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(54) **Title**: COMPRESSION SEALING APPARATUS AND METHOD FOR USE OF THE SAME

(57) **Abstract**: A compression sealing apparatus for efficiently repairing leaks in pipes and storage/containment structures. The apparatus includes an externa! compression member, an internal compression member, and a compression mechanism that is operative to draw the compression members towards each other to clamp the wall containing the leak between the compression members. Sealing can be enhanced by injecting sealant material through the apparatus to sea! a cavity formed by the apparatus. The compression seal apparatus can also include an expandable insert plug that is installed in a hole in the wall of the pipe or storage/containment structure.

COMPRESSION SEALING APPARATUS AND METHOD FOR USE OF THE SAME

PRIORITY INFORMATION

This application is being filed as a PCT International Patent Application in the name of Windsor Innovations, Ltd. and claims the benefit of US Provisional Application Number 61/059393 filed June 6, 2008 entitled COMPRESSION SEALING APPARATUS AND METHOD FOR USE OF THE SAME, which is hereby incorporated by reference in its entirety.

FIELD

This disclosure relates generally to pipe and fluid storage/containment structures repair. More particularly, this disclosure relates to a mechanical sealing apparatus for efficiently repairing pipe and fluid storage/containment structure having a leakage gap in a wall thereof.

BACKGROUND

Piping and storage/containment systems are critical to industry in the conveyance, operations and storage of fluid material. Industry spends billions of dollars every year worldwide repairing pipes that carry critical fluids that are leaking as a result of failures and damage that may be caused by mechanical harm, corrosion, erosion, damaged coatings, failing insulation, adverse operating conditions, weather, and so on. Shutting down of systems dependent upon these leaking pipes may not be immediately feasible or possible. The decision to shut a critical system down to repair and/or replace a pipe segment is influenced by, for example, cost considerations, impact on a production cycle, impact on critical life support systems, socioeconomic impact, and lack of immediate resources to repair in a timely manner.

As an example, peak construction of pipelines for conveying gas and liquid petroleum occurred 30-40 years ago, with many constructed prior to World War II still being in service. As a result of their age, billions are spent maintaining the integrity of the aging pipeline infrastructures. Pipeline repair considerations may include the environment such as undersea or submerged in a body of water, labor, material, equipment requirements, available capital, economic return, repair life, pipeline downtime, and so forth. Regardless, pipeline repair remains an especially important concern of the industry since it can have a significant impact on pipeline productivity.

Current approaches for repairing a pipe include external clamping mechanisms which are limited by diameter and require access to the whole outside diameter surface of the pipe; welding, which may not be feasible due to the material being conveyed or stored; and insertion of sleeves and liners which require access to the inside of the pipe or storage system and their being shut down and evacuated.

With respect to fluid storage/containment systems, such as a fluid storage tank, standard practice is to drain the tank of the fluid at least to a level below the area needing repair before effecting the repair. If the area needing repair is near the base of the tank, this means draining nearly the entire tank.

For these and other reasons, there is a substantial need for providing a practical and effective procedure for sealing a leakage gap in fluid piping or storage/containment systems without disrupting their operations.

SUMMARY

A mechanical compression sealing apparatus and method of use are described that can be used for sealing a leakage gap, such as a hole, crack or break, in a wall of a pipe or a storage/containment system. The sealing apparatus can be installed while the pipe or storage/containment system are in use, e.g. while fluid is flowing through the pipe or fluid is in the storage/containment system, providing a practical and effective procedure for sealing the leakage gap in the fluid piping or storage/containment system without disrupting operations of the system. The compression sealing apparatus can be used for sealing in many kinds of systems that convey or store various kinds of materials, have various conveyance or storage pressures, and are located in various environments including undersea/underwater, above-ground and below ground systems.

In one embodiment, a compression sealing apparatus for sealing a leakage gap in a wall of a pipe or storage/containment structure includes an external compression member configured to substantially cover an outer surface area that is greater than an area of the leakage gap, an internal compression member configured to substantially cover an inner surface area that is greater than an area of the leakage gap, and a compression mechanism for driving together the external and internal compression members to clamp the pipe and/or storage/containment structure containing the leakage gap therebetween. The compression members form an enclosed cavity into which a sealing material is injected for sealing the cavity to prevent fluid leakage from the pipe or storage/containment structure.

In some applications, for example where internal or external pressures are low enough, the external compression member is optional. Instead, the compression mechanism includes a flanged plug that can be used to help clamp the internal compression member to the inside surface of the pipe or storage/containment structure.

In one embodiment, the compression mechanism comprises a threaded shaft. In another embodiment, the compression mechanism also includes an expandable compression insert plug having a plurality of side wings and a base insert threaded onto the threaded shaft and having a horizontal dimension larger than that of the vertical member. The side wings of the compression insert plug form a cavity having an inverted conical shape. Upon rotation of the threaded shaft the base insert is drawn upward into the inverted conical cavity which expands the side wings of the compression insert plug thereby pressing the wings against an inside surface of the leakage gap to help reinforce the leakage gap. In this embodiment, the leakage gap is a hole, preferably an inverted conically-shaped hole, that is cut in the wall of the pipe or storage/containment structure around the area needing repair. The expandable compression insert plug can be implemented together with the internal and external compression members, or separately therefrom.

DESCRIPTION OF THE DRAWINGS

The drawings, which are not necessarily drawn to scale, illustrate generally, by way of example, but not by way of limitation, various embodiments discussed in this application.

Fig. 1 is an illustration of one embodiment of a compression sealing apparatus in a non-deployed state.

Fig. 2 is an illustration of the compression sealing apparatus of Figure 1 after being inserted through a leakage gap in a wall of a pipe or storage/containment structure.

Fig. 3 is an illustration of the compression sealing apparatus with an internal compression member being partially unfolded.

Fig. 4 is an illustration of the compression sealing apparatus with the internal compression member being completely unfolded.

Fig. 5 is an illustration of the compression sealing apparatus with the internal compression member being drawn towards an inner surface of the wall.

Fig. 6 is an illustration of the compression sealing apparatus installed in sealing position prior to injection of sealant.

Fig. 7 is an illustration of another embodiment of a compression sealing apparatus that includes a compression insert plug that has a barbed outside surface.

Fig. 8 is an illustration of yet another embodiment of a compression sealing apparatus that includes an expandable compression insert plug that has a plurality of side wings and an inverted cone shape base insert.

Fig. 9 is an illustration of still another embodiment of a compression sealing apparatus that includes an expandable compression insert plug that has a plurality of side wings and a ball shape base insert.

Figure 10 illustrates an embodiment of a compression sealing apparatus with a compression mechanism using a rivet.

DETAILED DESCRIPTION

In the following detailed description, reference is made to the accompanying drawings which form a part hereof, and in which is shown, by way of illustration, specific embodiments in which the inventive concepts may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention, and it is to be understood that the embodiments may be combined or used separately, or that other embodiments may be utilized and that structural and procedural changes may be made without departing from the spirit and scope of the inventive concepts. The following detailed description provides examples, and the scope of the present invention is defined by the claims to be added and their equivalents.

