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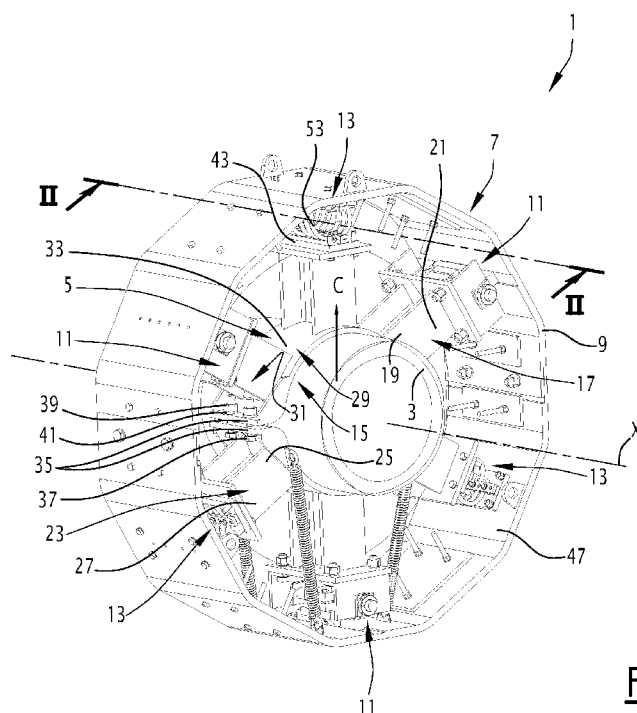


FIG.1

(57) Abstract: The tuned mass damper (1) comprises: - a mounting bracket (5) secured to the pipe (3); - a dynamic mass (7) comprising an annular member (9) extending around the pipe (3); - at least one linear guide (11) connecting the dynamic mass (7) to the mounting bracket (5), such that the dynamic mass (7) is freely movable in a given direction with respect to the mounting bracket (5); - at least one resilient damper (13), connecting the dynamic mass (7) to the mounting bracket (5) such that vibrations transmitted from the pipe (3) to the dynamic mass (7) along said given direction are damped by the resilient damper (13).



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TUNED MASS DAMPER FOR A PIPE

The present invention concerns a tuned mass damper for a pipe, and more specifically a guided tuned mass damper for a pipe.

5 PWR (Pressurized Water Reactor) nuclear reactors comprise a primary circuit in which pressurized water is circulated between the pressure vessel and one or several steam generators. The nuclear fuel elements are located in the pressure vessel.

The pressure in the primary circuit is controlled by mean of a pressurizer, fluidically connected to the primary circuit via a so-called expansion line.

10 The pressurizer is partially filled with water and partially filled with steam. It is equipped with heating rods. When the pressure inside the primary circuit must be increased, the heating rods are triggered on. A part of the water contained in the pressurizer is evaporated into steam, thereby increasing the static pressure inside the pressurizer. The pressure inside the primary circuit is increased as a consequence.

15 Conversely, the pressure inside the primary circuit is decreased by reducing the amount of steam inside the pressurizer.

The pressure variations inside the pressurizer create flows of water through the expansion line, thereby possibly creating sudden changes of the expansion line temperature. As a consequence, the expansion line might expand or retract as a function
20 of the thermal transient it is submitted to.

As the rest of the primary circuit, the surge line might also be subjected to vibrations originating from fluid turbulence, acoustic modes or dynamical movements of the primary circuit at its extremities.

It is particularly important to reduce the vibrations of the expansion line to acceptable
25 levels, in order to ensure a sufficient life expectancy for the expansion line and reduce maintenance requirements.

It is possible to use tuned mass dampers in order to reduce vibrations in a structure. A tuned mass damper usually comprises a dynamic mass connected to the vibrating structure by a resilient organ giving stiffness, and by a damper absorbing the mechanical
30 energy coming from the structure. The resilient organ is typically a metallic spring. The damper is typically a viscous damper.

The weight of the mass and the stiffness of the resilient organ are chosen such that the tuned mass damper interacts dynamically with the vibrating structure and energy is transferred from the vibrating structure to the tuned mass damper.

35 The tuned mass damper can be enclosed in a box, directly secured to the line by a collar.

It is particularly difficult to arrange such a tuned mass damper on the expansion line of a nuclear reactor. The expansion line is at a high temperature. It is covered by a layer of thermal insulation material.

In that context, the purpose of the invention is proposing a tuned mass damper that can be implemented on the expansion line of a PWR nuclear reactor or any pipes having similar operational conditions.

To that end, the invention is directed to a tuned mass damper for a pipe comprising:

- a mounting bracket secured to the pipe;
- a dynamic mass comprising an annular member extending around the pipe;
- at least one linear guide connecting the dynamic mass to the mounting bracket, such that the dynamic mass is freely movable in a given direction with respect to the mounting bracket;
- at least one resilient damper, connecting the dynamic mass to the mounting bracket such that vibrations transmitted from the pipe to the dynamic mass along said given direction are damped by the resilient damper.

The dynamic mass is located away from the line. A layer of thermal insulation, if necessary can be arranged between the dynamic mass and the pipe. Only the mounting bracket is secured to the pipe, and it can be arranged under the layer of thermal insulation.

Since the dynamic mass comprises an annular member extending around the pipe, it is possible to distribute the mass around the pipe and it is possible to avoid creating a bending moment in the pipe.

Since the at least one linear guide and the at least one resilient damper are arranged between mounting bracket and the annular dynamic mass, they can be located radially outside the layer of thermal insulation.

The linear guide make it possible to control the displacement of the dynamic mass, ensuring that there is no interaction between the dynamic mass and the environment, especially the layer of thermal insulation.

