US 20140079468A1

(19) United States
(12) Patent Application Publication
Jensen et al.

(10) Pub. No.: US 2014/0079468 A1
(43) Pub. Date: Mar. 20, 2014

(54) **JET PUMP STABILIZER**

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(21) Appl. No.: **14/032,550**

(22) Filed: **Sep. 20, 2013**

Related U.S. Application Data

(60) Provisional application No. 61/703,734, filed on Sep. 20, 2012.

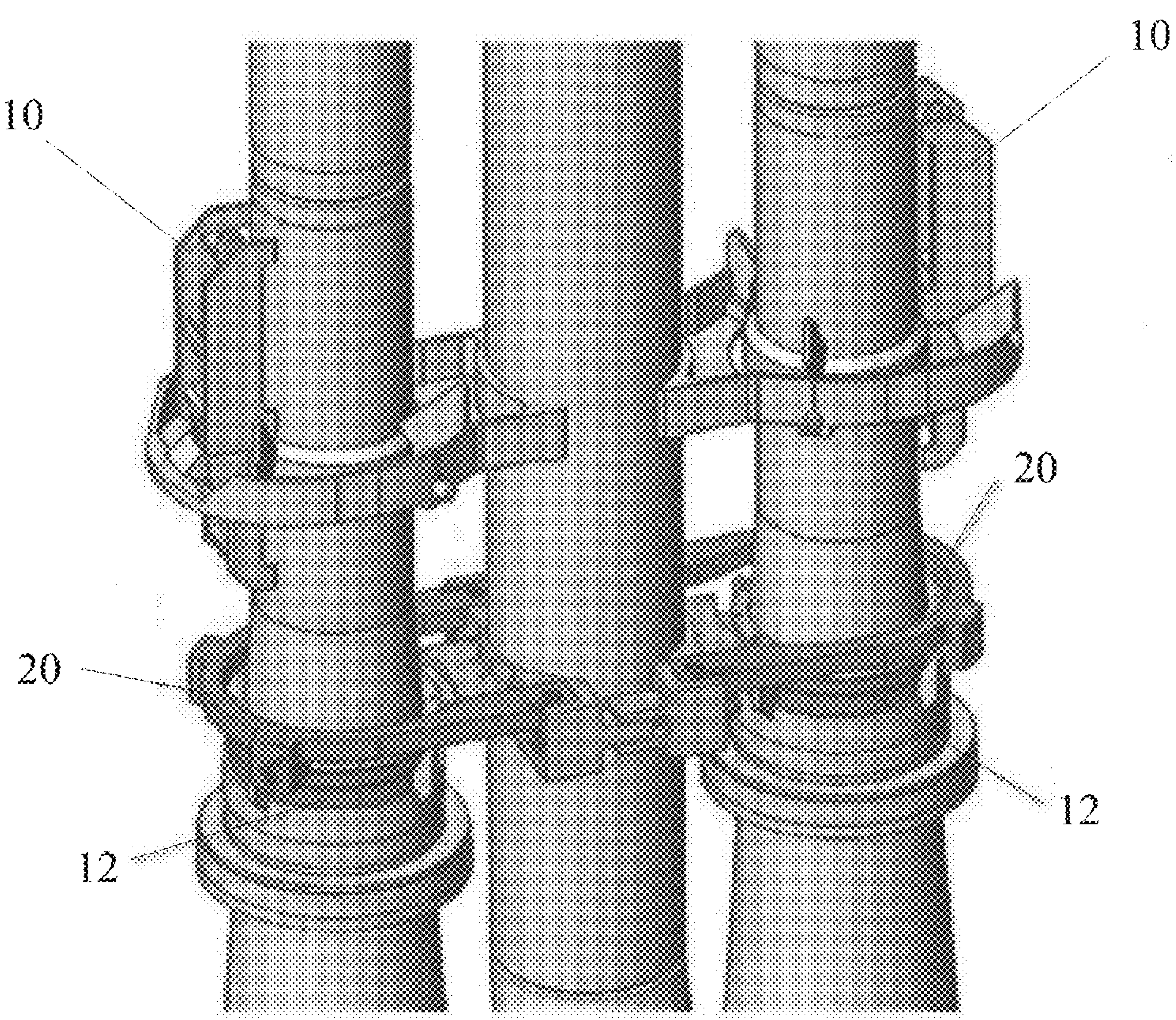
Publication Classification

(51) **Int. Cl.**
F04F 5/44 (2006.01)

(52) **U.S. Cl.**
CPC ***F04F 5/44*** (2013.01)
USPC **403/188**

(57) **ABSTRACT**

A jet pump stabilizer is disclosed and claimed. The stabilizer includes a clamp body that is affixed about the riser pipe. Two U-clamps are connected to the clamp body, each U-clamp positioned about a jet pump mixer section. A wedge assembly is positioned between the clamp body and each mixer pipe, cooperating with the clamp body and U-clamps to laterally restrain the mixer sections. A clamp ring is positioned about each mixer section and retained in place by the U-clamps, wedge assemblies, and clamp body. A sealing ring is moveably connected to the clamp ring such that it is biased toward engagement with the jet pump diffuser. Seals provided on the stabilizer engage the jet pump assembly above and below the slip joint, preventing vibration-inducing leakage through the slip joint.