The terms "above," "on," "under," "top," "bottom," "up," "down," "horizontal," and "vertical" and the like used herein are in reference to the relative positions of the compression sealing apparatus, and its constituent parts, in use when oriented as in Figs. 1-9.

Compression sealing apparatuses and methods are described herein in relation to applications involving sealing a leakage gap, e.g., holes, cracks, breaks and the like, in a wall of a pipe or storage/containment structure. The compression sealing apparatuses and methods will be described in an application involving sealing a leakage gap in a wall of an undersea petroleum pipeline that conducts petroleum. However, it is to be understood that the present apparatuses and methods may be employed in other applications, including, but not limited to, above and below ground pipe or storage/containment structures, and submerged storage/containment structures. It will also be understood that the apparatuses and methods described herein may be employed in pipe or storage/containment systems that are not conducting or holding fluid. In addition, the pipe or storage/containment structures can be used to conduct or hold materials other than fluids. For sake of convenience, pipes and storage/containment structures can be referred to collectively as material containers.

Fig. 1 is an illustration of one embodiment of a compression sealing apparatus 20 in a non-deployed state. The compression sealing apparatus 20 includes an external compression member 22, an internal compression member 24, and a compression mechanism 25 that is operative to draw the compression members 22, 24 towards each other. The apparatus 20 generally has a longitudinal axis 90 which in the embodiment illustrated in Figure 1 is generally vertical.

The sealing apparatus 20 is designed to seal a leakage gap 42 in a wall 40 of a pipe. The leakage gap 42 can be any hole, crack, break and the like in the wall 40 of the pipe through which fluid within the pipe can leak, and which is large enough to allow installation of the sealing apparatus 20. For sake of convenience, the leakage gap 42 will be described as being a hole. The hole can be an existing hole in the pipe, or the hole can be cut into the pipe around the area of an existing hole or gap so as to make the existing hole or gap large enough to receive the apparatus 20. In the case of an undersea petroleum pipeline, the hole can be cut using a water jet cutter. The hole will be described herein as being cut in the wall 40.

With reference to Figures 1-2, the external compression member 22 comprises a rigid, plate-like structure that is curved to conform to the contour of an outer surface 92 of the wall 40. The size of the external compression member 22 is substantially greater than the outer area of the hole 42 so that the compression member 22 covers an area of the outer surface 92 that is greater than the area of the hole 42. The compression member 22 includes an outer metal plate 70 and an inner gasket layer 72 for sealing with the outer surface 92. The inner gasket layer 72 can be made of any material that is suitable for sealing with the outer surface 92, for example, an elastomer. It will be understood that the external compression member 22 is made of materials that are compatible with the environment with which it is located during use and compatible with the material of the wall 40. For example, for undersea use, the materials of the plate 70 and gasket 72 would not corrode in salt water or initiate corrosion on the surface of the wall 40 as a result of chemical or electrolytic reaction.

With reference to Figures 1-6, the internal compression member 24 includes a plurality of generally rigid spring arms 54 that radiate outwardly from a central connection point near the axis 90. The arms 54 are connected to the central connection point in such a manner as to allow the spring arms to be pivoted to a folded position shown in Figures 1-2 and provide a resilient bias tending to pivot the arms to an unfolded position shown in Figure 4.

A generally circular, foldable plate structure 27 is connected to the arms 54 which in use is sized to cover an area of an inner surface 94 of the wall 40 that is greater than the inner area of the hole 42. The plate structure 27 comprises a first layer 74 and a second gasket layer 76 for sealing with the inner surface 94. In one embodiment, the first layer 74 is made of a wire mesh or cloth such as stainless steel which is coated with a conformal elastomeric material to make it air and fluid impervious, while retaining its flexibility and assisting in the seal as it is compressed against the gasket material 76. Similar to the gasket layer 72 of the external compression member 22, the gasket layer 76 can be made of any material that is suitable for sealing with the inner surface 94, for example an elastomer. As shown in Figures 1-3, the plate structure 27 is designed to fold with the spring arms 54 to the folded position, and unfold under the resilient bias force provided by the spring arms during deployment.

Thus, the compression member 24 with the spring arms 54 and plate structure 27 resembles and functions somewhat like an umbrella, with a folded position shown in Figures 1-2 to facilitate insertion of the apparatus 20 through the hole 42, and an unfolded position shown in Figure 4 which is achieved during deployment as a result of the resilient bias of the spring arms 54. As shown in Figures 1-3, a sheath 50 surrounds the compression member 24 to maintain the compression member in its folded state. The sheath 50 must first be removed to allow deployment of the compression member 24 to its unfolded state. Sheath removal can be performed in any manner one finds suitable, including manually, mechanically or automatically. One way to achieve sheath removal is to use compresses air as discussed further below. Preferably, the sheath is made of material that is degradable in the fluid that is within the pipe. For example, the sheath 50 can be made of thin walled cellulose with perforations. Therefore, when the apparatus 20 is installed through the hole 42 as shown in Figure 2, the sheath 50 can be broken apart by using compressed air as will be discussed below, which will remove the sheath and allow the compression member 24 to deploy. The remnants of the sheath will then degrade in the fluid in the pipe.

The compression mechanism 25 comprises a threaded shaft 26 having one end connected to the center of the compression member 24 and its opposite end extending through and above the compression member 22. As shown in Figures 4 and 6, the threaded shaft 26 is not threaded near its bottom end. A compression insert plug 36 is disposed around the shaft 26 and is disposed through a hole in the compression member 22. The plug 36 has an outer shape, for example circular, that generally corresponds to the shape of the hole 42. Further, as shown in Figures 2-4, the length of the plug 36 is generally less than the length of the hole 42 between the inner 94 and outer surface 92 and the thickness of the compression member 22.

The plug includes a flange 38 at its upper end having a dimension that is larger than the outer surface of the compression insert plug 36. The dimension of the flange 38 is chosen so that the flange 38 engages the upper surface of the compression member 22 so as to force the compression member 22 downward during installation. With reference to Figure 6, a plurality of vent holes 58 are formed in the plug 36 that extend from the base thereof upwardly to and through the flange 38. The vent holes 58 allow water and/or oil to be evacuated from a space formed by the apparatus when a pressured gas is injected as discussed below. In addition, a nut 34 is threaded onto the upper end of the shaft 26 for use in driving the compression members together when the nut 34 is rotated using a suitable tool, for example a wrench or pneumatic socket.

With reference to Figure 6, the shaft 26 includes a fluid passageway 56 extending longitudinally therethrough from its top end to near its bottom end generally parallel to the axis

90. At the top end of the shaft 26 a valve mechanism 80 controls the flow of fluid into the fluid passageway 56. A plurality of holes 52 are formed near the bottom end of the shaft 26 that lead from the passageway 56 to the exterior of the shaft 26. The passageway 56 and holes 52 allow communication of fluids through the shaft 26 to the bottom thereof and to the exterior of the shaft near the bottom for a purpose which will be described below.