The tune mass damper may include one or several of the following features, alone or according to any technically feasible combination:

- the mounting bracket comprises a clamp secured to the pipe, at least one guide arm having a proximal end secured to the clamp and a distal end connected to the dynamic mass by the at least one linear guide, and at least one damper arm having a proximal end secured to the clamp and a distal end connected to the dynamic mass by the at least one resilient damper;

- the at least one resilient damper comprises an inner plate secured to the at least one damper arm and an outer plate secured to the dynamic mass, the inner plate and the outer plate having respective inner and outer holes, the at least one resilient damper comprising a wire rope connecting the inner and outer plates to one another by passing through the inner holes and through the outer holes ;

- the clamp comprises two half-clamps clamping the pipe between them in a given clamping direction, and securing means securing the two half-clamps to one another while allowing a resilient displacement of the two half-clamps with respect to one another along the clamping direction ;

- the tuned mass damper comprises at least two linear guides, each linear guide connecting the dynamic mass to the mounting bracket such that the dynamic mass is freely movable in said given direction with respect to the mounting bracket, the at least two linear guides being angularly shifted around the pipe with respect to one another;

- the at least two linear guides connect at least two guide arms to the dynamic mass, the at least two guide arms being angularly shifted around the pipe with respect to one another;

- the at least one linear guide comprises a rail connected to one of the mounting bracket or the dynamic mass and a slide connected to the other of the mounting bracket or the dynamic mass and cooperating with the rail ;

- the at least one linear guide comprises a connection connecting the rail or the slide to the mounting bracket and allowing a translation of the rail or the slide with respect to the mounting bracket in a direction substantially radial to a central axis of the pipe ;

- the connection allows a rotation of the rail or the slide with respect to the mounting bracket in a direction substantially parallel to the central axis of the pipe ;

- the connections of the at least two linear guides allow an angular displacement of the at least two guide arms with respect to one another around the pipe.

Other features and advantages of the invention will become apparent from the detailed description thereof provided below, purely by way of an indication and without any limitation, reference being made to the following figures:

- the figure 1 is a view in perspective of a tuned mass damper according to the invention;

- the figure 2 is a section of a resilient damper of the figure 1, taken along the line II-II of the figure 1;

- the figure 3 is a view in perspective, enlarged, of a linear guide of the figure 1;

- the figure 4 is a section of the linear guide of the figure 3, taken along the line IV-IV of the figure 3;

- the figures 5 and 6 are two other sections of the linear guide of the figure 3, taken along the lines V-V and VI-VI respectively of the figure 4;

- the figure 7 is a section similar to the section of the figure 4, depicting another embodiment of the connection to the mounting bracket; and

5 - the figure 8 is a side view of the linear guide with a partial section showing a detail of the connection between the slide and the mounting bracket.

The tuned mass damper shown on the figure 1 is for damping the vibrations in the pipe 3.

10 The pipe 3 is typically the expansion line fluidically connecting the pressurizer of a PWR nuclear reactor to the primary circuit.

Alternatively, the pipe 3 is another pipe submitted to high temperatures, and particularly submitted to cycles of thermal expansions and contractions.

The pipe 3 may as well be a pipe which is not submitted to high temperatures, and which is not submitted to cycles of thermal expansions and contractions.

15 The pipe 3 belongs to a PWR nuclear reactor, or to another type of nuclear reactor, or belongs to an industrial facility which is not a nuclear reactor.

The tuned mass damper 1 comprises:

- a mounting bracket 5 secured to the pipe 3;

- a dynamic mass 7 comprising an annular member 9 extending around the pipe 3;

20 - at least one linear guide 11 connecting the dynamic mass 7 to the mounting bracket 5, such that the dynamic mass 7 is freely movable in a given direction with respect to the mounting bracket 5, and

25 - at least one resilient damper 13, connecting the dynamic mass 7 to the mounting bracket 5 such that vibrations transmitted from the pipe 3 to the dynamic mass 7 along said given direction are damped by the resilient damper 13.

The annular member 9 is cylindrical or polyhedral. Its central axis X is aligned with the central axis of the pipe 3. Weights 10 (figure 3) are secured to the inner surface of the annular member by screws.

30 The annular member 9 has a closed contour and extends all around the pipe 3. Its inner section is empty, and sufficiently large to accommodate the mounting bracket 5, at least one linear guide 11, and at least one resilient damper 13.

35 The mounting bracket 5 comprises a clamp 15 secured to the pipe 3, at least one guide arm 17 having a proximal end 19 secured to the clamp 15 and a distal end 21 connected to the dynamic mass 7 by the at least one linear guide 11, and at least one damper arm 23 having a proximal end 25 secured to the clamp 15 and a distal end 27 connected to the dynamic mass 7 by the at least one resilient damper 13.

The clamp 15 comprises two half-clamps 29 clamping the pipe 3 between them in a given clamping direction C, and securing means 31 securing the two half-clamps 29 to one another while allowing a resilient displacement of the two half-clamps 29 with respect to one another along the clamping direction C.

Each half-clamp 29 has a central part 33 with a shape chosen to adapt around the pipe 3. The central part 33 is directly in contact against the outer surface of the pipe 3, and covers substantially half the perimeter of the pipe 3.

Each half-clamp 29 has two ends 35, one on each side of the central part 33, defining a flange.

The two ends 35 extend in a plane substantially perpendicular to the clamping direction.

The securing means 31 secure the flanges of the two half-clamps 29 to one another.

The securing means 31 comprise for example several screws 37, one nut 39 screwed on each screw, and resilient washers 41 interposed between each nut and the corresponding flange.

The resilient washer 41 allows keeping the two half-clamps 29 tightly clamped to the pipe, even though the pipe is submitted to thermal expansion/contraction cycles.

The mounting bracket 5 typically comprises several damper arms 23 and a resilient damper 13 associated to each damper arm 23. Each damper arm 23 has a proximal end 25 secured to the clamp 15 and a distal end 27 connected to the dynamic mass 7 by the corresponding resilient damper 13.

The damper arms 23 extend substantially radially with respect to the central axis X of the pipe 3.

The damper arms 23 are angularly shifted with respect to one another around the central axis X, preferably regularly shifted with respect to one another.

In the example depicted on the figures, the mounting bracket 5 has three damper arms 23 and three resilient dampers 13. The arms extend radially and are arranged at 120° from one another around the central axis C.

As shown on the figure 2, the at least one resilient damper 13 comprises an inner plate 43 secured to the at least one damper arm 23 and an outer plate 45 secured to the dynamic mass 7.

The inner plate 43 is secured to the distal end 27 of the corresponding damper arm. The outer plate 45 is secured to the inner surface 47 of the annular member 9.

The inner plate 43 and the outer plate 45 have respective inner and outer holes 49, 51.

The inner holes 49 are arranged in a line substantially parallel to the central axis X.

The outer holes 51 are arranged as well in a line substantially parallel to the central axis X.