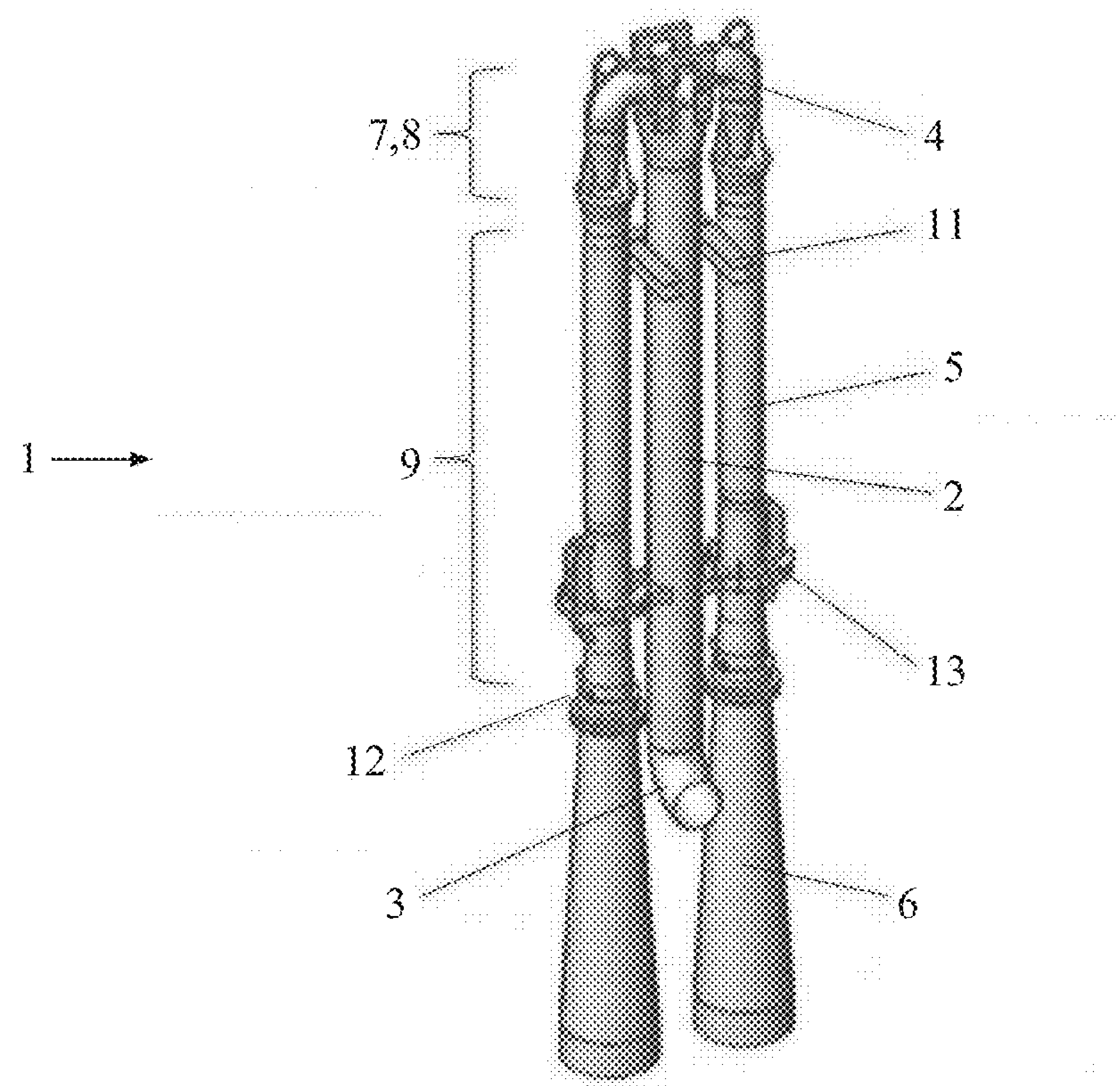


FIG. 1
Prior Art

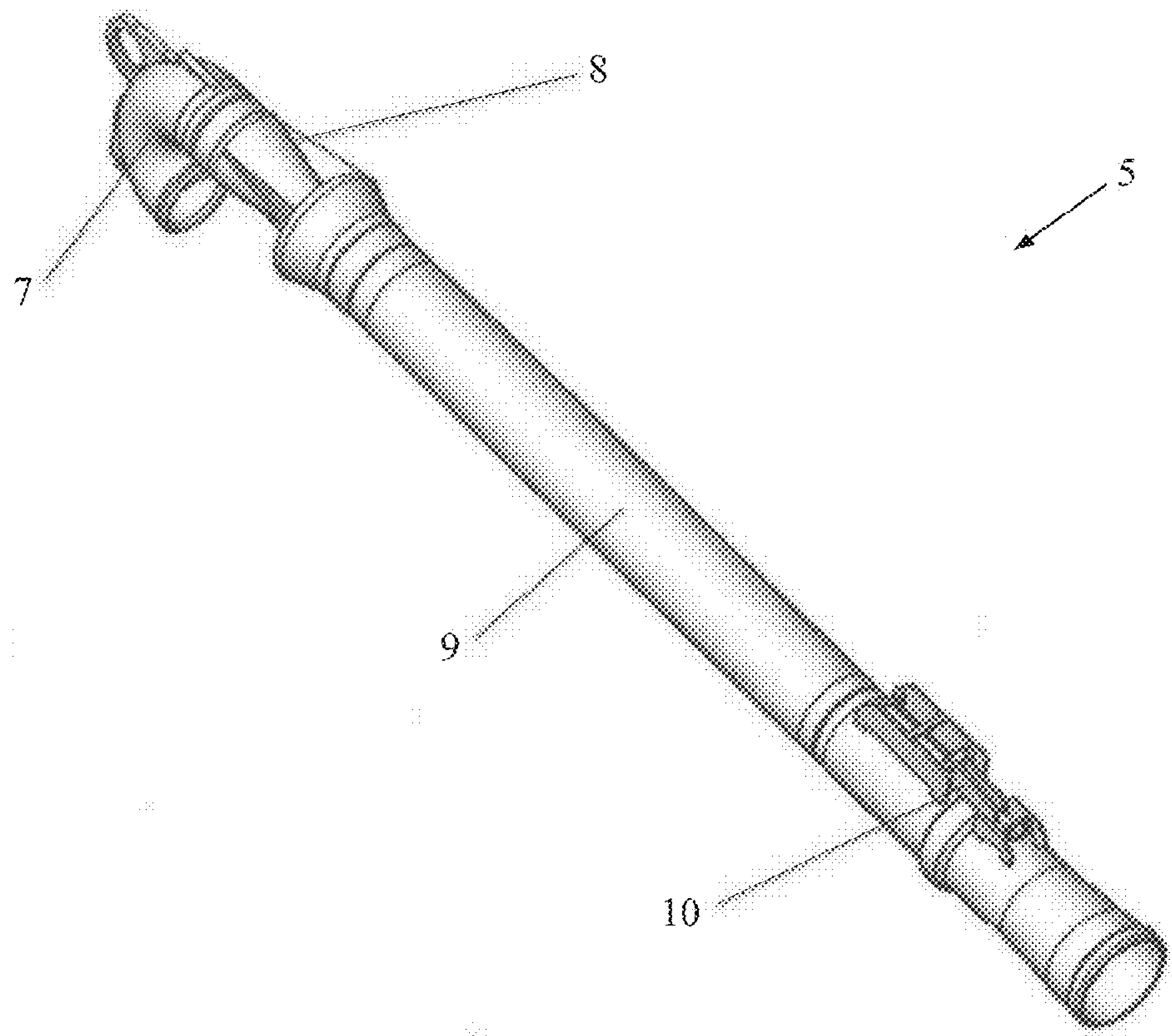


FIG. 2
Prior Art

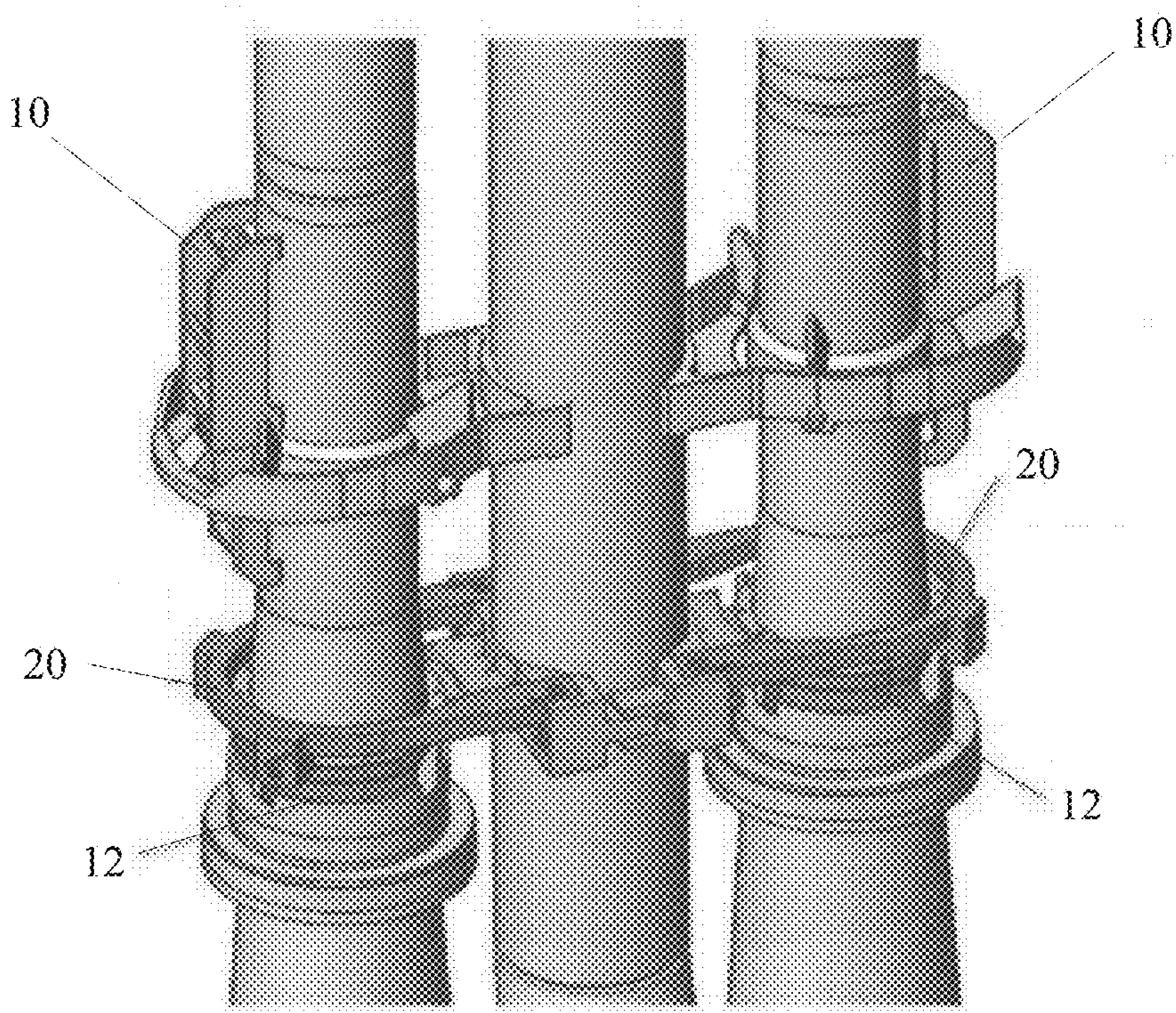


FIG. 3

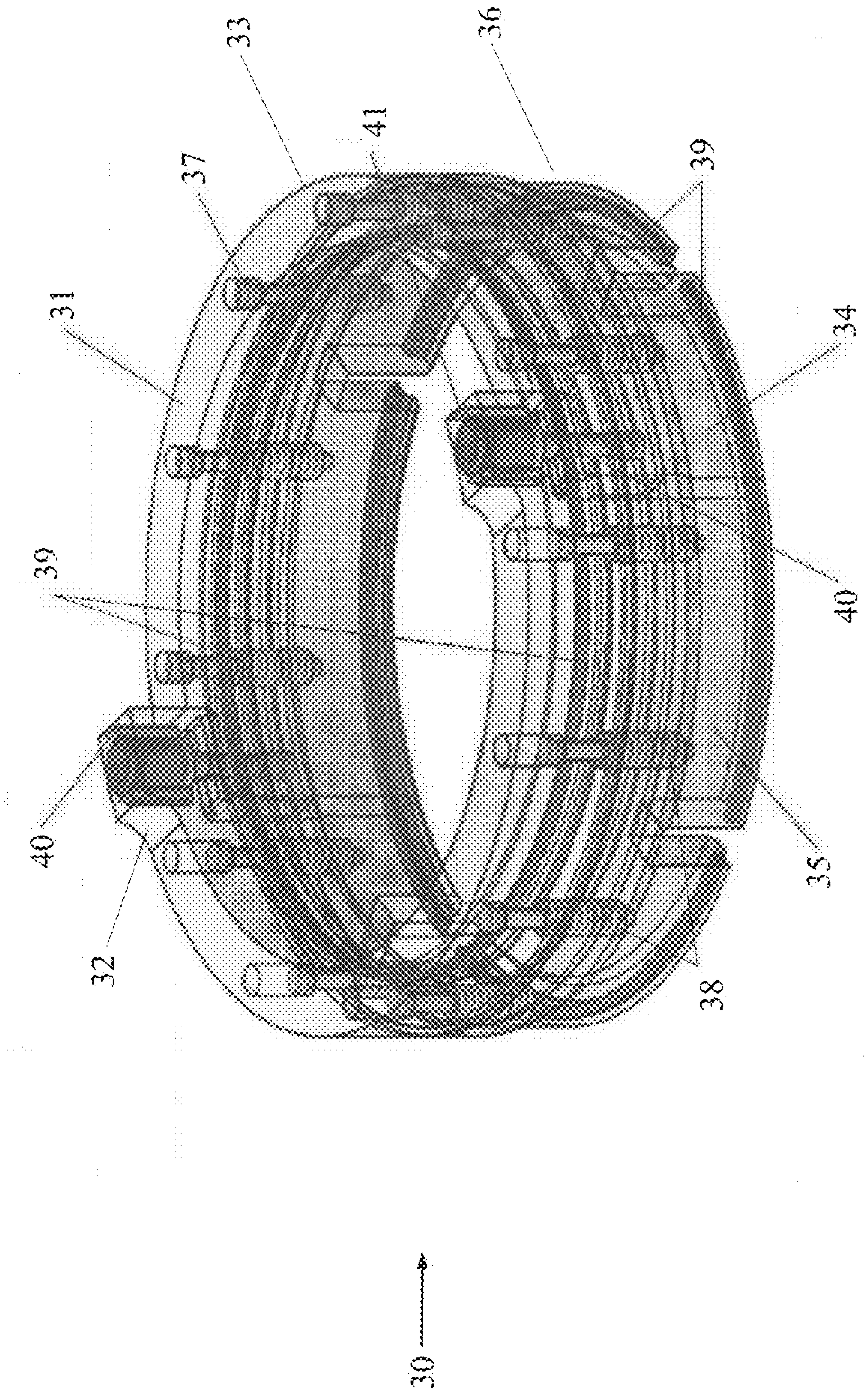


