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F16J 15/14 (2006.01)
F16J 15/02 (2006.01)

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CPC ***E21B 33/1212*** (2013.01); ***F16J 15/028*** (2013.01); ***E21B 33/12*** (2013.01); ***F16J 15/128*** (2013.01); ***E21B 33/128*** (2013.01)

(58) **Field of Classification Search**
USPC 277/334, 336-341, 605, 607, 645
See application file for complete search history.

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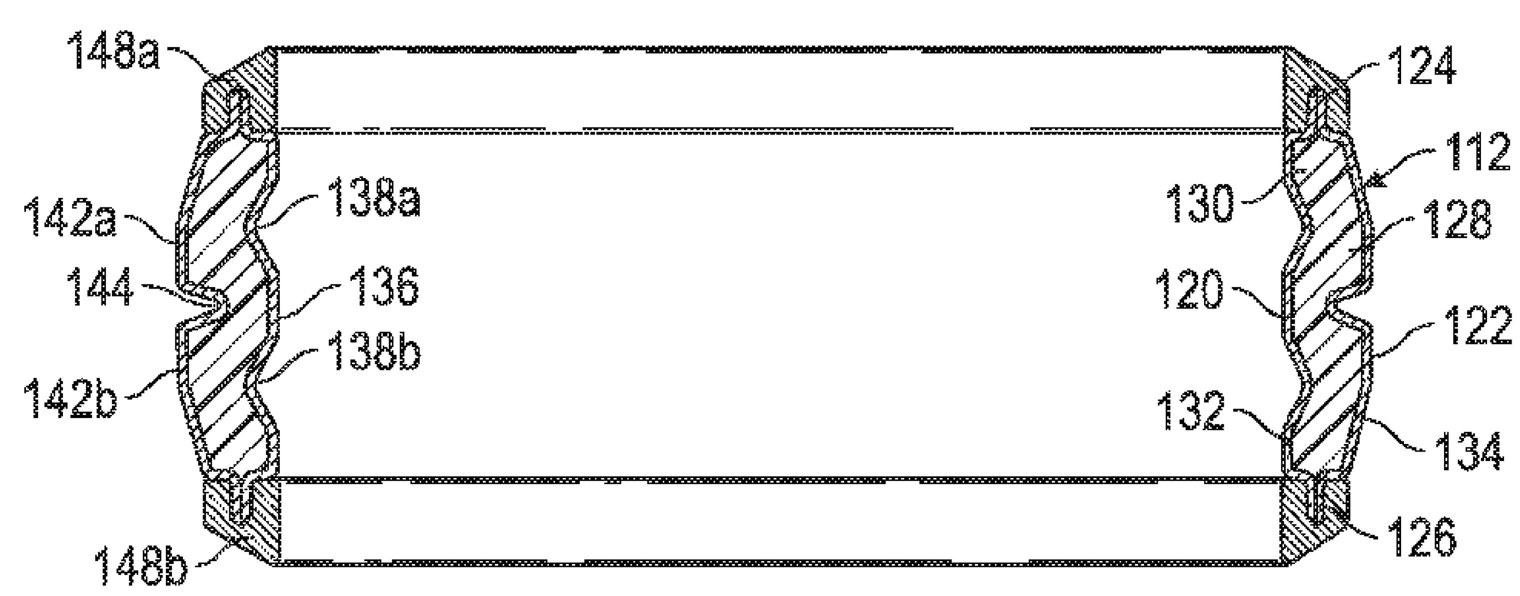
(57) **ABSTRACT**

An annular sealing element to seal between metal surfaces for use in flanges, joints, packers and the like, located in oil and gas exploration and production equipment. The sealing element has inner and outer metal deformable surfaces joined at ends, defining an interior volume which is entirely filled with a plastic deformable material. The surfaces are arranged such that on compression of the element from the ends, the element will deform in a controlled manner on a cantilever principle. The volume of filler and the interior volume remain substantially equal during compression so that delamination does not occur. Thus the sealing element provides a seal combining the flexibility of elastomer seals with the integrity of a metal to metal seal.

27 Claims, 5 Drawing Sheets



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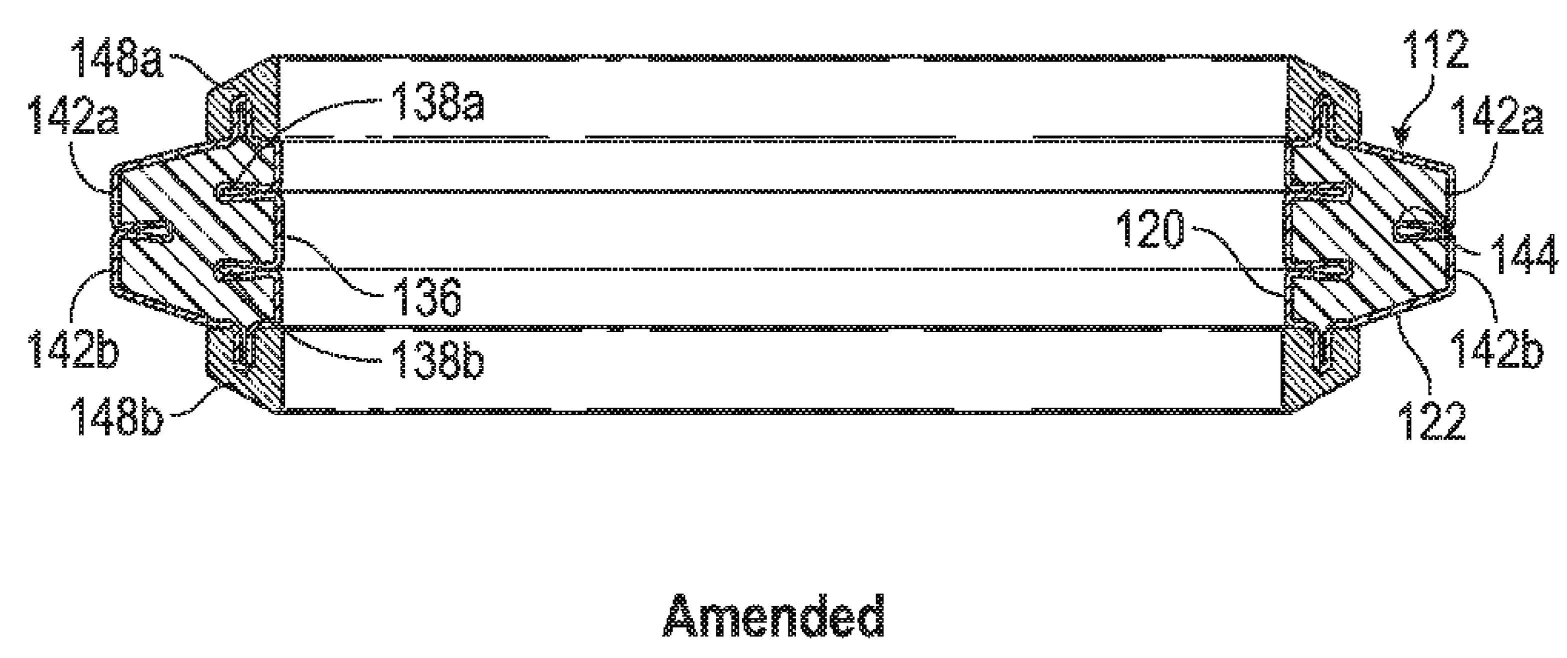

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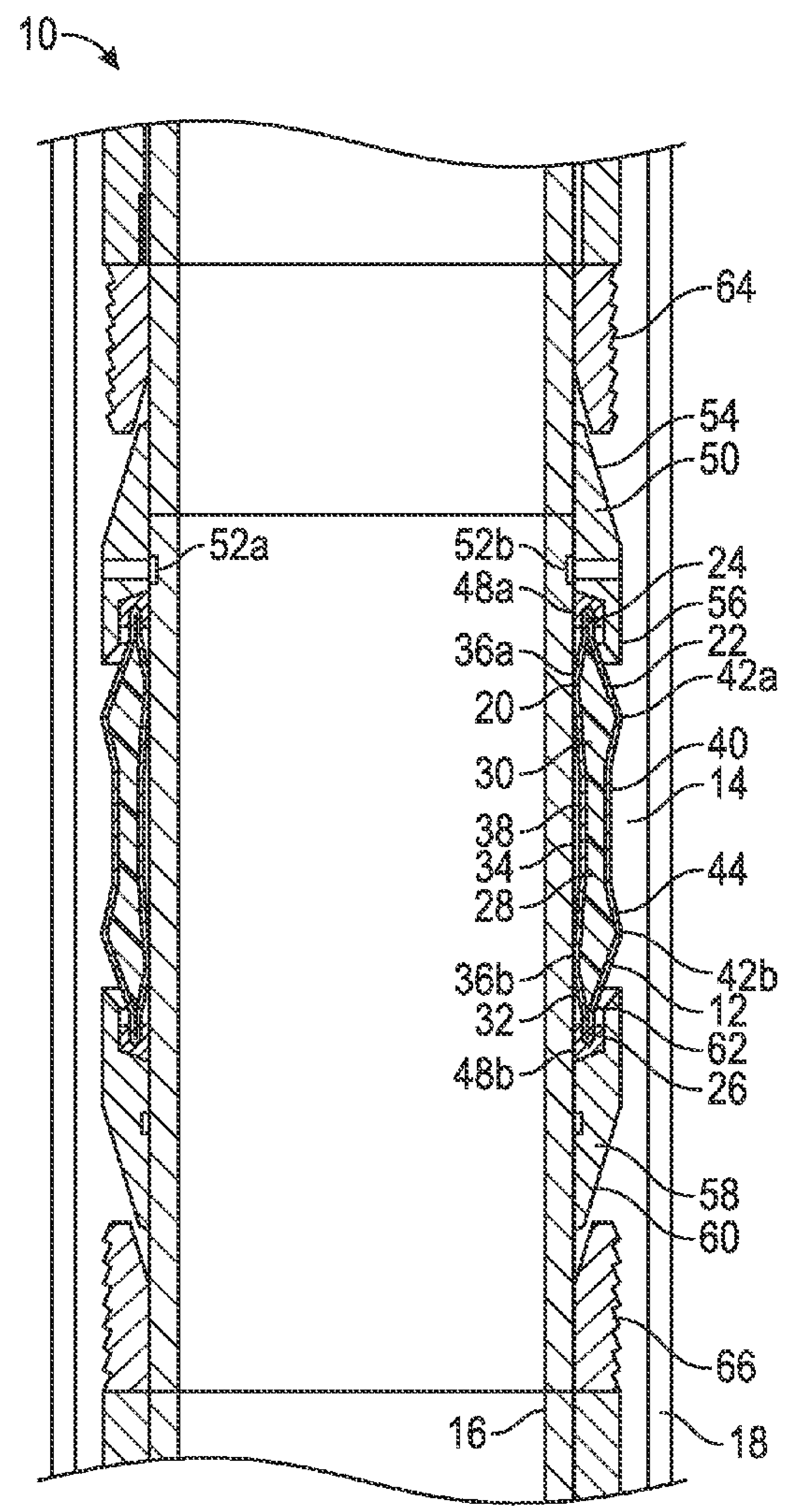