Advantageously, the at least one resilient damper 13 comprises a wire rope 53 connecting the inner and outer plates 43, 45 to one another by passing through the inner holes 49 and through the outer holes 51.

The wire rope 53 is a rope made of wires of metal, the wires being weaved against one another to constitute the rope.

The wire rope 53 is passed alternatively through one inner hole 49 and one outer hole 51, forming substantially an helix having its axis parallel to the central axis X.

As indicated above, a usual tuned mass damper has a resilient organ giving stiffness and a damper absorbing the mechanical energy coming from the vibrating structure. In the invention, the at least one resilient damper 13 ensures the function of both the resilient organ and the damper. It is rather stiff due to its structure with a wire rope arranged in an helix. The mechanical energy coming from the pipe is dissipated by the wire ropes rubbing against one another.

It must be pointed out that the damper is dry, and does not require using a liquid, for example an oil of the type usually used in a viscous damper. This is a significant advantage when the tuned mass damper is implemented in a nuclear reactor, since using such organic liquid should be avoided in a nuclear facility.

The tuned mass damper 1 preferably comprises at least two linear guides 11.

Each linear guide 11 connects the dynamic mass 7 to the mounting bracket 5 such that the dynamic mass 7 is freely movable in said given direction with respect to the mounting bracket 5.

The at least two linear guides 11 are angularly shifted around the pipe 3 with respect to one another, preferably regularly angularly shifted around the pipe 3.

The mounting bracket 5 in that case comprises at least two guide arms 17.

The at least two linear guides 11 connect the at least two guide arms 17 to the dynamic mass 7. More precisely, each linear guide 11 connects the distal end 21 of a corresponding guide arm 17 to the annular member 9.

The at least two guide arms 17 are angularly shifted around the pipe 3 with respect to one another, preferably regularly angularly shifted around the pipe 3.

In the example depicted on the figures, the mounting bracket 5 comprises three guide arms 17 angularly shifted of 120° around the pipe 3, the three corresponding linear guides 11 being angularly shifted of 120° around the pipe 3.

The dynamic mass 7 is guided by the at least one linear guide along a given direction which typically is defined by the central axis X of the pipe. A guiding in a direction

making an angle to the pipe axis is also possible by rotating the linear guides 11 and the dynamic mass 7 relative to the guide arms 17.

For example, the given direction is substantially parallel to the central axis X.

The or each linear guide 11 comprises a rail 55 secured to one of the mounting bracket 5 or the dynamic mass 7, and a slide 57 secured to the other of the mounting bracket 5 or the dynamic mass 7.

The slide 57 cooperates with the rail 55 for guiding the dynamic mass 7.

The or each linear guide 11 comprises a connection 59 connecting the rail 55 or the slide 57 to the mounting bracket 5 and allowing a translation of the rail 55 or the slide 57 with respect to the mounting bracket 5 in a direction substantially radial to the central axis X of the pipe 3.

Advantageously, the connection 59 allows a rotation of the rail 55 or the slide 57 with respect to the mounting bracket 5 in a direction substantially parallel to the central axis X of the pipe 3.

In the example depicted on the figures 3 to 6, the rail 55 is secured to the dynamic mass 7, and the slide 57 to the bracket 5.

The rail 55 is secured to the inner surface of the annular member 9. It is substantially parallel to the given direction.

The or each connection 59 comprises an axle 61 secured to the slide 57. The axle 61 is substantially parallel to the rail 55. It has a round cross section, as shown on the figure 6.

The or each connection 59 comprises two plates 63 facing one another. Said plates are substantially perpendicular to the axle 61. They are spaced apart from one another along the given direction.

The plates 63 are secured to a supporting plate 65, itself secured to the distal end 21 of the corresponding guide arm 17.

Each plate 63 has a slot 67, elongated along a direction substantially radial to the central axis X of the pipe 3. In the example depicted, the slot 67 is closed radially inward, and opened radially outward.

A guide block 69 is inserted in each slot 67 and is free to travel radially along the slot 67. Each guide block 69 has two opposite grooves 71 (figure 5), the opposite edges 73 of the slot 67 being inserted in the grooves 71 and cooperating with the grooves 71 for guiding the travel of the guide block 69.

Each guide block 69 has a hole 75. The opposite ends 77 of the axle 61 are rotatably received in the holes 75. In other words, the two guide blocks 69 define bearings in which the axle 61 is free to pivot with respect to the bracket 5.

Stop rings 79 are secured to the two opposite ends 77 of the axle 61. Each stop ring 79 is located toward the free end of the axle with respect to the guide block 69 mounted on the same end 77. It bears against said guide block 69.

Therefore, the two stop rings 79 prevent the axle from disengaging from the holes 75 of the guide blocks 69.

The connections 59 associated to two given guide arms 17 preferably allow an angular displacement of said the guide arms 17 with respect to one another around the pipe 3.

In this case, a free space 81 is left between the edges 73 of the slot 67 and the guide block 69, such that the guide arm 17 is able to move circumferentially around the central axis X with respect to the dynamic mass 7 (figure 7).

Preferably, the pipe 3 is covered by a layer of thermal insulation material, not depicted on the figures. The length of guide arms 17 and of the damper arms 23 is chosen such that the distal ends 21 and 27 are located outside the insulation material.

The behavior of the tuned mass damper 1 will be explained below.

Vibrations are transmitted from the pipe 3 to the dynamic mass 7 through the damper arms 23 and the or each resilient damper 13.

The displacement of the dynamic mass 7 with respect to the bracket 5 is guided along the given direction by the or each linear guide 11. The given direction corresponds to the central axis of the pipe 3 in the example depicted on the figures. The dynamic mass 7 is guided by the or each rail 55 moving along the corresponding slide 57.

The displacement of the dynamic mass 7 with respect to the bracket 5 along the given direction is damped by the or each resilient damper 13. Said displacement changes the shape of the or each resilient damper 13, making the wires of the wire rope 53 rub against one another. This dissipates the mechanical energy transmitted by the vibrations from the pipe 3 to the dynamic mass 7.

When the pipe 3 expands, for example because its temperature increases, the guide arms 17 are displaced radially away from the central axis of the pipe 3. As a consequence, the edges 73 of each slot 69 slide radially in the grooves 71. The same happens when the pipe 3 contracts.