FIG. 4

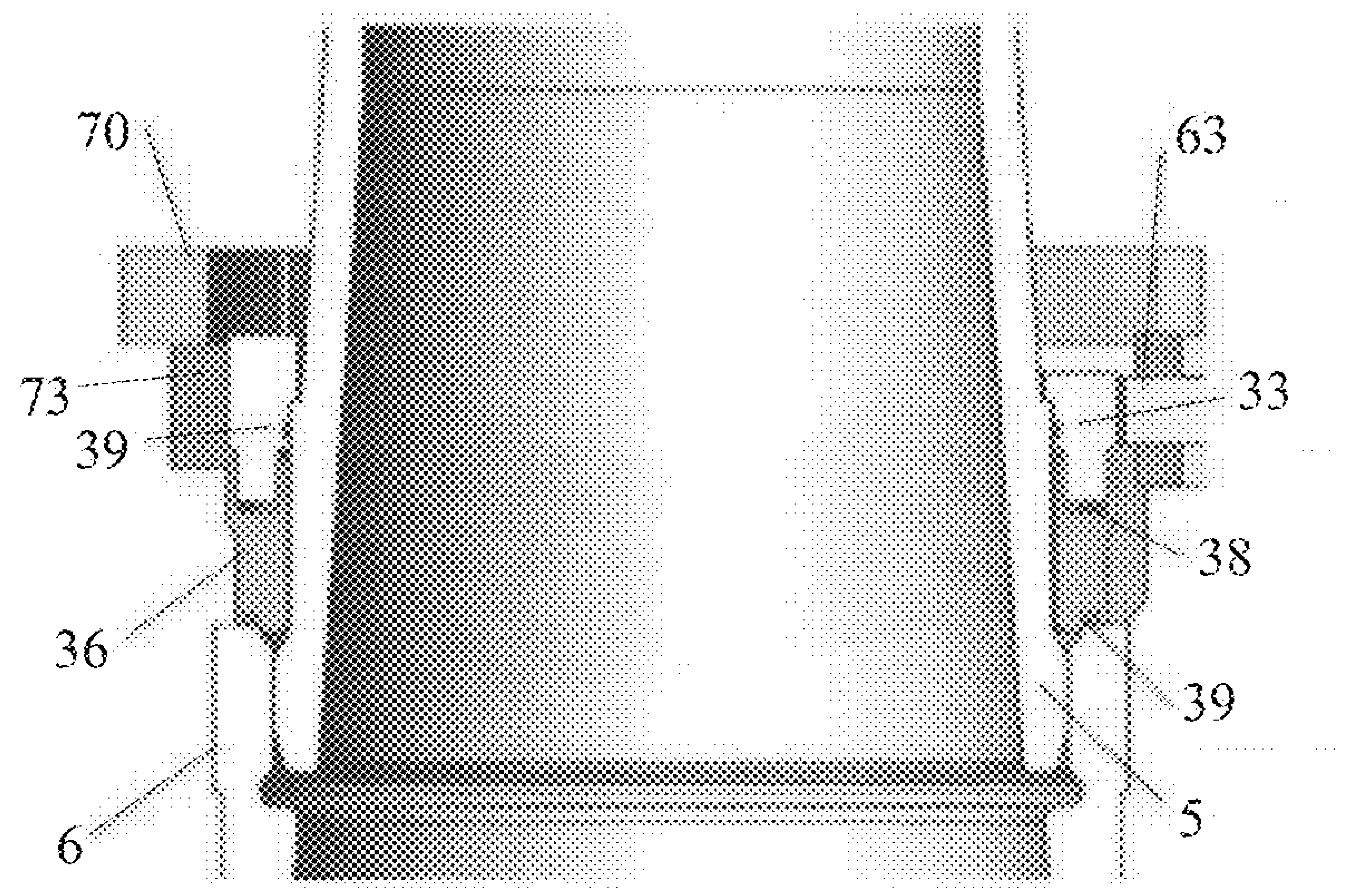


FIG. 5

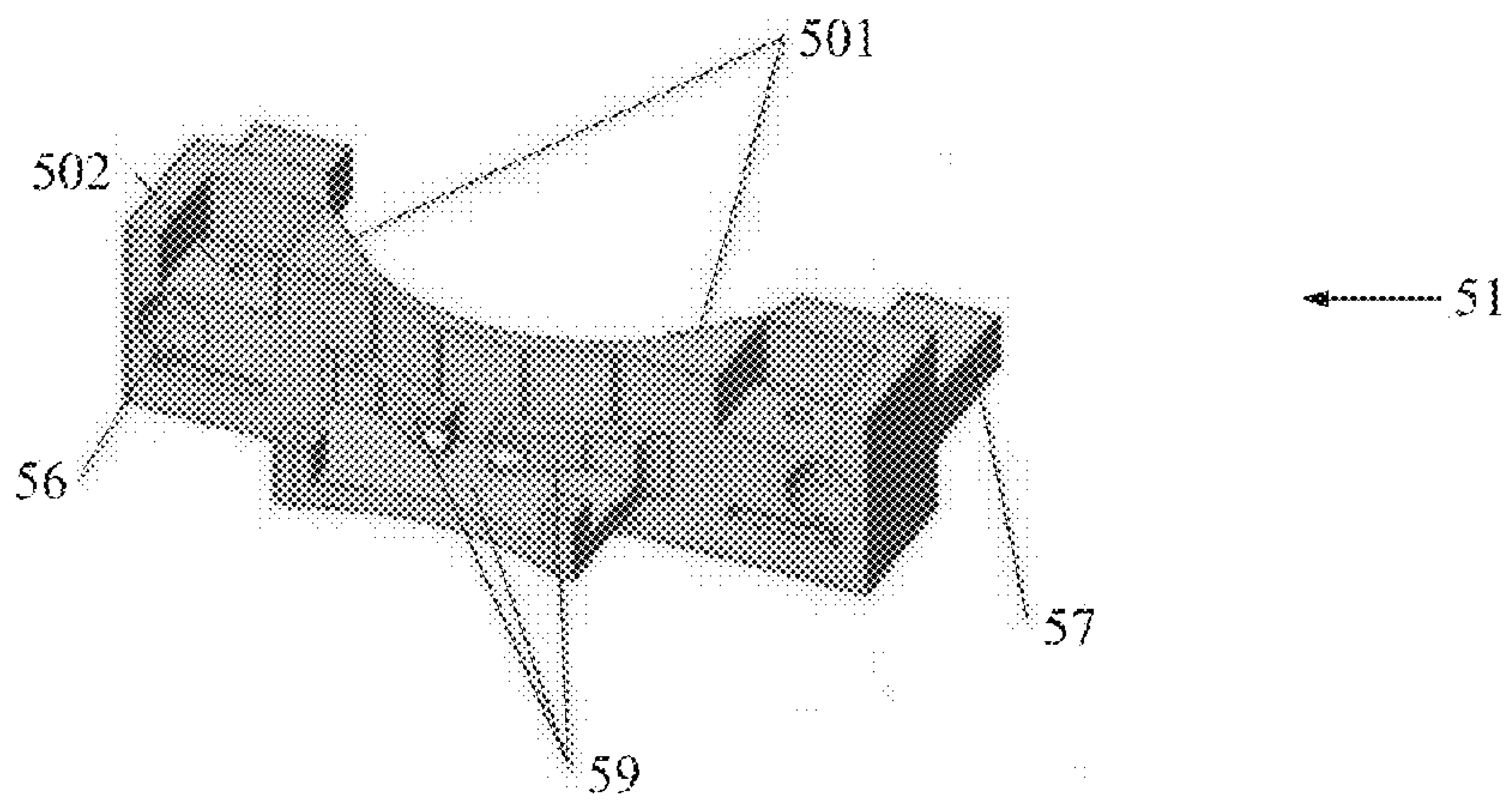


FIG. 6

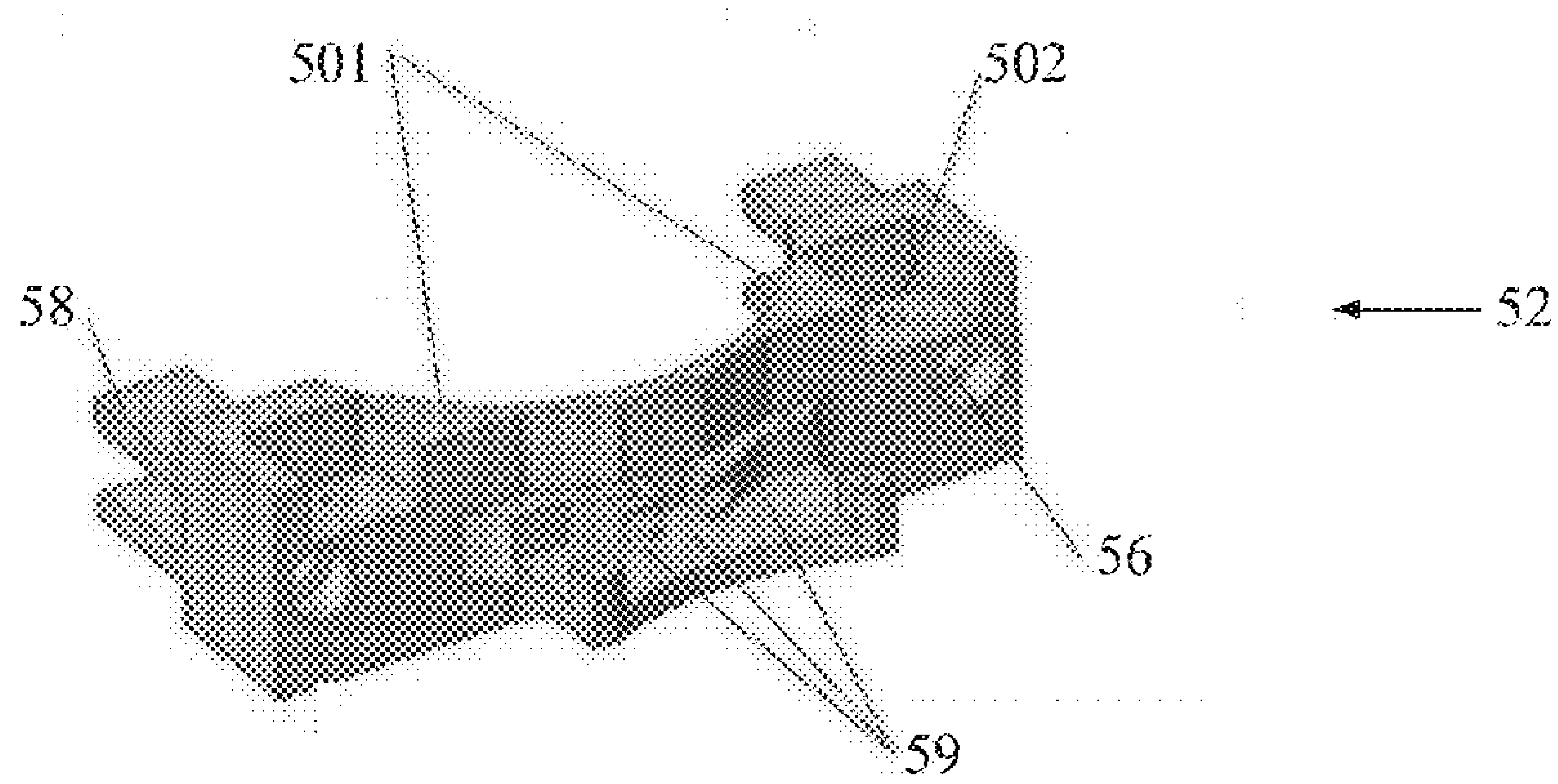


FIG. 7

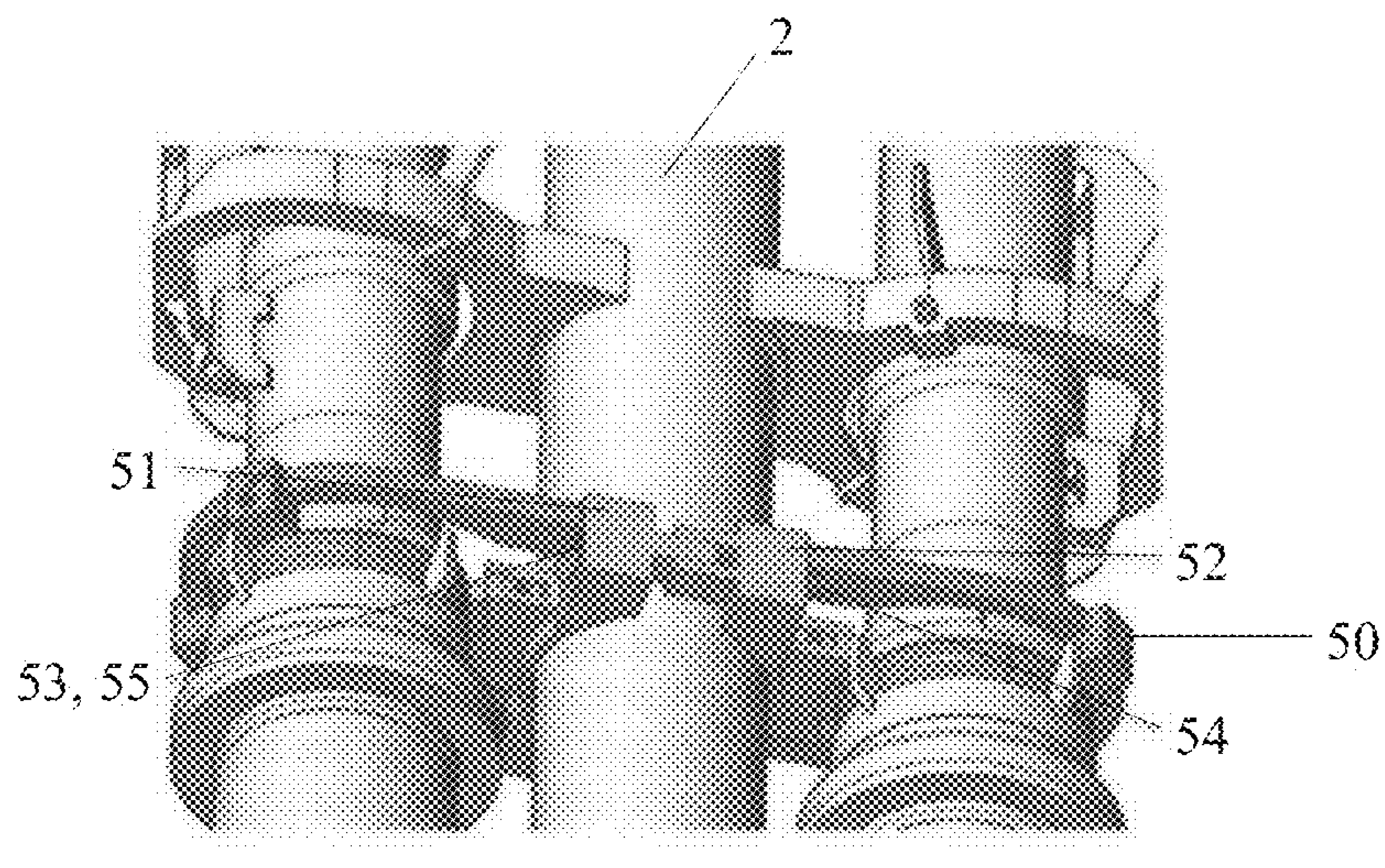


FIG. 8