With reference now to Figures 1-6, the use of the apparatus 20 will now be described. To aid in the description, the compression sealing apparatus 20 will be described as including a proximal end 28 and a distal end 30 that includes the compression member 24 and the sheath 50.

First, if the gap is not sufficient to allow installation of the apparatus, the hole 42 is prepared by suitably forming the hole to the desired size. As shown in Figure 2, the distal end 30 of the apparatus 20 is extended through the hole 42 until the outer compression member 22 rests on the outside surface 92 of the wall 40. The components of the apparatus are sized such that at this position, the entire internal compression member 24 extends beyond the inner surface 94 of the wall 40 to enable the compression member 24 to unfold.

With reference to Figure 3, a pressurized gas source is connected to the shaft 26 to inject pressured gas through the shaft 26 and out the holes 52 at the base of the shaft. The gas exiting the holes 52 acts on the central region of the compression member 24 causing a force to open the compression member. The pressure of the gas acting on the compression member 24 is sufficient to break apart the perforated cellulose sheath 50 and any degradation of the sheath caused by the fluid in the pipe. Once the sheath breaks loose, the compression member 24 continues to unfold under the bias of the spring arms 54 to the unfolded position in Figure 4. The compressed gas flow can be stopped once the sheath breaks away and the compression member 24 unfolds.

With reference to Figure 5, the compression mechanism 25 is then actuated to begin drawing the compression members 22, 24 toward each other. This is achieved by rotating the nut 34, which draws the base end of the shaft 26 upward. Since the compression member 24 is connected to the base of the shaft 26, the compression member 24 is drawn upward. At the same time, the flange 38 on the plug 36 keeps the compression member 22 in place. As the compression mechanism 25 continues to be actuated, the compression members 22, 24 are drawn closer and closer together. As illustrated in Figure 5, the bottom compression member 24 is initially concave upward. As the compression member 24 is advanced beyond the position shown in Figure 5, the perimeter edge of the compression member engages the inner surface 94 of the wall, flattening the compression member and ultimately bending the compression member 24 to conform to the curvature of the inner surface 94 as shown in Figure 6.

Figure 6 shows the apparatus 20 installed with the compression members 22, 24 fully drawn towards each other and clamping the wall therebetween. The sealing action of the compression members on the outer and inner surfaces of the wall forms a sealing cavity 82 the majority of which is formed by the hole 42, any spaces left between the compression members and the wall, and other gaps and crevices that may remain.

Depending upon the environment in which the pipe is located and the pressure of the fluid in the pipe, the sealing action by the compression members 22, 24 of the apparatus may be considered to be sufficient to prevent fluid leakage. Alternatively, sealing of the apparatus 20 can be enhanced by injecting a fast hardening sealant material into the sealing cavity. In addition to sealing, the sealant material also provides strength to the apparatus 20 and to the wall of the pipe which is already degraded in some form.

It will be understood that the sealant material can be any material that is compatible with material of pipe, hardens quickly and has high shear strength. For example, a metal epoxy can be used as a sealant material for metal pipes. In one embodiment, a material can be injected into the sealing cavity for cleaning the internal surfaces before the sealant material is injected. The cleaning material can also prep the walls of the cavity to provide better adherence and bonding of the sealant material to the cavity walls.

To prepare the cavity for injection of the sealant material, compressed air is introduced through the shaft 26. The compressed air exits out the holes 52 at the base of the shaft which are disposed in the cavity. The compressed air forces out any water that is in the cavity, the water exiting through the vent holes 58 in the plug 36. The sealant material is then injected under pressure through the passageway 56 in the shaft 26. The sealant material fills up the cavity 82, including any spaces left between the compression members and the wall, any spaces between the hole 42 and the plug 36, and other gaps and crevices that may remain. The sealant material also fills up the vent holes 58 in the plug as well as the passageway 56 and the holes 52 in the shaft 26, sealing them to prevent leakage from the pipe.

Figure 7 illustrates an alternative embodiment of a compression sealing apparatus 220 using a compression insert plug 236 that has a barbed outside surface 237. This embodiment is good for medium and low pressure applications. The apparatus 220 includes an exterior compression member 222, an internal compression member 224, and a threaded shaft 226 that are similar in construction and operation to the compression member 22, the compression member 24 and the threaded shaft 26 discussed above for Figures 1-6. The insert plug 236 also has a flange 238 that covers a much greater area of the exterior compression member 222 than the flange 38 in Figures 1-6. This enlarged flange 238 adds strength to the external compression member 222. This larger size of the flange 238 is optional. An inverted conical hole 242 is formed in the wall 240, for example by using a water jet cutter.

After the internal compression member 224 is inserted through the hole and the compression members 222, 224 compressed in the manner discussed above for Figures 1-6, a sealant material is injected into the cavity. For low pressure applications, a straight-sided hole such as illustrated in Figures 1-6, can be used. The barbs on the plug 236 provide a mechanism for the sealant material to adhere to and add shear strength against pressure exerted by the fluid within the pipe. This can help provide extra strength to the sealing apparatus and is more economical compared to the embodiments in Figures 8 and 9 which are intended for use in higher pressure applications.

Figure 8 illustrates another alternative embodiment a compression sealing apparatus 320 using a compression insert plug 336 that is expandable such that it can be compressed against the inside wall of the hole 342 to reinforce the hole. In particular, the apparatus 320 includes an external compression member 322, an internal compression member 324 and a threaded shaft 326 that are similar in construction and operation to the compression member 22, the compression member 24 and the threaded shaft 26 discussed above for Figures 1-6.

In the embodiment of Figure 8, an inverted conical hole 342 is formed in the wall 340, for example by using a water jet cutter. The compression insert plug 336 has a generally truncated conical shape formed by a plurality of circumferentially abutting but separate wings 337. Each wing 337 includes an inner surface that forms a cavity of an inverted conical shape and an outer surface that generally matches the angle of the hole 342. The inner surfaces of the wings 337 have an angle α relative to the axis 390 which is in a range of about 3.0 to about 10.0 degrees, more preferably about 3.0 to about 5.0 degrees, dependent upon the thickness of the wall 40 of the pipe. The wings 337 of the plug 336 have an initial unexpanded configuration allowing the apparatus 320 and the plug 336 to be inserted through the hole 342. In the unexpanded configuration, the largest outer diameter of the compression insert plug 336 is slightly smaller than the smallest diameter (i.e. the exterior opening) of the hole 342 to enable the plug 336 to be inserted into the hole 342.

A truncated conical insert 380 is threaded onto the shaft 326. The insert 380 is generally solid to provide reinforcement to the wings 337 during use. The outer surface of the insert 380 has an angle β relative to the axis 390 where β is substantially equal to the angle α of the inner surface of the wings 337.