FIG. 1
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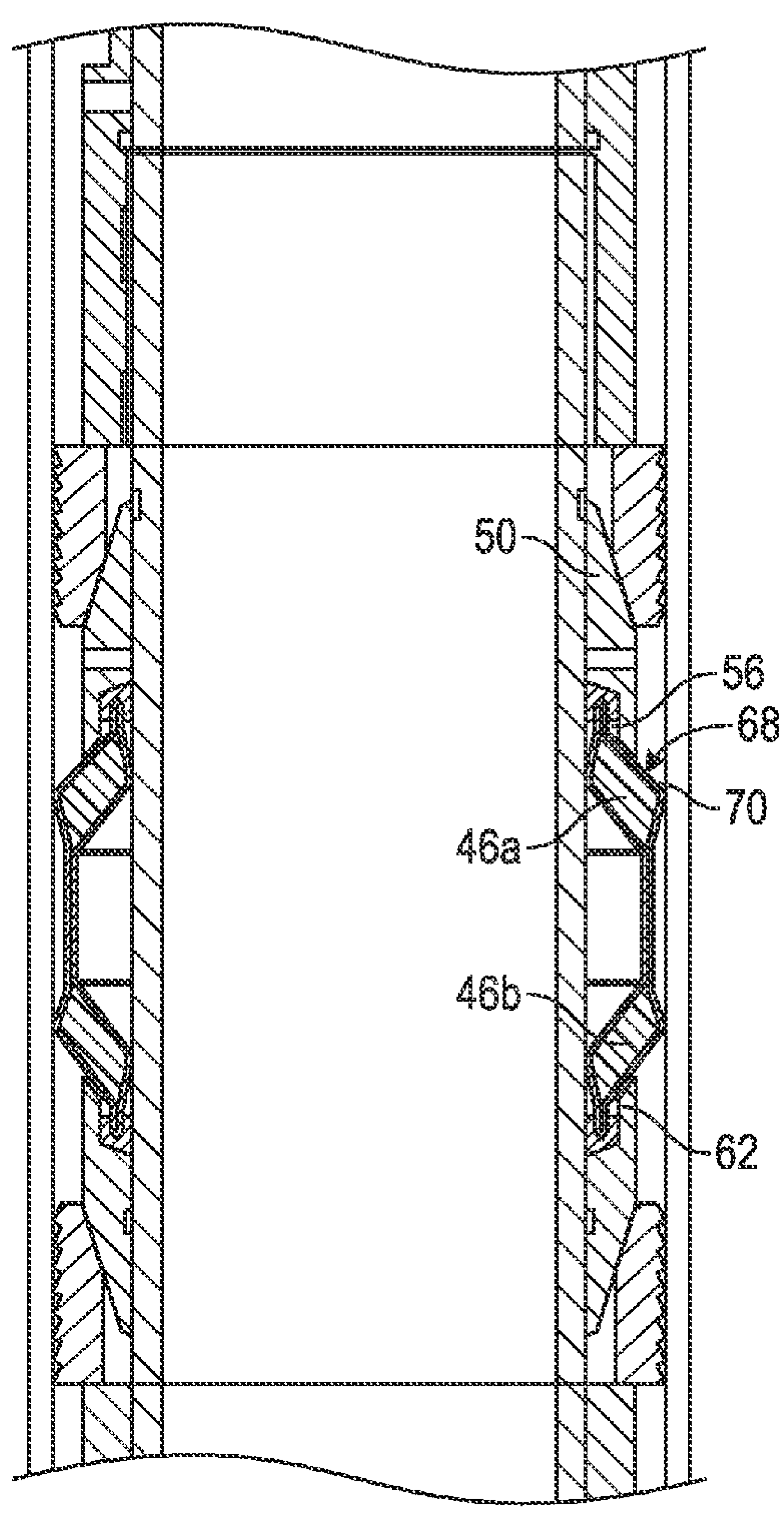

FIG. 2
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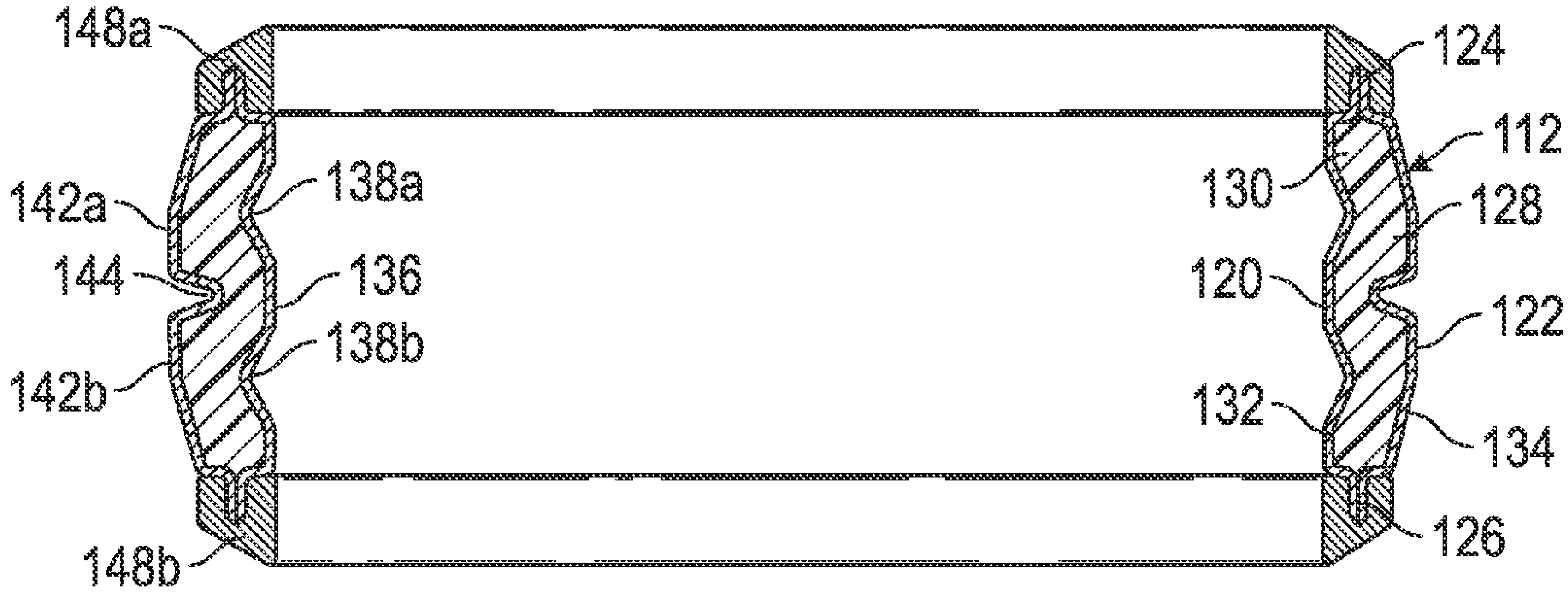