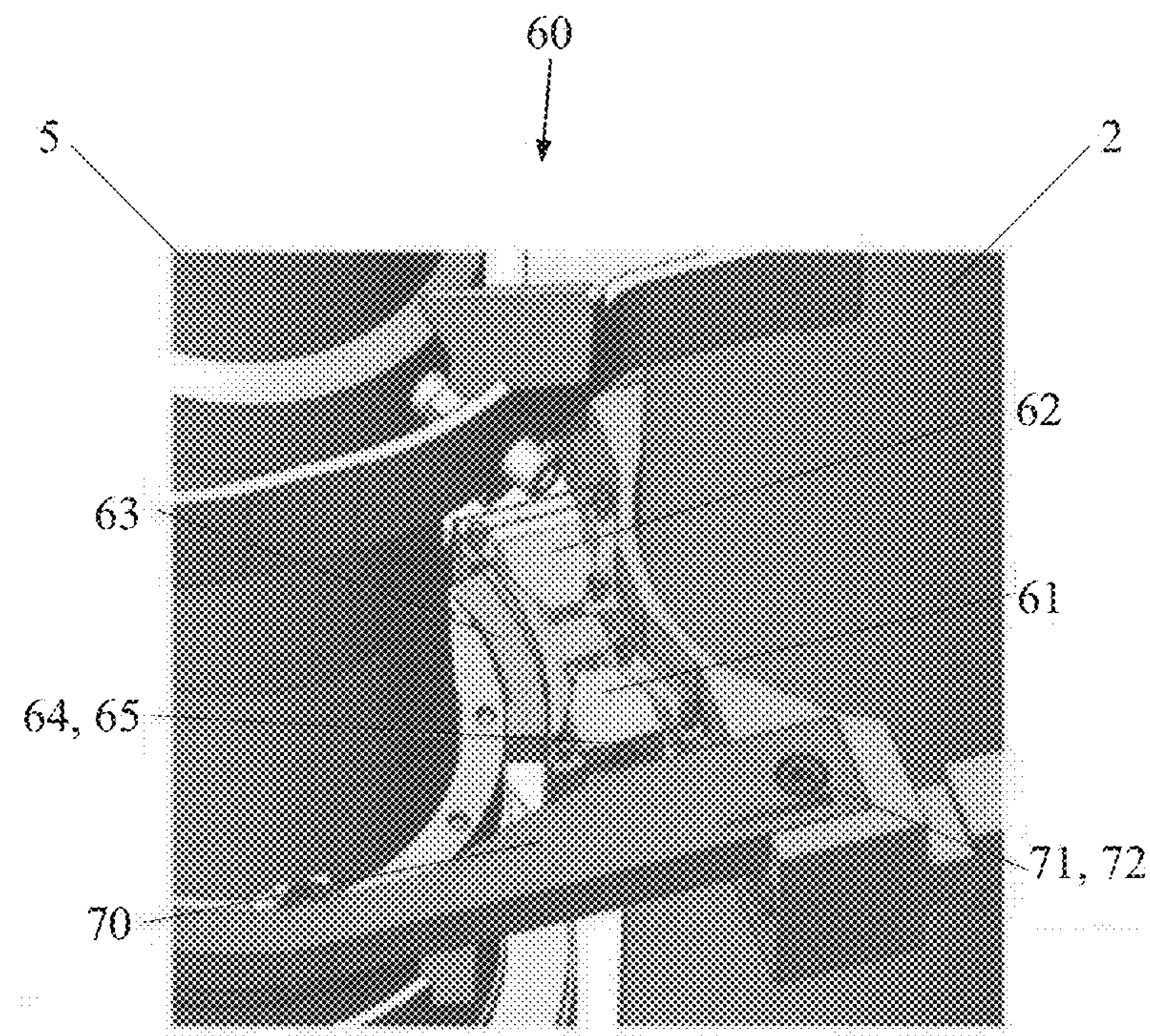


FIG. 9

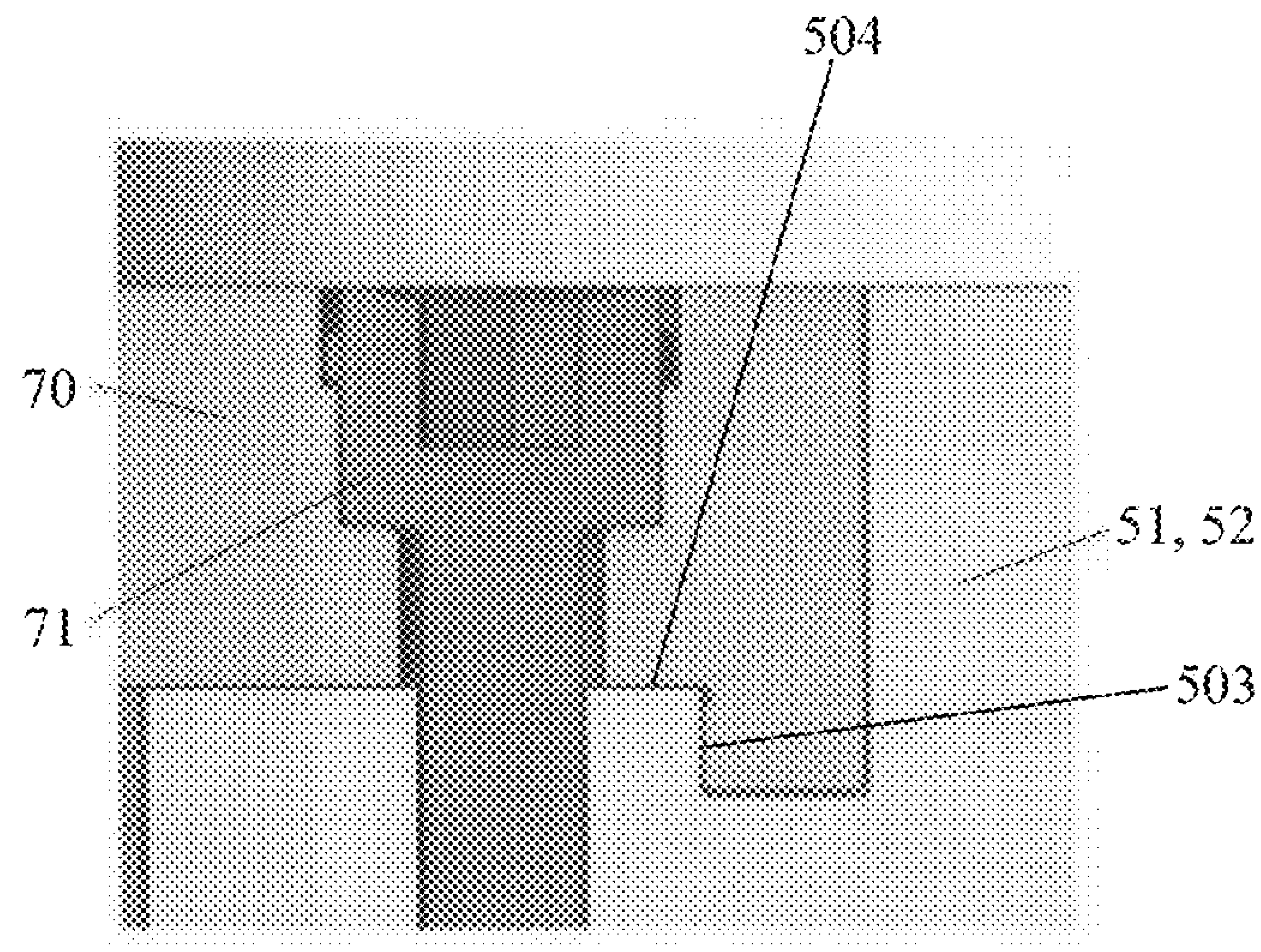


FIG. 10

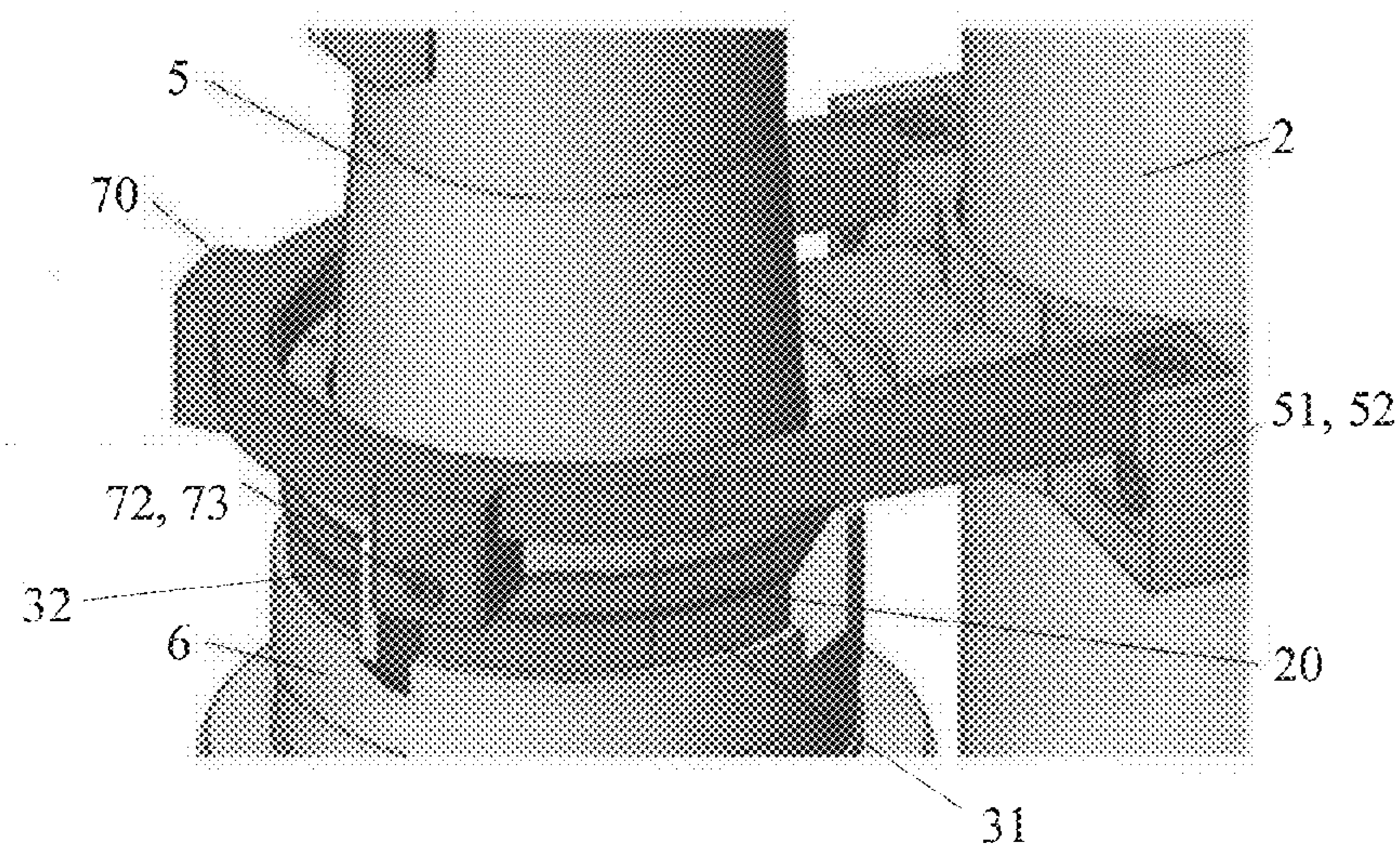


FIG. 11

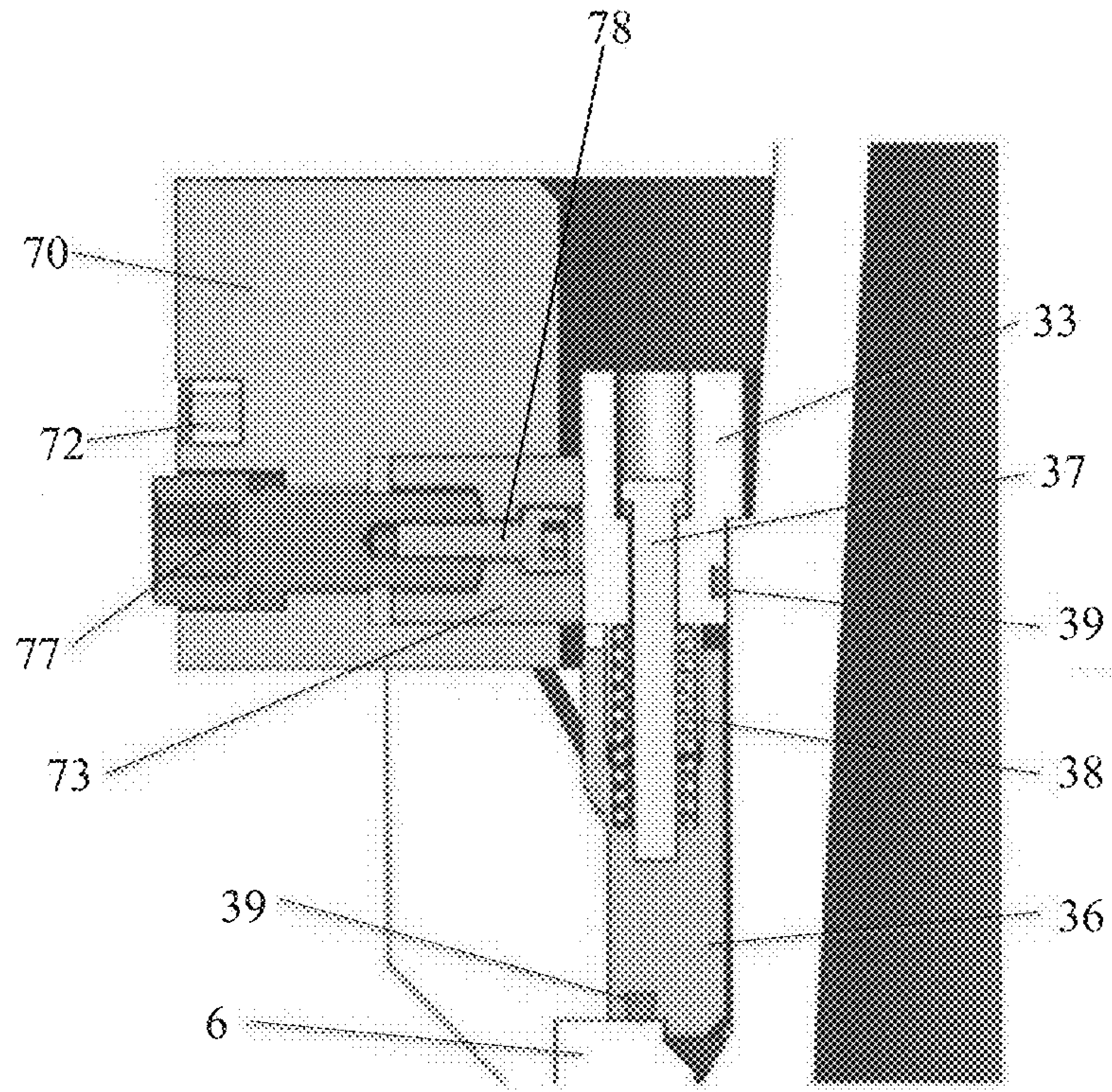


FIG. 12