Figure 8 illustrates the apparatus inserted into the hole 342 with the internal compression member 324 unfolded and prior to the point where the compression members 322, 324 are in their maximum compression positions. Continued rotation of the nut 334 draws the compression member 324 further upward. At the same time, the insert 380 is drawn upward relative to the plug 336. As the insert 380 is drawn upward, the outer surface of the insert 380 engages the inner surfaces of the wings 337, causing the wings to expand outward into engagement with the inner sloped surface of the hole 342. At the fully installed position of the apparatus 320, the compression members 322, 324 will be sealed with the surfaces of the wall 340, and the insert 380 is fully within the plug 336 with the wings 337 engaged against the inner surface of the hole 342. The expandable plug 336 helps reinforce the hole 342, as well as providing sealing between the wings and the hole, while the insert 380 reinforces the wings 337 and prevents their collapse.

Figure 9 illustrates another embodiment of a compression sealing apparatus 420 with an expandable plug 436 in the form of split collets. In this embodiment, expansion of the plug 436 is caused by a ball 480 that is fixed to the threaded shaft.

The embodiments in Figures 8 and 9 can be implemented with or without the use of sealant material as discussed above. In addition, in certain embodiments the external compression member is optional whereby adequate sealing is achieved by the internal compression member only, or by the combination of the internal compression member together with one or more of the sealant material and the expandable plug.

In one embodiment, a rivet can be used to drive together and compress the compression members 22, 24 in place of the compression mechanism 25 using the threaded shaft 26. With reference to Figure 10, a compression mechanism 525 is illustrated that includes a rivet 511. After the internal compression member 524 is inserted through the hole 542 and fully deployed, the upper end of the rivet 511 is compressed and deformed to draw the internal compression member 524 upward to the inner surface 594 by a suitable rivet installation tool, for example, a hydraulic rivet tool. The upper end of the rivet 511 is then expanded to form a head that is bigger than the hole 542. By using a rivet as a compression mechanism, the time required for driving the compression members 522, 524 together is significantly reduced. If the pipe is in operation, this reduction in time reduces spillage. Further, this will provide better compression control than using the threaded shaft 26. Rivet mechanisms other than that illustrated in Figure 10 can be used, including but not limited to blind rivets. The rivet is also preferably formed with a fluid passageway as discussed above for Figures 1-6 to allow introduction of compressed gas clearing the cavity and injection of sealant material into the cavity.

The embodiments disclosed in this application are to be considered in all respects as illustrative and not limitative. The scope of the invention is indicated by the appended claims rather than by the foregoing description; and all changes which come within the meaning and range of equivalency of the claims are intended to be embraced therein.

CLAIMS

1. A mechanical compression sealing apparatus for sealing a leakage gap in a wall of a containment unit in a containment system without disrupting operations of the system, comprising:

an external compression member sized to substantially cover an outer surface area of the wall, the outer surface area being greater than an area of the leakage gap on an outer surface of the wall;

an internal compression member sized to substantially cover an inner surface area of the wall, the inner surface area being greater than an area of the leakage gap on an inner surface of the wall; and

a compression mechanism operative to draw the external and internal compression members toward each other to clamp the wall containing the leakage gap therebetween,

wherein the compression members and the wall containing the leakage gap form an enclosed cavity to seal the leakage gap.

2. The mechanical compression sealing apparatus according to claim 1, wherein a sealing material is injected into the cavity for sealing the cavity to prevent fluid leakage from the containment unit.

3. The mechanical compression sealing apparatus according to any of claims 1-2, wherein the external compression member includes an outer plate for compressing against the outer surface of the wall containing the leakage gap, and an inner sealing layer for sealing with the outer surface, the external compression member being shaped to conform to a contour of the outer surface.

4. The mechanical compression sealing apparatus according to any of claims 1-3, wherein the internal compression member includes a foldable plate, and a biasing mechanism for biasing the foldable plate to deploy to an unfolded state, the biasing mechanism including a plurality of spring arms extending from a central connection point to the foldable plate.

5. The mechanical compression sealing apparatus according to claim 4, wherein the foldable plate includes a flexible, fluid impervious layer for compressing against the inner surface of the wall containing the leakage gap, and a sealing layer for sealing with the inner surface.

6. The mechanical compression sealing apparatus according to any of claims 1-5, wherein the internal compression member further includes a sheath surrounding the internal compression member to maintain the internal compression member in a folded state, the sheath being removable to allow deployment of the internal compression member to an unfolded state.

7. The mechanical compression sealing apparatus according to any of claims 1-6, wherein the leakage gap is an inverted conically-shaped hole cut in the wall of the containment unit in an area needing repair, the inverted conical hole including an inner sloped surface facing the inner surface of the wall.

8. The mechanical compression sealing apparatus according to any of claims 1-7, wherein the compression mechanism includes a plurality of vent holes adapted to allow fluid to be evacuated from the cavity and a fluid passageway adapted to allow fluid to be injected to the cavity.

9. The mechanical compression sealing apparatus according to any claims 1-8, wherein the compression mechanism includes a driving member having a first end connected to the internal compression member and a second end opposite the first end and extending through and beyond the external compression member, and a compression insert plug disposed around the driving member, the compression insert plug having an outer contour generally tracking an inner contour of the leakage gap, the driving member including a threaded shaft and a nut.

10. The mechanical compression sealing apparatus according to claim 9, wherein the compression insert plug includes a flange positioned and sized to engage a surface of the external compression member to compress the external compression member against the outer surface of the wall containing the leakage gap.

11. The mechanical compression sealing apparatus according to any of claims 9-10, wherein the compression insert plug includes a plurality of expandable wings adapted to expand outward into engagement with an inner surface of the leakage gap to reinforce sealing of the leakage gap.

12. The mechanical compression sealing apparatus according to any of claims 1-11, wherein the containment unit is adapted to convey and deliver a material in the containment system.

13. The mechanical compression sealing apparatus according to any of claims 1-12, wherein the external compression member is a flange of the compression insert plug, the flange being positioned and sized to engage the outer surface of the wall containing the leakage gap and form the cavity with the internal compression member and the wall.

14. A method for sealing a leakage gap in a wall of a containment unit in a containment system without disrupting operations of the system, comprising:

providing a mechanical compression sealing apparatus including an external compression member, an internal compression member and a compression mechanism,

extending the internal compression member from an outside of the containment unit into the leakage gap and beyond an inner surface of the wall;

injecting pressured gas through a fluid passageway defined in the mechanical compression sealing apparatus to force to the internal compression member to unfold;

operating a compression mechanism to drive the external and internal compression members toward each other to clamp the wall containing the leakage gap therebetween; and

forming an enclosed cavity by the compression members and the wall.

15. The method for sealing a leakage gap according to claim 14, further comprising injecting a sealant material into the cavity after the cavity is formed.