FIG. 3
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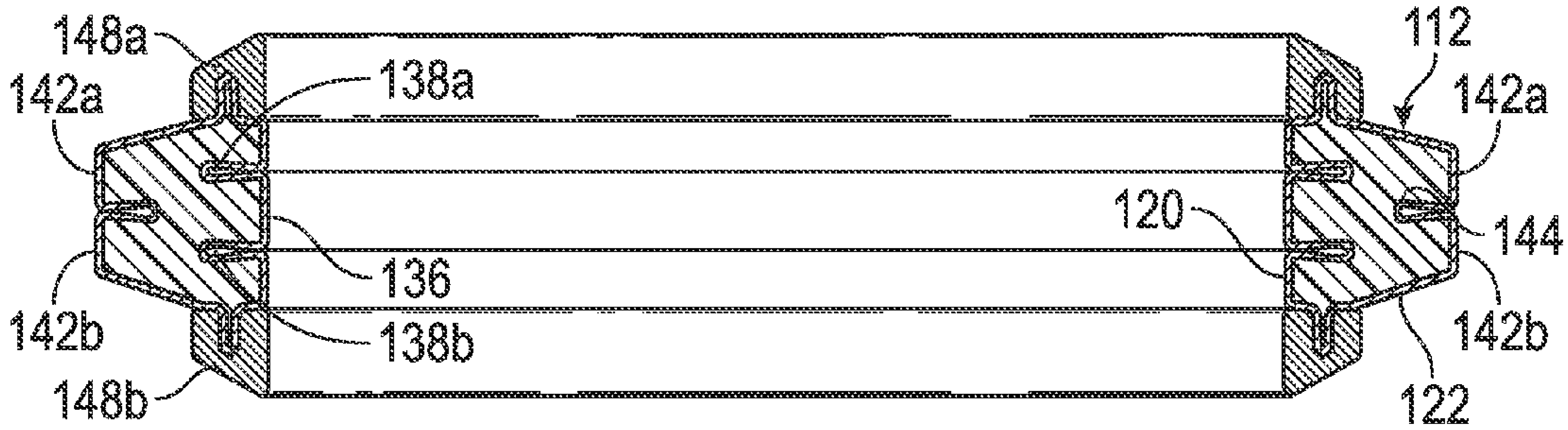

FIG. 4
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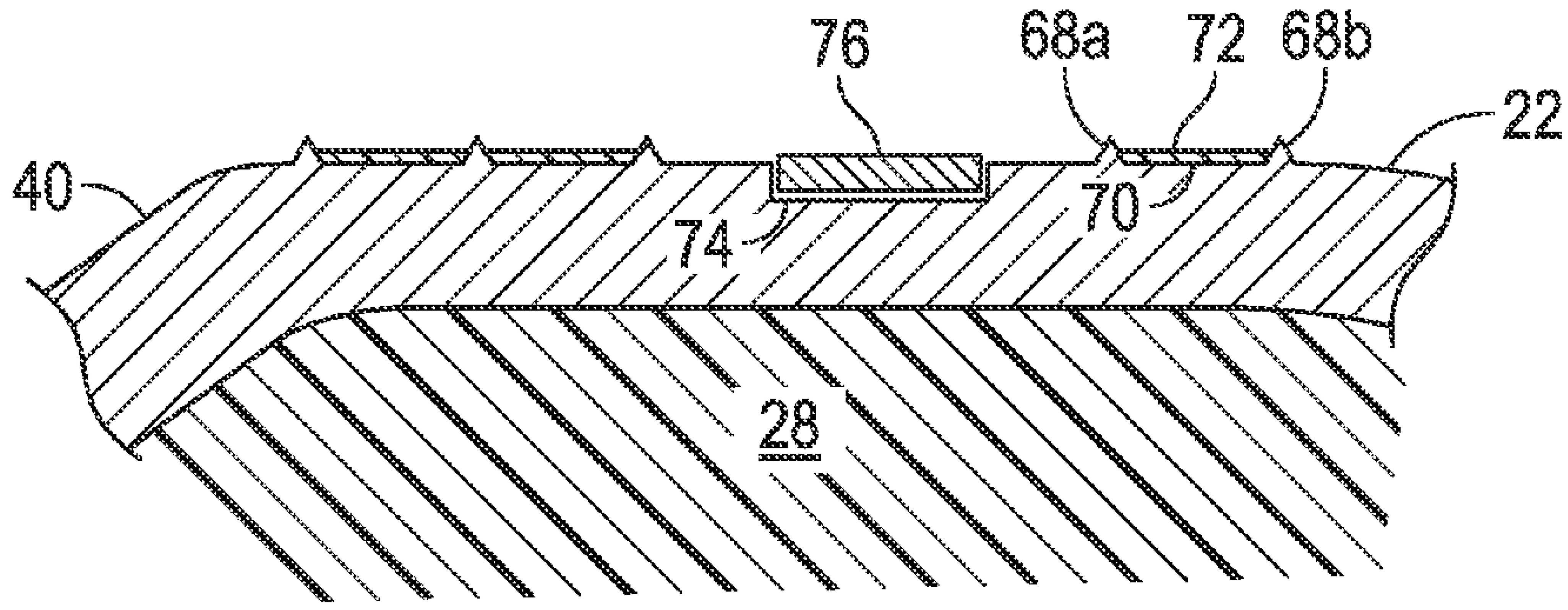

FIG. 5
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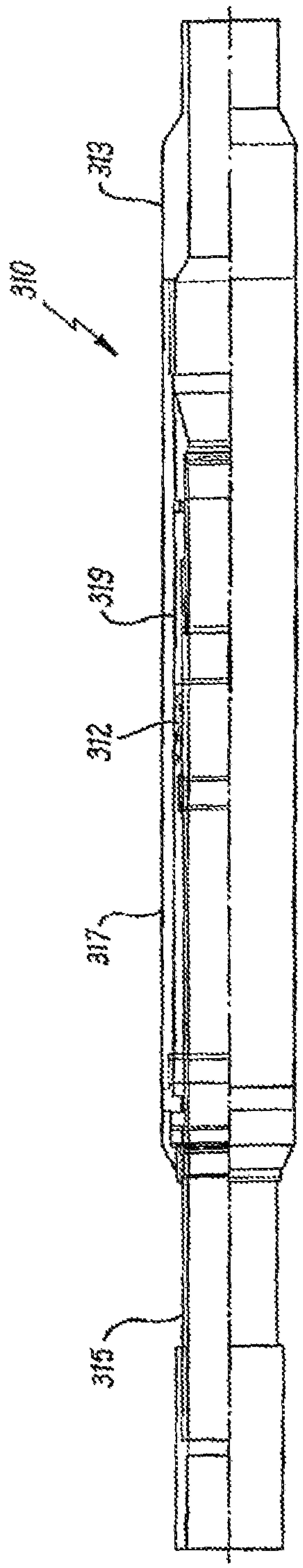

