



(86) Date de dépôt PCT/PCT Filing Date: 2002/05/03

(87) Date publication PCT/PCT Publication Date: 2002/11/14

(45) Date de délivrance/Issue Date: 2006/12/12

(85) Entrée phase nationale/National Entry: 2003/11/03

(86) N° demande PCT/PCT Application No.: US 2002/014146

(87) N° publication PCT/PCT Publication No.: 2002/090709

(30) Priorité/Priority: 2001/05/04 (US09/849,819)

(51) Cl.Int./Int.Cl. *E21B 33/06* (2006.01)

(72) Inventeurs/Inventors:

BERCKENHOFF, MICHAEL WAYNE, US;  
HEMPHILL, EDWARD RYAN, US

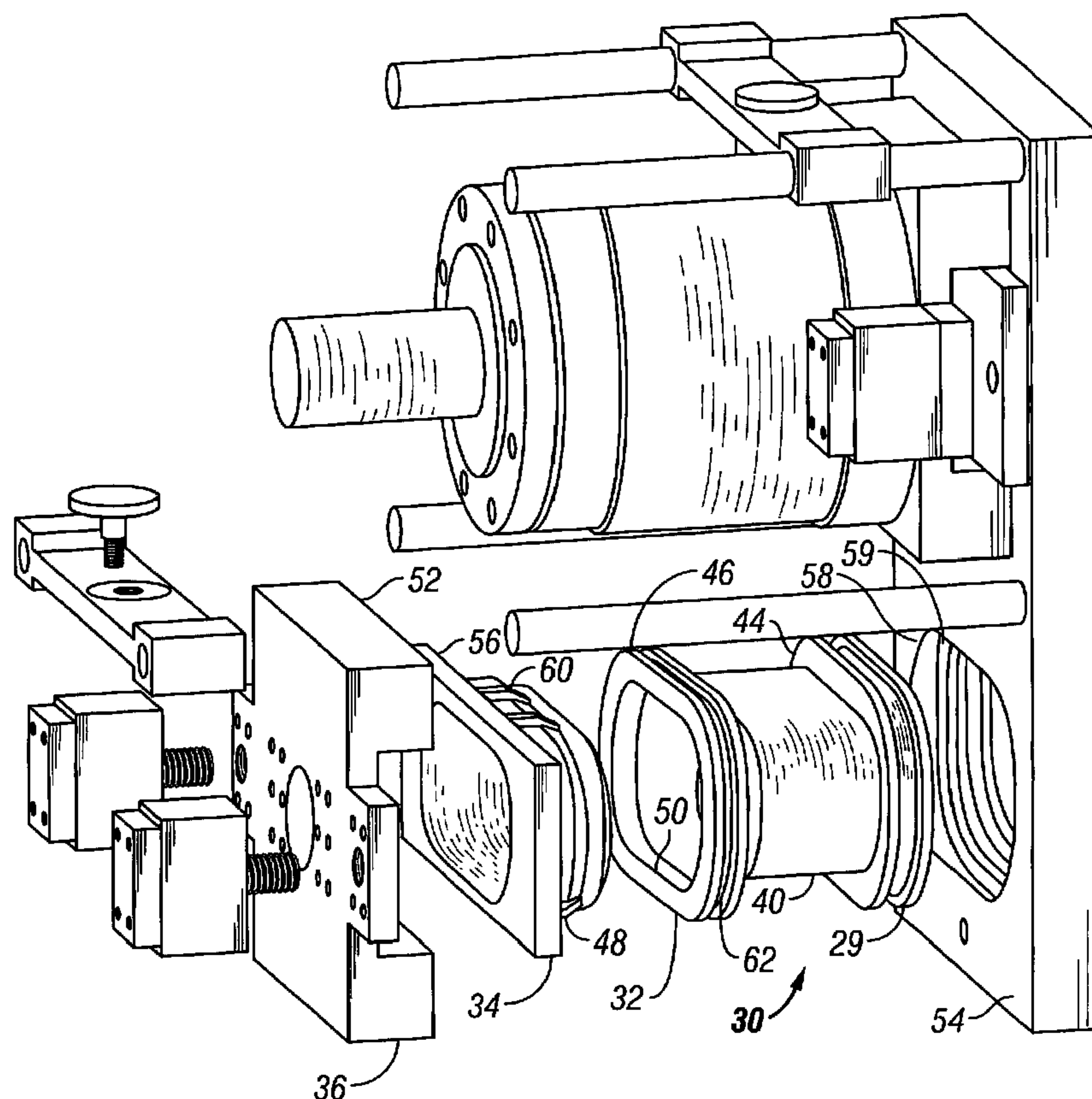
(73) Propriétaire/Owner:

HYDRIL COMPANY, US

(74) Agent: BORDEN LADNER GERVAIS LLP

(54) Titre : COIFFE D'OBTURATEUR DE PUITS A LIBERATION RAPIDE

(54) Title: QUICK RELEASE BLOWOUT PREVENTER BONNET



(57) Abrégé/Abstract:

A bonnet lock mechanism for a blowout preventer (10) that includes a radial lock (32). A radial lock displacement device (34) is coupled to at least one lock actuator (38). The radial lock displacement device (34) is adapted to radially displace the radial lock (32) to lock a bonnet (30) to a body (12) of the blowout preventer (10).

## (12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
14 November 2002 (14.11.2002)

PCT

(10) International Publication Number  
**WO 02/090709 A3**

(51) International Patent Classification<sup>7</sup>: **E21B 33/06**

(21) International Application Number: PCT/US02/14146

(22) International Filing Date: 3 May 2002 (03.05.2002)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:  
09/849,819 4 May 2001 (04.05.2001) US

(71) Applicant: **HYDRIL COMPANY** [US/US]; 3300 North Sam Houston Parkway East, Houston, TX 77032 (US).

(72) Inventors: **BERCKENHOFF, Michael, Wayne**; 30910 Coral Park Drive, Spring, TX 77386 (US). **HEMPHILL, Edward, Ryan**; 10727 Oak Acres Drive, Houston, TX 77065 (US).

(74) Agents: **ROSENTHAL, Alan, D.** et al.; Rosenthal & Osha L.L.P., Suite 2800, 1221 McKinney, Houston, TX 77010 (US).

(81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZM, ZW.

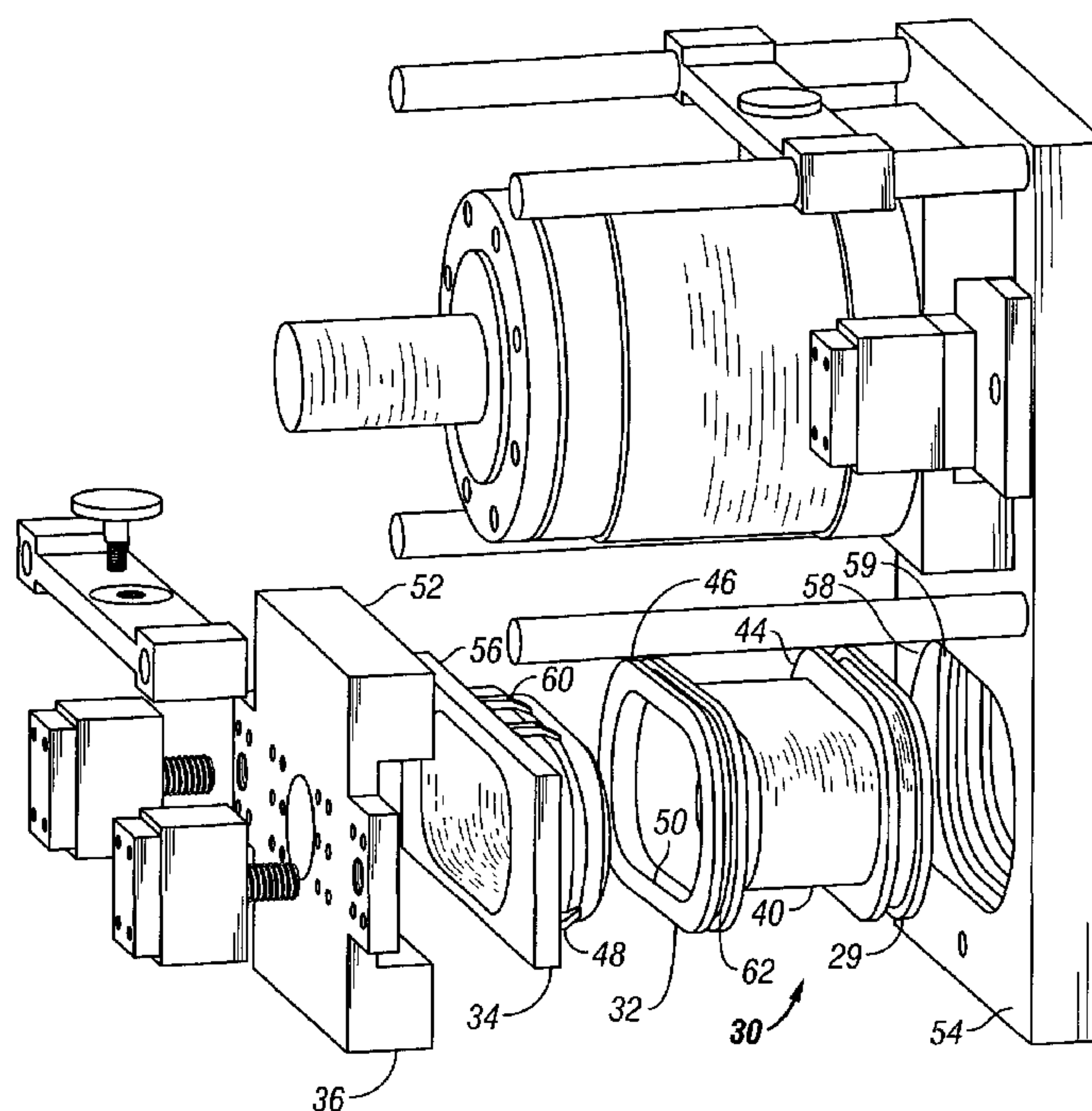
(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

**Declarations under Rule 4.17:**

- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii)) for all designations
- as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii)) for all designations

[Continued on next page]

(54) Title: QUICK RELEASE BLOWOUT PREVENTER BONNET



(57) Abstract: A bonnet lock mechanism for a blowout preventer (10) that includes a radial lock (32). A radial lock displacement device (34) is coupled to at least one lock actuator (38). The radial lock displacement device (34) is adapted to radially displace the radial lock (32) to lock a bonnet (30) to a body (12) of the blowout preventer (10).



**WO 02/090709 A3**

**WO 02/090709 A3**



**Published:**

— *with international search report*

*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

**(88) Date of publication of the international search report:**

12 December 2002

# QUICK RELEASE BLOWOUT PREVENTER BONNET

## Background of Invention

### Field of the Invention

[0001] The invention relates generally to blowout preventers used in the oil and gas industry. Specifically, the invention relates to a blowout preventer with a novel bonnet securing mechanism.

### Background Art

[0002] Well control is an important aspect of oil and gas exploration. When drilling a well in, for example, oil and gas exploration applications, devices must be put in place to prevent injury to personnel and equipment associated with the drilling activities. One such well control device is known as a blowout preventer (BOP).

[0003] Blowout preventers are generally used to seal a wellbore. For example, drilling wells in oil or gas exploration involves penetrating a variety of subsurface geologic structures, or "layers." Each layer generally comprises a specific geologic composition such as , for example, shale, sandstone, limestone, etc. Each layer may contain trapped fluids or gas at different formation pressures, and the formation pressures increase with increasing depth. The pressure in the wellbore is generally adjusted to at least balance the formation pressure by, for example, increasing a density of drilling mud in the wellbore or increasing pump pressure at the surface of the well.

[0004] There are occasions during drilling operations when a wellbore may penetrate a layer having a formation pressure substantially higher than the pressure maintained in the wellbore. When this occurs, the well is said to have "taken a kick." The pressure increase associated with the kick is generally produced by an influx of formation fluids (which may be a liquid, a gas, or a

combination thereof) into the wellbore. The relatively high pressure kick tends to propagate from a point of entry in the wellbore uphole (from a high pressure region to a low pressure region). If the kick is allowed to reach the surface, drilling fluid, well tools, and other drilling structures may be blown out of the wellbore. These “blowouts” often result in catastrophic destruction of the drilling equipment (including, for example, the drilling rig) and in substantial injury or death of rig personnel.

[0005] Because of the risk of blowouts, blowout preventers are typically installed at the surface or on the sea floor in deep water drilling arrangements so that kicks may be adequately controlled and “circulated out” of the system. Blowout preventers may be activated to effectively seal in a wellbore until active measures can be taken to control the kick. There are several types of blowout preventers, the most common of which are annular blowout preventers and ram-type blowout preventers.

[0006] Annular blowout preventers typically comprise annular elastomer “packers” that may be activated (*e.g.*, inflated) to encapsulate drillpipe and well tools and completely seal the wellbore. A second type of the blowout preventer is the ram-type blowout preventer. Ram-type preventers typically comprise a body and at least two oppositely disposed bonnets. The bonnets are generally secured to the body about their circumference with, for example, bolts. Alternatively, bonnets may be secured to the body with a hinge and bolts so that the bonnet may be rotated to the side for maintenance access.

[0007] Interior of each bonnet is a piston actuated ram. The rams may be either pipe rams (which, when activated, move to engage and surround drillpipe and well tools to seal the wellbore) or shear rams (which, when activated, move to engage and physically shear any drillpipe or well tools in the wellbore). The rams are typically located opposite of each other and, whether pipe rams or shear rams, the rams typically seal against one another proximate a center of the wellbore in order to completely seal the wellbore.

[0008] As with any tool used in drilling oil and gas wells, blowout preventers must be regularly maintained. For example, blowout preventers comprise high pressure seals between the bonnets and the body of the BOP. The high pressure seals in many instances are elastomer seals. The elastomer seals must be regularly checked to ensure that the elastomer has not been cut, permanently deformed, or deteriorated by, for example, chemical reaction with the drilling fluid in the wellbore. Moreover, it is often desirable to replace pipe rams with shear rams, or vice versa, to provide different well control options. Therefore, it is important that the blowout preventer includes bonnets that are easily removable so that interior components, such as the rams, may be accessed and maintained.

[0009] Developing blowout preventers that are easy to maintain is a difficult task. For example, as previously mentioned, bonnets are typically connected to the BOP body by bolts or a combination of a hinge and bolts. The bolts must be highly torqued in order to maintain a seal between a bonnet door and the BOP body. The seal between the bonnet and the BOP body is generally a face seal, and the seal must be able to withstand the very high pressures present in the wellbore.

[0010] As a result, special tools and equipment are necessary to install and remove the bonnet doors and bonnets so that the interior of the BOP body may be accessed. The time required to install and remove the bolts connecting the bonnet doors to the BOP body results in rig downtime, which is both expensive and inefficient. Moreover, substantially large bolts and a nearly complete "bolt circle" around the circumference of the bonnet door are generally required to provide sufficient force to hold the bonnet door against the body of the BOP. The size of the bolts and the bolt circle may increase a "stack height" of the BOP. It is common practice to operate a "stack" of BOPs (where several BOPs are installed in a vertical relationship), and a minimized stack height is desirable in drilling operations.

[0011] Several attempts have been made to reduce stack height and the time required to access the interior of the BOP. U.S. Patent No. 5,655,745 issued to Morrill shows a pressure energized seal carrier that eliminates the face seal between the bonnet door and the BOP body. The BOP shown in the '745 patent enables the use of fewer, smaller bolts in less than a complete bolt circle for securing the bonnet to the body. Moreover, the '745 patent shows that a hinge may be used in place of at least some of the bolts.

[0012] U.S. Patent No. 5,897,094 issued to Brugman *et al.* discloses an improved BOP door connection that includes upper and lower connector bars for securing bonnets to the BOP. The improved BOP door connection of the '094 patent does not use bolts to secure the bonnets to the BOP and discloses a design that seeks to minimize a stack height of the BOP.

### Summary of Invention

[0013] In one aspect, the invention comprises a bonnet lock mechanism for a blowout preventer. The bonnet lock mechanism comprises a radial lock, a radial lock displacement device, and at least one lock actuator operatively coupled to the radial lock displacement device. The radial lock displacement device is adapted to radially displace the radial lock to a form a locking engagement between a bonnet and a body of the blowout preventer.

[0014] In another aspect, the invention comprises a bonnet lock mechanism for a blowout preventer comprising a bonnet door operatively attached to a swivel slide mount. The swivel slide mount is adapted to slide in relation to a body of the blowout preventer. At least one lock actuator is coupled to the bonnet door, and a radial lock displacement device is operatively coupled to the at least one lock actuator. The bonnet is adapted to be slidably positioned proximate a side opening of the body of the blowout preventer. The at least one lock actuator is adapted to axially displace the radial lock displacement device so as to radially

displace a radial lock to form a locking engagement between the bonnet and the body of the blowout preventer.

[0015] In another aspect, the invention comprises a bonnet lock mechanism for a blowout preventer comprising a radial lock disposed in a body of the blowout preventer. At least one lock actuator is operatively coupled to the radial lock. The at least one lock actuator is adapted to radially displace the radial lock so that an internal surface of the radial lock forms a locking engagement with a bonnet.

[0016] In another aspect, the invention comprises a blowout preventer comprising a body, and a bonnet cooperatively attached to the body proximate each of at least two oppositely disposed side openings formed in the body. A radial locking mechanism is cooperatively attached to each bonnet and is adapted to secure each bonnet to the body proximate an inner perimeter of the at least two side openings.

[0017] In another aspect, the invention comprises a bonnet seal adapted to form a sealing engagement between a bonnet and a body of a blowout preventer.

[0018] In another aspect, the invention comprises a method for securing a bonnet to a body of a blowout preventer. The method comprises positioning the bonnet proximate a side opening of a body of the blowout preventer, activating at least one lock actuator operatively coupled to a radial lock displacement device, axially displacing the radial lock displacement device, and radially displacing the radial lock with the radial lock displacement device so as to form a locking engagement between the bonnet and the body of the blowout preventer.

[0019] In another aspect, the invention comprises a method for securing a bonnet to a body of a blowout preventer. The method comprises positioning the bonnet proximate a side opening of a body of the blowout preventer, activating at least one lock actuator operatively coupled to a radial lock, the radial lock disposed in the body of the blowout preventer, and radially

displacing the radial lock so as to form a locking engagement between the bonnet and the body of the blowout preventer.

[0020] Other aspects and advantages of the invention will be apparent from the following description and the appended claims.

### **Brief Description of Drawings**

[0021] Figure 1 shows a partial section and exploded view of a BOP comprising an embodiment of the invention.

[0022] Figure 2 shows an enlarged view of a portion of the embodiment shown in Figure 1.

[0023] Figure 3 shows an embodiment of a radial lock displacement device.

[0024] Figure 4 shows another embodiment of a radial lock displacement device.

[0025] Figure 5 shows an embodiment of the invention where a radial lock is pinned to a portion of a bonnet.

[0026] Figure 6 shows an embodiment of a radial lock comprising two halves.

[0027] Figure 7 shows an embodiment of a radial lock comprising four segments.

[0028] Figure 8 shows an embodiment of a radial lock comprising a plurality of segments.

[0029] Figure 9 shows an embodiment of a notched serpentine radial lock.

[0030] Figure 10 shows an embodiment of a locking mechanism used in an embodiment of the invention.

[0031] Figure 11 shows an embodiment of a locking mechanism used in an embodiment of the invention.