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Fig. 1

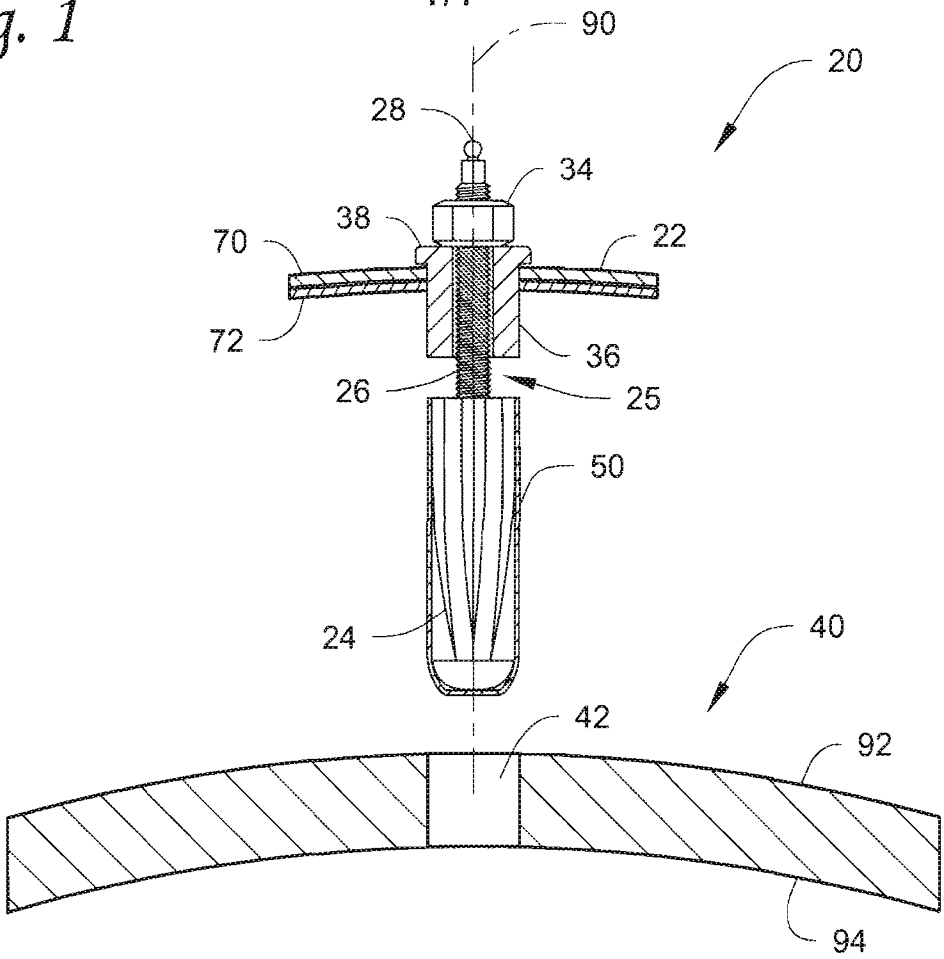

90
20
28
34
38
70
22
72
36
26
25
50
24
40
42
92
94

Fig. 2

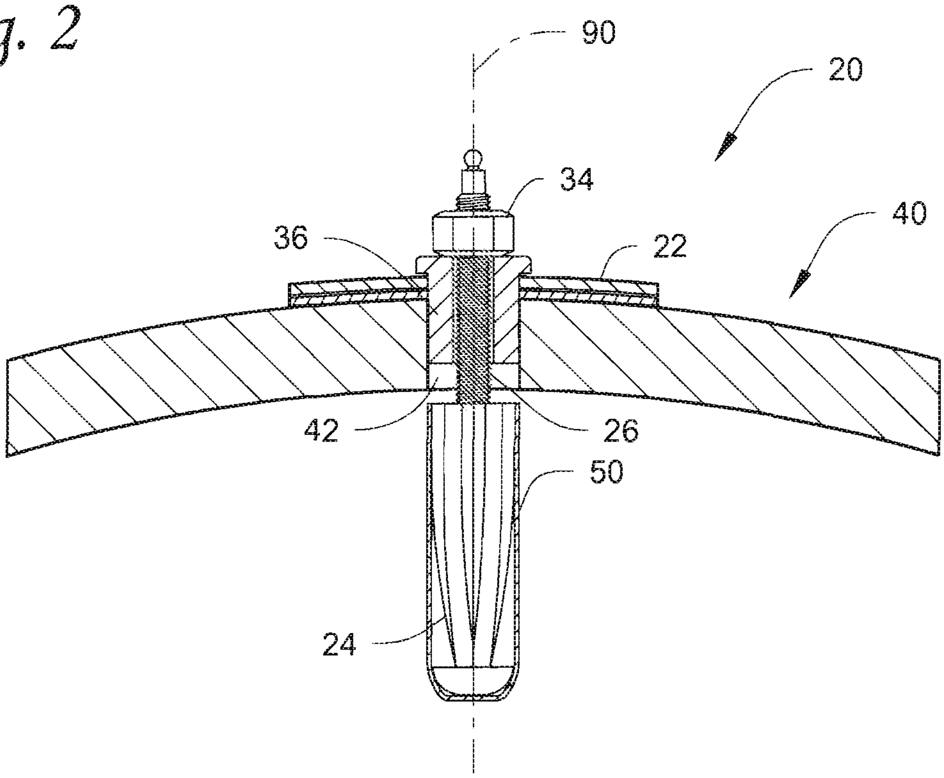