FIG. 6

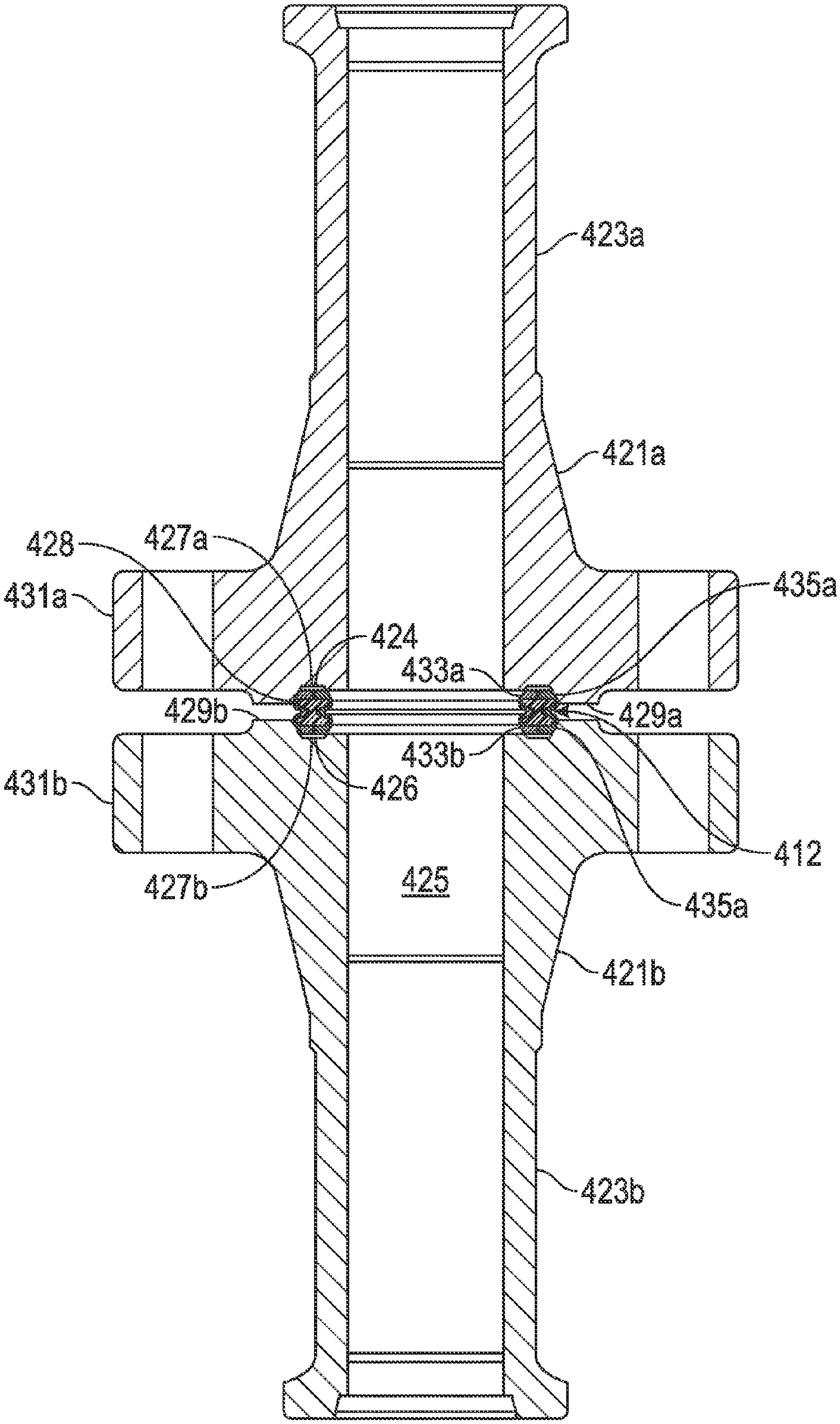

FIG. 7(a)
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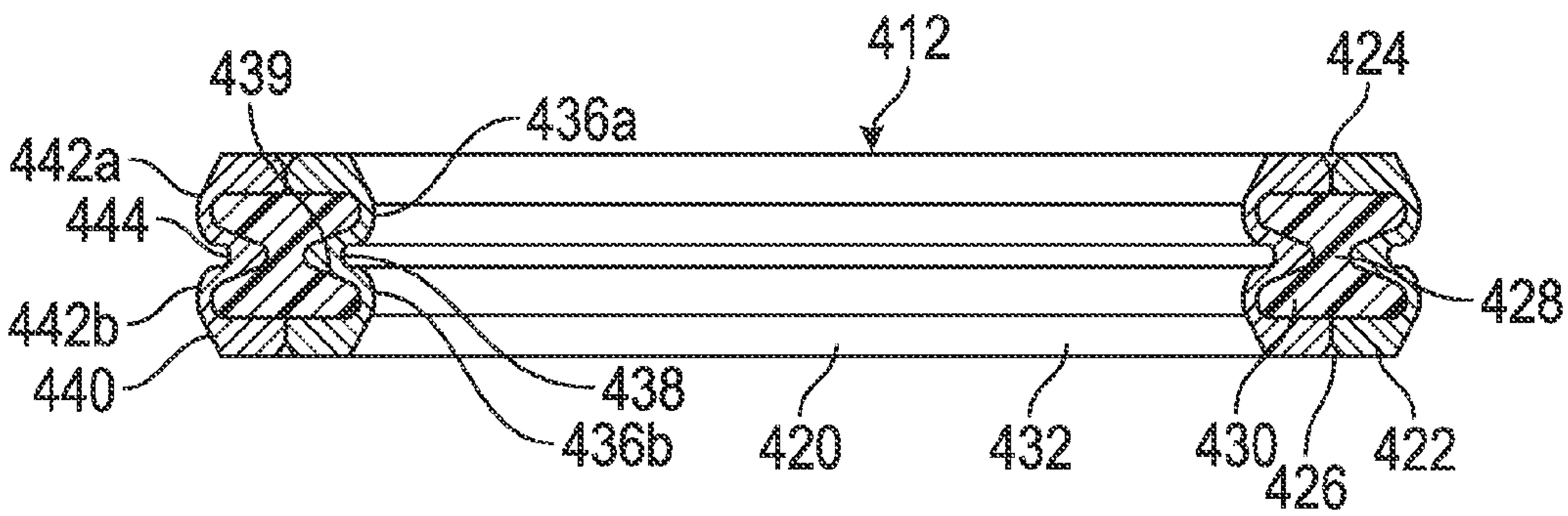

FIG. 7(b)
Amended

SEAL

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue; a claim printed with strikethrough indicates that the claim was canceled, disclaimed, or held invalid by a prior post-patent action or proceeding.

This application is a continuation of international application PCT/GB2004/003631, filed Aug. 26, 2004.

The present invention relates to seals used between metal surfaces and in particular, though not exclusively, to an annular seal for use in flanges, joints and packers located in oil and gas exploration and production equipment.

Typical annular seals used to prevent the passage of fluid between two surfaces are elastomeric o-rings. The material makes them flexible enough to mould into any deformities in the metal surface, while their compressibility aids in providing a large sealing area. However, these seals can go beyond their operational limits when used within well bores during oil and gas exploration and production, due to the extremes of pressure, temperature and the harsh substances which are used. In order to overcome these problems, metal to metal seals have been developed to provide increased seal strength and reduce seal degradation.

These metal to metal seals have found application in flanges, for example. When API 6A or similar flanges are manufactured, the groove has an exact geometry and surface finish. The sealing ring is a solid metal ring, which is compressed against the seal ring grooves to make the metal-to-metal seal. This is typically achieved by tightening the bolts on the flange. As there is no or little flexibility in the seal, side loading can reduce or remove any seal formed between the groove and flange. Furthermore, older flanges, which are subject to corrosion, can leak. As there is no compliance within the solid metal ring, once a leak appears the seal cannot be re-seated without re-tightening the bolts. In sub-sea applications, it is very expensive to monitor each flange and tighten the bolts as part of a maintenance programme.

To overcome this problem, seals incorporating the strength of metals together with the flexible characteristics of elastomers have been developed. EP 1136734, DE 3633335 and DE 3712814 all disclose flange ring seals using metal and elastomeric parts. These seals generally comprise a metal insert in the elastomeric material. While this design provides a seal with improved rigidity, the seal against the flange is made by the elastomer, which has the inherent disadvantage of seal degradation.

In packers, it is known to position an elastomeric sleeve around a tubing, the sleeve being limited by upper and lower retainers. In order to provide an annular seal and/or anchor the tubing in a well bore, one or both of the retainers are moved toward the other. This results in compression of the sleeve so that it deforms radially outwardly to fill the space between the tubing and a bore hole wall or tubular and adhere to the bore hole wall or tubular. Various arrangements have been provided in an attempt to ensure a sufficient portion of the sleeve contacts the borehole or tubular wall to effect a good seal while maintaining the sleeve within the retainers during compression. In addition, the surface of the seals have been modified to improve adhesion to the borehole wall. Further, metal to metal seals as described above, have been incorporated.

WO 02/04783 to Moyes discloses a deformable member comprising a generally hollow cylindrical body defining a

wall, the wall includes three circumferential lines of weakness in the form of grooves, with two grooves provided in an outer surface of the member wall, and the other groove provided in an inner surface. The member is deformed outwardly to provide a seal, by folding about the lines of weakness. The member is typically made of a tough malleable material such as carbon steel. A disadvantage of this seal is that by introducing lines of weakness to help the seal deform, the whole structure is weakened. As a result thick sections are required to prevent the element from collapsing under pressure differentials.

U.S. Pat. No. 5,988,276 to Oneal discloses a compact retrievable well packer which also utilises deformable cylindrical members to form the annular seal and also to lock the well packer in situ. As with Moyes, thick sections are required to prevent the sealing element from collapsing under pressure differentials.

U.S. Pat. No. 5,961,123 to Ingram et al discloses a seal arrangement which is designed to prevent the seal from extruding uphole or downhole when subjected to extremes of differential pressure. In this arrangement the seal material is bounded at either end by metal back-up rings, these rings may be attached to the seal or, as disclosed in U.S. Pat. No. 5,961,123, be attached to one of the retainers. This seal has the typical disadvantages of elastomeric based seals which can be degraded easily by heat and chemicals used downhole.

U.S. Pat. No. 5,775,429 to Arizmendi et al discloses a seal including a deformable sheath having a body and first and second ends for defining an interior volume proximate to a tool surface. The tool surface is the tubing. A material located within the interior volume is deformable, when the sheath second end is moved toward the sheath first end. The sheath is typically a relatively thin walled tubular member formed from materials like stainless steel or titanium. The filler material within the interior volume plastically deforms to advantageously allow the seal to be used oval shaped bore holes. Unfortunately this seal does not perform well in practice. As the filler material is restrained by the tubing, volumetric changes in the seal distort the seal and reduce the effectiveness of contact with the bore hole wall or tubular. These volumetric changes occur as the sheath ends are brought together before the seal meets the bore hole wall or tubular and is pressurised. It is an object of at least one embodiment of the present invention to provide a sealing element which is flexible, like an elastomer seal, but is fully metal to metal.

It is a further object of at least one embodiment of the present invention to provide a sealing element having a fully enclosed filler material to provide improved sealing properties of the element.

It is a yet further object of at least one embodiment of the present invention to provide a sealing element which deforms in a controlled manner on a cantilever principle. According to a first aspect of the present invention there is provided a sealing element for providing a seal between a first and a second surface, the element comprising an inner deformable surface, an outer deformable surface, the inner and outer surfaces being joined at opposed first and second ends, providing a body defining an interior volume entirely bounded by the said surfaces and said ends, a deformable filler material within said interior volume, wherein the element deforms in a predetermined manner to seal between the first and second surfaces when said ends are brought toward each other.

By entirely enclosing the deformable filler material within the element, the material acts as a filler within a continuous body. This allows the shape of the volume of the element to change as the ends are brought together but minimises any change in the said interior volume. By minimising any change in the interior volume until pressure is applied across the seal, the seal will deform in a predetermined manner. As discussed hereinbefore, as a disadvantage with respect to the seal of U.S. Pat. No. 5,775,429, delamination of the filler from the said surfaces will occur unless the volume change is minimised. This feature of the seal helps prevent the seal collapsing when pressure is applied across the seal, between the inner and outer surfaces.