[0032] Figure 12 shows an embodiment of a locking mechanism used in an embodiment of the invention.

- [0033] Figure 13 shows an embodiment of a high pressure seal used in an embodiment of the invention.
- [0034] Figure 14 shows an embodiment of a high pressure seal used in an embodiment of the invention.
- [0035] Figure 15 shows an embodiment of a high pressure seal used in an embodiment of the invention.
- [0036] Figure 16 shows an embodiment of a high pressure seal used in an embodiment of the invention.
- [0037] Figure 17 shows an embodiment of a high pressure seal used in an embodiment of the invention.
- [0038] Figure 18 shows an embodiment of the invention wherein a radial lock is disposed in a recess in a side passage of a BOP body.
- [0039] Figure 19 shows an embodiment of a radial lock comprising two halves.
- [0040] Figure 20 shows an embodiment of a radial lock comprising four segments.
- [0041] Figure 21 shows an embodiment of a radial lock comprising a plurality of kerfs.
- [0042] Figure 22 shows an embodiment of a radial lock comprising graduated kerfs.
- [0043] Figure 23 shows a side perspective view of an embodiment of a swivel slide mount used in an embodiment of the invention.
- [0044] Figure 24 shows a front perspective view of an embodiment of a swivel slide mount used in an embodiment of the invention.
- [0045] Figure 25 shows a top perspective view of an embodiment of a swivel slide mount used in an embodiment of the invention.

## Detailed Description

[0046] An embodiment of the invention is shown in Figure 1. A ram-type blowout preventer (BOP) 10 comprises a BOP body 12 and oppositely disposed bonnet assemblies 14. The BOP body 12 further comprises couplings 16 (which may be, for example, flanges) on an upper surface and a lower surface of the BOP body 12 for coupling the BOP 10 to, for example, another BOP or to another well tool. The BOP body 12 comprises an internal bore 18 therethrough for the passage of drilling fluids, drillpipe, well tools, and the like used to drill, for example, an oil or gas well. The BOP body 12 further comprises a plurality of side passages 20 wherein each of the plurality of side passages 20 is generally adapted to be coupled to a bonnet assembly 14.

[0047] The bonnet assemblies 14 are coupled to the BOP body 12, typically in opposing pairs as shown in Figure 1. Each bonnet assembly 14 further comprises a plurality of components adapted to seal the bonnet assembly 14 to the BOP body 12 and to activate a ram piston 22 within each bonnet assembly 14. Components of the bonnet assemblies 14 comprise passages therethrough for movement of the ram piston 22.

[0048] Each bonnet assembly 14 generally comprises similar components. While each bonnet assembly 14 is a separate and distinct part of the BOP 10, the operation and structure of each bonnet assembly 14 is similar. Accordingly, in order to simplify the description of the operation of the BOP 10 and of the bonnet assemblies 14, the components and operation of one bonnet assembly 14 will be described in detail. It should be understood that each bonnet assembly 14 operates in a similar manner and that, for example, opposing bonnet assemblies 14 typically operate in a coordinated manner.

[0049] Proceeding with the description of the operation of one bonnet assembly 14, the piston 22 is adapted to be coupled to a ram (not shown) that may be, for example, a pipe ram or a shear ram. Each ram piston 22 is coupled to a ram actuator cylinder 24 that is adapted to displace the ram piston 22 axially within

the bonnet assembly **14** in a direction generally perpendicular to an axis of the BOP body **12**, the axis of the BOP body **12** being generally defined as a vertical axis of the internal bore **18** (which is generally parallel with respect to a wellbore axis). A ram (not shown) is generally coupled to the ram piston **22**, and, if the rams (not shown) are shear rams, the axial displacement of the ram piston **22** generally moves the ram (not shown) into the internal bore **18** and into contact with a corresponding ram (not shown) coupled to a ram piston **22** in a bonnet assembly **14** disposed on an opposite side of the BOP **10**.

[0050] Alternatively, if the rams (not shown) are pipe rams, axial displacement of the ram piston generally moves the ram (not shown) into the internal bore **18** and into contact with a corresponding ram (not shown) and with drillpipe and/or well tools present in the wellbore. Therefore, activation of the ram actuator cylinder **24** displaces the ram piston **22** and moves the ram (not shown) into a position to block a flow of drilling and/or formation fluid through the internal bore **18** of the BOP body **12** and, in doing so, to form a high pressure seal that prevents fluid flow from passing into or out of the wellbore (not shown).

[0051] The ram actuator cylinder **24** further comprises an actuator **26** which may be, for example, a hydraulic actuator. However, other types of actuators are known in the art and may be used with the invention. Note that for purposes of the description of the invention, a "fluid" may be defined as a gas, a liquid, or a combination thereof.

[0052] For example, if the ram (not shown) is a pipe ram, activation of the ram piston **22** moves the ram (not shown) into position to seal around drillpipe (not shown) or well tools (not shown) passing through the internal bore **18** in the BOP body **12**. Further, if the ram (not shown) is a shear ram, activation of the ram piston **22** moves the ram (not shown) into position to shear any drillpipe (not shown) or well tools (not shown) passing through the internal bore **18** of the BOP body **12** and, therefore, seal the internal bore **18**.

Radial Lock Mechanism for Coupling Bonnets to BOPs

[0053] An important aspect of a BOP 10 is the mechanism by which the bonnet assemblies 14 are sealed to the body 12. Figure 1 shows a radial lock mechanism 28 that is designed to provide a high pressure radial seal between the bonnet assembly 14 and the BOP body 12. Moreover, the radial lock mechanism 28 is designed to simplify maintenance of the bonnet assembly 14 and the rams (not shown) positioned therein.

[0054] In the embodiments shown in the Figures, the side passages 20 and other components of the BOP 10 designed to be engaged therewith and therein are shown as being oval or substantially elliptical in shape. An oval or substantially elliptical shape (e.g., an oval cross-section) helps reduce the stack height of the BOP, thereby minimizing weight, material used, and cost. Other shapes such as circular shapes, however, are also suitable for use with the invention. Accordingly, the scope of the invention should not be limited to the shapes of the embodiments shown in the Figures.

[0055] The radial lock mechanism 28 is positioned within the bonnet assembly 14 and within the side passage 20 of the BOP body 12. In this embodiment, the radial lock mechanism 28 comprises a bonnet seal 29 disposed on a bonnet body 30, a radial lock 32, a radial lock displacement device 34, a bonnet door 36, and lock actuators 38. The bonnet seal 29 cooperatively seals the bonnet body 30 to the BOP body 12 proximate the side passage 20. The bonnet seal 29 comprises a high pressure seal that prevents fluids from the internal bore 18 of the BOP body 12 from escaping via the side passage 20. Various embodiments of the bonnet seal 29 will be discussed in detail below.

[0056] When the bonnet seal 29 is formed between the bonnet body 30 and the BOP body 12, the bonnet body 30 is in an installed position and is located proximate the BOP body 12 and at least partially within the side passage 20. Because the bonnet seal 29 is a high pressure seal, the radial lock mechanism

**28** must be robust and able to withstand very high pressures present in the internal bore **18**.

[0057] The embodiment shown in Figure 1 comprises a novel mechanism for locking the bonnet assembly **14** (and, as a result, the bonnet seal **29**) in place. Referring to Figure 2, the radial lock **32** has an inner diameter adapted to fit over an exterior surface **40** of the bonnet body **30** and slide into a position adjacent a sealing end **45** of the bonnet body **30**. The radial lock **32** shown in Figure 2 comprises two halves separated by a center cut **46**. However, the radial lock **32** may comprise additional segments and the two segment embodiment shown in Figure 2 is not intended to limit the scope of the invention. Additional embodiments of the radial lock **32** will be described in greater detail below.

[0058] The radial lock displacement device **34** also has an inner diameter adapted to fit over the exterior surface **40** of the bonnet body **30**. Moreover, the radial lock displacement device **34** further comprises a wedge surface **48** on an external diameter that is adapted to fit inside an inner diameter **50** of the radial lock **32**. The radial lock displacement device **34** also comprises an inner face **56** that is adapted to contact an outer surface **54** of the BOP body **12**. In an installed position, the bonnet body **30**, the radial lock **32**, and the radial lock displacement device **34** are positioned between the BOP body **12** and the bonnet door **36**. An inner surface **52** of the bonnet door **36** is adapted to contact the outer surface **54** of the BOP body **12**. Note that the engagement between the bonnet door **36** and the BOP body **12** is not fixed (e.g., the bonnet door **36** is not bolted to the BOP body **12**).

[0059] The bonnet assembly **14** is adapted to slidably engage at least one rod **70** through a swivel slide mount **74** (note that two rods **70** are shown slidably engaged, through the swivel slide mounts **74**, with each bonnet assembly **14** in Figure 1). As a result of the slidable engagement, the bonnet assembly **14** may slide along the rods **70**. As will be discussed below, the slidable engagement

permits the bonnet assembly 14 to be moved into and out of locking and sealing engagement with the BOP body 12.

[0060] The lock actuators 38 are coupled to the bonnet door 36 with either a fixed or removable coupling comprising bolts, adhesive, welds, threaded connections, or similar means known in the art. The lock actuators 38 are also cooperatively coupled to the radial lock displacement device 34 in a similar fashion. Additionally, the coupling between the lock actuators 38 and the radial lock displacement device 34 may be a simple contact engagement. Note that the embodiments in Figure 1 shows two lock actuators 38 coupled to each bonnet door 36. However, a single lock actuator cylinder 38 or a plurality of lock actuators 38 may be used with the invention. The lock actuators 38 shown are generally hydraulic cylinders; however, other types of lock actuators (including, for example, pneumatic actuators, electrically powered motors, and the like) are known in the art and may be used with the invention.

[0061] Moreover, the lock actuators 38 may also be manually operated. The lock actuators 38 shown in the present embodiment are typically controlled by, for example, an external electrical signal, a flow of pressurized hydraulic fluid, etc. As an alternative, the radial lock 32 may be activated by manual means, such as, for example, a lever, a system of levers, a threaded actuation device, or other similar means known in the art. Further, if, for example, the lock actuators 38 comprise hydraulic cylinders, the hydraulic cylinders may be activated by a manual pump. Accordingly, manual activation of the radial lock 32 is within the scope of the invention.

[0062] A fully assembled view 15 of the bonnet assembly 14 including the radial lock mechanism 28 is shown in Figure 2. During operation of the radial lock mechanism 28, the bonnet assembly 14 is first moved into position proximate the BOP body 12 by sliding the bonnet assembly 14 toward the BOP body 12 on the rods 70. The lock actuators 38 are then activated so that they axially displace (wherein an axis of displacement corresponds to an axis of the

side passage 20) the radial lock displacement device 34 in a direction toward the BOP body 12. As the radial lock displacement device 34 moves axially toward the BOP body 12, the wedge surface 48 contacts the inner diameter 50 of the radial lock 32, thereby moving the radial lock 32 in a radially outward direction (e.g., toward an inner radial lock surface 58 of the side passage 20). When the activation of the radial lock mechanism 28 is complete, an inner nose 60 of the radial lock displacement device 34 is proximate a load shoulder 44 of the bonnet body 30, and an outer perimeter 62 of the radial lock 32 is lockingly engaged with the inner radial lock surface 58. Moreover, as will be described below, both the radial lock 32 and the inner radial lock surface 58 typically comprise angled surfaces (refer to, for example, the engagement surfaces described in the discussion of Figures 10 and 11 *infra*). When the radial lock 32 engages the inner radial lock surface 58, the angled surfaces are designed to provide an axial force that “pulls” the bonnet door 36 in an axially inward direction and firmly against the exterior of the BOP body 12 and thereby completes the locking engagement of the radial lock mechanism 28.

[0063] When the radial lock 32 is secured in place by the activation of the lock actuators 38 and the radial lock displacement device 34, the bonnet body 30 and the bonnet assembly 14 are axially locked in place with respect to the BOP body 12 without the use of, for example, bolts. However, an additional manual locking mechanism (not shown) may also be used in combination with the invention to ensure that the radial lock 32 remains securely in place. Once the radial lock 32 is secured in place by, for example, hydraulic actuation, a manual lock (not shown), such as a pinned or threaded mechanism, may be activated as an additional restraint. The secured radial locking mechanism 28 is designed to hold the bonnet assembly 14 and, accordingly, the high pressure bonnet seal 29 in place. The radial lock 32 and the high pressure bonnet seal 29 can withstand the high forces generated by the high pressures present within the internal bore 18 of the BOP body 12 because of the locking engagement

between the radial lock 32 and the inner radial lock surface 58 of the BOP body 12.

[0064] The radial lock mechanism 28 may be disengaged by reversing the activation of the lock actuators 38 (*e.g.*, after the pressure in the internal bore 18 has been relieved). As a result, the invention comprises a radial lock mechanism 28 that includes a positive disengagement system (*e.g.*, the lock actuators 38 must be activated in order to disengage the radial lock mechanism 28).

[0065] The wedge surface 48 used to radially displace the radial lock 32 may comprise any one of several embodiments. Referring to Figure 3, in one embodiment, the wedge surface 48 of the radial lock displacement device 34 may comprise a single actuation step 80. In another embodiment shown in Figure 4, the wedge surface 48 may comprise a dual actuation step 82. Note that the single actuation step (80 in Figure 3) generally has a shorter actuation stroke than the dual actuation step (82 in Figure 4). Further, an actuation step angle (84 in Figures 3 and 4) is designed to maximize a radial actuation force and minimize a linear actuation force. In one embodiment of the invention, the actuation step angle (84 in Figures 3 and 4) is approximately 45 degrees. In another embodiment of the invention, the actuation step angle (84 in Figures 3 and 4) is less than 45 degrees.

[0066] In another embodiment shown in Figure 5, the radial lock displacement device 34 further comprises a slot 90 and at least one retention pin 92 designed to retain the radial lock 32 against the load shoulder 44 of the bonnet body 30. In this embodiment, the radial lock 32 is retained in place by the at least one retention pin 92, and the bonnet body 30 and the radial lock 32 are held in a fixed relationship after the radial lock 32 has been actuated and is in locking engagement with the inner radial lock surface (58 in Figure 2) of the side passage (20 in Figure 1).

[0067] The radial lock (32 in Figure 1) may also comprise any one of several embodiments. The radial lock 32 shown in the embodiment of Figure 1 comprises two radial mirrored halves 94, 96, as further shown in Figure 6. In another embodiment, as shown in Figure 7, a radial lock 100 may be formed from at least two substantially linear segments 102 and at least two semicircular end segments 104. In another embodiment, as shown in Figure 8, a radial lock 106 may be formed from a plurality of substantially straight dogs 108 and a plurality of curved dogs 110. The embodiments shown in Figures 7 and 8 essentially comprise radial locks 100, 106 similar to the radial lock (32 in Figures 1 and 6) of the first embodiment but divided into a plurality of segments. The radial locks 100, 106 could be manufactured by, for example, manufacturing a solid radial lock and sequentially saw cutting the solid radial lock into two or more segments. However, other manufacturing techniques are known in the art and may be used to manufacture the radial lock.

[0068] In another embodiment shown in Figure 9, a radial lock 112 may be formed from a notched serpentine structure 114 similar to a “serpentine belt.” The radial lock 112 is formed, for example, as a single solid piece and then cut 117 through an inner perimeter 113 or an outer perimeter 116. The cuts 117 can either completely transect the radial lock 112 or may include only partial cuts. Further, if the cuts 117 transect the radial lock 112, the individual segments can be attached to a flexible band 118 so that the radial lock 112 can be actuated with an actuating ring (34 in Figure 1). The flexible band 118 may comprise a material with a relatively low elastic modulus (when compared to, for example, the elastic modulus of the individual segments) so that the flexible band 118 can radially expand in response to the radial displacement produced by the radial lock displacement device (34 in Figure 1). Radial expansion of the flexible band 118 results in a locking engagement between the radial lock 112 and the inner radial lock surface (58 in Figure 2) of the BOP body (12 in Figure 1).

- [0069] The engagement between the radial lock (32 in Figure 1) and the inner radial lock surface (58 in Figure 2) may also comprise different embodiments. In one embodiment, as shown in Figure 10, a radial lock 120 may comprise a single profile engagement including a single radial lock engagement surface 122. The single radial lock engagement surface 122 is designed to lockingly engage a BOP engagement surface (59 in Figure 2) formed on the inner radial lock surface (58 in Figure 2) of the side passage (20 in Figure 1).
- [0070] In another embodiment, as shown in Figure 11, a radial lock 124 comprises a dual profile engagement including two radial lock engagement surfaces 126. Moreover, the radial lock 124 may also comprise a plurality of radial lock engagement surfaces designed to lockingly engage a corresponding number of BOP engagement surfaces (59 in Figure 2) formed on the inner radial lock surface (58 in Figure 2) of the side passage (20 in Figure 1) of the BOP body (12 in Figure 1).
- [0071] The radial locks described in the referenced embodiments are designed so that the cross-sectional area of engagement between the radial lock engagement surfaces with the BOP engagement surfaces (59 in Figure 2) is maximized. Maximizing the cross-sectional areas of engagement ensures that the radial locks positively lock the bonnet assembly (14 in Figure 1) and, as a result, the bonnet seal (29 in Figure 1) in place against the high pressures present in the internal bore (18 in Figure 1) of the BOP (10 in Figure 1). Moreover, as discussed previously, angles of the engagement surfaces may be designed to produce an axial force that firmly pulls the bonnet door (36 in Figure 1) against the BOP body (12 in Figure 1) and that in some embodiments may assist in the activation of the bonnet seal (29 in Figure 1).
- [0072] The radial locks and the engagement surfaces described in the foregoing embodiments may be coated with, for example, hardfacing materials and/or friction reducing materials. The coatings may help prevent, for example, galling, and may prevent the radial locks from sticking or "hanging-up" in the

engagement surfaces during the activation and/or deactivation of the radial lock mechanism (28 in Figure 1). The coatings may also increase the life of the radial locks and the engagement surfaces by reducing friction and wear.

[0073] Another embodiment of the lock ring 127 is shown at 127 in Figure 12. The radial lock 127 comprises a plurality of saw cuts 128, a plurality of holes 129, or a combination thereof. The saw cuts 128 and/or holes 129 decrease the weight and area moment of inertia of the radial lock 127, thereby reducing the actuation force required to radially displace the radial lock 127. In order to permit some elastic deformation of the radial lock 127, the radial lock 127 may be formed from a material having a relatively low modulus of elasticity (when compared to, for example, steel). Such materials comprise titanium, beryllium copper, *etc.* Moreover, modifications to the radial lock 127 geometry, in addition to those referenced above, may be made to, for example, further reduce the area moment of inertia of the radial lock 127 and reduce bending stresses.

[0074] The radial locks described above are designed to operate below an elastic limit of the materials from which they are formed. Operation below the elastic limit ensures that the radial locks will not permanently deform and, as a result of the permanent deformation, lose effectiveness. Accordingly, material selection and cross-sectional area of engagement of the engagement surfaces is very important to the design of the radial lock mechanism (28 in Figure 1).

[0075] Referring to Figure 1, the bonnet seal 29 is designed to withstand the high pressures present in the internal bore 18 of the BOP body 12 and to thereby prevent fluids and/or gases from passing from the internal bore 18 to the exterior of the BOP 10. The bonnet seal 29 may comprise several different configurations as shown in the following discussion of Figures 13-17. Moreover, the seals disclosed in the discussion below may be formed from a variety of materials. For example, the seals may be elastomer seals or non-elastomer seals (such as, for example, metal seals, PEEK seals, *etc.*). Metal

seals may further comprise metal-to-metal C-ring seals and/or metal-to-metal lip seals. Further, the sealing arrangements shown below may include a combination of seal types and materials. Accordingly, the type of seal, number of seals, and the material used to form radial and face seals are not intended to limit the bonnet seal 29.