90
20
34
40
36
22
42
26
50
24

Fig. 3

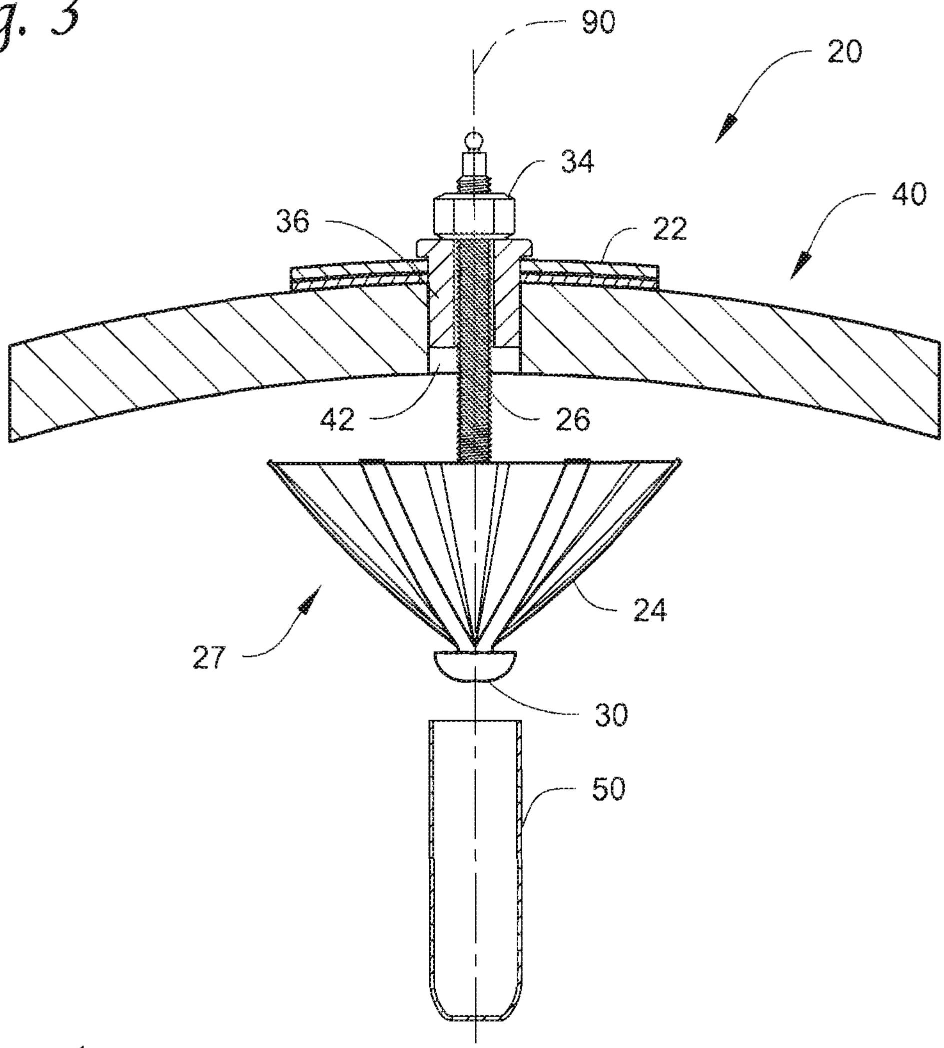


Fig. 4

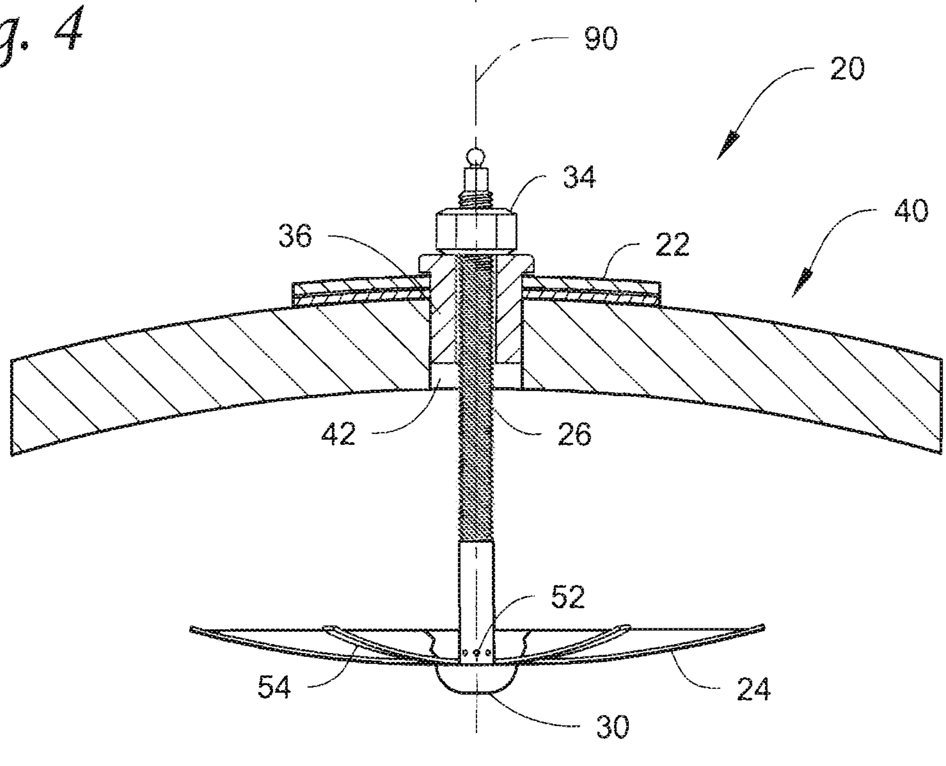
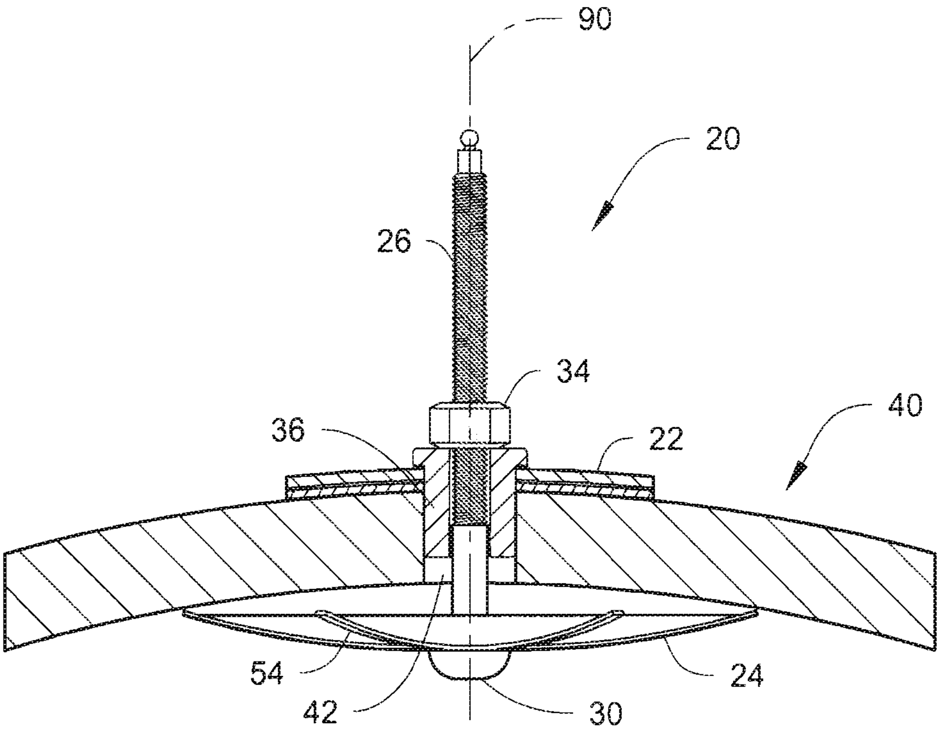