The tuned mass damper 1 preferably includes at least two linear guides, angularly shifted around the pipe with respect to one another, to make sure that the radial displacement of the guide arms and the damper arms does not prevent the linear guides from guiding the dynamic mass along the given direction.

The fact that the or each axle 61 can pivot with respect to the corresponding guide arm 17 allows accommodating small difference in parallelism between the internal surface of the dynamic mass 7 and the surface of the distal end 21 of the guiding arm 17.

5 The or each plate 63 is connected to the distal end 21 of the guiding arm 17 by a bolted connection comprising several screws 83 cooperating with nuts 85. Elongated holes 87 (figure 8) are arranged into the plate 63 so as to provide some circumferential gap around each screw 83. The circumferential gaps allow accommodating small changes of angles (up to 1°) between two successive guiding arm 17 due to thermal deformations.

10 The invention has been described with linear guides in which the rail is secured to the dynamic mass and the slide is connected to the corresponding guide arm.

Alternatively, the slide is secured to the dynamic mass and the rail is connected to the corresponding guide arm. In this case, the connection is typically arranged as described above, except that the axle 61 is secured to the rail, instead of the slide.

CLAIMS

1.- A tuned mass damper for a pipe, the tuned mass damper (1) comprising:

- a mounting bracket (5) secured to the pipe (3) ;

- a dynamic mass (7) comprising an annular member (9) extending around the pipe (3) ;

- at least one linear guide (11) connecting the dynamic mass (7) to the mounting bracket (5), such that the dynamic mass (7) is freely movable in a given direction with respect to the mounting bracket (5) ;

- at least one resilient damper (13), connecting the dynamic mass (7) to the mounting bracket (5) such that vibrations transmitted from the pipe (3) to the dynamic mass (7) along said given direction are damped by the resilient damper (13).

2.- The tuned mass damper according to the claim 1, wherein the mounting bracket (5) comprises a clamp (15) secured to the pipe (3), at least one guide arm (17) having a proximal end (19) secured to the clamp (15) and a distal end (21) connected to the dynamic mass (7) by the at least one linear guide (11), and at least one damper arm (23) having a proximal end (25) secured to the clamp (15) and a distal end (27) connected to the dynamic mass (7) by the at least one resilient damper (13).

3.- The tuned mass damper according to the claim 2, wherein the at least one resilient damper (13) comprises an inner plate (43) secured to the at least one damper arm (23) and an outer plate (45) secured to the dynamic mass (7), the inner plate (43) and the outer plate (45) having respective inner and outer holes (49, 51), the at least one resilient damper (13) comprising a wire rope (53) connecting the inner and outer plates (43, 45) to one another by passing through the inner holes (49) and through the outer holes (51).

4.- The tuned mass damper according to the claim 2 or 3, wherein the clamp (15) comprises two half-clamps (29) clamping the pipe (3) between them in a given clamping direction (C), and securing means (31) securing the two half-clamps (29) to one another while allowing a resilient displacement of the two half-clamps (29) with respect to one another along the clamping direction (C).

5.- The tuned mass damper according to anyone of the claims 1 to 4, wherein the tuned mass damper (1) comprises at least two linear guides (11), each linear guide (11) connecting the dynamic mass (7) to the mounting bracket (5) such that the dynamic mass (7) is freely movable in said given direction with respect to the mounting bracket (5), the at least two linear guides (11) being angularly shifted around the pipe (3) with respect to one another.

6.- The tuned mass damper according to the claim 5 and to the claim 2, wherein the at least two linear guides (11) connect at least two guide arms (17) to the dynamic mass (7),

the at least two guide arms (17) being angularly shifted around the pipe (3) with respect to one another.

7.- The tuned mass damper according to anyone of the claims 1 to 6, wherein the at least one linear guide (11) comprises a rail (55) connected to one of the mounting bracket (5) or the dynamic mass (7) and a slide (57) connected to the other of the mounting bracket (5) or the dynamic mass (7) and cooperating with the rail (55).

8.- The tuned mass damper according to the claim 7, wherein the at least one linear guide (11) comprises a connection (59) connecting the rail (55) or the slide (57) to the mounting bracket (5) and allowing a translation of the rail (55) or the slide (57) with respect to the mounting bracket (5) in a direction substantially radial to a central axis (X) of the pipe (3).

9.- The tuned mass damper according to the claim 8, wherein the connection (59) allows a rotation of the rail (55) or the slide (57) with respect to the mounting bracket (5) in a direction substantially parallel to the central axis (X) of the pipe (3).

10.- The tuned mass damper according to the claim 9 and to the claim 6, wherein the connections (59) of the at least two linear guides (11) allow an angular displacement of the at least two guide arms (17) with respect to one another around the pipe (3).