[0076] The embodiment in Figure 13 comprises a bonnet seal 130 formed on a radial perimeter 132 of a bonnet body 133. The radial seal 130 further comprises two o-rings 134 disposed in grooves 136 formed on the radial perimeter 132 of the bonnet body 133. The o-rings 134 sealingly engage an inner sealing perimeter 138 of the side passage (20 in Figure 1) in the BOP body 12. The embodiment shown in Figure 13 comprises two grooves 136, but a single groove or a plurality of grooves may be suitable for use with the o-rings 134. Moreover, while the embodiment shows two o-rings 134, a single o-ring or more than two o-rings may be used in the invention.

[0077] In another embodiment shown in Figure 14, a bonnet seal 140 comprises at least two packing seals 146 (which may be, for example, t-seals, lip seals, or seals sold under the trademark PolyPak, which is a mark of Parker Hannifin, Inc.) disposed in grooves 148 formed on a radial perimeter 142 of a bonnet body 144. The packing seals 146 sealingly engage an inner sealing perimeter 150 of the side passage (20 in Figure 1) of the BOP body 12. The embodiment shown in Figure 14 comprises two grooves 148, but a single groove or a plurality of grooves may be suitable for use with the packing seals 146. Moreover, while the embodiment shows two packing seals 146, a single seal or more than two seals may be used in the invention.

[0078] In another embodiment shown in Figure 15, the bonnet seal 152 comprises a radial seal 154 disposed in a groove 166 formed on a radial perimeter 160 of a bonnet body 162. Moreover, the embodiment comprises a face seal 156 disposed in a groove 164 formed on a mating face surface 168 of the bonnet body 162. The radial seal 154 is adapted to sealingly engage an

inner sealing perimeter **158** of the side passage (**20** in Figure 1) of the BOP body **12**. The face seal **156** is adapted to sealingly engage an exterior face **170** of the BOP body **12**. The radial seal **154** and face seal **156** shown in the embodiment are both o-rings and are disposed in single grooves **166**, **164**. However, a different type of seal (such as, for example, a packing seal) and more than one seal (disposed in at least one groove) may be used with the invention.

[0079] In another embodiment shown in Figure 16, the bonnet seal **172** comprises a radial seal **174** disposed in a groove **178** formed on a seal carrier **180**. The seal carrier **180** is disposed in a groove **182** formed in a bonnet body **184** and also comprises a face seal **176** disposed in a groove **177** formed on the seal carrier **180**. The face seal **176** is adapted to sealingly engage mating face surface **186** of the BOP body **12**, and the radial seal **174** is adapted to sealingly engage an inner sealing perimeter **188** formed in the bonnet body **184**. The bonnet seal **172** may also comprise an energizing mechanism **190** that is adapted to displace the seal carrier **180** in a direction toward the exterior surface **186** of the BOP body **12** so as to energize the face seal **176**. The energizing mechanism **190** may comprise, for example, a spring, a thrust washer, or a similar structure.

[0080] The energizing mechanism **190** helps ensure that the face seal **176** maintains positive contact with and, thus, maintains a high pressure seal with the exterior surface **186** of the BOP body **12**. However, the energizing mechanism **190** is not required in all embodiments. For example, the seal carrier **180** may be designed so that both the radial seal **174** and the face seal **176** are pressure activated without the assistance of an energizing mechanism **190**.

[0081] In the embodiment without an energizing mechanism, a diameter and an axial thickness of a seal carrier (such as the seal carrier **180** shown in Figure 16) are selected so that high pressure from the internal bore first moves the seal

carrier toward the exterior surface of the BOP body. Once the face seal sealingly engages the exterior surface, the high pressure from the internal bore causes the seal carrier to radially expand until the radial seal sealingly engages the groove in the seal carrier. A similar design is disclosed in U.S. Patent No. 5,255,890 issued to Morrill and assigned to the assignee of the present invention. The '890 patent clearly describes the geometry required for such a seal carrier.

[0082] In the embodiment shown in Figure 16, the face seal **176** and the radial seal **174** may be, for example, o-rings, packing seals, or any other high pressure seal known in the art. Moreover, Figure 16 only shows single seals disposed in single grooves. However, more than one seal, more than one groove, or a combination thereof may be used with the invention.

[0083] In another embodiment shown in Figure 17, the seal carrier **192** as shown in the previous embodiment is used in combination with a backup seal **194** disposed in a groove **196** on an external surface **198** of a bonnet body **200**. The backup seal **194** may be an o-ring, a packing seal, a metal seal, or any other high pressure seal known in the art. The backup seal **194** further maintains a high pressure seal if, for example, there is leakage from the seals disposed on the seal carrier **192**. Note that the embodiment shown in Figure 17 does not include an energizing mechanism.

[0084] Advantageously, some of the seal embodiments reduce an axial force necessary to form the bonnet seal. The bonnet seals shown above greatly reduce the sensitivity of the bonnet seal to door flex by maintaining a constant squeeze regardless of wellbore pressure. The radial seal arrangements also reduce the total area upon which wellbore pressure acts and thus reduces a separation force that acts to push the bonnet door away from the BOP body.

[0085] In another embodiment of the radial lock shown in Figure 18, the radial lock mechanism **220** comprises a radial lock **222** disposed in a recess **224** formed on an internal surface **226** of a side passage **228** of a BOP body **230**.

The operation of the radial lock mechanism **220** differs from the embodiments described above in that securing a bonnet body **232** and, accordingly, a bonnet door (not shown) and a bonnet assembly (not shown), in place is accomplished by actuating the radial lock mechanism **220** in radially *inward* direction.

[0086] The structure of the embodiment shown in Figure 18 is similar to the structure of the embodiments described above except for the direction of actuation of the radial lock mechanism **220**. Therefore, the discussion of the present embodiment will include a description of how the alternative radial lock mechanism **220** differs from those shown above. Common elements of the embodiments (such as, for example, the bonnet door **36**, the linear rods **70**, *etc.*) will not be described again in detail. Moreover, it should be noted that the embodiment of Figure 18 does not require, for example, actuator cylinders or a radial lock displacement device (*e.g.*, the embodiment of Figure 18 does not require an *internal* actuation mechanism).

[0087] Actuation of the radial lock **222** is in a radially inward direction. Accordingly, the radial lock **222** must be coupled to an actuation mechanism that differs from, for example, the radial lock displacement device (**34** in Figure 1) and the lock actuators (**38** in Figure 1) described in the previous embodiments. In one embodiment of the invention, the radial lock **222** comprises a structure similar to those shown in Figures 6 and 7. As shown in Figure 19, separate halves **236**, **238** of the radial lock **222** may be coupled to radially positioned actuators **240**. When the bonnet body **232** is moved into a sealing engagement with the BOP body **230**, the actuators **240** are activated to displace the halves **236**, **238** of the radial lock **222** in a radially inward direction so that the radial lock **222** engages a groove (**244** in Figure 18) formed on an exterior surface (**246** in Figure 18) of the bonnet body (**232** in Figure 18). The radial lock mechanism (**220** in Figure 18) locks the bonnet body (**232** in Figure 18) and, therefore, the bonnet door (not shown) and the bonnet assembly (not shown) in place and energizes the high pressure seal (**234**

in Figure 18). Note that the high pressure seal (**234** in Figure 18) may be formed from any of the embodiments shown above (such as the embodiments described with respect to Figures 13-17). Moreover, the radial lock **222** and the groove **244** may comprise angled surfaces (as disclosed in previous embodiments) that produce an axial force that pulls the bonnet body **232** (and the bonnet assembly (not shown) and bonnet door (not shown)) toward the BOP body **230** and further ensure a positive locking engagement.

[0088] Moreover, as shown in Figure 20, the radial lock **222** may comprise more than two parts. If a radial lock **250** comprises, for example, four parts **252, 254, 256, 258**, an equal number of actuators **240** (e.g., four) may be used to actuate the radial lock **250**. Alternatively, fewer actuators **240** (e.g., less than four in the embodiment shown in Figure 20) may be used if an actuator **240** is, for example, coupled to more than one part parts **252, 254, 256, 258** of the radial lock **250**. The actuators **240** may be hydraulic actuators or any other type of actuator known in the art. Moreover, the actuators **240** may be disposed within the BOP body (**230** in Figure 18) or may be positioned external to the BOP body (**230** in Figure 18). The actuators **240** may be coupled to the radial lock **250** with, for example, mechanical or hydraulic linkages (not shown). On another embodiment, the radial lock **222** comprises a plurality of dies or dogs (not shown) that are coupled to and activated by a plurality of actuators (not shown).

[0089] In another embodiment of the invention shown in Figure 21, a radial lock **270** may be formed from a single segment **272**. The radial lock **270** is actuated by circumferential actuators **274** coupled to the radial lock **270** and disposed proximate ends **276, 278** of the segment **272**. When activated, the circumferential actuators **274** move the ends **276, 278** of the segment **272** towards each other and in a radially inward direction as shown by the arrows in Figure 21. The dashed line in Figure 21 represents an inner surface **277** of the radial lock **270** *after* actuation. The radial lock **270**, when actuated, engages

the bonnet body (232 in Figure 18) in a manner similar to that shown in Figure 18.

[0090] The segment 272 of the radial lock 270 may be produced by forming a plurality of kerfs 284 proximate the end segments 280, 282. The kerfs 284 may be designed to ease installation of the radial lock 270 in the recess (224 in Figure 18) and to improve flexibility for radial deformation of the radial lock 270. The kerfs may be of any shape known in the art. For example, Figure 22 shows rectangular kerfs 284. However, the kerfs 284 may preferably be formed in a manner that reduces stress concentrations or stress risers at the edges of the kerfs 284. For example, if the kerfs 284 are formed as rectangular shapes, stress risers may form at the relatively sharp corners. Accordingly, the kerfs 284 may comprise filleted corners (not shown) or, for example, substantially trapezoidal shapes (not shown) to minimize the effects of stress risers.

[0091] Moreover, the kerfs 284 may be “graduated,” as shown in Figure 22, to produce a substantially smooth transition between relatively stiff straight segments 286 and relatively flexible end segments 280, 282. Graduation of the kerfs 284 effects a smooth stiffness transition that helps prevent stress risers at the last kerf (*e.g.*, at the last kerf proximate the straight segments 286).

[0092] The radial lock 270 may be formed from a single material or from different materials (comprising, for example, steel, titanium, beryllium copper, or combinations and/or alloys thereof). For example, the curved end segments 280, 282 may be formed from a material that is relatively compliant when compared to a relatively rigid material forming the straight segments 286 (*e.g.*, the curved and segments 280, 282 may be formed from a material with an elastic modulus ( $E_C$ ) that is substantially lower than an elastic modulus ( $E_S$ ) of the straight segments 286). Regardless of the materials used to form the radial lock 270, the radial lock 270 must be flexible enough to permit installation into and removal from the recess (224 in Figure 18).

[0093] Alternatively, the radial lock 270 of Figure 21 may comprise more than one segment (e.g., two halves or a plurality of segments) coupled to and actuated by a plurality of circumferential actuators. The radial lock 270 may also comprise a plurality of separate dies or dogs coupled by a flexible band. The dies may be separated by gaps, and the distance of separation may be selected to provide a desired flexibility for the radial lock 270.

[0094] The dies and the flexible banding may comprise different materials. For example, the dies may be formed from a substantially stiff material (e.g., a material with a relatively high modulus of elasticity) comprising, for example, steel or nickel based alloys. The flexible banding, in contrast, may be formed from materials having a relatively lower modulus elasticity and comprising, for example, titanium alloys or pultruded flats or shapes comprising fiberglass, carbon fibers, or composite materials thereof. As described above, the radial locks of the embodiments shown in Figures 19-22 may be coated with, for example, hardfacing materials (comprising, for example, tungsten carbide, boron nitride, and similar materials known in the art) or low-friction materials (comprising, for example, polytetrafluoroethylene and similar materials known in the art) to, for example, reduce friction and wear and improve the longevity of the parts. The material composition of the radial lock 270 is not intended to be limiting.

[0095] The embodiments shown in Figures 19-22 may be advantageous because of a reduced bonnet assembly weight and accordingly, reduced overall weight of the BOP. Moreover, there is a potential to retrofit old BOPs to include the radial lock mechanism.

Swivel Slide Mount for Bonnet Assemblies

[0096] Referring again to Figure 1, another important aspect of the invention is the swivel slide mounts 74 cooperatively attached to the rods 70 and to each of the bonnet assemblies 14. As described previously herein, the bonnet assemblies 14 are coupled to the swivel slide mounts 74, and the swivel slide

mounts **74** are slidably engaged with the rods **70**. The swivel slide mounts **74** are adapted to allow the bonnet assemblies **14** to rotate proximate their axial centerlines so that the rams (not shown) and the interior components of both the bonnet assemblies **14** and the BOP body **12** may be accessed for maintenance, to change the rams, *etc.*

[0097] An embodiment of the swivel slide mount **74** is shown in Figures 23 and 24. The swivel slide mount **74** comprises a swivel slide mounting bar **76** and a swivel plate **78**. The swivel slide mounting bar **76** is slidably attached to the rods **70**. The slidable attachment between the swivel slide mounting bar **76** and the rods **70** may be made with, for example, linear bearings **87** that are coupled to the swivel slide mounting bar **76**. However, other slidable attachments known in the art may be used with the invention to form the slideable attachment. Moreover, bushings (not shown), or a combination of linear bearings **87** and bushings (not shown) may be used with the invention. The swivel plate **78** is rotationally attached to the swivel slide mounting bar **76** and is cooperatively attached to an upper surface **75** of the bonnet assembly **14**. The cooperative attachment of the swivel slide mount **74** to the bonnet assembly **14** is made substantially at an axial centerline of the bonnet assembly **14**.

[0098] The rods **70** are designed to be of sufficient length to permit the bonnet assembly **14** to disengage from the BOP body **12** and slide away from the BOP body **12** until the ram (not shown) is completely outside the side passage **20**. Moreover, a point of attachment **82** where the swivel slide mount **74** is cooperatively attached to the upper surface **75** of the bonnet assembly **14** may be optimized so that the point of attachment **82** is substantially near a center of mass of the bonnet assembly **14**. Positioning the point of attachment **82** substantially near the center of mass reduces the force required to rotate the bonnet assembly **14** and also reduces the bending stress experienced by the swivel plate **78**.

[0099] The swivel plate 78 may further include a bearing 85. For example, the bearing 85 may be cooperatively attached to the swivel slide mounting bar 76 and adapted to withstand both radial and thrust loads generated by the rotation of the bonnet assembly 14. The bearing 85 may comprise, for example, a combination radial bearing and thrust bearing (such as, for example, a tapered roller bearing). Alternatively, the bearing 85 may comprise, for example, a roller bearing to support radial loads and a thrust washer to support axial loads. However, other types of bearing arrangements are known in the art and may be used with the swivel plate 78.

[00100] When the ram (not shown) is completely out of the side passage 20, the bonnet assembly 14 can rotate about a rotational axis of the swivel plate 78 so that the ram (not shown) and the side passage 20 may be accessed for maintenance, inspection, and the like. In the embodiment shown in Figures 23 and 24, the lower bonnet assembly 14 is shown to be rotated approximately 90 degrees with respect to the BOP body 12 while the upper bonnet assembly 14 remains in locking engagement with the BOP body 12. A ram block attachment point 80 is clearly visible.

[00101] Figure 25 shows a top view of the BOP 10 when one of the bonnet assemblies 14 has been disengaged from the BOP body 12 and rotated approximately 90 degrees. As shown, the ram block attachment point 80 is clearly visible and may be vertically accessed. Vertical access is a significant advantage because prior art bonnets that include hinges generally pivot about an edge of the bonnet door. Therefore, if, for example, a lower BOP bonnet was unbolted and pivoted open, the ram could not be vertically accessed because the body of the upper BOP bonnet was in the way. Vertical access to the ram is important because it makes it much easier to maintain or replace rams, thus reducing the time required to maintain the BOP and increasing the level of safety of the personnel performing the maintenance. Further, vertical

access enables, for example, maintenance of a lower BOP bonnet while an upper bonnet is locked in position (see, for example, Figures 23-25).

**[00102]** The bonnet assembly **14** may also be rotated approximately 90 degrees in the other direction with respect to an axis of the side passage (**20** in Figure 1), thereby permitting approximately 180 degrees of rotation. However, other embodiment may be designed that permit rotation of greater than or less than 180 degrees. The range of rotation of the swivel slide mount **74** is not intended to limit the scope of the invention.

**[00103]** The swivel slide mount **74** advantageous because of the simplicity of the design and attachment to the bonnet assembly **14**. For example, prior art hinges are generally complex, difficult to manufacture, and relatively expensive. Further, prior art hinges have to be robust because they carry the full weight of the BOP bonnet about a vertical axis positioned some distance away from the center of mass of the bonnet. The bending moment exerted on the hinge is, as a result, very high and deformation of the hinge can lead to “sagging” of the bonnet.

**[00104]** While the invention has been described with respect to a limited number of embodiments, those skilled in the art, having benefit of this disclosure, will appreciate that other embodiments can be devised which do not depart from the scope of the invention as disclosed herein. Accordingly, the scope of the invention should be limited only by the attached claims.

**CLAIMS:**

1. A bonnet lock mechanism for a blowout preventer comprising:  
a radial lock;  
a radial lock displacement device; and  
at least one lock actuator operatively coupled to the radial lock displacement device,  
wherein the radial lock displacement device is adapted to radially displace the radial lock to form a locking engagement between a bonnet and a body of the blowout preventer.
2. The bonnet lock mechanism of claim 1, wherein an external surface of the radial lock is adapted to form a locking engagement with an internal surface of a side opening of the body of the blowout preventer.
3. The bonnet lock mechanism of claim 1, wherein the radial lock comprises two radially mirrored halves.
4. The bonnet lock mechanism of claim 1, wherein the radial lock comprises a plurality of radial lock segments.
5. The bonnet lock mechanism of claim 4, wherein the plurality of radial lock segments are cooperatively attached to a flexible band.
6. The bonnet lock mechanism of claim 5, wherein the flexible band is formed from a material having a lower modulus of elasticity than a material from which the plurality of radial lock segments are formed.
7. The bonnet lock mechanism of claim 2, wherein the external surface of the radial lock comprises at least one radial lock engagement surface adapted to form a locking engagement with at least one radial engagement surface formed on the internal surface of the side opening.

8. The bonnet lock mechanism of claim 7, wherein the at least one radial lock engagement surface and the at least one radial engagement surface comprise engagement angles of approximately 45 degrees.
9. The bonnet lock mechanism of claim 7, wherein a cross sectional area of the locking engagement is maximized.
10. The bonnet lock mechanism of claim 1, further comprising a bonnet seal.
11. The bonnet lock mechanism of claim 10, wherein the bonnet seal further comprises at least one radial seal adapted to sealingly engage an inner radial sealing surface of the side opening.
12. The bonnet lock mechanism of claim 10, wherein the bonnet seal comprises at least one face seal adapted to sealingly engage an inner face sealing surface of the side opening.
13. The bonnet lock mechanism of claim 10, wherein the bonnet seal further comprises:
  - a seal carrier ring disposed within a groove formed on an interior end of the bonnet body;
  - at least one radial seal disposed in a groove formed on a radial surface of the seal carrier ring and adapted to sealingly engage a radial sealing surface of the groove on the bonnet body; and
  - at least one face seal disposed in a groove formed on an interior surface of the seal carrier ring and adapted to sealingly engage a face sealing surface of the side opening.
14. The bonnet lock mechanism of claim 1, wherein formation of the locking engagement moves a bonnet door into a contact engagement with the body.
15. The bonnet lock mechanism of claim 1, wherein the radial lock comprises a hardfacing material.