Fig. 5



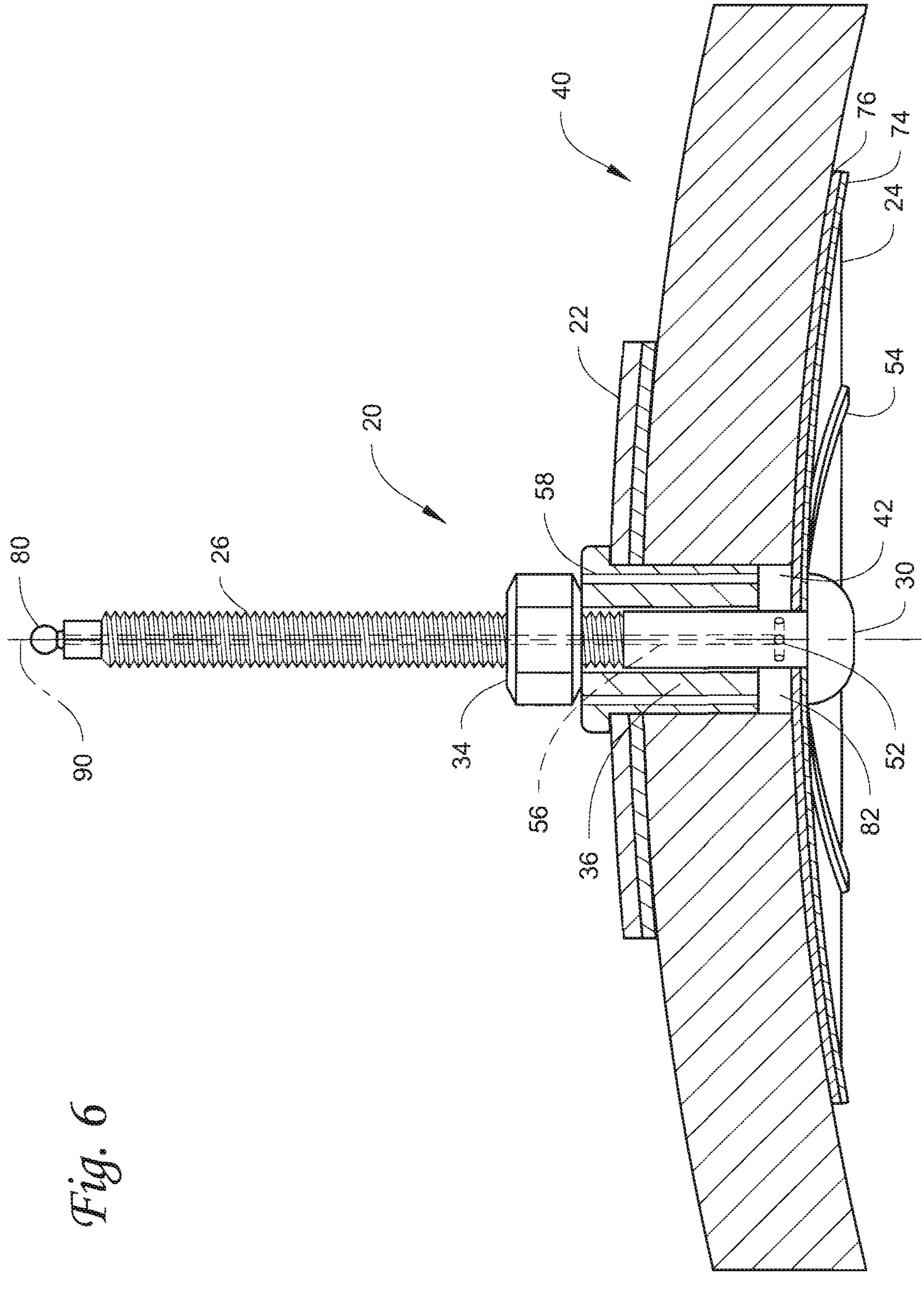
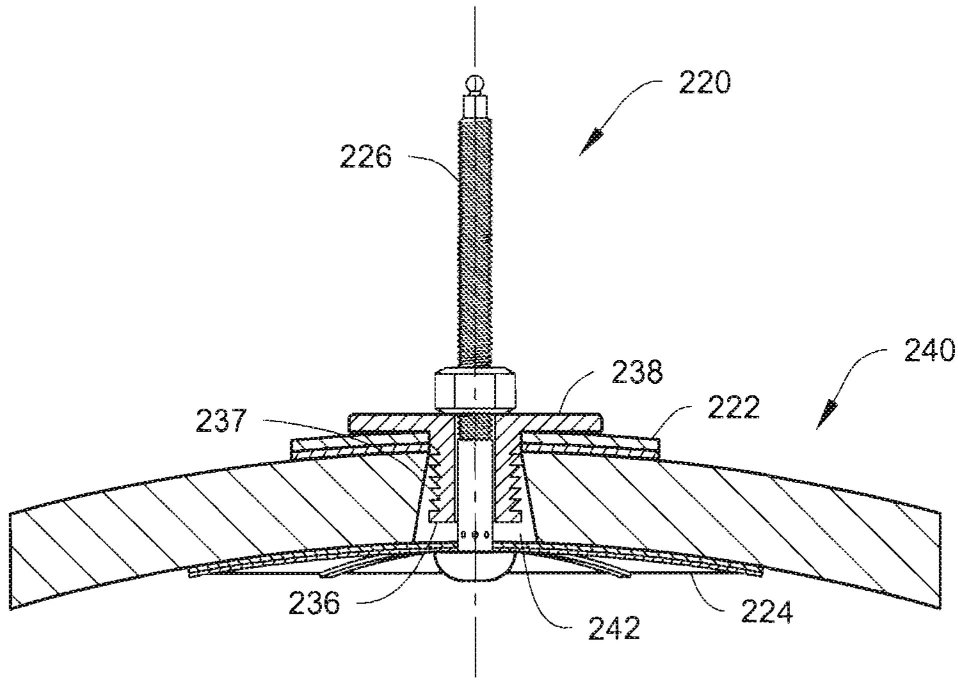


Fig. 6

Fig. 7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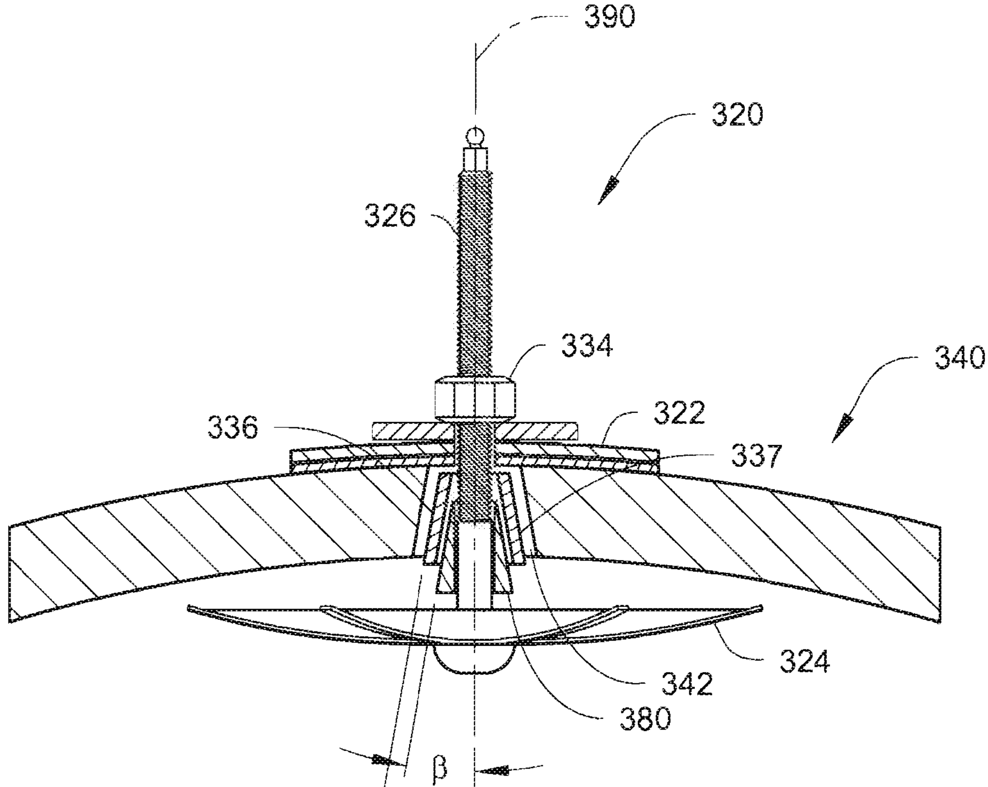
224