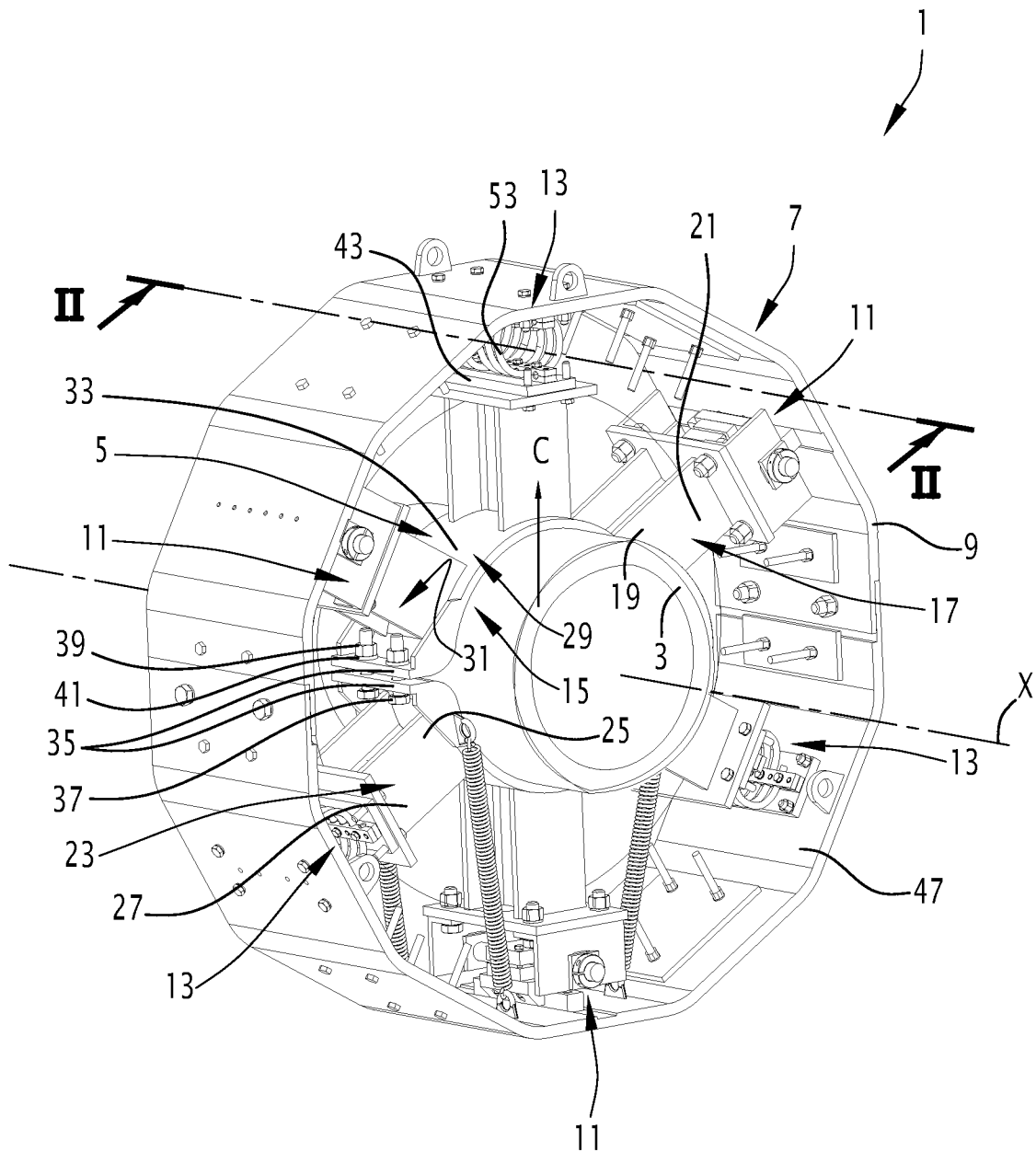


FIG.1

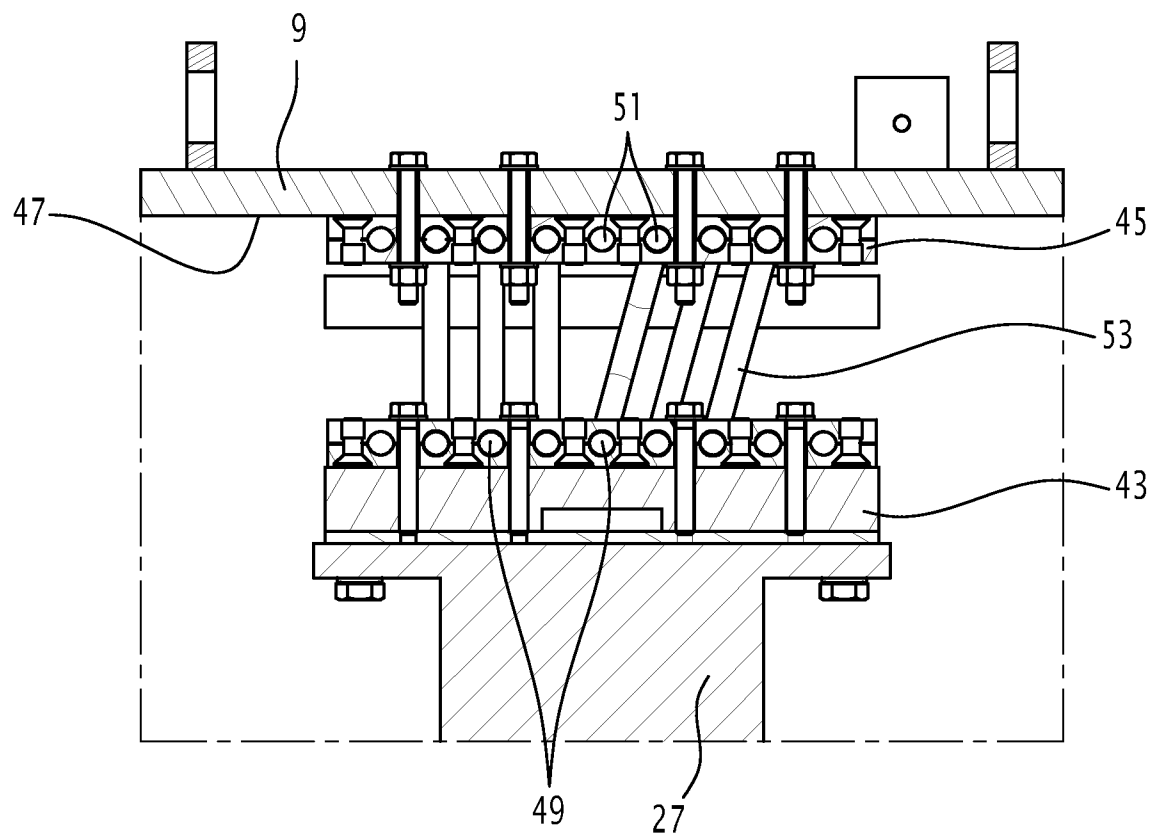


FIG.2

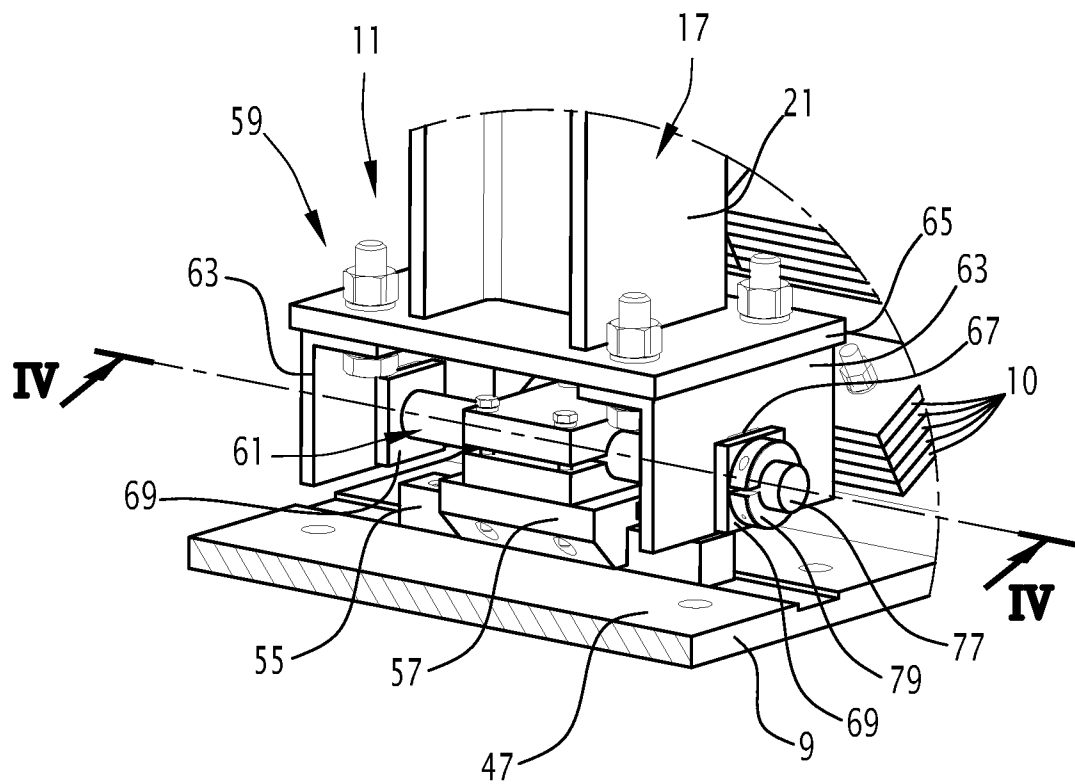


FIG.3

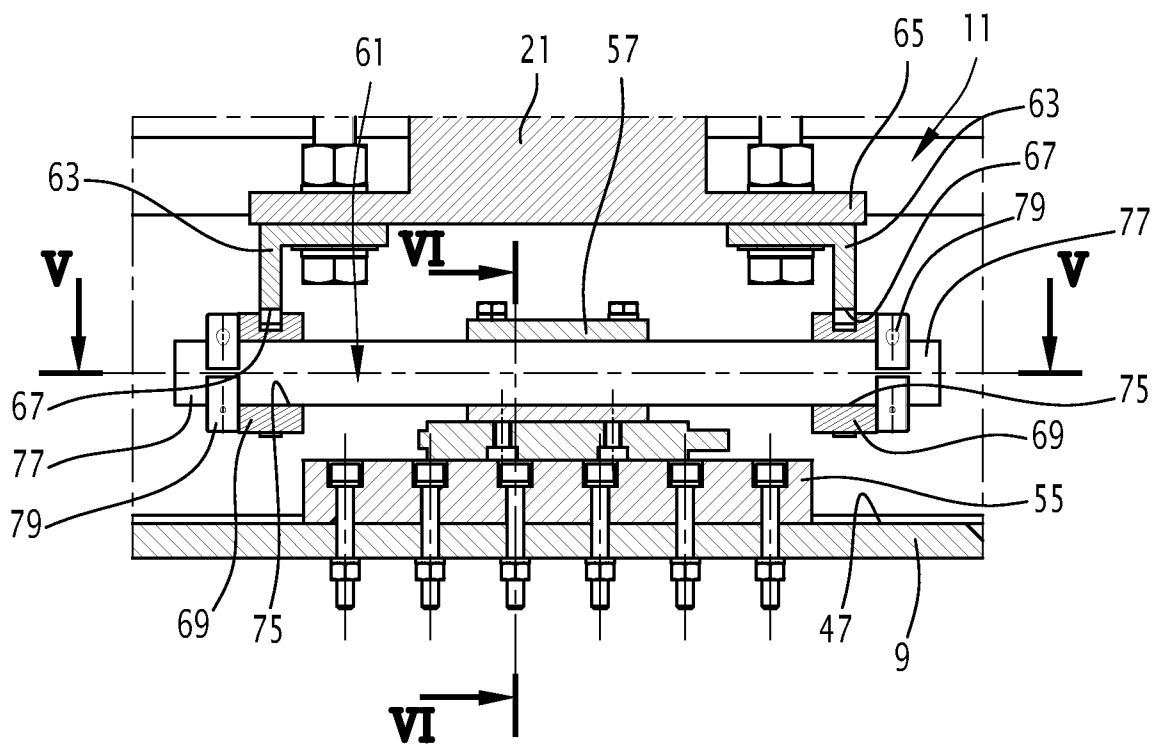


FIG. 4

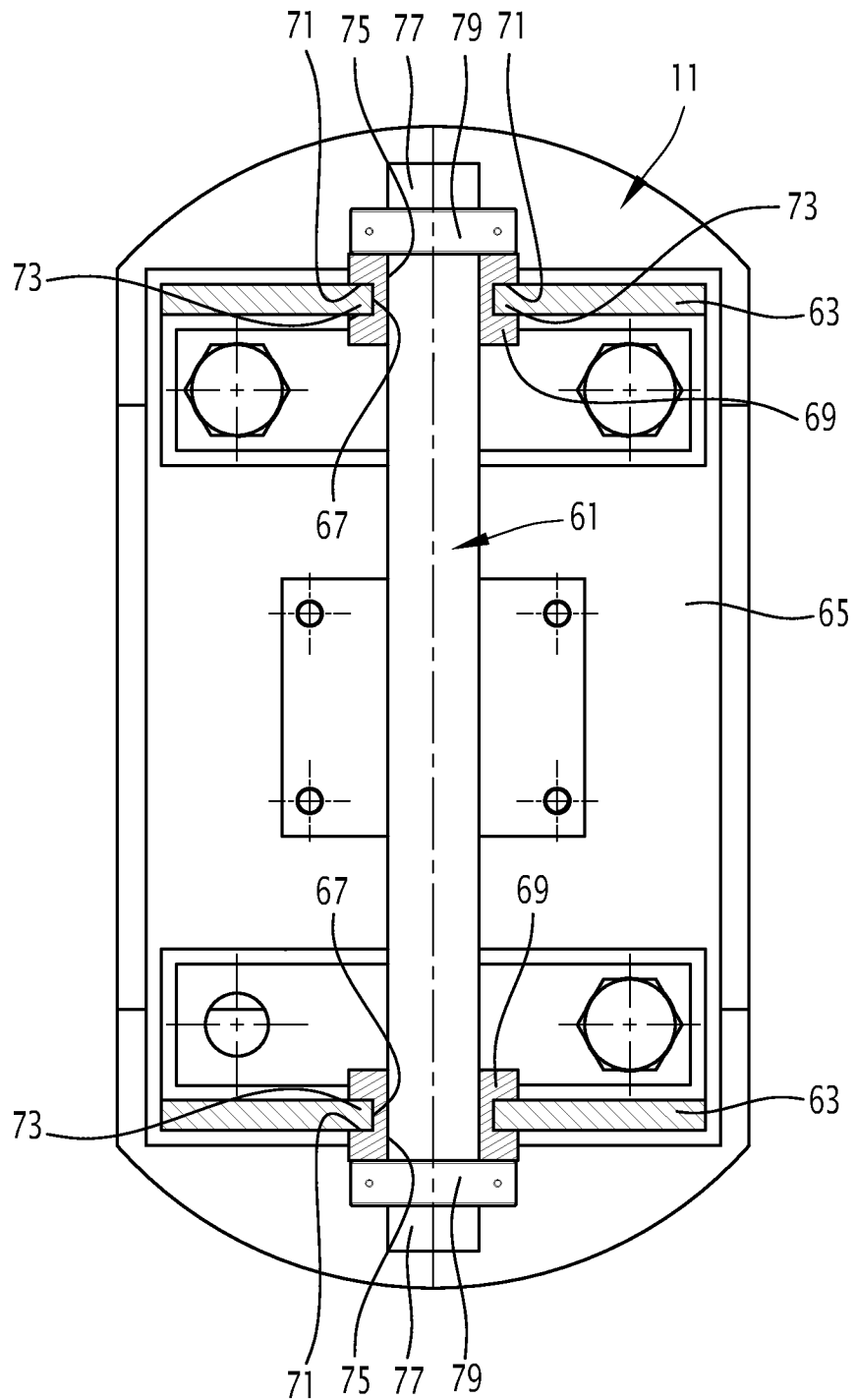


FIG.5

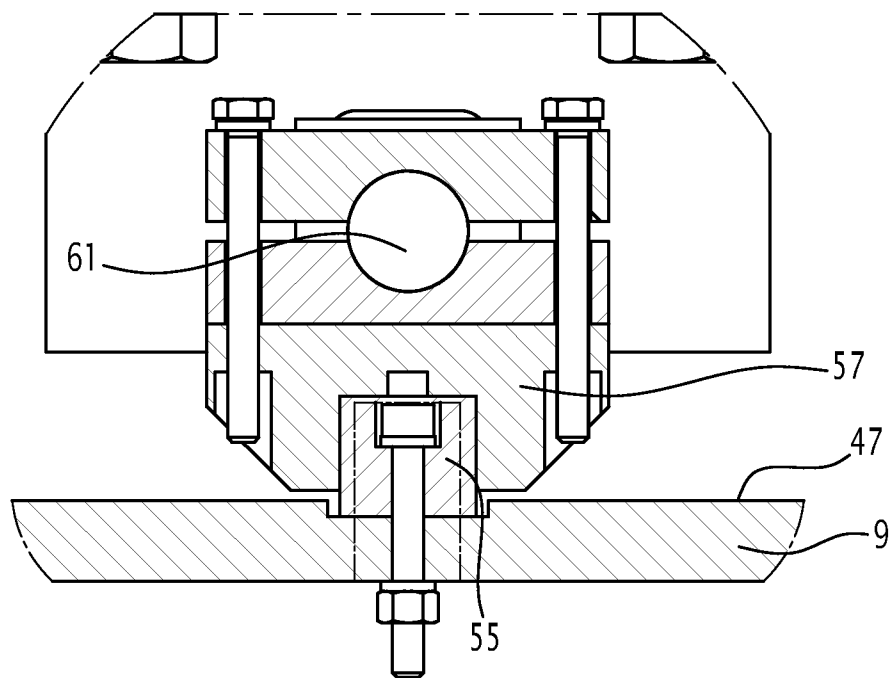


FIG. 6

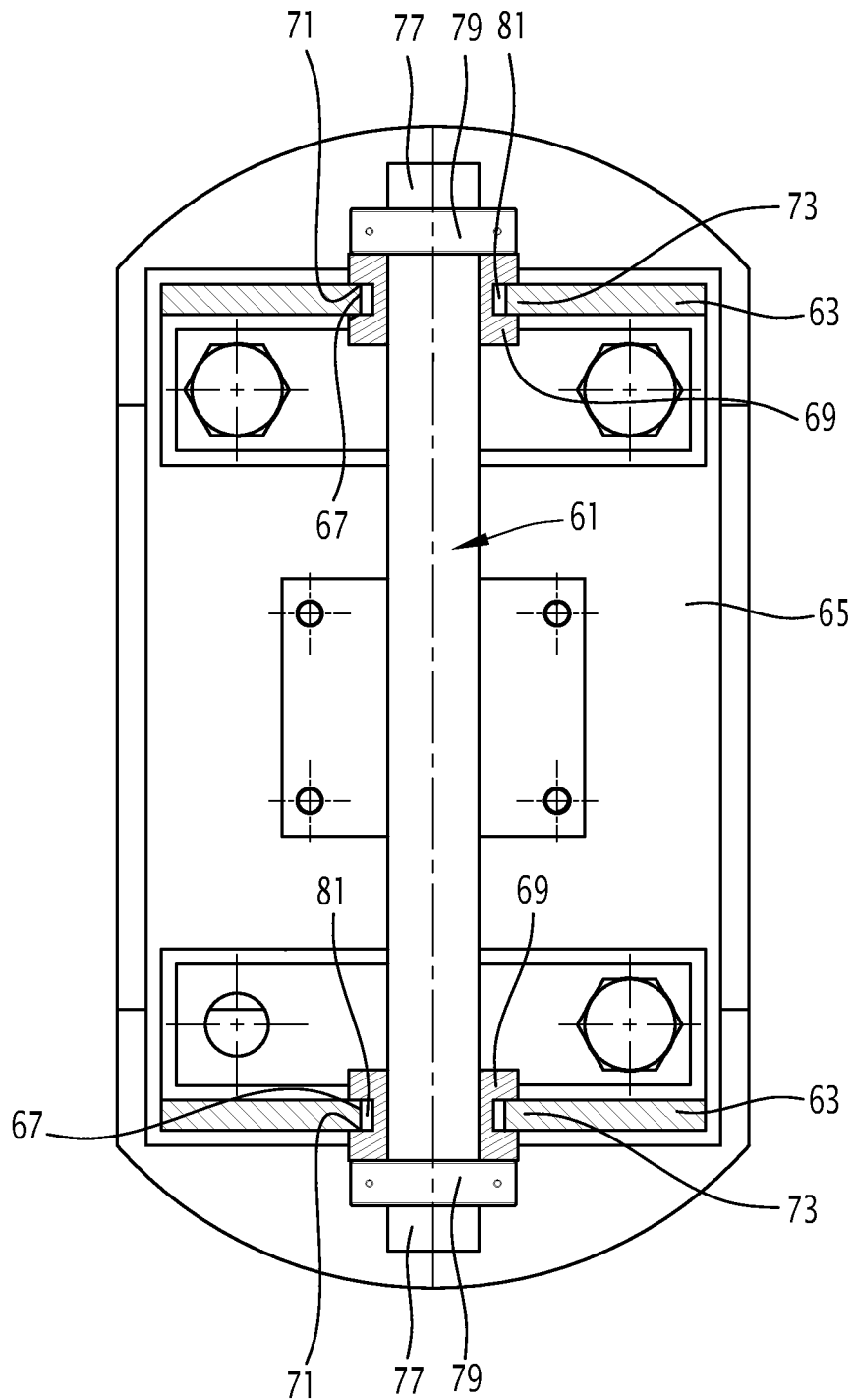