16. The bonnet lock mechanism of claim 1, wherein the radial lock comprises a friction reducing material.
17. The bonnet lock mechanism of claim 2, wherein the internal surface of the side opening comprises a hardfacing material.
18. The bonnet lock mechanism of claim 2, wherein the internal surface of the side opening comprises a friction reducing material.
19. The bonnet lock mechanism of claim 1, further comprising a bonnet door coupled to the bonnet, wherein the at least one lock actuator is cooperatively attached to the bonnet door.
20. The bonnet lock mechanism of claim 2, wherein the at least one lock actuator is adapted to axially displace the radial lock displacement device.
21. A bonnet lock mechanism for a blowout preventer comprising:
  - a bonnet door operatively attached to a bonnet and to a swivel slide mount, the swivel slide mount adapted to slide in relation to a body of the blowout preventer;
  - at least one lock actuator coupled to the bonnet door;
  - a radial lock displacement device operatively coupled to the at least one lock actuator; and
  - a radial lock,
 wherein the bonnet is adapted to be slidably positioned proximate a side opening of the body of the blowout preventer, and the at least one lock actuator is adapted to axially displace the radial lock displacement device so as to radially displace the radial lock to form a locking engagement between the bonnet and the body of the blowout preventer.
22. The bonnet lock mechanism of claim 21, wherein the bonnet is adapted to slide in relation to the body of the blowout preventer along a line parallel to an axis of the side opening.

23. The bonnet lock mechanism of claim 21, wherein the at least one lock actuator is coupled to an external surface of the bonnet door, the lock actuator being adapted to pass through an opening in the bonnet door and operatively engage the radial lock displacement device.
24. The bonnet lock mechanism of claim 21, further comprising a bonnet seal.
25. The bonnet lock mechanism of claim 24, wherein the bonnet seal is adapted to sealingly engage an interior sealing surface of the side opening.
26. The bonnet lock mechanism of claim 21, wherein an external surface of the radial lock displacement device comprises a wedge surface including at least one actuation step.
27. The bonnet lock mechanism of claim 26, wherein the at least one actuation step comprises an actuation step angle of approximately 45 degrees.
28. The bonnet lock mechanism of claim 26, wherein the at least one actuation step comprises an actuation step angle of less than 45 degrees.
29. The bonnet lock mechanism of claim 21, wherein the radial lock is slidably attached to the radial lock displacement device.
30. A bonnet lock mechanism for a blowout preventer comprising:
  - a radial lock disposed in a body of the blowout preventer; and
  - at least one lock actuator operatively coupled to the radial lock,
  - wherein the at least one lock actuator is adapted to radially displace the radial lock so that an internal surface of the radial lock forms a locking engagement with a bonnet positioned in a side opening of the body of the blowout preventer.
31. The bonnet lock mechanism of claim 30, wherein the radial lock comprises at least one segment, the at least one segment comprising at least one substantially straight segment and at least two curved segments.

32. The bonnet lock mechanism of claim 31, wherein the at least two curved segments comprises a plurality of kerfs.
33. The bonnet lock mechanism of claim 32, wherein the kerfs comprise substantially rectangular shapes.
34. The bonnet lock mechanism of claim 32, wherein the kerfs comprise substantially trapezoidal shapes.
35. The bonnet lock mechanism of claim 31, wherein the at least one substantially straight segment is formed from a different material than a material forming the at least two curved segments.
36. The bonnet lock mechanism of claim 1, wherein the at least one lock actuator is coupled to the bonnet.
37. The bonnet lock mechanism of claim 1, wherein the at least one lock actuator is coupled to a bonnet door that is coupled to the bonnet.
38. The bonnet lock mechanism of claim 37, wherein the at least one lock actuator is coupled to an exterior surface of the bonnet door.
39. The bonnet lock mechanism of claim 1, wherein the at least one lock actuator comprises a hydraulic actuator.
40. The bonnet lock mechanism of claim 1, wherein the at least one lock actuator comprises a pneumatic actuator.
41. The bonnet lock mechanism of claim 1, wherein the at least one lock actuator comprises an electrically powered motor.
42. The bonnet lock mechanism of claim 1, wherein the at least one lock actuator comprises a manually operated actuator.

43. The bonnet lock mechanism of claim 1, further comprising a manual locking mechanism.
44. A blowout preventer comprising:  
a body;  
a bonnet cooperatively attached to the body proximate each of at least two oppositely disposed side openings formed in the body; and  
a radial locking mechanism cooperatively attached to each bonnet and adapted to secure each bonnet to the body proximate an inner perimeter of the at least two side openings.
45. The blowout preventer of claim 44, wherein the radial locking mechanism further comprises:  
a radial lock; and  
at least one lock actuator operatively coupled to the radial lock,  
wherein the at least one lock actuator is adapted to radially displace the radial lock so as to form a locking engagement between an external surface of the radial lock and an internal surface of the at least two side openings.
46. The blowout preventer of claim 44, wherein the radial locking mechanism further comprises:  
a radial lock;  
a radial lock displacement device; and  
at least one lock actuator operatively coupled to the radial lock displacement device,  
wherein the at least one lock actuator is adapted to axially displace the radial lock displacement device so as to radially displace the radial lock and form a locking engagement between an external surface of the radial lock and an internal surface of the at least two side openings.

47. A blowout preventer comprising:

- a body;
  - a bonnet cooperatively attached to the body proximate each of at least two oppositely disposed side openings formed in the body;
  - a bonnet door coupled to the bonnet;
  - a radial lock;
  - a radial lock displacement device;
  - at least one lock actuator operatively coupled to the radial lock displacement device and to a bonnet door, and
  - a bonnet seal adapted to form a sealing engagement between the bonnet and the at least two side openings,
- wherein the at least one lock actuator is adapted to axially displace the radial lock displacement device, the radial lock displacement device adapted to radially displace the radial lock so as to form a locking engagement between the bonnet and the at least two side openings.

48. A blowout preventer comprising:

- a body;
  - a bonnet cooperatively attached to the body proximate each of at least two oppositely disposed side openings formed in the body;
  - a radial lock disposed in the body;
  - at least one lock actuator operatively coupled to radial lock, and
  - a bonnet seal adapted to form a sealing engagement between the bonnet and the at least two side openings,
- wherein the at least one lock actuator is adapted to radially displace the radial lock so as to form a locking engagement between the bonnet and the body proximate the at least two side openings.

49. A method for securing a bonnet to a body of a blowout preventer, the method comprising:

positioning the bonnet proximate a side opening of a body of the blowout preventer;

activating at least one lock actuator operatively coupled to a radial lock

displacement device;

axially displacing the radial lock displacement device; and

radially displacing the radial lock with the radial lock displacement device so as to form a locking engagement between the bonnet and the body of the blowout preventer.

50. The method of claim 49, wherein the activating further comprises powering a hydraulic cylinder coupled to the radial lock displacement device.
51. The method of claim 49, wherein the activating further comprises activating a manual actuator coupled to the radial lock displacement device.
52. The method of claim 49, further comprising engaging a manual locking mechanism after forming the locking engagement.
53. The method of claim 49, further comprising:  
forming a sealing engagement between the bonnet and the body of the blowout preventer.
54. A method for securing a bonnet to a body of a blowout preventer, the method comprising:  
positioning the bonnet proximate a side opening of a body of the blowout preventer;  
activating at least one lock actuator operatively coupled to a radial lock, the radial lock disposed in the body of the blowout preventer; and  
radially displacing the radial lock so as to form a locking engagement between the bonnet and the body of the blowout preventer.

55. The method of claim 54, further comprising:  
forming a sealing engagement between the bonnet and the body of the  
blowout preventer.
56. The method of claim 54, wherein the activating further comprises powering a  
hydraulic cylinder coupled to the radial lock.

**1/11**

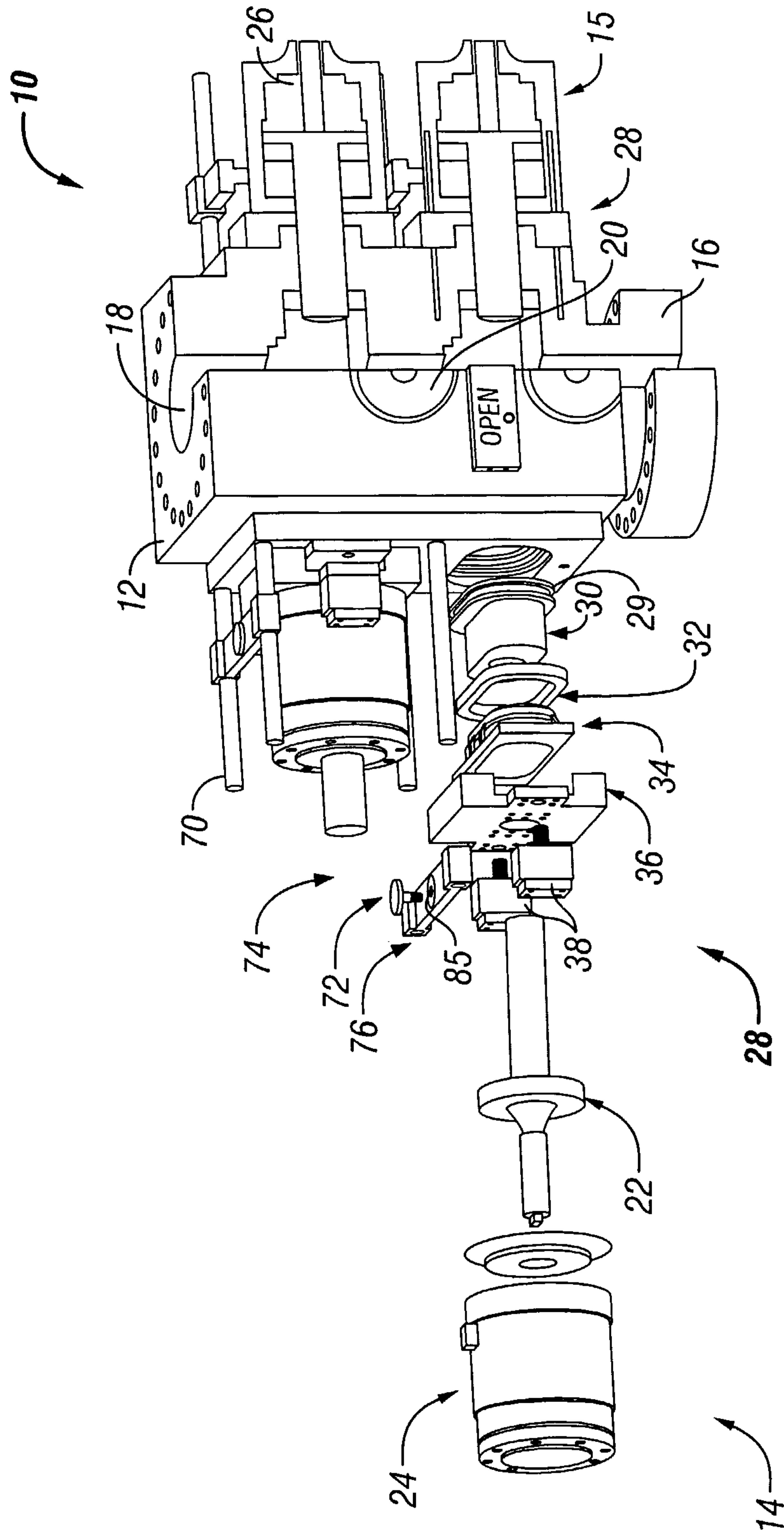
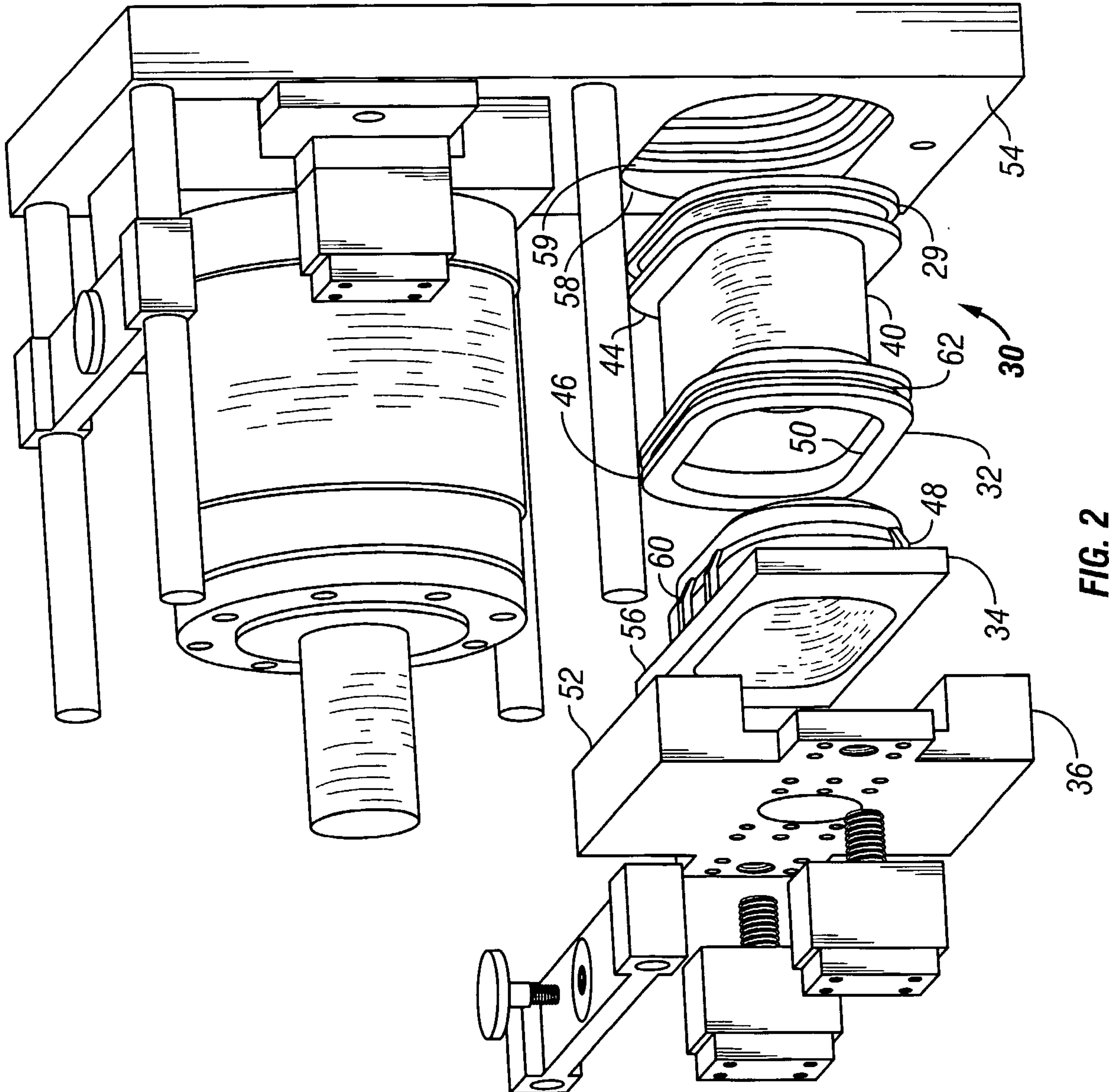
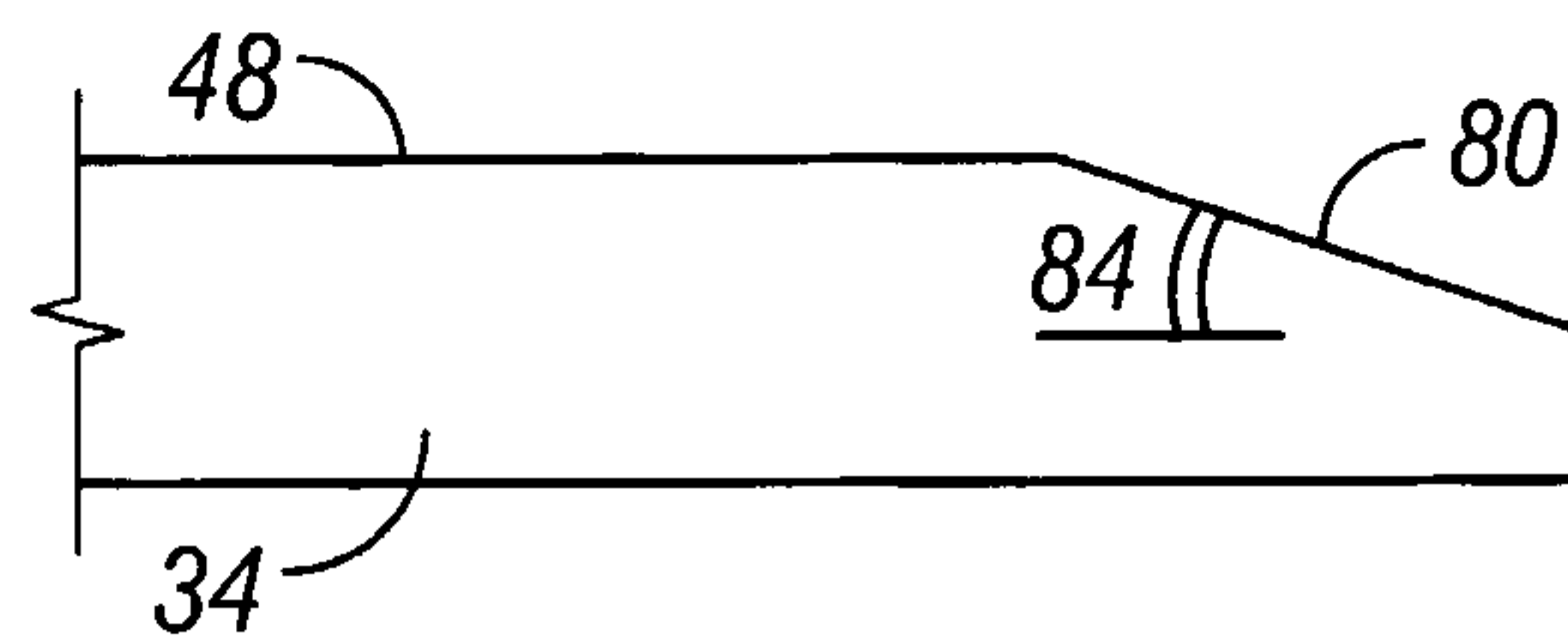
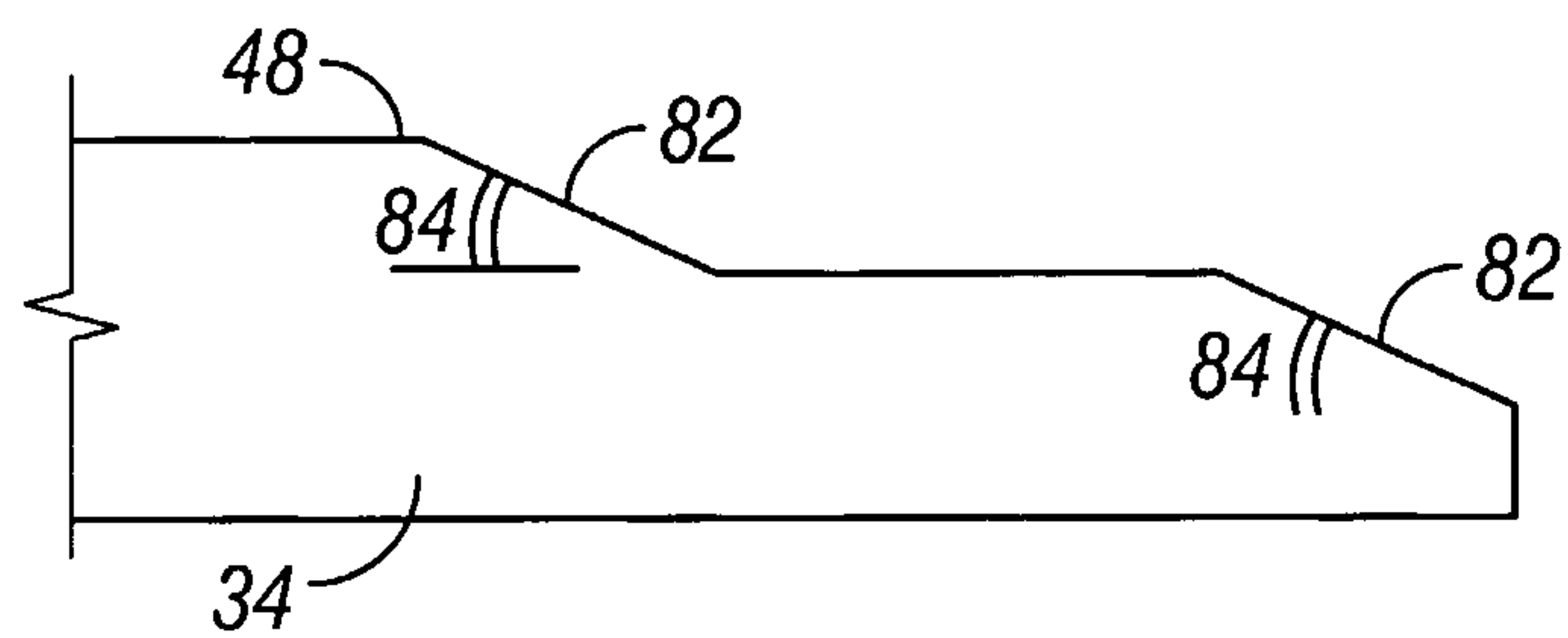
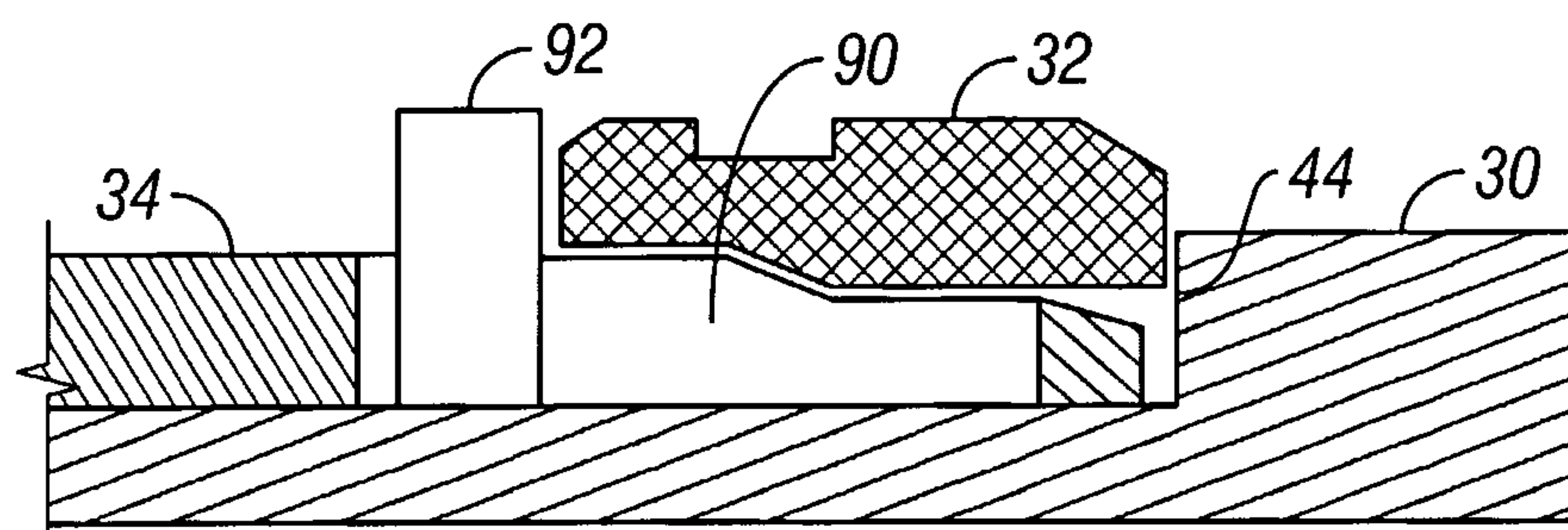
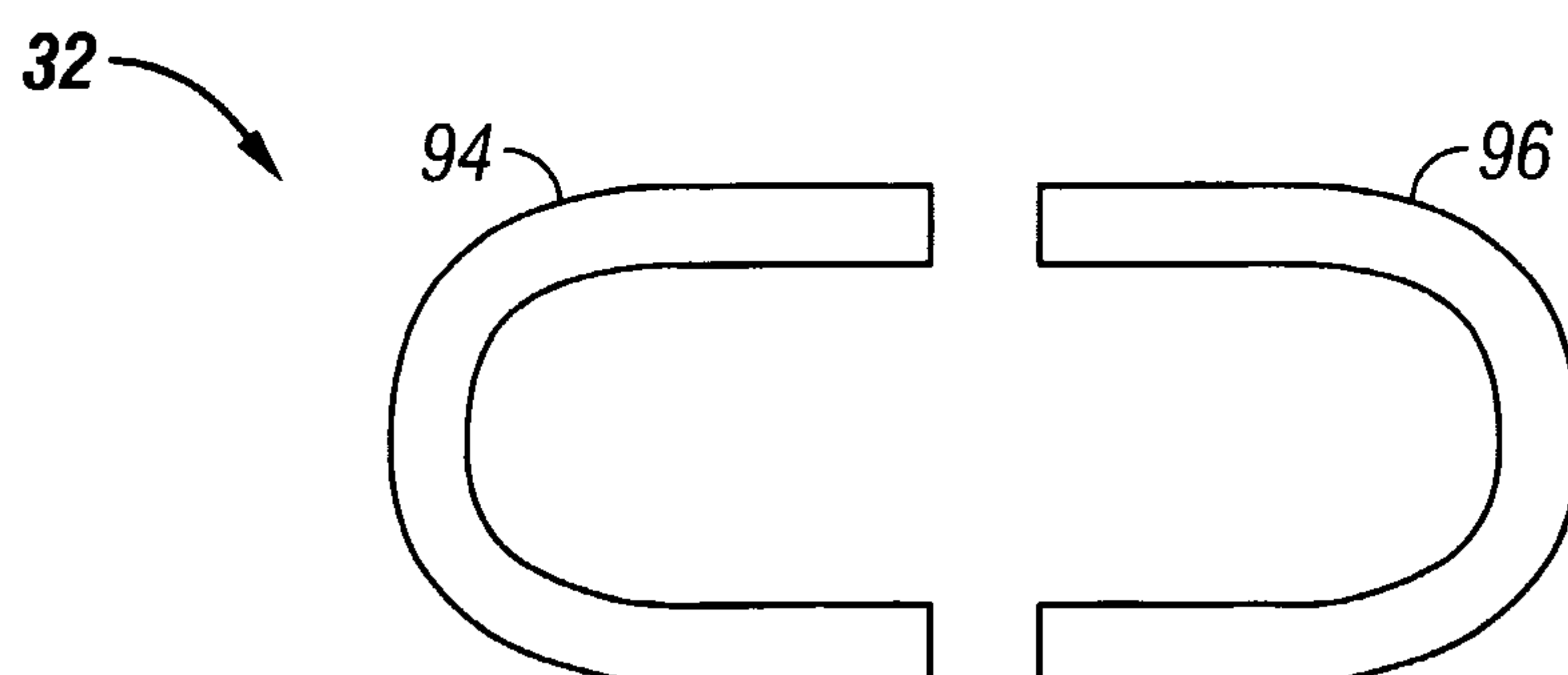