Preferably, the inner and outer deformable surfaces are sleeves, the element thereby being annular. Such an arrangement can provides a seal around a mandrel or tubing. Alternatively the arrangement can provide an annular seal for a flange. Preferably the inner and outer surfaces are deformable metal sleeves. Preferably the inner and outer surfaces define a first shape containing the interior volume. Following deformation the inner and outer surface define a second shape. Preferably the second shape is a cantilever structure arranged longitudinally between the ends. Preferably the first and second shapes are predetermined. The first and second shapes may be annular having a **[**polygon**]** *polygonal shape* in longitudinal cross-section. *For purposes herein, the term "polygon" refers to a polygonal shape or a closed multi-sided shape, and is not necessarily limited to a closed planar shape bounded by straight lines.* Advantageously the polygon is symmetrical across the horizontal plane. In a first embodiment the polygon has ten sides. In a preferred embodiment the polygon has fifteen sides. The shape of the polygon, but not the number of sides, varies as the sealing element is deformed. Preferable the outer surface defines at least two peaks and at least one trough. Preferably also the inner surface defines at least two peaks and at least one trough. In a preferred embodiment the outer surface defines two peaks and one trough and the inner surface defines three peaks and two troughs.

Preferably the deformable filler material has a first volume. Advantageously the first volume equals the interior volume and both remain substantially equal as the ends are brought together. The deformable filler material may be an elastomer, plastic or other flexible material. Advantageously the filler material is a plastic. Use of a plastic is possible as the filler material will allow the seal to have a higher temperature rating than an elastomer, but being entirely encased in metal will not extrude as can be seen with elastomers and such plastics which have unsuitable mechanical properties.

Preferably the outer surface includes a plurality of outer ridges. The outer ridges bite into the second surface. The is advantageous when the second surface is a wall of the well bore, in a well which is open hole, or a tubing wall for a well which is cased. Preferably the outer ridges are arranged circumferentially around the outer surface. Advantageously a sealant material is applied to at least a portion of the outer surface. More preferably the portion is between the outer ridges. The sealant material may be Teflon® or the like. The sealant material provides a seal in the event that the primary metal seal of the outer surface fails to work.

Optionally at least one metal insert is located on at least a portion of the outer surface. More preferably the portion is between the outer ridges. Preferably the metal insert is a ductile inert metal. More preferably, the metal insert is gold. The metal insert could be the primary seal, instead of the deformable surfaces or the sealant material. The ductile insert could deform to accommodate any scratches or other discontinuities, which the outer surface may not.

According to a second aspect of the present invention there is provided a method of providing a seal between a first and a second surface, the method comprising the steps: (a) providing a sealing element according to the first aspect, having a first interior volume and a first shape with a filler having a first volume substantially equal to the first interior volume; (b) arranging the element adjacent the first surface and opposite the second surface; (c) moving one or both ends of the sealing element toward the opposing end; (d) deforming the sealing element in a controlled manner to provide a second shape while keeping the first interior volume and the first volume substantially equal; (e) contacting the sealing element on the first and second surfaces to provide the seal; and (f) further moving one or both ends of the sealing element toward the opposing end to provide a pressure across the sealing element between the inner and outer surfaces.

By keeping the volumes substantially equal, delamination of the filler material from the inner and outer surfaces is prevented. By avoiding delamination this helps prevent the sealing element collapsing when the pressure is applied across the sealing element in step (f).

Preferably, the sealing element forms a cantilever structure during deformation. Preferably the method includes the step of deforming the outer and inner surfaces of the sealing element.

Preferably also the method includes the step of abutting ridges of the sealing element onto at least the second surface. Advantageously the step includes the ridges biting into the second surface.

Preferably the method further includes the step of abutting a sealing material of the sealing element to at least the second surface to improve the sealing characteristics.

Preferably the method further includes the step of abutting a metal insert of the sealing element to at least the second surface to improve the sealing characteristics. According to a third aspect of the present invention there is provided apparatus for providing a seal between a first and a second surface within in a well bore, the apparatus comprising a substantially tubular body upon which is located the first surface; a sealing element located around the tubular body, comprising an inner deformable surface, an outer deformable surface, the inner and outer surfaces being joined at opposed first and second ends, providing a sealing body defining an interior volume entirely bounded by the said surfaces and said ends, a deformable filler material within said interior volume; at least one actuating element arranged around and longitudinally moveable relative to the body; the actuating element including means for affixing an end of the sealing element; wherein the sealing element deforms in a predetermined manner to seal between the first and second surfaces when said ends are brought toward each other by movement of the actuating element.

Preferably the apparatus comprises a packer or other downhole tool. More preferably the apparatus comprises a retrievable packer. Alternatively the apparatus comprises an expansion joint or other travelling seal.

Preferably the at least one actuating element is a cone. The cone having a bore therethough for passage of the sealing body. Preferably there are two cones, one located at each end of the sealing element. Preferably also at least one cone is releasably retained to the tubular body. The cone may be retained by shear pins.

Alternatively the at least one actuating element is a threaded ring. By tightening the ring against an end, the sealing element is pre-loaded.

Preferably, the inner and outer deformable surfaces are sleeves, the element thereby being annular. Such an arrangement provides a seal around a mandrel or tubing. Preferably the inner and outer surfaces are deformable metal sleeves. Preferably the inner and outer surfaces define a first shape containing the interior volume. Following deformation the inner and outer surface define a second shape. Preferably the second shape is a cantilever structure arranged longitudinally between the ends. Preferably the first and second shapes are predetermined. The first and second shapes may be annular having a [polygon] *polygonal shape* in longitudinal cross-section. Advantageously the polygon is symmetrical on the across the horizontal plane. In a first embodiment the polygon has ten sides. In a preferred embodiment the polygon has fifteen sides. The shape of the polygon, but not the number of sides, varies as the sealing element is deformed. Preferable the outer surface defines at least two peaks and at least one trough. Preferably also the inner surface defines at least two peaks and at least one trough. In a preferred embodiment the outer surface defines two peaks and one trough and the inner surface defines three peaks and two troughs.

Preferably the deformable filler material has a first volume. Advantageously the first volume equals the interior volume and both remain substantially equal as the ends are brought together. The deformable filler material may be an elastomer or a plastic. Advantageously the filler material is a plastic. Use of a plastic is possible as the filler material will not be affected by heat, being entirely encased in metal.

Preferably the outer surface includes a plurality of outer ridges. The outer ridges bite into the second surface in the well bore. The second surface may be a wall of the well bore, when the well is open hole, or tubing wall when the well is cased. Preferably the outer ridges are arranged circumferentially around the outer surface. Advantageously a sealant material is applied to at least a portion of the outer surface. More preferably the portion is between the outer ridges. The sealant material may be Teflon® or the like. The sealant material provides a seal in the event that the primary metal seal of the outer surface fails to work.

Optionally at least one metal insert is located on at least a portion of the outer surface. More preferably the portion is between the outer ridges. Preferably the metal insert is a ductile inert metal. More preferably, the metal insert is gold. The metal insert could be the primary seal, instead of the deformable surfaces or the sealant material. The ductile insert could deform to accommodate any scratches or other discontinuities, which the outer surface may not.

According to a fourth aspect of the present invention there is provided a method of anchoring an apparatus to an inner surface of a well bore, the method comprising the steps: (a) providing an apparatus according to the third aspect, having a first interior volume and a first shape with a filler having a first volume substantially equal to the first interior volume; (b) running the apparatus on a work string in the well bore; (c) moving one or both ends of the sealing element toward the opposing end; (d) deforming the sealing element in a controlled manner to provide a second shape while keeping the first interior volume and the first volume substantially equal; (e) contacting the sealing element on the first and second surfaces; and (f) further moving one or both ends of the sealing element toward the opposing end to provide a pressure across the sealing element between the inner and outer surfaces thereby anchoring the apparatus to the second surface.

Preferably, the sealing element forms a cantilever structure during deformation.

Preferably the method includes the step of deforming the outer and inner surfaces of the sealing element.

Preferably also the method includes the step of abutting ridges of the sealing element onto the second surface. Advantageously the step includes the ridges biting into the second surface.

Preferably the method further includes the step of abutting a sealing material of the sealing element to the second surface to improve the sealing characteristics.

According to a fifth aspect of the present invention there is provided a flange ring seal for location in a groove of a mating plate of a flange, the seal comprising an inner deformable surface, an outer deformable surface, the inner and outer surfaces being joined at opposed first and second ends, providing a sealing body defining an interior volume entirely bounded by the said surfaces and said ends, a deformable filler material within said interior volume; wherein an end is arranged to locate in the groove of the flange and wherein the seal deforms in a predetermined manner an opposing mating plate is brought against the mating plate to seal between the plates.

Preferably, the inner and outer deformable surfaces are sleeves, thus forming the ring. Preferably the inner and outer surfaces are deformable metal sleeves. Preferably the inner and outer surfaces define a first shape containing the interior volume. Following deformation the inner and outer surface define a second shape. Preferably the second shape is a cantilever structure arranged longitudinally between the ends. Preferably the first and second shapes are predetermined. The first and second shapes may be annular having a [polygon] *polygonal shape* in longitudinal cross-section. Advantageously the polygon is symmetrical on the across the horizontal plane. In a first embodiment the polygon has ten sides. In a preferred embodiment the polygon has fifteen sides. The shape of the polygon, but not the number of sides, varies as the sealing element is deformed. Preferable the outer surface defines at least two peaks and at least one trough. Preferably also the inner surface defines at least two peaks and at least one trough. In a preferred embodiment the outer surface defines two peaks and one trough and the inner surface defines three peaks and two troughs.