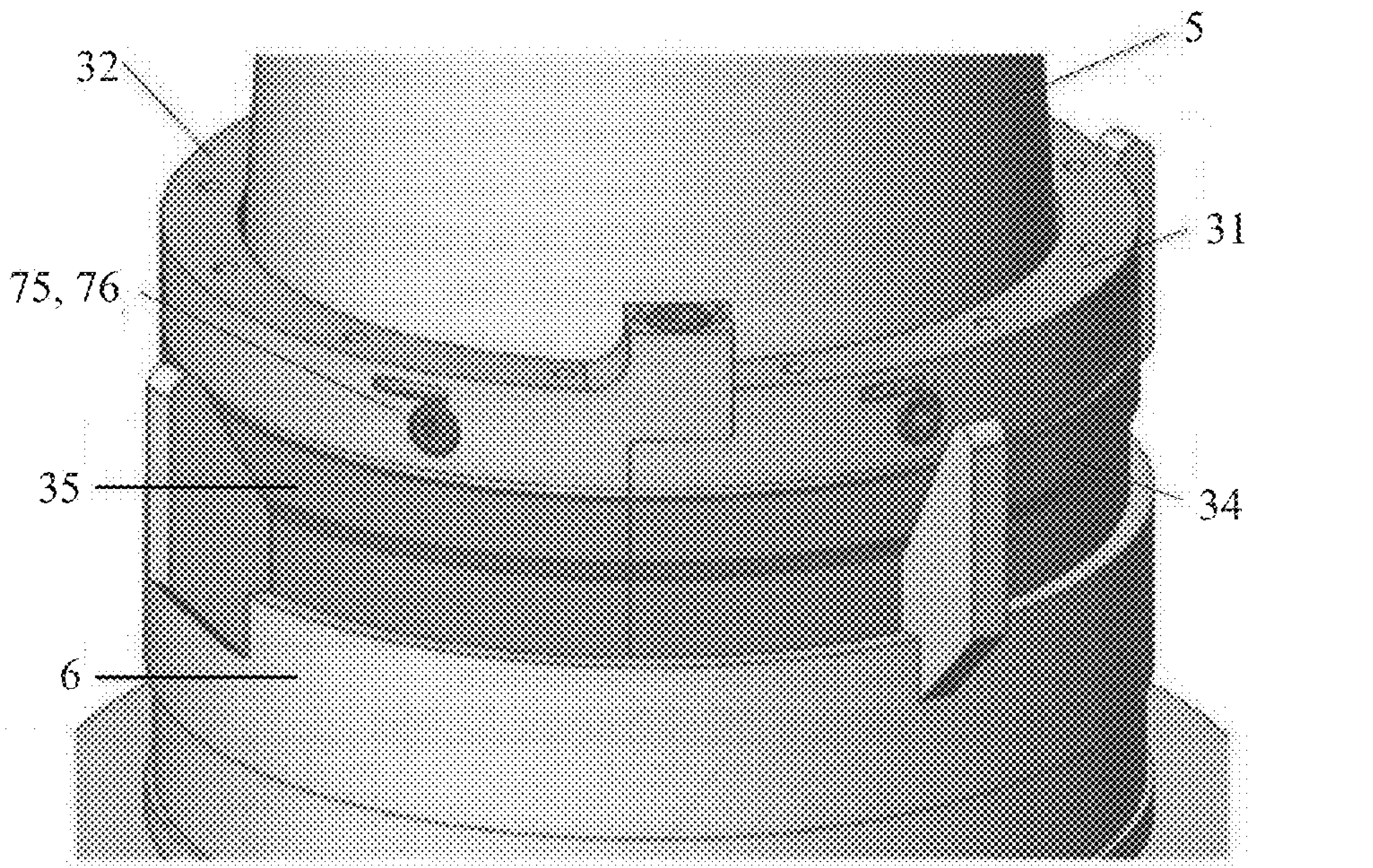


FIG. 13

JET PUMP STABILIZER

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This patent application claims the benefit of U.S. Provisional Patent Application No. 61/703,734 filed on Sep. 20, 2012, which is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates to a clamp, and, more particularly, the present invention relates to a repair device for use, for example, with boiling water reactor jetpumps.