**FIG. 1**

2/11



**3/11****FIG. 3****FIG. 4****FIG. 5****FIG. 6**

4/11

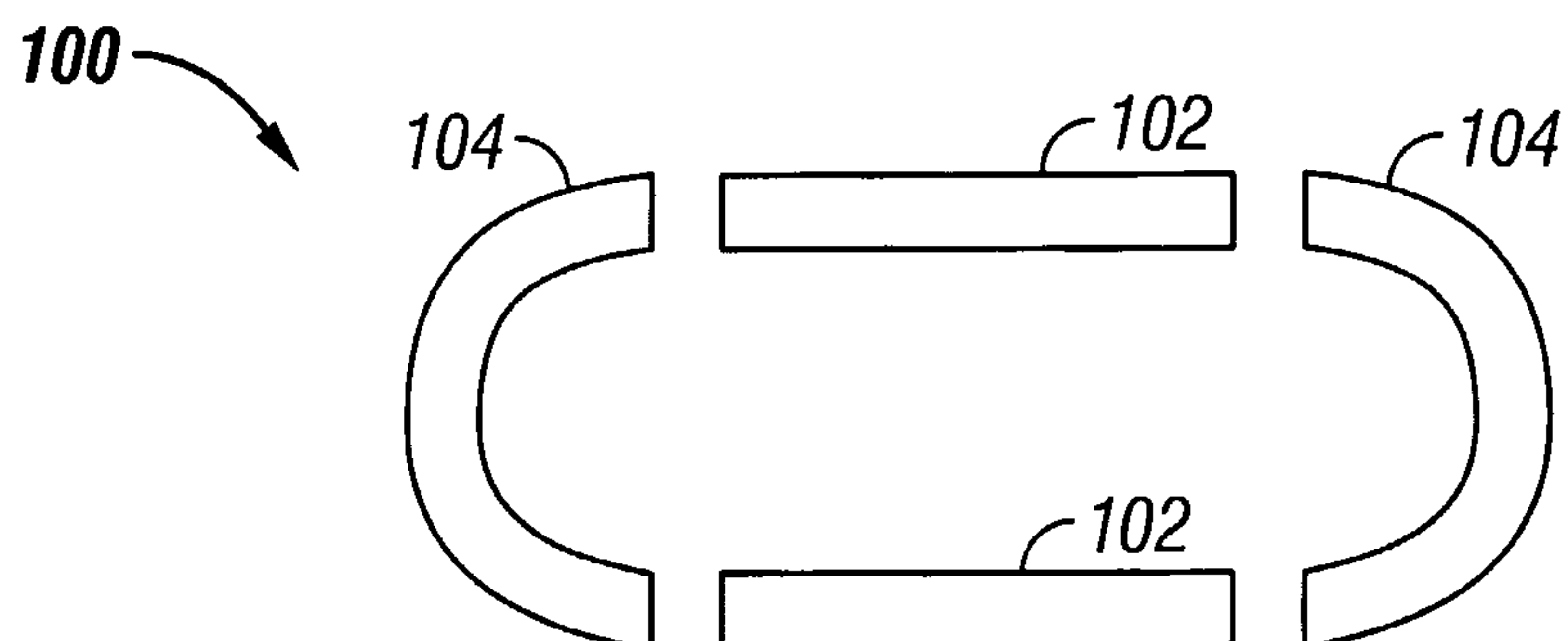


FIG. 7

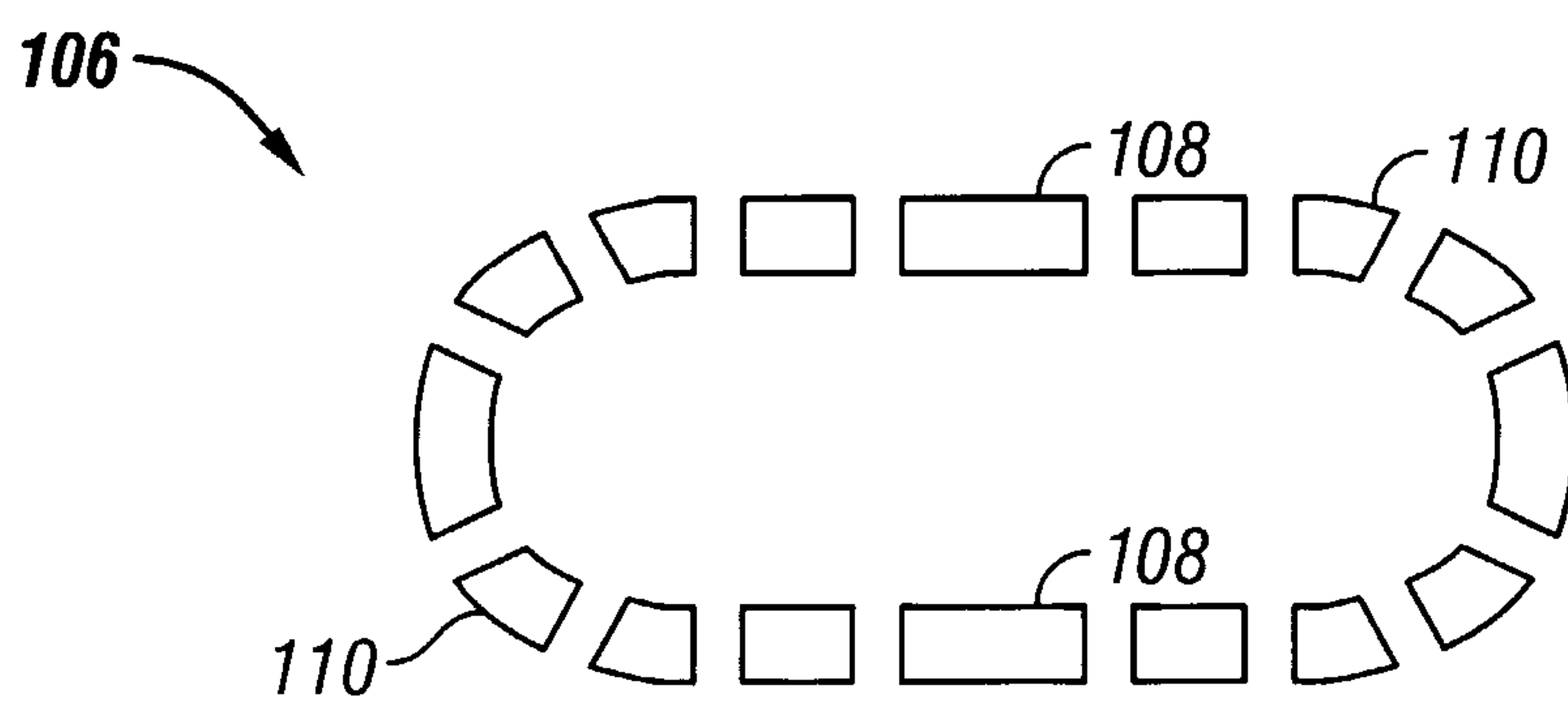


FIG. 8

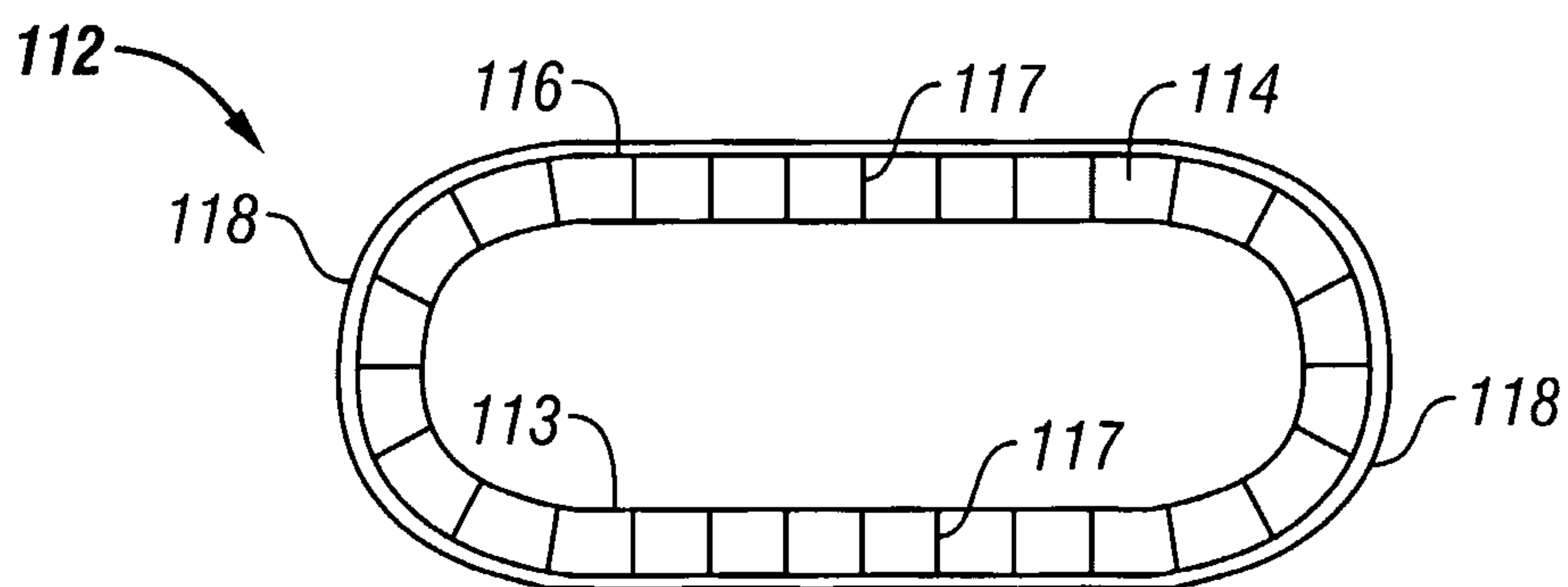


FIG. 9