Preferably the deformable filler material has a first volume. Advantageously the first volume equals the interior volume and both remain substantially equal as the ends are brought together. The deformable filler material may be an elastomer or a plastic. Advantageously the filler material is a plastic. Use of a plastic is possible as the filler material will not be affected by heat, being entirely encased in metal.

Embodiments of the present invention will now be described, by way of example only, with reference to the following drawings of which:

FIG. **1** is a cross-sectional view a packer tool incorporating a sealing element according to an embodiment of the present invention, with the element un-set;

FIG. **2** is a cross-sectional view through the tool of FIG. **1**, now shown in the set position;

FIG. **3** is a cross-sectional view a packer tool incorporating a sealing element according to a further embodiment of the present invention, with the element un-set;

FIG. **4** is a cross-sectional view through the tool of FIG. **4**, now shown in the set position;

FIG. **5** is a part cross-sectional view of a portion of the outer surface of a sealing element according to a further embodiment of the present invention;

FIG. **6** is a part cross-sectional view of an expansion joint incorporating a sealing element according to a further embodiment of the present invention; and

FIG. **7**(a) is a schematic cross-sectional view through mating flanges incorporating a sealing element, shown in detail in FIG. **7**(b), according to a further embodiment of the present invention.

Referring initially to FIG. **1**, there is illustrated a downhole tool, generally indicated by reference numeral **10**, according to an embodiment of the present invention. Downhole tool **10** is a packer, being an apparatus for providing a seal between a first and a second surface within in a well bore. Located on the tool **10**, is a sealing element **12**, according to an embodiment of the present invention. Tool **10** operates by filling the space **14** between the tool body **16** and a bore hole wall, such as a casing **18**, to provide a seal between the tool **10** and the casing **18**.

Sealing element **12** comprises a generally cylindrical sleeve which surrounds the tool body **16**. Element **12** is formed as two concentric metal sleeves, an inner sleeve **20** and an outer sleeve **22**. The sleeves are joined at upper **24** and lower **26** ends. Between the sleeves **20**,**22** is located a filler **28**. The filler is entirely contained within the sealing element **12** and bounded on all sides by the metal sleeves **20**,**22**. Thus an interior volume **30** defined by the metal sleeves **20**,**22** contains an equal volume of the filler **28**.

The sleeves **20**,**22** are made of a deformable metal. The metal is typically stainless steel and the thickness of the sleeve **20**,**22** is selected to ensure that the steel is deformable under pressure. The sleeves are pinched together at the ends **24**,**26**. The filler **28** is also of a deformable material. The filler may be a plastic or elastomer. However, as the filler **28** is entirely encased in metal, it is not affected by heat and thus a plastic, such as Teflon®, is preferable.

The inner sleeve **20** provides an inner surface **32** facing an outer surface **34** of the tool body **16**. Inner surface **20** is geometrically arranged to provide two symmetrical peaks **36**a, b running circumferentially around the surface **20**. Peaks **36**a,b rest on the surface **34** of the tool body **16**. A trough **38** lies between the two peaks **36**a,b. Trough **38** has symmetrical sloping side walls with a flat base lying parallel to the surface **34** of the tool body **16**.

The outer sleeve **22** has a similar geometrical arrangement on its outer surface **40** to that of the inner surface **32**. However peaks **42**a,b are somewhat closer together providing a narrower trough **44**. The bases of each trough **38**,**44** are approximately equal in length.

When viewed together in cross-section, the surfaces **32**,**40** provide a polygon having ten sides. Each side is substantially linear. The polygon is symmetrical on a plane perpendicular to the well bore. The geometrical arrangement of the sealing element **12** is selected so that when the ends **24**,**26** are brought together the element **12** will deform in a controlled manner. The peaks **36**,**42** and troughs **38**,**44** will act like fold lines on the sleeves **20**,**22** and the element **12** will form a cantilever structure, best seen in FIG. **2**.

In FIG. **2**, the ends **24**,**26** have been brought together by the longitudinal displacement of the end **24** towards the element **12**. Trough **38** has been forced radially outwards and meets trough **44**. With the sleeves **20**,**22** meeting, the filler material is contained in two chambers **46**a,b. The peaks **36**,**42** are now more acute so that the element **12** bridges the space **40**. It should be noted that the element **12** provides a cantilever structure which supports the seal **12** and allows the tool **10** to be anchored to the casing **18** by the slips **66**. The filler **28** supports the seal **12** to prevent the seal from collapsing with pressure applied from the end **24**. The interior volume **30** and the volume of the filler **28** remain substantially the same between the two positions, FIG. **1** and FIG. **2**. The filler **28** has remained in contact with the continuous surface formed by the sleeves **20**,**22** and defining the interior volume **30**. As delamination has not occurred, the filler **28** helps prevent the seal **12** collapsing when pressure is applied across the seal between the surfaces **32**,**40** when the seal **12** is in contact with the casing **18**.

Returning to FIG. **1**, sealing element **12** is mounted upon tool body **16**. The ends **24**,**26** locate into opposed fixings **48**a,b. The fixings **48**a,b hold the sleeves **20**,**22** together to provide the interior volume **30** where the filler **28** is located. At the upper end **24** of the seal **12** is located an upper cone **50**, which is formed as a sleeve having a sloping surface **54**. Cone **50** fits over the tool body **16** and is held against the body by shear pins **52**a,b. The cone **50** has an outer sloping section **54** and a lower lip **56**. Lip **56** provides an overhang across the seal **12** and the seal **12** rests upon it. The lip **56** covers the fitting **48**a, thereby protecting the end **24** of the seal during operation.

At the lower end **26** of the seal **12** is located a lower cone **58**. Cone **58** includes a sloping surface **60** and a lip **62** in an identical manner to cone **50**. Cone **58** is bolted to the tool body **16** so that it cannot move during operation of the tool **10**. Located outside the cones **50**,**58** are slips **64**,**66** as are known in the art.

In use, tool **10** is mounted on a work string (not shown) and run into a well bore. The seal **12** is not set, as illustrated in FIG. **1**, so that seal **12** lies toward the body **16** and a space **14** exits between the tool **10** and the casing **18** within the well bore. In this unset configuration the tool **10** can be run without interfering with any other operations performed in the well bore. When the tool **10** has reached a location within the well bore where an annular seal is required between the tool **10** and the casing, the tool **10** can be set. This is achieved by moving the cone **50** towards the lower sleeve **58**. It will be appreciated by those skilled in the art that either or both cones **50**,**58** could be moved. It will also be known by those in the art that various actuation mechanisms such as weight-setting and hydraulic actuation can be used to cause movement of the cone **50**. Shear pins **52**a,b are sheared in the actuation to allow the cone **50** to move along the tool body **16**. If cone **50** is the lower cone, then holding the cone in position will provide actuation by the relative movement of the work string and the tool **10** through the cone.

Effectively, cone **50** is moved towards sleeve **58**. The compression applies pressure longitudinally onto the seal **12**. The pressure causes the peaks **36**,**42** to move away from each other while the troughs **38**,**44** move toward each other. It is the geometrical arrangement of the peaks and troughs which cause the seal **12** to deform in this controlled manner. Deformation is complete when the troughs meet. This is illustrated in FIG. **2**. During the deformation, the polygon has changed in shape, but the interior volume **30** and the volume of the filler **28** have remained substantially equal and constant throughout.

Continued pressure forces the outer peaks **42** against the casing **[38]** *18* while the inner peaks meet the surface **34** of the tool body **16**. A seal is thus formed between the tool **16** and the casing **[38]** *18*. Additionally the seal **12** now anchors the tool **10** against the casing **[38]** *18* at this location. The seal **12** is set. The seal **12** provides a cantilever structure from the overhangs at lips **56**,**62**. The filler **28** located now in the two chambers **46**a,b supports the seal and prevents any collapsing as additional force is applied from the cone **50**, and across the seal from the casing **18**. Slips **64**,**66** have been forced up the slopes **54**,**60** to provide additional anchorage to the tool **10**.

Sealing element **12** has ridges **68** located upon its outer surface **40**. The ridges **68** bite into the casing **[38]** *18* in order to effect the seal. A sealant material, Teflon®, is located between the ridges **68** to provide an improved seal if the primary metal seal of the ridges **68** fail. This is described with reference to FIG. **[6]** *5*.

The tool **10** can be retrieved from the well bore, by moving the ends **24**,**26** apart via movement of one or both of the cones

50,**58**. Separation of the ends **24**,**26** pulls the seal longitudinally and the seal **12** returns close to its original shape. A space **14** is thus created between the tool **10** and the casing **18** so that the work string can be pulled from the hole.

Referring now to FIG. **3**, there is illustrated a sealing element, generally indicated by reference numeral **112**, according to a preferred embodiment of the present invention. Like parts to the sealing element **12** of FIGS. **1** and **2** have been given the same reference numeral with the addition of one hundred. Sealing element **112** operates in an identical manner to sealing element **12** in providing a seal between two surfaces. For ease of interpretation, ends are shown held in opposed fixings **148**a,b as described hereinbefore with reference to FIGS. **1** and **2**.

