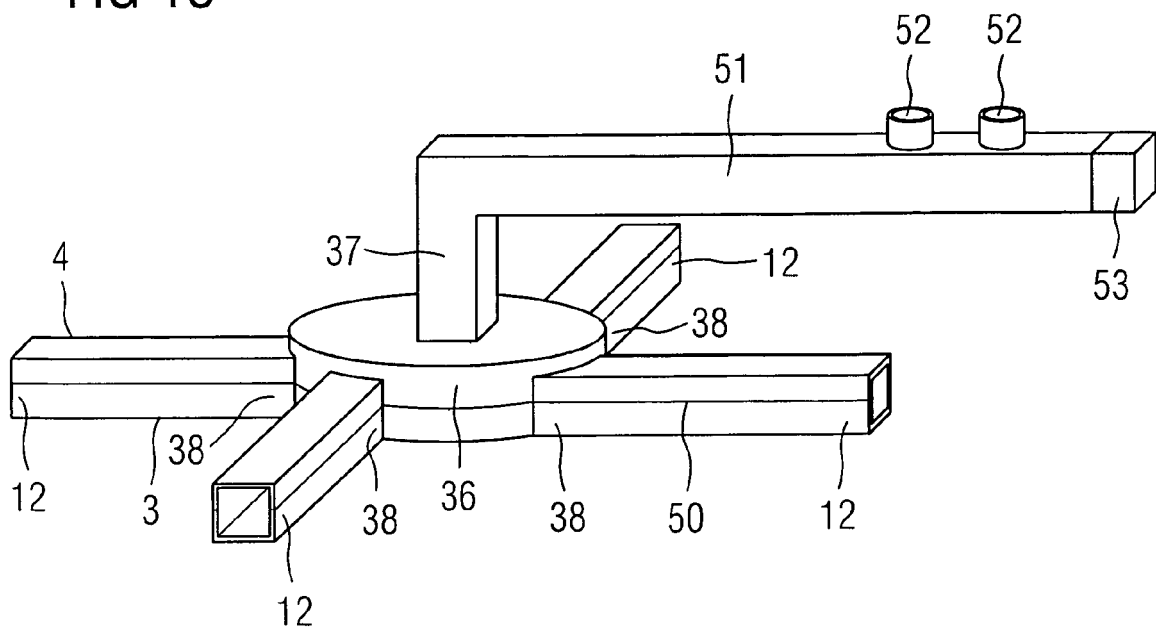


FIG 14

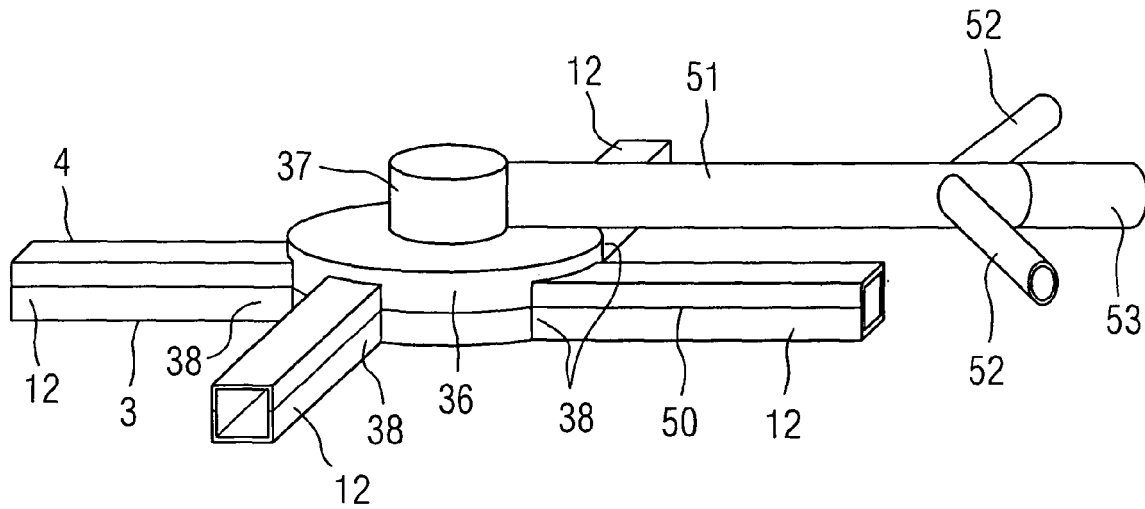


FIG 15

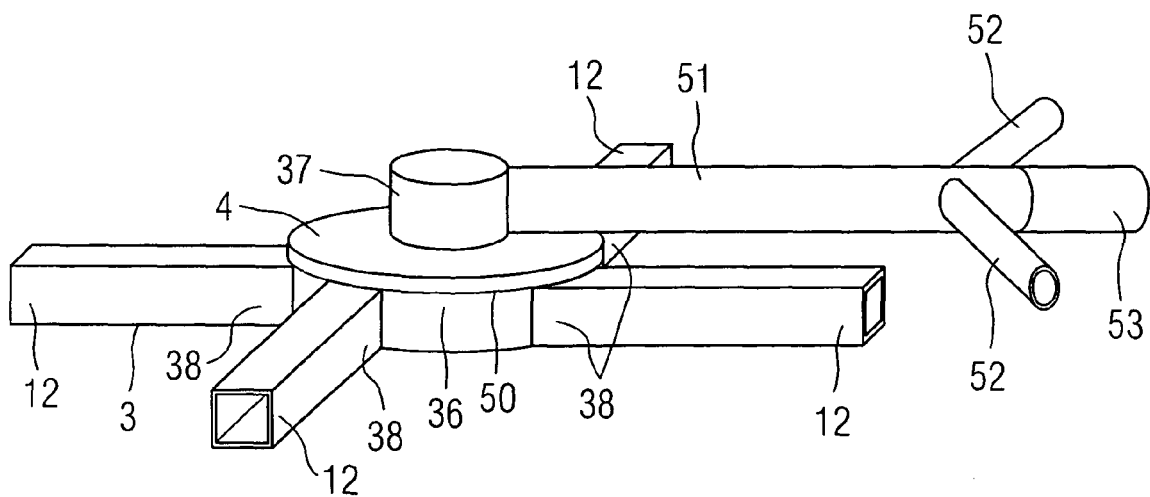
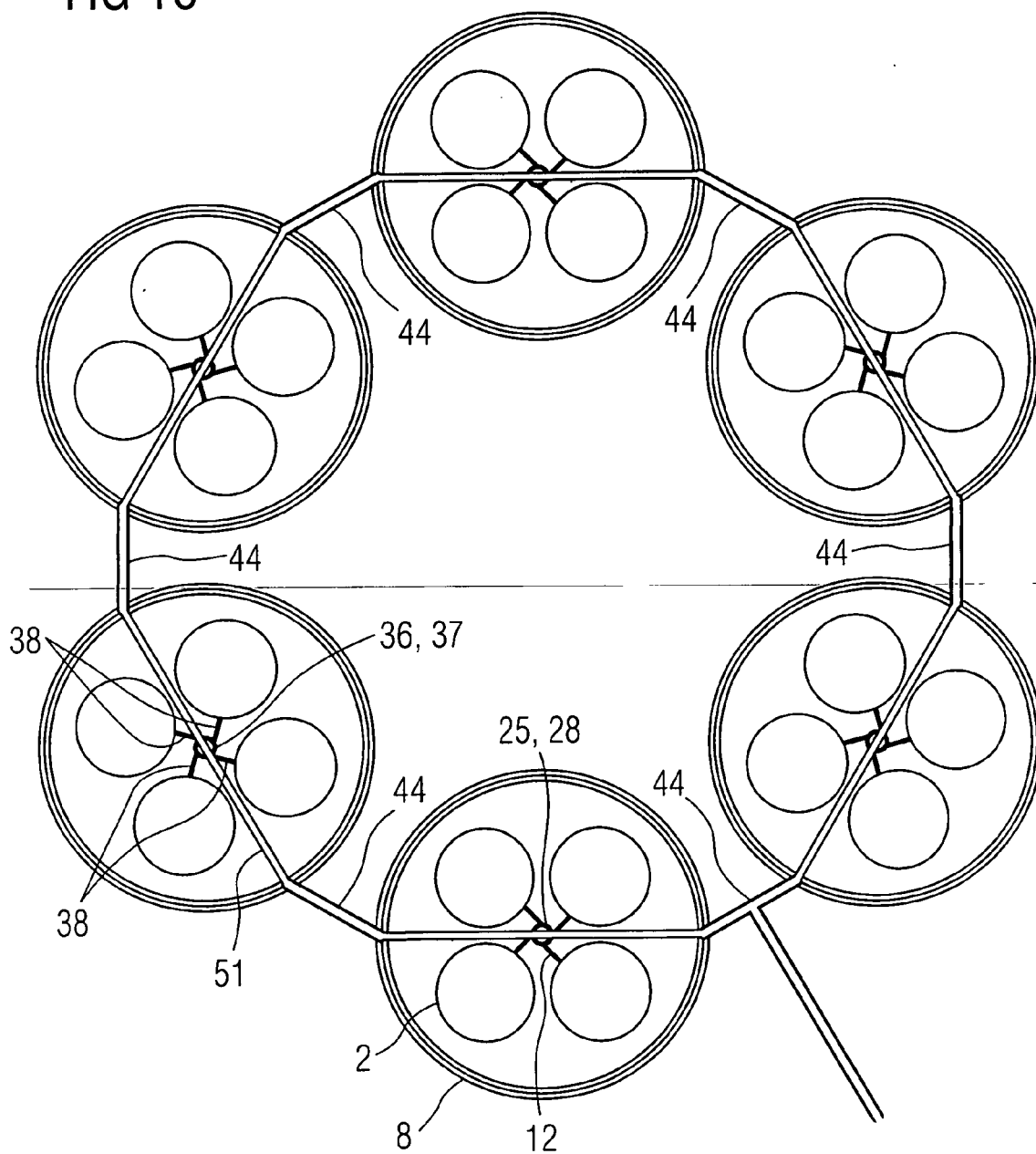


FIG 16





European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 07 00 2936

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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 9 July 2007	Examiner Mougey, Maurice
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EPO FORM 1503 03.82 (P04C01)



European Patent
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EUROPEAN SEARCH REPORT

Application Number
EP 07 00 2936

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Place of search The Hague		Date of completion of the search 9 July 2007	Examiner Mougey, Maurice
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