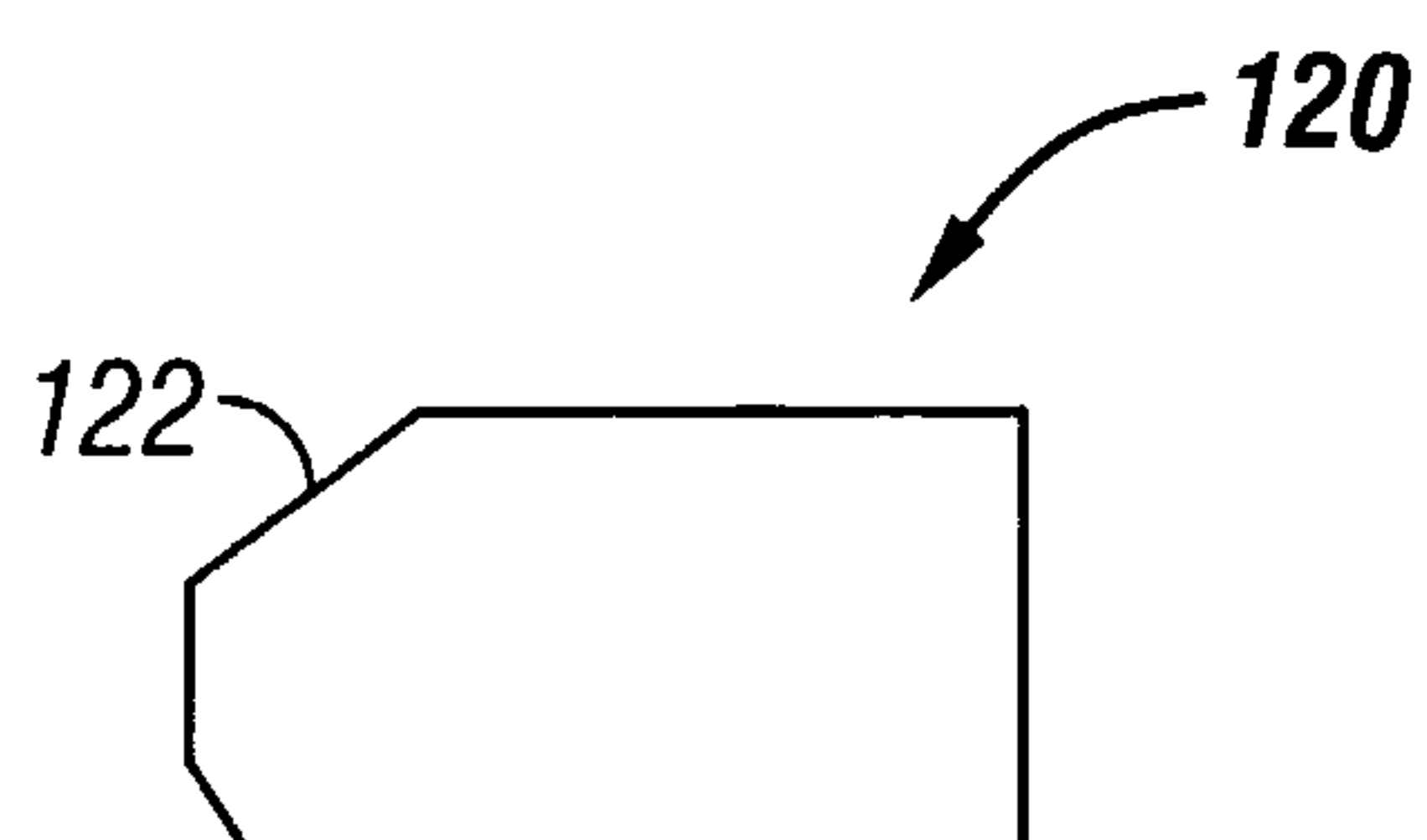
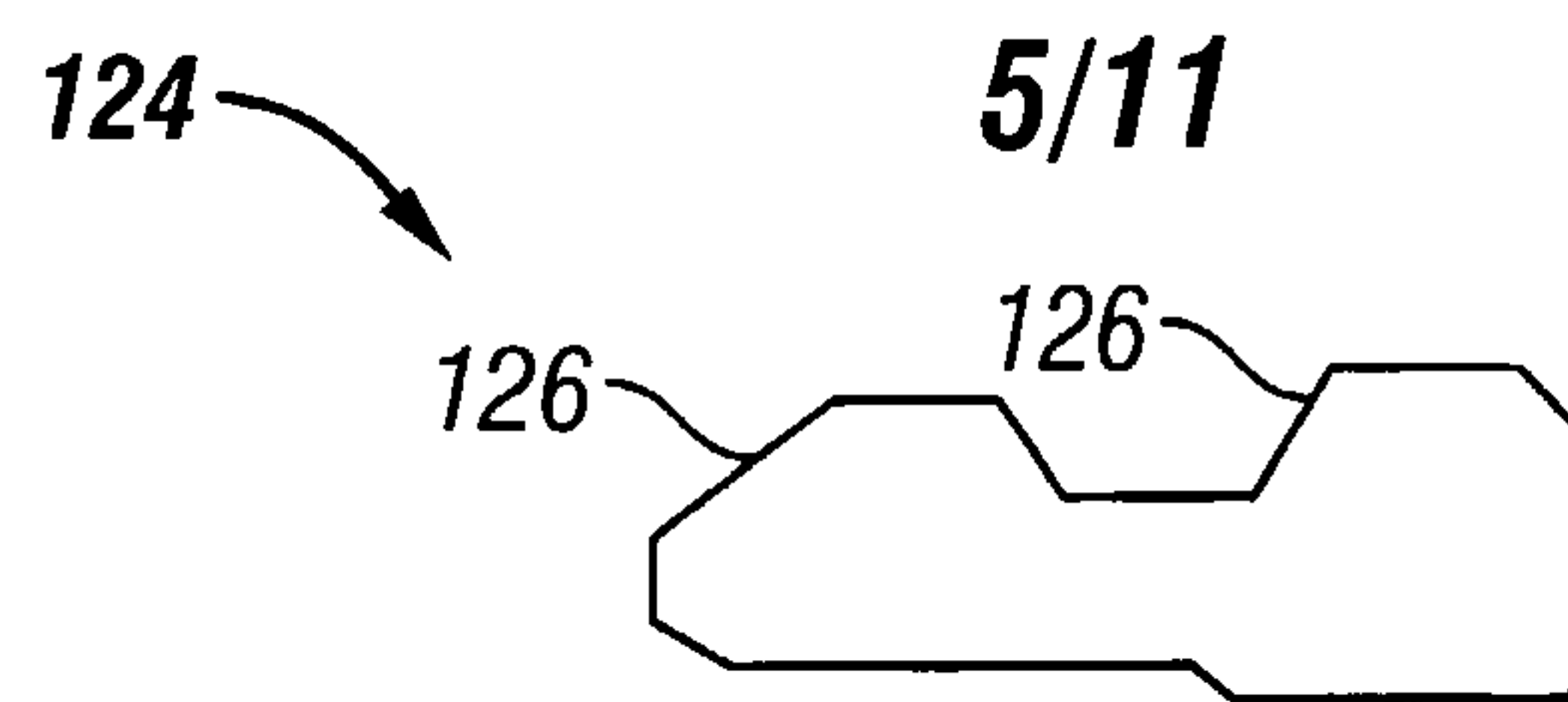
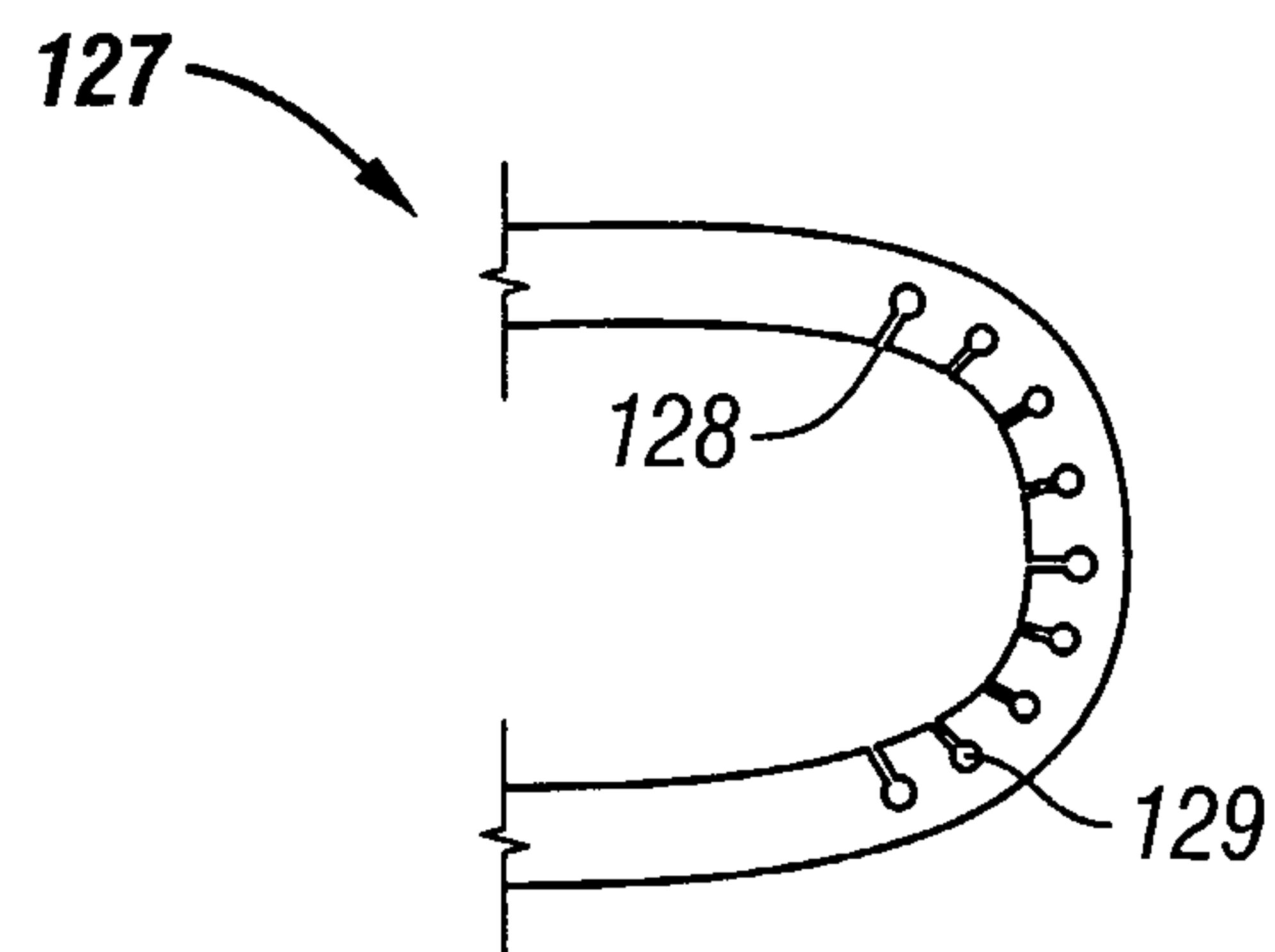
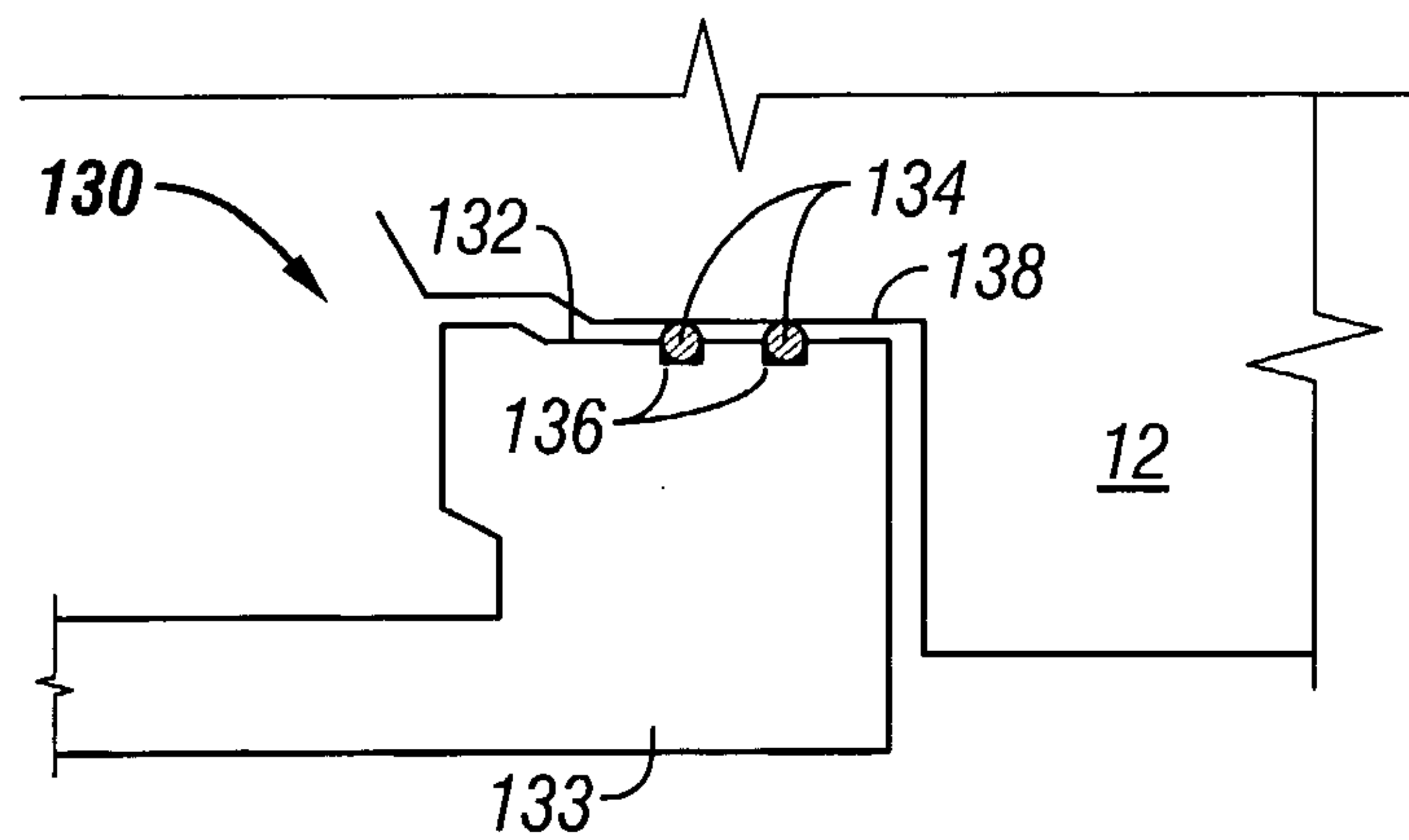
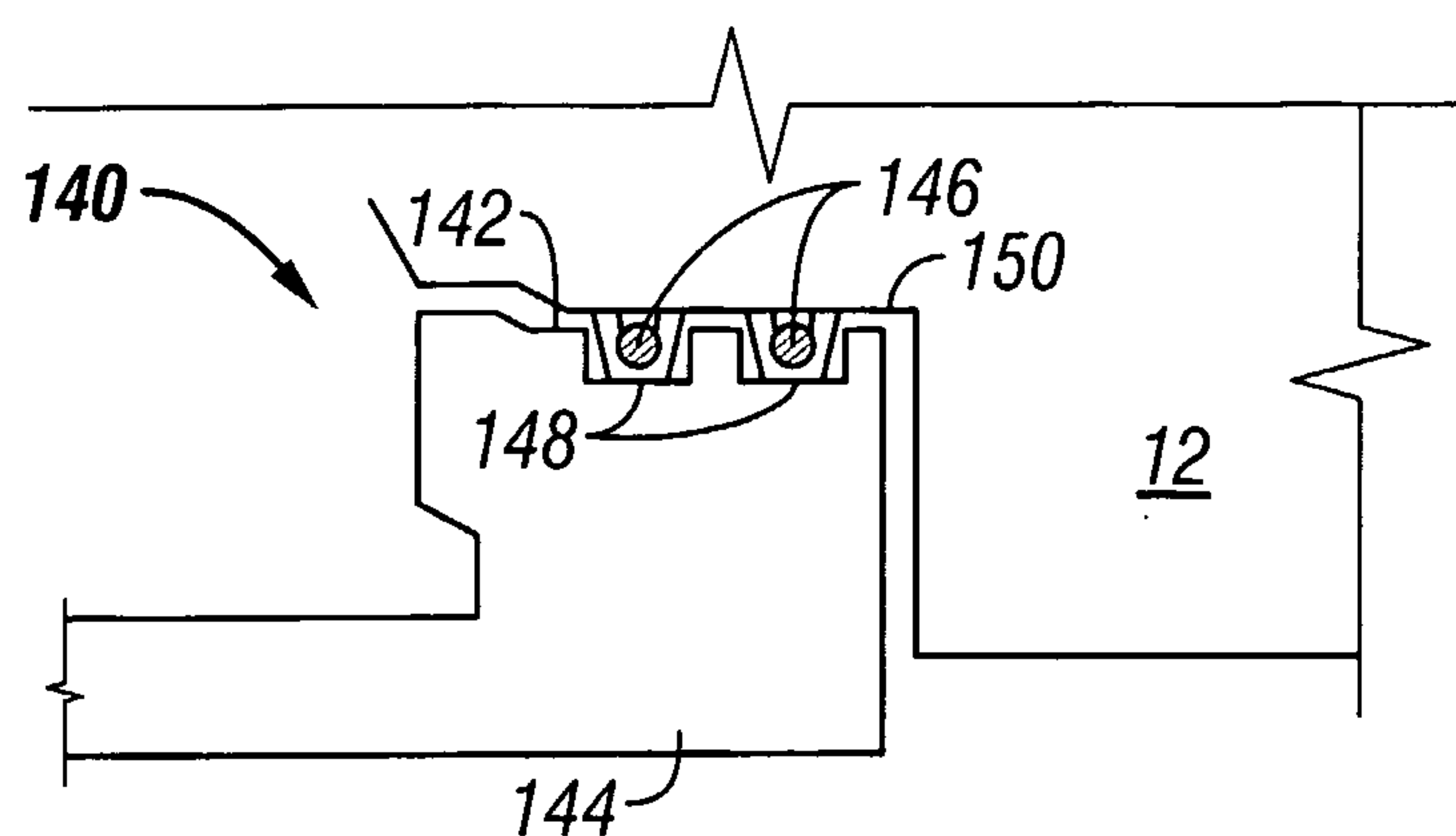
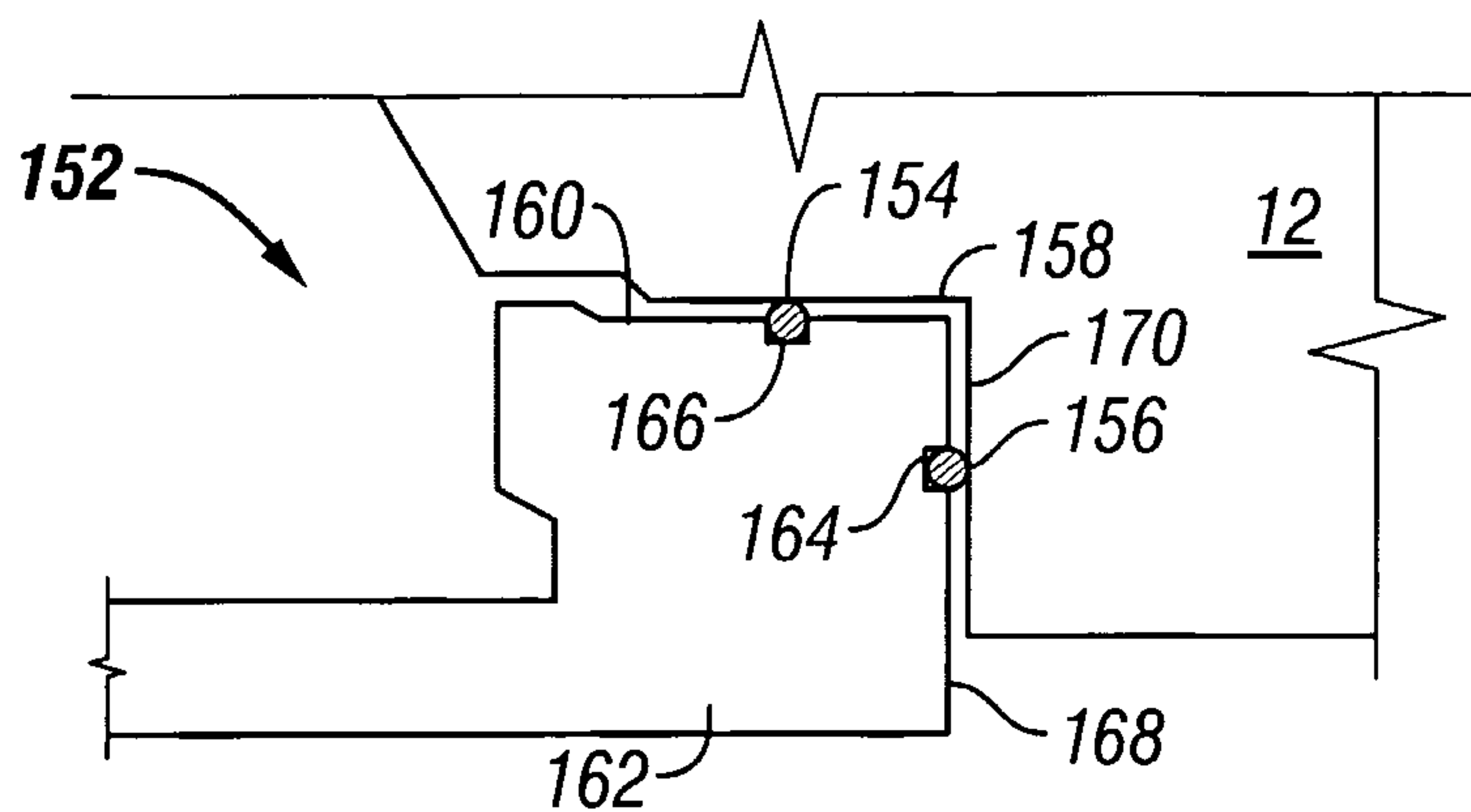