Sealing element **112** comprises a continuous cylindrical annulus which may be described as a torus. The element **112** is formed from two metal sleeves, a first **120** being arranged inside and coaxial with a second **122**. The sleeves, **120**,**122** are joined at upper **124** and lower **126** ends by having adjacent sides of the sleeves meeting over a short distance. The ends **124**,**126** of the sleeves **120**,**122** are held together by the fixing elements **148**a,b. A resultant interior volume **130** is created which is entirely hounded by the sleeves **120**,**122** and the ends **124**,**126**. The interior volume **130** is completely filled with a filler **128**. The filler **128** contacts the sleeves **120**,**122** and ends **124**,**126**. Each sleeve **120**, **122** is formed of a metal continuous metal strip. The metal is preformed into a shape calculated to deform in a predetermined manner when the ends **124**,**126** are brought together. The inner sleeve **120**, in longitudinal cross-section, has a surface **132** which is symmetrically shaped through a horizontal plane equidistant from the ends **124**,**126**. The surface **132** forms a series of peaks and troughs. There are two troughs **138**a,b which comprise opposing sloping surfaces, bounding a single peak **136** which is a plateau bounded by the sloping surfaces of the troughs **138**a, b. The outer sleeve **122** has a profile **134** in reverse to the inner sleeve **120** with respect to the element **112**. There are not distinct peaks **142**a,b, opposing the troughs **138**a,b. These have been levelled to provide a sharp sloping surface into the trough **144** opposite the peak **138**. Each surface **132**,**134** is made up of a series of straight sections so that the metal of the sleeve can be bent along fold lines to create the shape required. In longitudinal cross-section through the torus, a polygon is created which defines the interior volume **30** and the volume of filler **128**.

By mirroring the profiles of the sleeves **120**,**122**, when the ends **124**,**126** are brought together the interior volume **130** remains substantially constant while the shape of the sleeves **120**,**122** ie. the polygon, deforms in a manner to accentuate the peaks and troughs. As the interior volume **130** remains substantially constant the filler **128** will deform with the element **112**, but will remain in contact with the entire inside surface of the sleeves **120**,**122** at all times. In this way delamination is prevented which would otherwise cause air pockets in the seal, weakening its ability to withstand both longitudinal pressure applied from the ends **124**,**126** and transverse pressure applied horizontally between the sleeves **120**,**122**.

Reference is now made to FIG. **4** of the drawings which illustrates the seal **112** of FIG. **3** when the ends **124**,**126** have been brought toward each other. This represents the seal **112** in the 'set' position. Like parts to those of FIG. **3** have been given the same reference numeral to aid clarity. It can be seen that the peaks **142**a,b now sit proud of the fixing elements **148**a,b. As the peaks **136**, **138**, **142** are plateau like, they provide planar surfaces to improve the sealing properties of the element **112**. The area of contact of the sealing element **112** is thus predetermined by the dimension of the peaks **136**, **138**, **142** in the shape of the original sleeves **120**,**122**. Further the arrangement of opposing peaks and troughs, with a trough **144**/peak **136** on the horizontal plane bounded by symmetrically arranged peaks **142** and troughs **138**, provides a cantilever structure which strengthens the sealing element **112**.

As described herein with reference to FIGS. **1** and **2** the peaks **142**a,b on the outer sleeve **122** may include ridges or other material to improve the grip of the sealing element **112** when these positions contact a surface within a well bore. Such additional features are illustrated with reference to FIG. **5**.

FIG. **5** shows a part cross-sectional view through the outer sleeve **22** of a sealing element **12**. Like parts to those of FIGS. **1** and **2** have been given the same reference numeral to aid clarity. Outer surface **40** of the sleeve **22** has a number of ridges **68**a,b located thereon. The ridges **68** are protrusions extending from the surface. While they are illustrated as triangular in cross-section, it will be understood that a variety of forms could be used as long as they provide a 'bite' for the seal **12** against the second surface (not shown).

Located between the ridges **68**a,b on a portion **70** of the surface is a sealant material **72**. The material **72** can be a coating or may be a treatment applied to the surface **70**. The coating could be metal, plastic or another material which will conform to the second surface on contact. While the material **72** is shown as only located between the ridges **68** it will be understood that the ridges could additionally or independently be coated. Teflon® or the like, would be a suitable material **72**.

A further feature of the surface **40** is in the provision of a groove **74** for an insert **76**. At discrete locations over the surface **40**, grooves **74** in the form of indents can be arranged. Into each groove **74** an insert **76** is fitted. It will be appreciated that any suitable technique may be used for attaching the insert **76** to the groove **74**. The insert **76** is a metal, which is preferably a ductile, inert metal, such as gold. In use, the insert **76** would be the primary seal, instead of the outer surface **40** or the sealant material **72**. The ductile insert **76** will deform to accommodate any scratches or other discontinuities, which the outer surface **40** may not.

A further example application of use of the sealing element of the present invention, is in an expansion joint. FIG. **6** illustrates an expansion joint, generally indicated by reference numeral **310**, as may be found in a tool string run in a well bore. The joint **310** operates by allowing one portion, such as a sleeve **313** to move axially relative to the mandrel **315**. A seal **312** is located between the moving parts with a pressure differential between the outside and the tubing string. The seal **312** is as described hereinbefore with reference to FIGS. **1**-**4**. The seal **312** is held on a mandrel **315**, within a seal bore **317**. Alternatively, the seal could be held on a housing, with a moveable mandrel. The seal **312** is activated by applying a pre-load to deform it slightly. A threaded ring **319** is used to apply the pre-load, but other methods could be equally be used. The surface of the seal bore **317** is treated in such a manner that friction and wear are minimised. This could be done with tungsten carbide coating or other such methods, which are well understood. In use, the seal **312** slides within the seal bore **317**, maintaining a dynamic seal during axial movement of the mandrel **315** within the stationary seal bore **317**.

Reference is now made to FIGS. **7**(a) and **7**(b), illustrating a sealing element, generally indicated by reference numeral **412**, being used as a flange sealing ring. When flanges **421**a,b are brought together to join adjacent pipe sections **423**a,b, a seal is needed to prevent the escape of fluid from the pipe bore **425**. Each flange **421**a,b includes a circular groove **427**a,b located on the surface **429**a,b of the flange plate **431**a,b. The seal **412** is sized to locate within the grooves **427**a,b. Indeed the grooves **427**a,b are profiled to match the outer surface of the ends **424**,**426** of the seal **412**. Sealing between the flanges **421**a,b is achieved at the first surface, being a combination of the inner edges **433**a,b of the grooves **427**a,b respectively, and the second surface, being a combination of the outer edges **435**a,b of the grooves **427**a,b respectively.

Sealing element **412** is as described with reference to FIGS. **1-4**, comprising an annular body. Element **412** is formed as two concentric metal sleeves, an inner sleeve **420** and an outer sleeve **422**. The sleeves are joined at upper **424** and lower **426** ends. Joining is by welding of the sleeves **420**,**422**. Between the sleeves **420**,**422** is located a filler **428**. The filler is entirely contained within the sealing element **412** and bounded on all sides by the metal sleeves **420**,**422**. Thus an interior volume **430** defined by the metal sleeves **420**,**422** contains an equal volume of the filler **428**.

Inner sleeve **420** is geometrically arranged to provide two symmetrical peaks **436**a,b running circumferentially around the surface **432**. A trough **438** lies between the two peaks **436**a,b. Trough **438** has symmetrical sloping side walls with a flat base **439**. The outer sleeve **422** has a similar geometrical arrangement on its outer surface **440** to that of the inner surface **432**. However peaks **442**a,b are somewhat closer together providing a narrower trough **444** without a flat base.

As is seen in FIGS. **7**(a) and (b) geometrical arrangement of the sealing element **412** is selected so that when the ends **424**,**426** are brought together the element **412** will deforms in a controlled manner. The peaks **436**,**442** and troughs **438**,**444** act like fold lines on the sleeves **420**,**422** forming a cantilever structure, which supports the seal. The filler **428** supports the seal **412** to prevent the seal from collapsing with pressure applied from the ends **424**. The interior volume **430** and the volume of the filler **428** remain the same during compression of the seal **412**. The filler **428** remains in contact with the continuous surface formed by the sleeves **420**,**422**. Delamination does not occur, thus the filler **428** helps prevent the seal **412** collapsing when pressure is applied across the seal.

The principal advantage of the present invention is that by entirely enclosing a filler material within two sleeves, volumetric changes in the sealing element are minimised and the seal will deform in a controlled manner.

A further advantage of an embodiment of the present invention is that it provides a sealing element, which by forming a cantilever structure on deforming, produces a strong seal which can be used to anchor tools in a well bore.

A yet further advantage of an embodiment of the present invention is that it provides a sealing element which does not collapse under pressure differentials. This is done without the need to thicken the sleeves as it is achieved by the 'rubber pressure' of the filler within the sealing element.

A still further advantage of an embodiment of the present invention is that it provides a sealing element which does not use elastomers, thus heat and chemicals typically found in well bores will not affect the operation of the seal.

A still further advantage of an embodiment of the present invention is that it provides a sealing element which has the benefits of flexibility, like an elastomer seal, but is fully metal-to metal.

A yet further advantage of at least one embodiment of the present invention is that it provides a sealing element which can be used in dynamic applications where it must slid while maintaining a seal.

It will be appreciated by those in the art that various modifications may be made to the invention hereindescribed without departing from the scope thereof. For example, the overall size of the sealing element can be varied to suit the tool used. The applications describe use in a packer, joint and flange mating but the sealing element could equally be applied to a range of subsea/downhole tools and equipment where a seal and/or anchoring is required.