Fig. 8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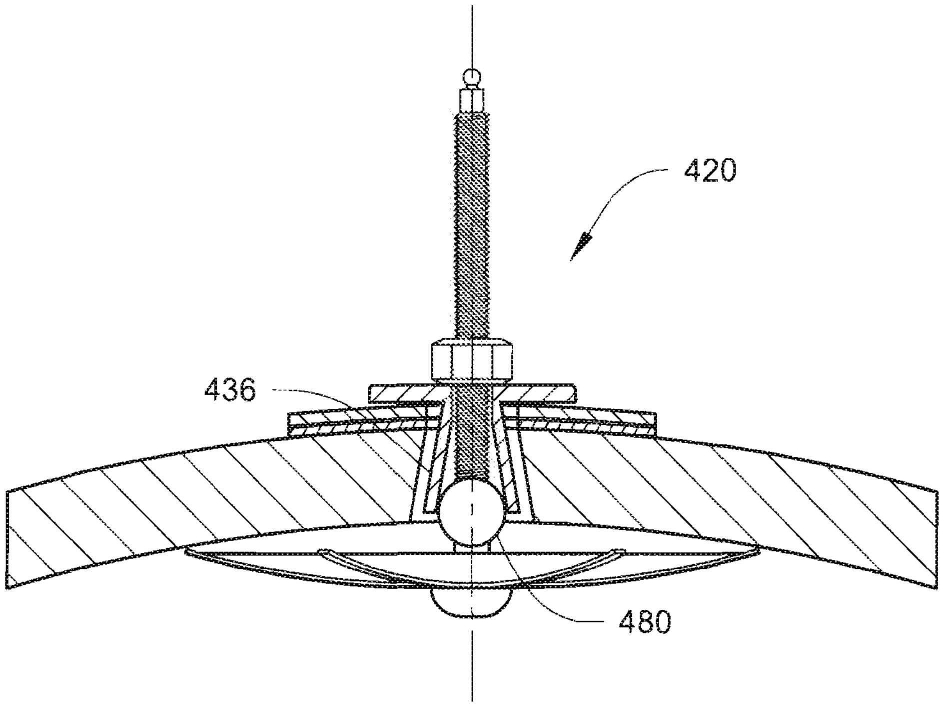
337
324
342
380
β
α

Fig. 9



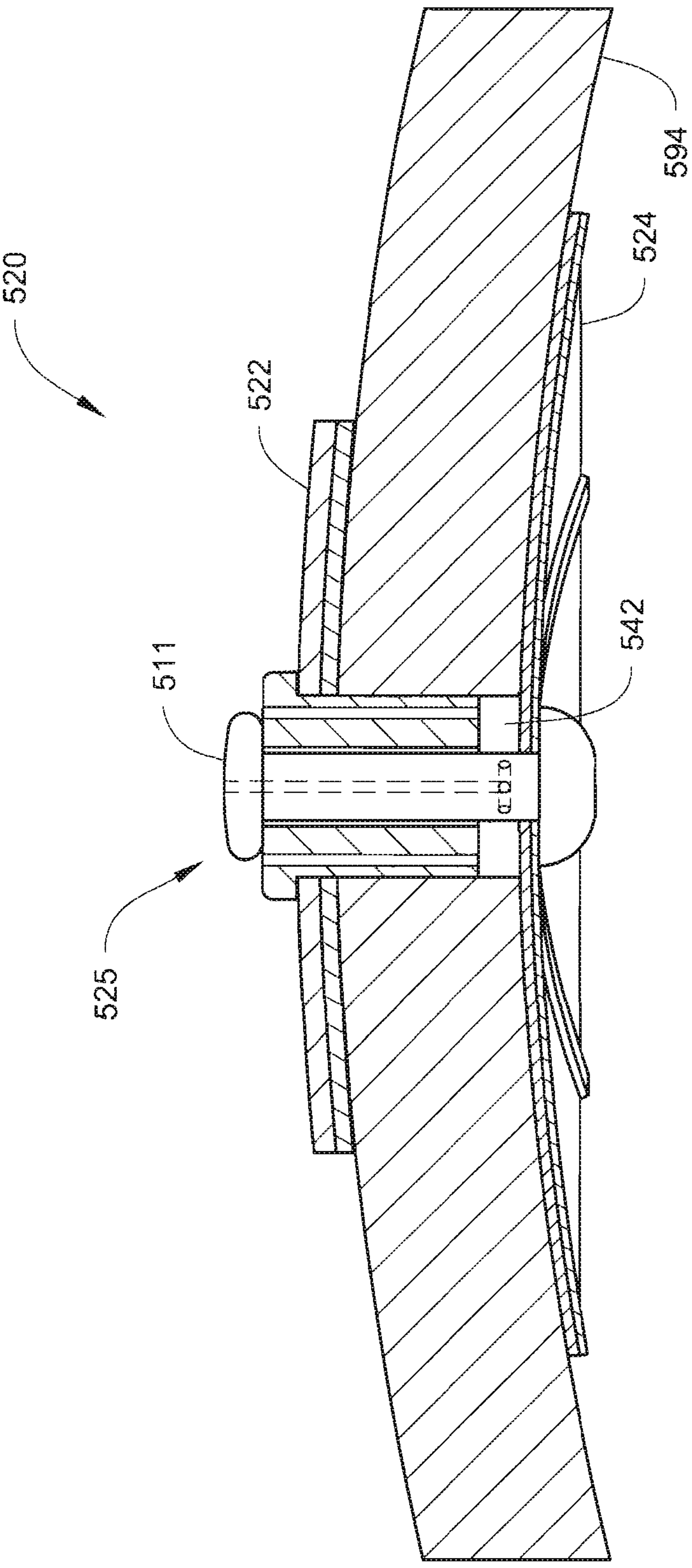


Fig. 10