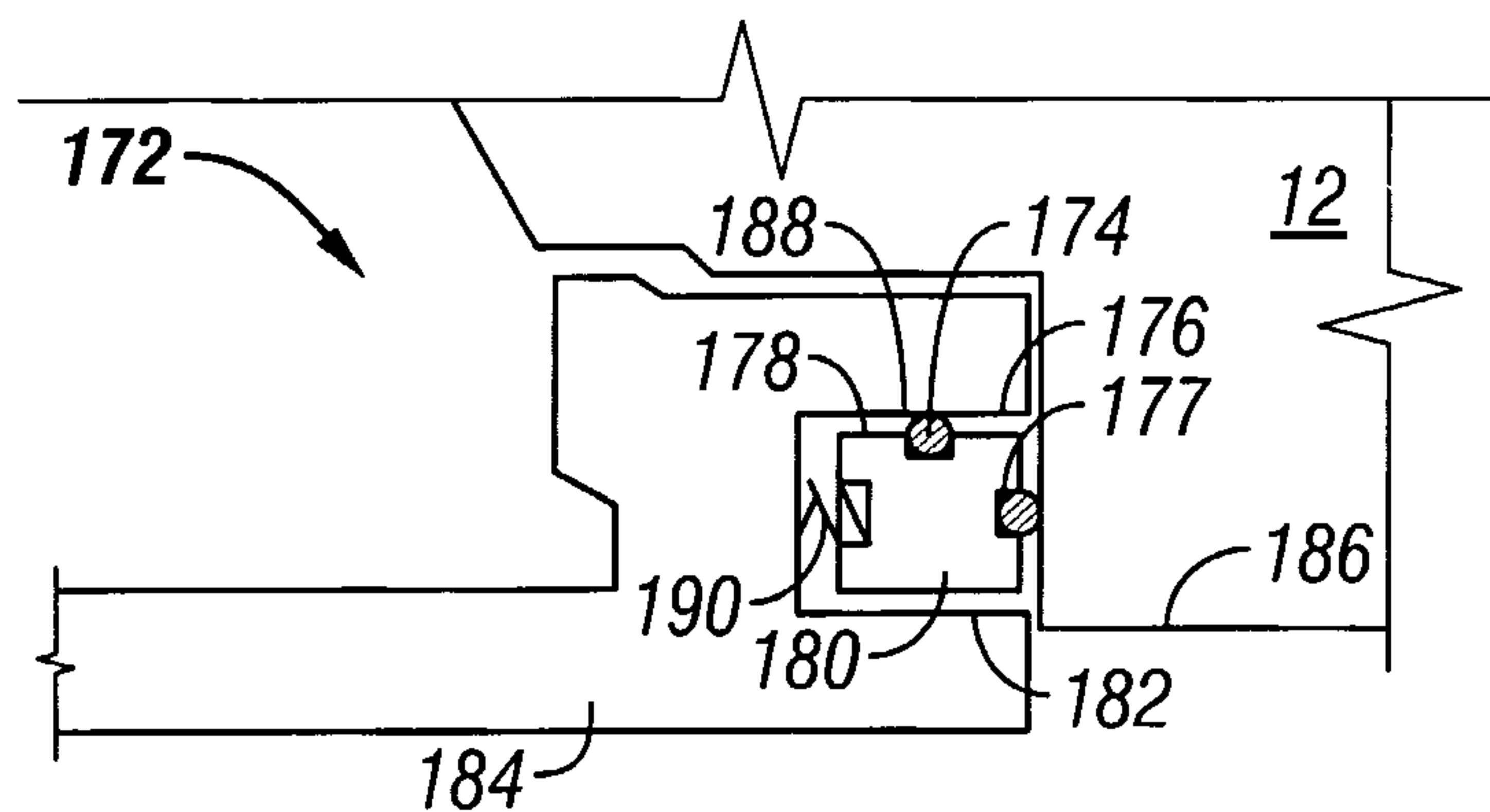
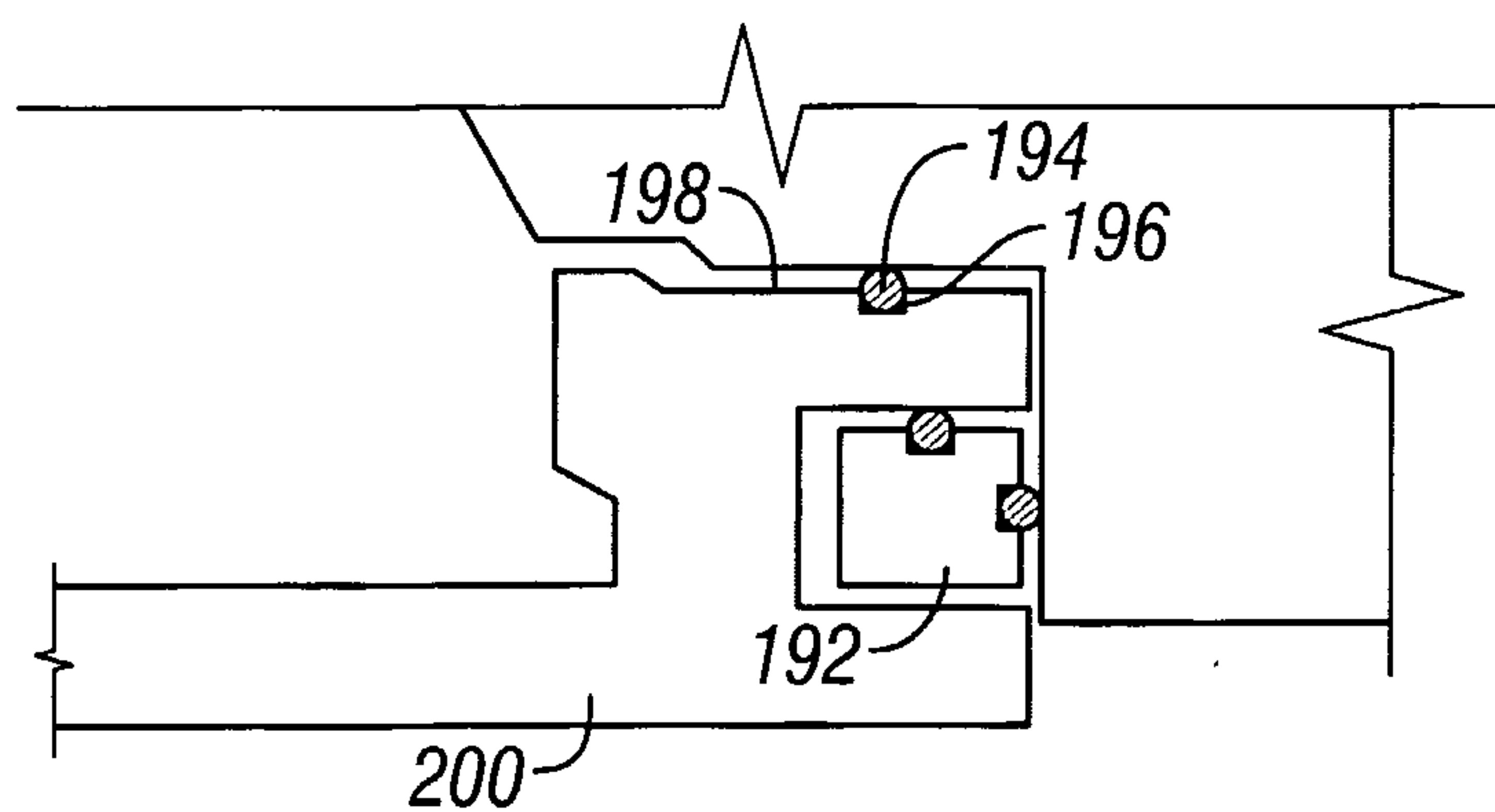
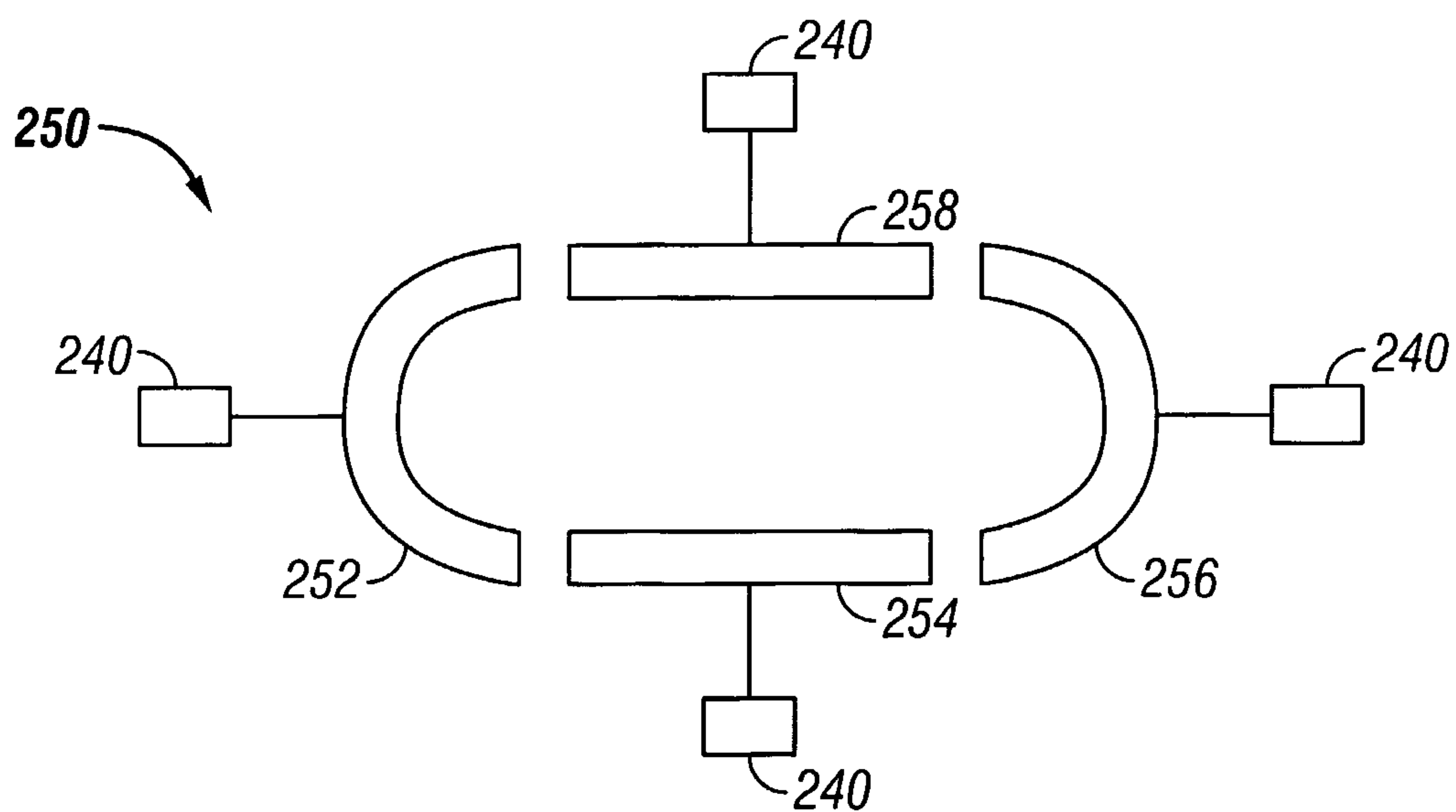
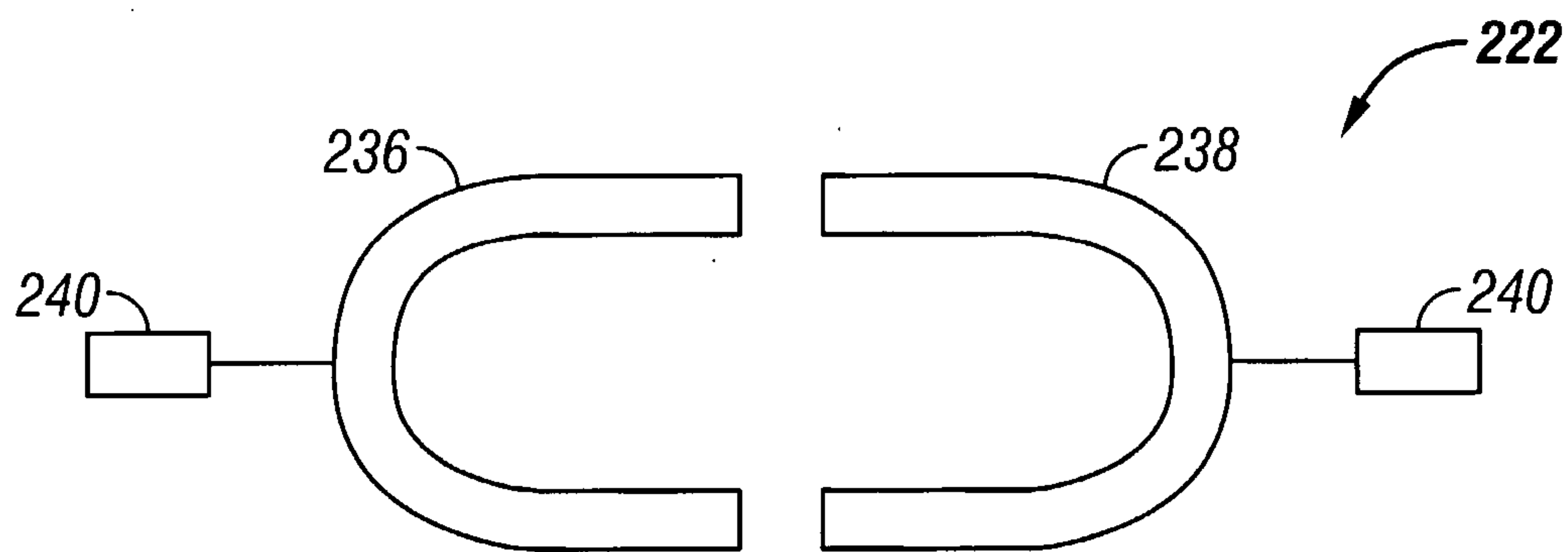
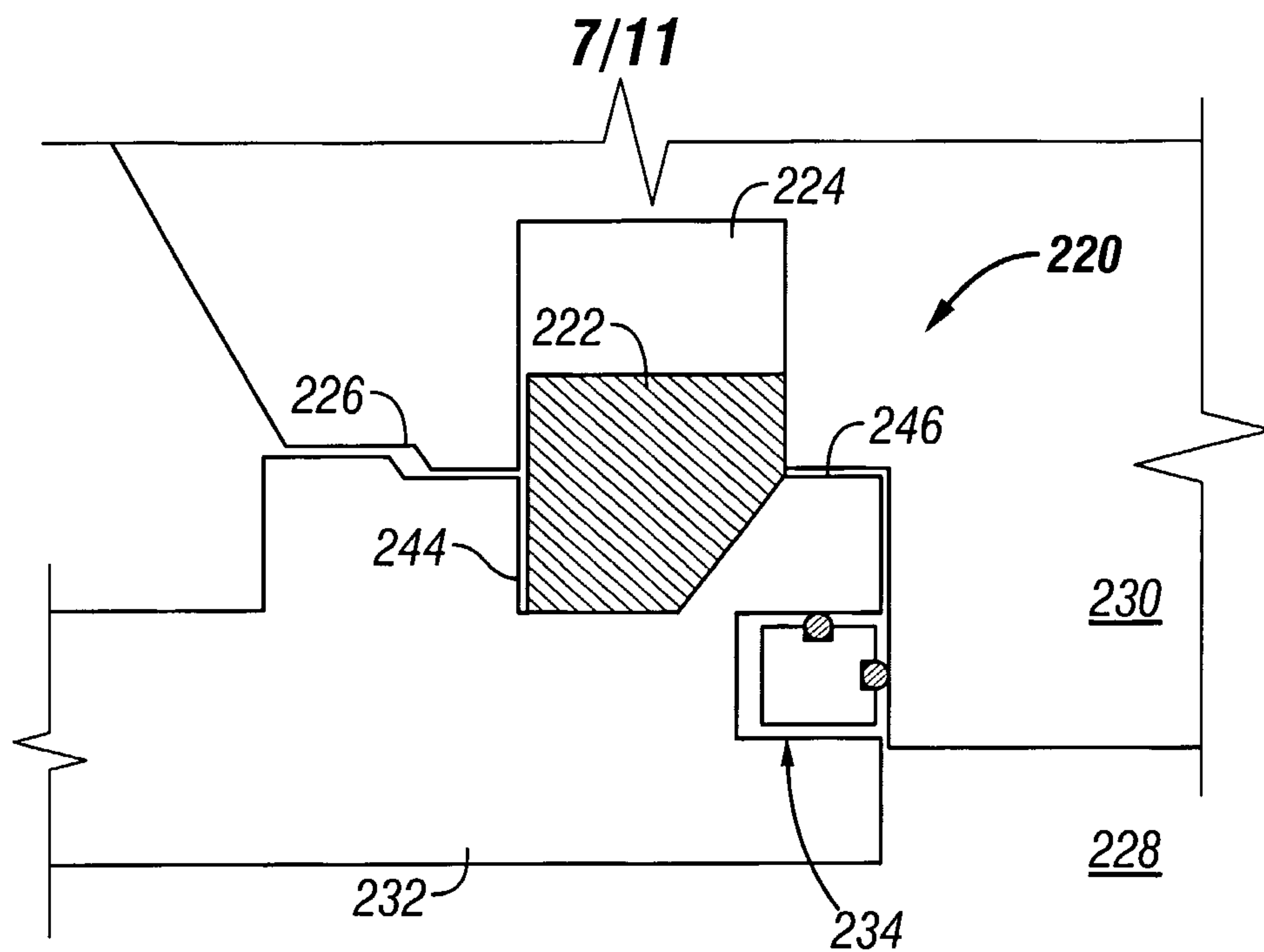