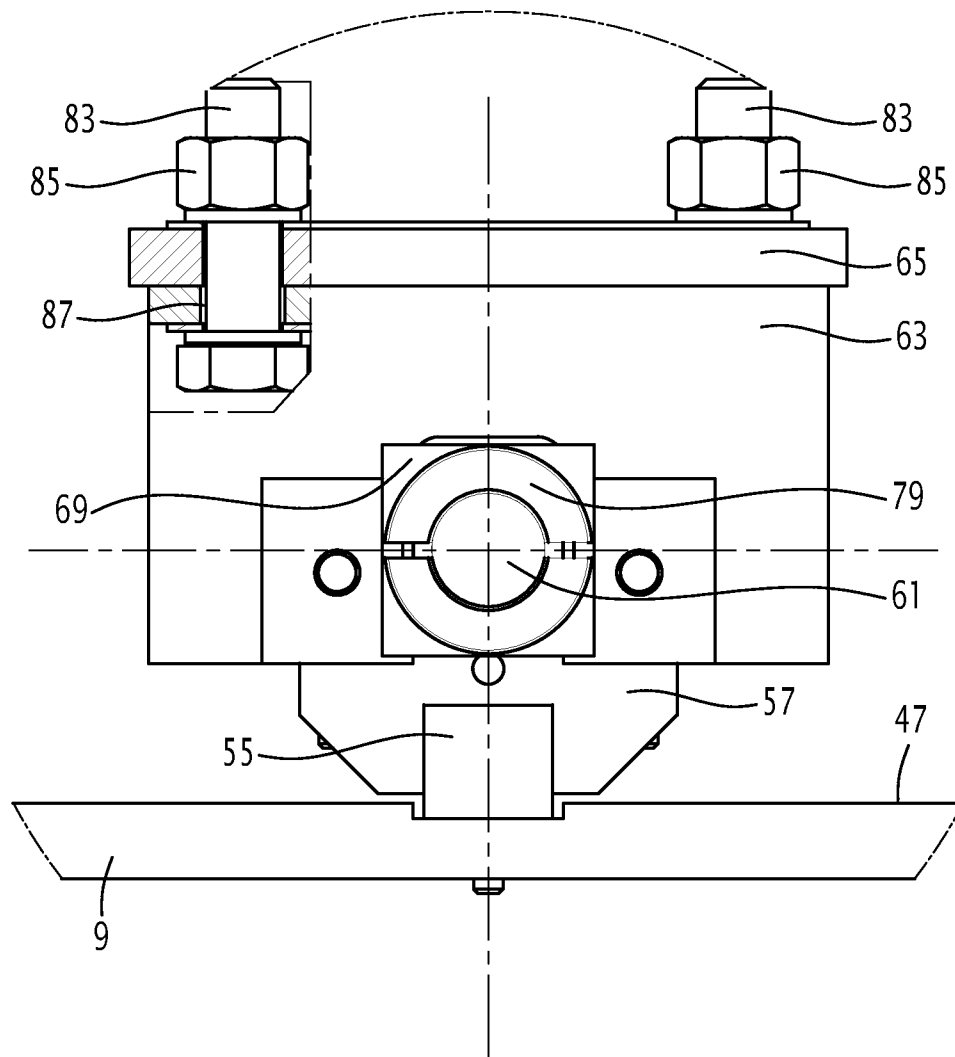


FIG. 7

8/8

**FIG. 8**

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2019/000555

A. CLASSIFICATION OF SUBJECT MATTER
INV. F16F7/14 F16F7/116
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F16F F16L

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 102 052 518 A (UNIV ZHEJIANG) 11 May 2011 (2011-05-11)	1,2,5,6
A	figures 1, 2 -----	3,4,7-10
A	KR 2013 0056743 A (KOREA GAS CORP [KR]) 30 May 2013 (2013-05-30) figures 1-5 -----	1
A	DE 10 2007 025301 A1 (BOA BALG UND KOMPENSATOREN TEC [DE]) 6 December 2007 (2007-12-06) abstract; claim 3; example 3 -----	1
A	US 2011/017561 A1 (TANAKA MAKOTO [JP]) 27 January 2011 (2011-01-27) abstract; figures 4, 7, 25 -----	3

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

☒ See patent family annex.

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Date of the actual completion of the international search

22 October 2019

Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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