[0004] 2. Description of the Related Art

[0005] While the present invention may be used in a variety of industries, the environment of a boiling water reactor (BWR) nuclear power plant will be discussed herein for illustrative purposes. In a BWR, a steam-water mixture is produced when reactor coolant (water) moves upward through the core, absorbing heat produced by the fuel. The steam-water mixture leaves the top of the core and enters a moisture separator, where water droplets are removed before the steam is allowed to enter the steam line. The steam line directs the steam to the main turbine, causing it to turn the turbine and the attached electrical generator. The steam is then exhausted to a condenser where it is condensed into water. The resulting water is pumped out of the condenser back to the reactor vessel, Recirculation pumps and jet pumps allow the operator to vary coolant flow through the core and change reactor power.

[0006] Within the BWR vessel, core shrouds surround the core to provide a barrier to separate the downward coolant flow through the annulus/downcomer (the space between the core shroud and the reactor vessel wall) from the upward flow through the core and fuel bundles. In a typical boiling water reactor, jet pumps are located in the downcomer and provide forced flow of coolant through the reactor vessel in order to yield higher reactor power output than would be possible with natural circulation. Twenty jet pumps are located in two semi-circular groups in the annular downcomer region of the reactor. Two jet pumps and a common inlet header or riser pipe comprise a jet pump assembly as shown in FIG. **1**. Each jet pump assembly **1** includes an inlet riser pipe **2**, a short radius elbow **3** welded at the bottom of the riser pipe **2**, a transition piece **4** welded to the top of the riser pipe **2**, two inlet mixer assemblies **5**, and two conical diffuser assemblies **6**.

[0007] FIG. **2** shows a typical inlet mixer assembly **5**. Each inlet mixer assembly **5** includes an elbow **7** and associated converging nozzle **8**, a flow mixing section **9**, and a gravity wedge apparatus **10** that is employed the lateral restraint of the inlet mixer **5**.

[0008] Inlet risers **5** are utilized for each jet pump assembly **1** to permit the reactor recirculation inlet nozzles to be located below the active fuel region. This prevents significant fast neutron exposure which could adversely affect the mechanical properties of the nozzle penetration welds. Additionally, riser brace arms **11** provide lateral support for the upper end of the jet pump assembly **1** and also allow for the vertical differential expansion between the riser **2** and the reactor vessel during plant heat-up and cool-down.

[0009] The inlet mixer elbow **7** and converging nozzle **8** sections redirect the coolant flow stream 180° and increase the velocity of the flow stream as the coolant passes through the nozzle **8**. This increase in fluid flow velocity results in lower static pressure of the driving flow. This decreased static pressure in the upper end of the inlet mixer **5** draws higher pressure water from the downcomer plenum and the two flows (driving and drive are then combined together in the mixing section **9** of the inlet mixer **5**. The inlet mixer **5** interfaces with the diffuser assembly **6** at the slip joint **12** of the jet pump. The slip joint **12** provides means to remove the inlet mixer assembly **5** from a jet pump assembly **1** and also accommodates the differential thermal expansion that occurs in the jet pump assembly **1** during plant heat-up and cool-down. This differential thermal expansion is the result of the riser pipe **2** being anchored in the low alloy carbon steel of the reactor vessel and the differing lengths of stainless steel jet pump components. The inlet mixer assemblies **5** are supported laterally by a restrainer bracket **13** that is welded to the riser pipe **2**. The gravity wedge **10** of the inlet mixer and two opposing set screws that are mounted to the restrainer bracket **13** are designed to restrain the inlet mixer **5**.

[0010] The inlet mixers **5** are subject to flow induced vibration resulting from the mixing action of the drive and driven flow components in the mixing section **9** of the inlet mixer **5**. In addition, unstable pressure fluctuations result from the passage of coolant through the slip joint **12** to the lower pressure downcomer annulus. Consequently, abnormal wear of jet pump assembly **1** components has been experienced at several BWR plants. Components affected have been the inlet mixer **5** and diffuser collar **6** at the slip joint location **12**, and the gravity wedge **10** and interfacing surface of the restrainer bracket **13**. Isolated cracking has also been experienced at the set screw tack welds, riser brace **11** to riser pipe **2** weld, and short radius elbow **3** to thermal sleeve weld.

[0011] Thus, there is a need to provide a simple mechanical device which will minimize or limit coolant leakage at the slip joint location and also provide supplemental structural support to the jet pump assembly.

SUMMARY OF THE INVENTION

[0012] The jet pump stabilizer disclosed and claimed herein restricts coolant leakage at the jet pump slip joint. A clamp body is provided in two parts to interconnect around the jet pump riser pipe. In this manner, it can be placed in position without removal of any jet pump assembly components. Two U-clamps are connected to the clamp body, each U-clamp fitted around a separate one of the jet pump inlet mixer pipes. A wedge subassembly is positioned intermediate the riser pipe and each mixer pipe. The wedge assemblies impart a force to the mixer pipe in a direction that is substantially opposite the force imparted to the mixer pipe by the U-clamp. Thus, the mixer is restrained against movement, including flow-induced vibration. The connections between the U-clamp and the clamp body can incorporate mating spherical seats to accommodate any misalignment between the two mixer pipes and the riser pipe.

[0013] A clamp ring is provided for each jet pump mixer. Each clamp ring is provided in two parts to interconnect around the jet pump mixer pipe. In this manner, the clamp rings can be placed in position without removal of any jet pump assembly components. An outboard portion (that is, a portion away from the riser pipe) of each clamp ring is placed between the U-clamp and the mixer pipe, and may be mechanically connected thereto. An inboard portion (that is, a portion towards or adjacent to the riser pipe) of each clamp ring is placed between the wedge and the mixer pipe, and may be mechanically connected thereto. In this manner, the clamp ring is held in the desired position about the jet pump inlet mixer. A seal, preferably a malleable seal, may be provided on the inner perimeter of the clamp ring such that it is in contact with the mixer above the slip joint. This clamp ring seal limits leakage past the jet pump slip joint in an upward direction.

[0014] A sealing ring is attached to each clamp ring. Each sealing ring is provided in two parts to interconnect around the jet pump mixer pipe. In this manner, the sealing rings can be placed in position without removal of any jet pump assembly components. Each sealing ring is connected to its corresponding clamp ring by one or more spring-biased connection pins, allowing movement of the sealing ring relative the clamp ring. A seal, preferably a malleable seal, may be provided on a lowermost portion of the sealing ring. The springs bias the sealing ring downward, causing the seal to contact the jet pump diffuser collar below the slip joint. This sealing ring seal limits leakage past the jet pump slip joint in a downward direction. Slots may be provided in the sealing ring to accommodate the jet pump diffuser guide vanes. The relative movement between the sealing ring and the clamp ring accommodate any thermal expansion or contraction at the slip joint.

DESCRIPTION OF THE DRAWINGS

[0015] The present invention is described with reference to the accompanying drawings, which illustrate exemplary embodiments and in which like reference characters reference like elements. It is intended that the embodiments and figures disclosed herein are to be considered illustrative rather than restrictive.

[0016] FIG. **1** shows a typical jet pump assembly.

[0017] FIG. **2** shows a typical inlet mixer assembly.

[0018] FIG. **3** shows a slip joint clamp of the present invention.

[0019] FIG. **4** shows a slip joint clamp subassembly of the slip joint clamp of FIG. **3**.

[0020] FIG. **5** shows a cross-sectional view of the slip joint clamp of FIG. **3** in place on a jet pump assembly as shown in FIG. **1**.

[0021] FIG. **6** shows a first clamp body of the slip joint clamp subassembly of FIG. **3**.

[0022] FIG. **7** shows a second clamp body of the slip joint clamp of FIG. **3**.

[0023] FIG. **8** shows an inlet mixer restraint assembly of the slip joint clamp of FIG. **3** mounted at a preferred elevation on the riser pipe of the jet pump assembly of FIG. **1**.

[0024] FIG. **9** shows a stabilizing wedge system of the slip joint clamp of FIG. **3**.

[0025] FIG. **10** shows a cross-sectional view of a U-clamp subassembly of the slip joint clamp of FIG. **3**.

[0026] FIG. **11** shows the connection of one U-clamp of the slip joint clamp of FIG. **3** to its corresponding restraint clamp body about the inlet mixer of the jet pump assembly of FIG. **1**.

[0027] FIG. **12** shows a cross-sectional view of a U-clamp pad of the slip joint clamp of FIG. **3** in contact with the outboard clamp ring of the slip joint clamp.

[0028] FIG. **13** shows optional stop bolts that can be used in the slip joint clamp of FIG. **3**.

DETAILED DESCRIPTION OF THE INVENTION

[0029] FIG. **3** shows a slip joint clamp **20** of the present invention, and FIG. **4** shows a slip joint clamp subassembly **30** thereof. The subassembly **30** includes inboard **31** and outboard **32** semicircular clamp segments, which are joined together by a pair of slip joint bolts **40** and bolt keepers **41** to form a circular clamp ring **33**. A seal ring **36** includes inboard **34** and outboard **35** semicircular seal segments that are joined to the clamp ring **33** by several guide pins **37**. Captive to the guide pins **37** are spring elements **38**, which collectively provide a separation force between the stationary clamp ring **33** and the moveable seal ring **36**. The seal ring **36** is designed to move axially upward in response to the thermal growth of the diffuser **6** relative to the inlet mixer **5**. This upward axial movement is resisted by the compressive action of the spring elements **38**.

[0030] The inboard **31** and outboard **32** semi-circular clamp segments are configured with an opposing tongue-and-groove design to ensure proper alignment of these two clamp segments. Additionally, slots are provided in the seal ring **36** to allow for clearance with the diffuser **6** guide vanes. These engineered slots are sized to minimize slip joint coolant leakage by providing a tight fit with the diffuser guide vanes.