FIG. 10

**FIG. 11****FIG. 12****FIG. 13****FIG. 14**

**6/11****FIG. 15****FIG. 16****FIG. 17**



8/11

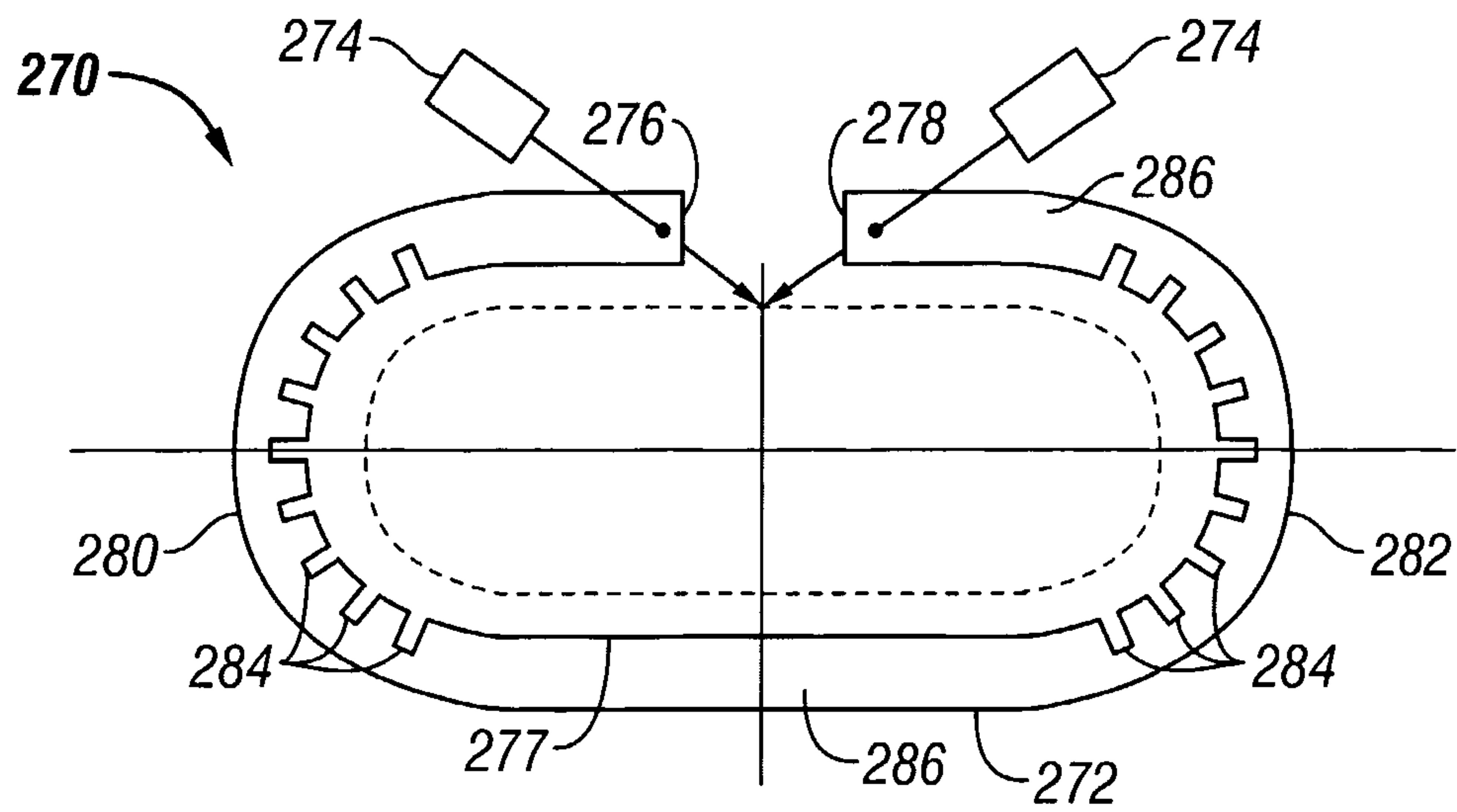


FIG. 21

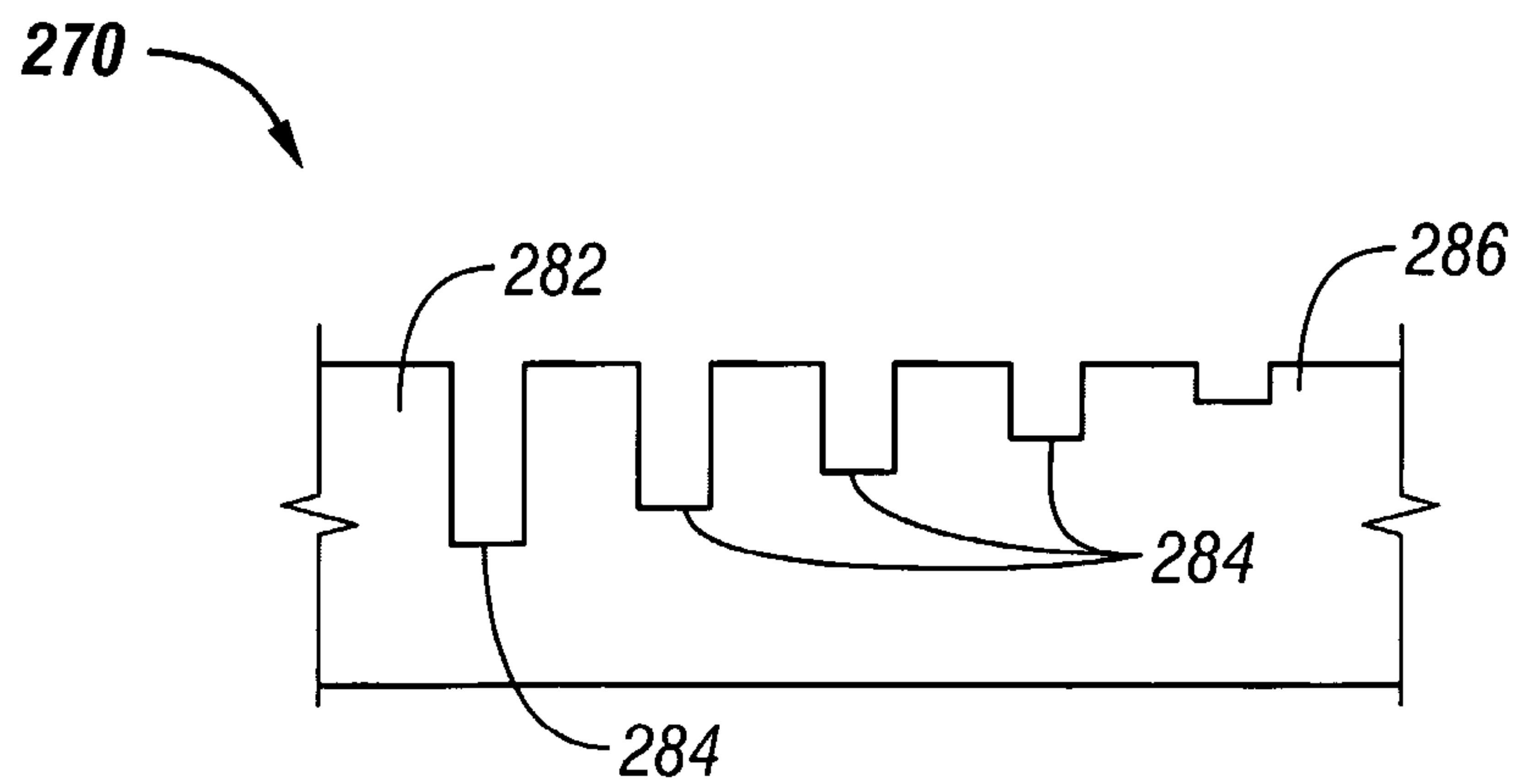
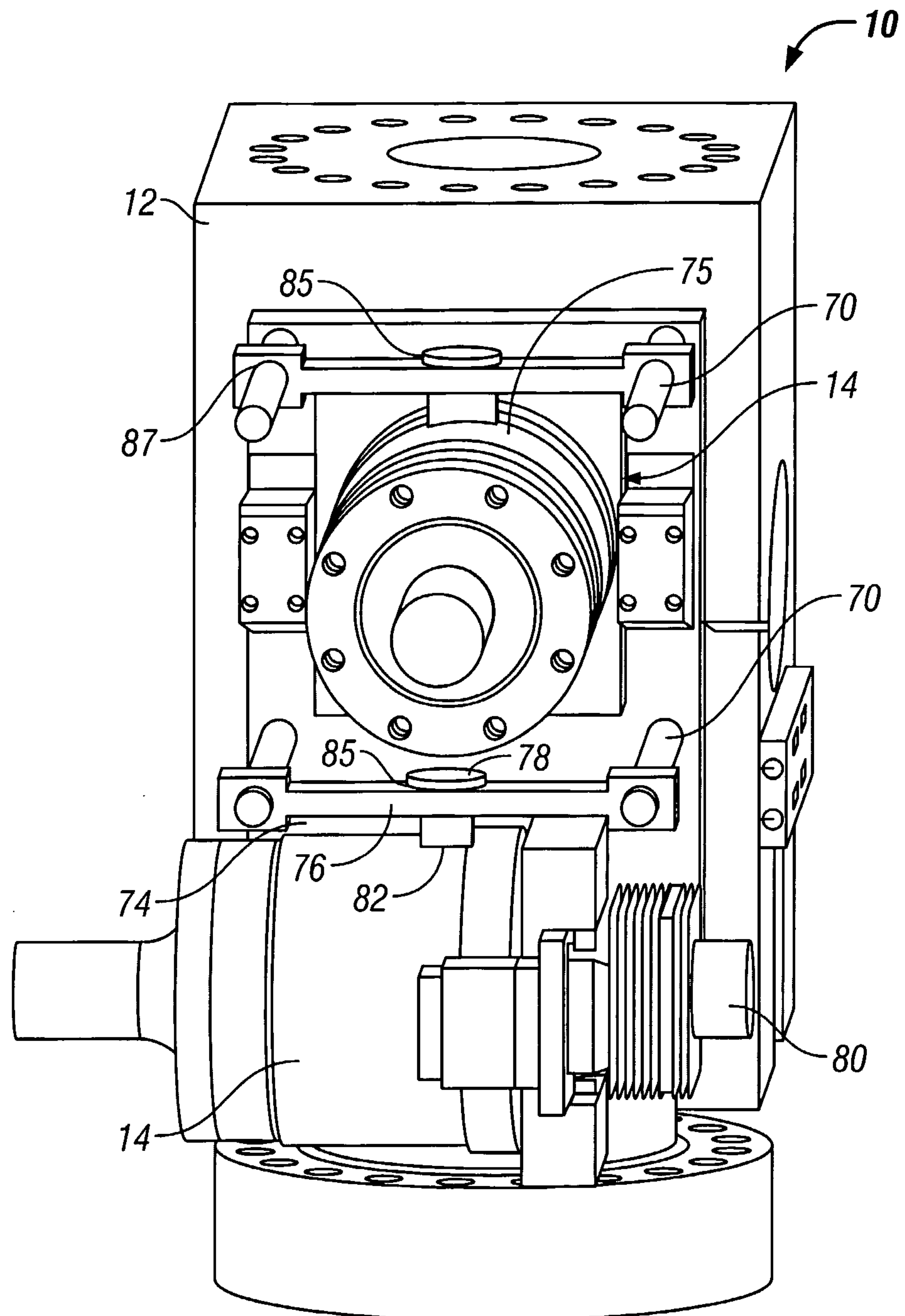
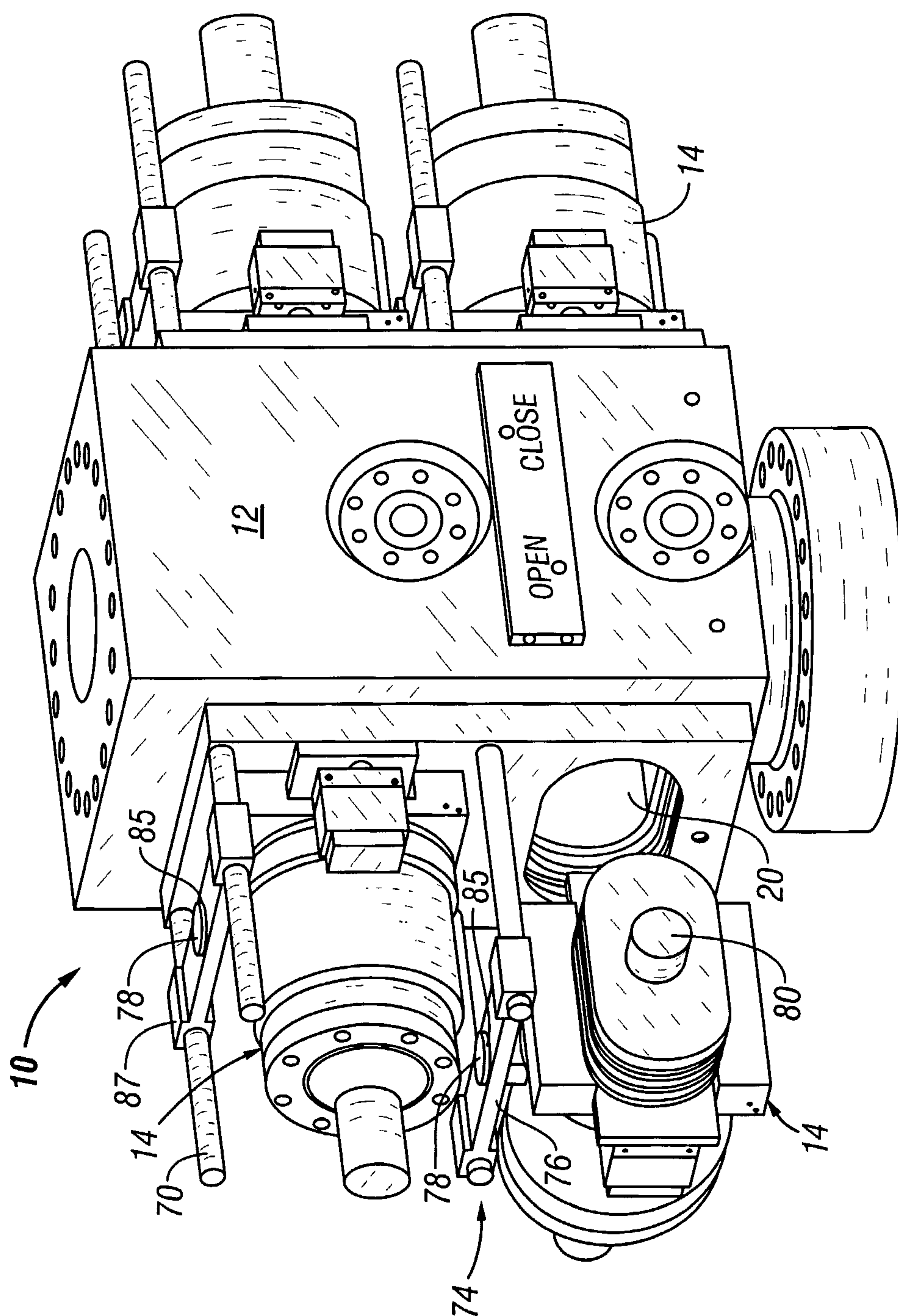
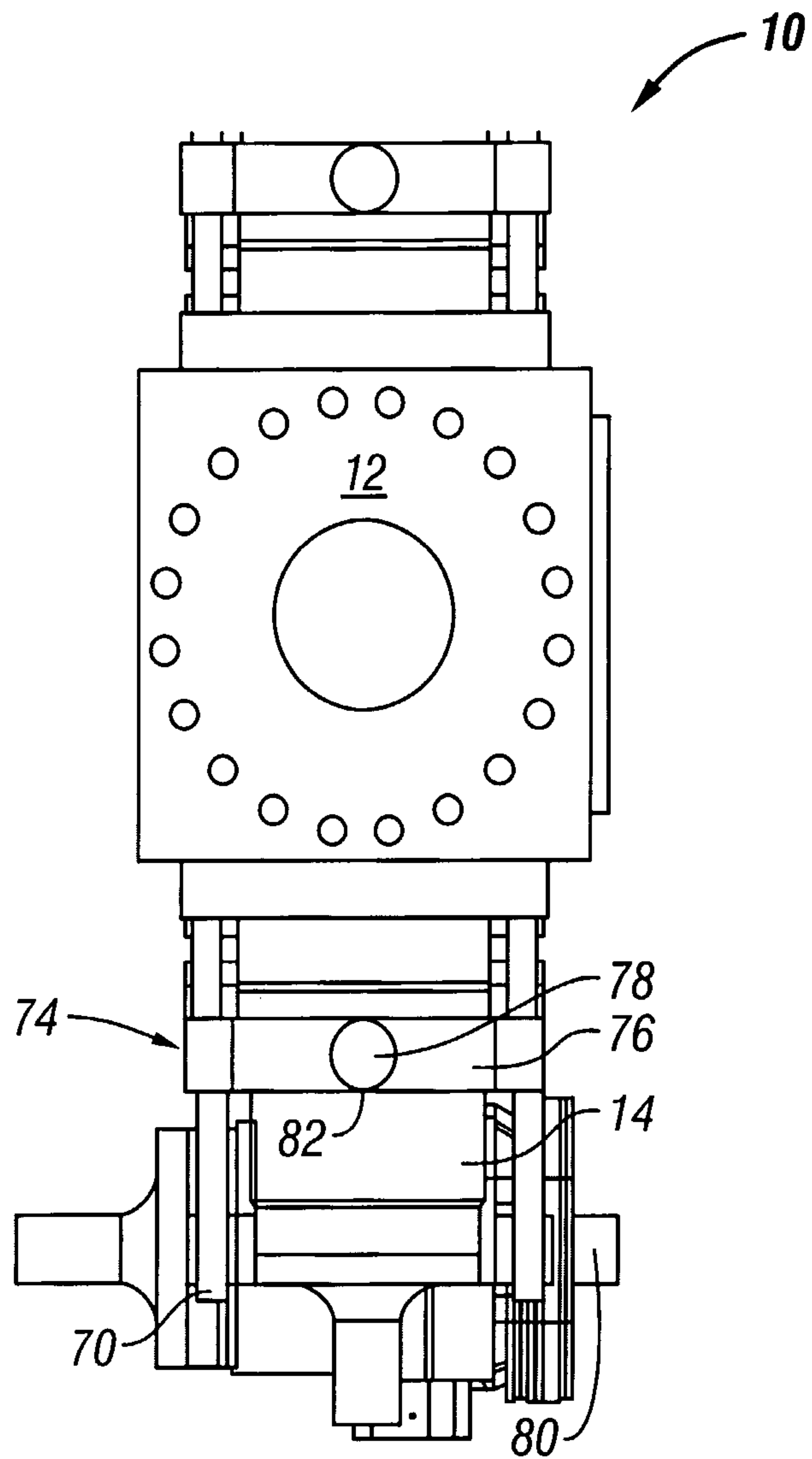


FIG. 22

**9/11****FIG. 23**

10/11



**11/11****FIG. 25**