What is claimed is:

1. An annular sealing element (**12**) for a downhole tool for providing a seal between a first (**32**) and a second surface, comprising:

an inner sleeve (**20**) providing an inner deformable surface and arranged concentric with an outer sleeve (**22**) providing an outer deformable surface, each of the inner and outer sleeves being formed of a material liable to plastic deformation, the inner and outer sleeves being joined at respective junctions of opposed first ends (**24**) and second ends (**26**), providing a body defining an interior volume (**30**) entirely bounded by [the] said surfaces and said ends, and a deformable filler material (**28**) within said interior volume, wherein the filler material (**28**) is a plastic;

wherein the inner and outer sleeves each comprise a plurality of fold lines;

wherein the element (**12**) deforms in a predetermined manner when said first ends (**24**) are brought toward said second ends (**26**) by deformation of the inner and outer sleeves about their respective fold lines, to thereby seal between the first (**32**) and second surfaces,

wherein the inner and outer sleeves (**20**, **22**) define a first shape containing said interior volume (**30**), and following deformation the inner and outer sleeves (**20**, **22**) define a second shape, which is a cantilever structure arranged longitudinally between the ends (**24**, **26**), and

wherein the first and second [shape] *shapes* are annular [having a polygon] *and are polygonal* in longitudinal cross-section.

2. The sealing element (**12**) of claim **1** wherein the inner and outer sleeves (**20**, **22**) are deformable metal sleeves.

3. The sealing element (**12**) of claim **1** wherein the [polygon is] *polygonal longitudinal cross section of the first and second shapes are each* symmetrical about a horizontal plane, equidistant from the ends (**24**, **26**).

4. The sealing element (**12**) of claim **1** wherein the deformable filler material (**28**) has a first volume which equals the interior volume (**30**) and both remain substantially equal as the ends (**24**, **26**) are brought together.

5. The sealing element (**12**) of claim **1** wherein the outer surface includes a plurality of outer ridges (**68**).

6. The sealing element (**12**) of claim **1** wherein a sealant material is applied to at least a portion of the outer surface.

7. The sealing element (**12**) of claim **1** wherein at least one metal insert (**76**) is located in at least a portion of the outer surface.

8. A method of providing a seal between a first (**32**) and a second surface *of a downhole tool*, comprising the steps of:

(a) providing [the] *an annular* sealing element (**12**) [of claim **1**], *wherein the element (12) comprises:*

an inner sleeve (20) providing an inner deformable surface and arranged concentric with an outer sleeve (22) providing an outer deformable surface, each of the inner and outer sleeves being formed of a material liable to plastic deformation, the inner and outer sleeves being joined at respective junctions of opposed first ends (24) and second ends (26), providing a body defining an interior volume (30) entirely bounded by said surfaces and said ends, and a deformable filler material (28) within said interior volume, wherein the filler material (28) is a plastic;

wherein the inner and outer sleeves each comprise a plurality of fold lines;

wherein the element (12) deforms in a predetermined manner when said first ends (24) are brought toward said second ends (26) by deformation of the inner and outer sleeves about their respective fold lines, to thereby seal between the first (32) and second surfaces,

wherein the inner and outer sleeves (20,22) define a first shape containing said interior volume (30), and following deformation the inner and outer sleeves (20, 22) define a second shape, which is a cantilever structure arranged longitudinally between the ends (24, 26), and

wherein the first and second shapes are annular and are polygonal in longitudinal cross-section;

[having a first interior volume (**30**) and a first shape, and**]** wherein the filler (**28**) has a first volume substantially equal to the **[**first**]** interior volume;

(b) arranging the element (**12**) adjacent the first surface (**32**) and opposite the second surface;

(c) moving one or both ends (**24**, **26**) of the sealing element (**12**) toward the opposing end (**24**, **26**);

(d) deforming the inner and outer sleeves and the plastic filler material of the sealing element (**12**) in a controlled manner to provide **[**a**]** *the* second shape while keeping the **[**first**]** interior volume (**30**) and the first volume substantially equal, wherein the sealing element (**12**) forms **[**a**]** *the* cantilever structure during deformation;

(e) contacting the sealing element (**12**) on the first (**32**) and second surfaces to provide the seal; and

(f) further moving one or both ends (**24**, **26**) of the sealing element (**12**) toward the opposing end (**24**, **26**) to provide a pressure across the sealing element (**12**) between the inner and outer surfaces (**32**, **34**).

[9. The method of claim **8** wherein the method includes the step of deforming the outer and inner sleeves (**22**, **20**) of the sealing element (**12**).**]**

10. The method of claim **8** wherein the method includes the step of abutting ridges (**68**) of the sealing element (**12**) onto at least the second surface (**34**).

11. The method of claim **8** wherein the method includes the step of abutting a sealing material (**72**) of the sealing element (**12**) to at least the second surface (**34**).

12. The method of claim **8** wherein the method includes the step of abutting a metal insert (**76**) of the sealing element (**12**) to at least the second surface (**34**).

13. **[**A**]** *The* method as claimed in claim **8**, wherein the method is a method of anchoring an apparatus (**10**) to an inner surface of a well bore and providing a seal between the first (**32**) and second surfaces, the inner surface of the well bore defining the second surface; and wherein the step of providing the sealing element (**12**) comprises providing an apparatus (**10**) including the sealing element (**12**); and wherein the step of arranging the element (**12**) adjacent the first surface (**32**) and opposite the second surface comprises running the apparatus (**10**) on a work string in the well bore and so arranging the element (**12**); and further wherein the step of further moving one or both ends (**24**, **26**) of the sealing element (**12**) toward the opposing end (**24**, **26**) also anchors the apparatus (**10**) to the second surface.

14. The method of claim **13**, wherein the first surface comprises an outer cylindrical surface having a smaller diameter relative to the second surface.

15. The method of claim **8**, wherein the first and second surfaces comprise respective opposing outer and inner surfaces of coaxial tubular members.

16. **[**Apparatus**]** *An apparatus* (**10**) for providing a seal between a first (**32**) and a second surface within a well bore, comprising:

a substantially tubular body (**16**) upon which is located the first surface (**32**);

a sealing element (**12**) according to claim **1** located around the tubular body (**16**);

at least one actuating element (**50**, **58**) arranged around and longitudinally moveable relative to the tubular body (**16**), the actuating element (**50**, **58**) including means (**54**, **56**; **60**, **62**) for contacting an end (**24**, **26**) of the sealing element (**12**);

wherein the sealing element (**12**) deforms in a predetermined manner to seal between the first and second surfaces (**32**) when said ends (**24**, **26**) are brought toward each other by movement of the actuating element (**50**, **58**).

17. The apparatus (**10**) of claim **16** wherein the at least one actuating element (**50**, **58**) is a cone, the cone having a bore therethrough for passage of the tubular body (**16**).

18. The apparatus (**10**) of claim **16** wherein the at least one actuating element (**50**, **58**) is a threaded ring.

19. The apparatus as claimed in claim **16**, wherein the first surface comprises an outer cylindrical surface and the second surface comprises an opposing inner cylindrical surface.

20. **[**A**]** *The* sealing element as claimed in claim **1**, wherein each of the inner and outer sleeves is rigid.

21. **[**A**]** *The* sealing element as claimed in claim **1**, wherein the ends of the inner and outer sleeves are located in abutment and held together by respective fixing elements.

22. **[**A**]** *The* sealing element (**12**) as claimed in claim **1**, wherein the inner and outer sleeves (**20**, **22**) contain the deformable filler (**28**) when said ends of the sleeves are brought toward each other.

23. **[**A**]** *The* sealing element (**12**) as claimed in claim **1**, wherein the filler (**28**) is adapted to prevent the sealing element (**12**) from collapsing under applied pressure.

24. **[**A**]** *The* sealing element (**12**) as claimed in claim **1**, wherein the inner and outer sleeves are pinched together at the first ends (**24**) and second ends (**26**).

25. **[**A**]** *The* sealing element (**12**) as claimed in claim **1**, wherein the element (**12**) deforms in a predetermined manner to sealingly contact the first (**32**) and second surfaces at the respective fold lines of the inner and outer sleeves.

26. **[**A**]** *The* sealing element (**12**) as claimed in claim **1**, wherein the first and second surfaces comprise respective opposing outer and inner surfaces of coaxial tubular members and wherein the element (**12**) is disposed longitudinally between the first and second surfaces and deforms in a predetermined manner to sealingly contact the first and second surfaces at the respective fold lines of the inner and outer sleeves.

27. The annular sealing element (**12**) of claim **1**, wherein the inner sleeve (**20**) comprises at least two troughs and at least one peak **[**an**]** *and* wherein the inner and outer sleeves are asymmetrical.

28. An annular sealing element (**12**) for providing a seal between first (**32**) and second metallic cylindrical surfaces, comprising:

a metallic inner sleeve (**20**) providing an inner deformable surface, an outer metallic sleeve (**22**) providing an outer deformable surface, the inner and outer sleeves being joined together at upper and lower junctions at opposite ends of the sleeves to provide a body defining an elongated annular volume (**30**) entirely bounded by the said surfaces and said junctions, and a deformable plastic filler material (**28**) within said volume;

wherein the inner and outer sleeves each comprise a plurality of fold lines; and

wherein the element (**12**) deforms about the fold lines in a predetermined manner when the inner and outer sleeves are compressed at the opposite ends, to thereby form a metal-to-metal seal between the first (**32**) and second surfaces.

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