[0031] Malleable metal seals **39** may be integrated into the clamp **33** and seal **36** rings to provide a more positive seal against coolant leakage. A preferred spatial orientation of these metal seals is depicted in the cross-sectional view of FIG. **5**. The clamp ring **33** is held stationary and in the desired position on the inlet mixer **5** by the clamping action of the U-shaped clamp pads **73** and the mixer wedge element **63** of the wedge clamp **10** components of the inlet mixer restraint subassembly **50**.

[0032] The inlet mixer restraint assembly **50** preferably includes a right clamp subassembly **51** and a left clamp subassembly **52**. FIGS. **6** and **7** show preferred right **51** and left **52** clamp bodies, respectively. Bearing surfaces **501** of these subassemblies **51**, **52** are joined together at the desired elevation on the riser pipe **2** by a pair of clamp bolts **53** and clamp nuts **54**. Clamp bolt keepers **55** are also provided to prevent loss of mechanical preload in the bolted joint. Preferably, the design of the clamp bolts **53** and the clamp nuts **54** incorporates spherical seats **56** that interface with mating spherical seats **56** in the right **51** and left **52** clamp bodies. This ensures proper clamp fit-up in the event that the centerlines of the riser pipe **2** and attendant inlet mixers **5** are not coplanar.

[0033] One of the clamp body portions **51**, **52** may be provided with one or more “tongue” features **57** that interface with a corresponding pair of mating “groove” features **58** that may be provided on the other clamp body **52**, **51**. This tongue-and-groove arrangement can help ensure proper subassembly alignment and ease of remote installation. For example, the right clamp body **51** can incorporates a pair of tongue features **57** that interface with a pair of mating groove features **58** of the left clamp body **52** as shown in the illustrated embodiments of FIGS. **6** and **7**. FIG. **8** shows the inlet mixer restraint assembly **50**, with connected right **51** and left **52** clamp bodies, mounted at a preferred elevation on the jet pump riser pipe **2**.

[0034] The as-built distance between the riser pipe **2** and the inlet mixer **5** preferably is stabilized by a system of wedges **60**. A preferred system of wedges **60** is illustrated in FIG. **9**. Primary **61** and secondary **62** wedge elements bear on the wedge surfaces **59** of the right **51** or left **52** clamp bodies and the inlet mixer wedge element **63**. As the primary **61** and secondary **62** wedge elements are drawn closed together by virtue of the wedge bolt **64**, the inlet mixer wedge element **63** is brought to bear on the inboard clamp ring **31** of the slip joint clamp **30**. The primary **61** and secondary **62** wedge elements are identical in overall size and shape. The primary wedge **61** design accommodates the wedge bolt keeper **65** and the bearing surface of the wedge bolt **64**. The secondary wedge design **62** provides internal threads that interface with the threaded end of the wedge bolt **64**.

[0035] FIG. **9** also shows a U-clamp subassembly **70** of the restraint assembly. The U-clamp subassembly **70** is attached to both the right clamp body **51** and the left clamp body **52** by U-clamp bolts **71**. Ends of the U-clamp assembly **70** abut the right **51** and left **52** clamp bodies at horizontal surfaces **502** thereof. U-clamp bolt keepers **72** are provided to prevent loosening of the associated bolts **71**. As is the case with preferably all of the mechanical fasteners in the slip joint **30** and inlet mixer restraint clamp **50** assemblies, in a preferred form the bolt keepers are essentially cantilever beam elements with ratchet teeth that interface with mating ratchet teeth integral with the fasteners. The keepers are designed to deflect as the ratchet teeth of the bolts are rotated in a tightening direction, and to resist rotation of the bolt in a loosening direction. A crimp cup is another preferred form of bolt keeper **72**. In this design, the bolt includes a cup portion that surrounds the head and fits into a counter bore. After the bolt has been inserted and tightened, one or more locations along the cup portion are plastically deformed or crimped outward into the counter bore, which features a plurality of machined semi-cylindrical depressions or partial cylindrical features. The interference of the plastically deformed crimp collar with these counter bore features prevents rotation of the bolt.

[0036] In order to eliminate shear stress in the U-clamp bolts **71**, pockets can be provided in the right **51** and left **52** clamp bodies. As shown in the cross-sectional view of FIG. **10**, the U-clamp **70** is seated on a horizontal surface **504** of the clamp bodies **51**, **52**. A step feature is provided at both extremities of the U-clamp **70**, which are inserted into these pockets, thus providing a substantial bearing surface **503** to transmit loads from the U-clamp **70** into the clamp bodies **51**, **52**.

[0037] FIG. **11** shows the connection of one U-clamp **70** to its corresponding restraint clamp body **51**, **52** about the jet pump inlet mixer **5**, and FIG. **12** shows a cross-sectional view illustrating a preferred spatial arrangement of the U-clamp pad **73** in contact with the outboard clamp ring **32** of the slip joint clamp **30**. Mechanical preload can be generated in the U-clamp **70** by advancing the U-clamp pads **73** onto the outboard clamp ring **32** of the slip joint clamp subassembly **30**. This can be accomplished via a jack bolt **77**, which is coupled to the U-clamp pad **73** by, for example, a cap screw **78**. The forces thus imparted on the U-clamp pad **73** and the clamp ring **32** coupled with the force applied by the inlet mixer wedge **63** onto the slip joint inboard clamp ring **31** provide the necessary friction to maintain the slip joint clamp **30** in the desired position on the inlet mixer **5**.

[0038] FIG. **12** shows a cross-sectional view illustrating a preferred spatial arrangement of the U-clamp pad **73** in contact with the outboard clamp ring **32** of the slip joint clamp **20**.

[0039] Optionally, in lieu of relying solely on friction to maintain the slip joint clamp **30** in position on the jet pump inlet mixer **5**, stop bolts **75** and accompanying stop bolt keepers **76** can be employed. As illustrated in FIG. **13**, these stop bolts **75** can be inserted into blind holes that are machined into the inlet mixer **5**.

[0040] This disclosed jet pump stabilizer design restricts coolant leakage at the jet pump slip joint **12**, accommodates thermal expansion at the slip joint **12**, provides additional lateral support to the inlet mixers **5**, accommodates misalignment between the riser pipe **2** and adjacent inlet mixers **5**, and can be installed without removal of any jet pump assembly components, such as the inlet mixer **5**.

[0041] While the preferred embodiments of the present invention have been described above, it should be understood that they have been presented by way of example only, and not of to limitation. It will be apparent to persons skilled in the relevant art that various changes in form and detail can be made therein without departing from the spirit and scope of the invention. Thus the present invention should not be limited by the above-described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents. Furthermore, while certain advantages of the invention have been described herein, it is to be understood that not necessarily all such advantages may be achieved in accordance with any particular embodiment of the invention. Thus, for example, those skilled in the art will recognize that the invention may be embodied or carried out in a manner that achieves or optimizes one advantage or group of advantages as taught herein without necessarily achieving other advantages as may be taught or suggested herein.

What is claimed is:

1. A stabilizer for a jet pump having an inlet riser pipe, two mixers, and two diffusers, a first of the mixers being connected to a first of the diffusers by a first slip joint, and a second of the mixers being connected to a second of the diffusers by a second slip joint, the stabilizer comprising:

a clamp body configured to be affixed about the jet pump riser pipe;

two U-clamps, each of said U-clamps being coupled to said clamp body, a first of said U-clamps configured to be positioned about the first jet pump mixer, a second of said U-clamps configured to be positioned about the second jet pump mixer;

two clamp rings, a first of said clamp rings configured to be positioned about the first jet pump mixer and retained by said first U-clamp, a second of said clamp rings configured to be positioned about the second jet pump mixer and retained by said second U-clamp; and

two sealing rings, a first of said sealing rings coupled to said first clamp ring, a second of said sealing rings coupled to said second clamp ring.

2. The stabilizer of claim **1**, further comprising two wedges, each of said wedges being coupled to said clamp body, a first of said wedges positioned adjacent the first jet pump mixer, a second of said wedges positioned adjacent the second jet pump mixer.

3. The stabilizer of claim **2**, wherein said first clamp ring is further configured to be positioned adjacent to and in contact with said first wedge, and said second clamp ring is further configured to be positioned adjacent to and in contact with said second wedge.

4. The stabilizer of claim **3**, wherein said first wedge is adjustable to impart a variable force against the jet pump riser pipe and the first jet pump mixer, and said second wedge is adjustable to impart a variable force against the jet pump riser pipe and the second jet pump mixer.

5. The stabilizer of claim **1**, wherein said first sealing ring is moveably coupled to said first clamp ring, said first sealing ring being biased away from said first clamp ring and into contact with the first jet pump diffuser.

6. The stabilizer of claim **1**, wherein a first subassembly defined by said first U-clamp, said first clamp ring, and said first sealing ring includes two sealing members.

7. The stabilizer of claim **6**, wherein a first of said sealing members is positioned to be in contact with the jet pump on a first side of the first slip joint and a second of said sealing members is positioned to be in contact with the jet pump on a second side of the first slip joint,

8. The stabilizer of claim **7**, wherein said first sealing member is coupled to said first clamp ring and said second sealing member is coupled to said first seal ring.

9. The stabilizer of claim **6**, wherein said sealing members are formed of a malleable metal material.

* * * * *