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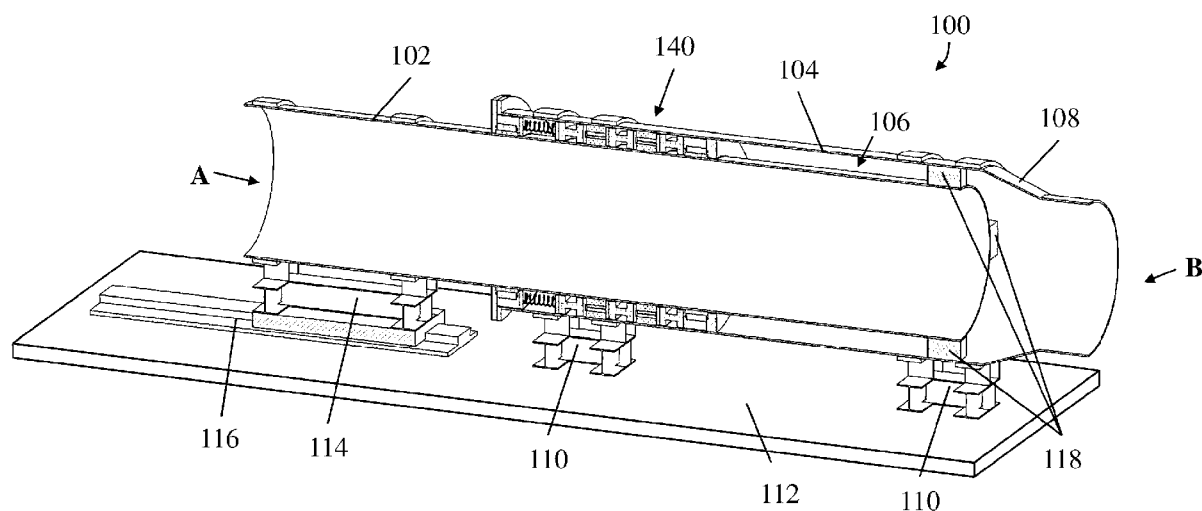


Fig. 1

(57) Abstract: In-line expansion joints for cryogenic liquid pipelines are described. In one embodiment, an expansion joint includes a slidable inner pipe and a fixed outer pipe arranged telescopically and a sealing assembly disposed within an annular region between the inner pipe and the outer pipe. The telescopic arrangement of the expansion joint allows the inner pipe to slide within the outer pipe to accommodate rotational and/or translational movement which may occur during thermal expansion and/or contraction of the pipeline. In another embodiment, an expansion joint includes an expansion element that connects two pipes, and a sealing assembly disposed within an annular region between at least one of the pipes and the expansion element. The sealing assembly includes one or more seals and a biasing element that applies a compressive force to the one or more seals to urge a packing material against the inner pipes and outer pipes or expansion elements. The one or more seals further include one or more components which contract at different rates in response to temperature reductions. The differing rates of thermal contraction result in thermal stresses being applied to the packing material to urge the packing material against the inner pipes and outer pipes or expansion elements, creating a tight seal when



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CRYOGENIC EXPANSION JOINT

FIELD

[0001] Disclosed embodiments are related to joints for use in pipelines and piping carrying cryogenic liquids.

BACKGROUND

[0002] Pipelines and piping transporting cryogenic liquids, such as liquid natural gas (LNG), are typically constructed with metal components which often have relatively high thermal expansion coefficients. The pipelines contract in length due to the large temperature differential that occurs when the pipelines transition from ambient temperatures to the low cryogenic operating temperatures, which may be as low as -170 to -200°C. Accordingly, LNG plants, LNG offloading jetties, and other facilities that handle LNG or other cryogenic liquids typically utilize expansion loops and or conventional in-line expansion joints (e.g., bellows-type joints) to accommodate for this thermal contraction. However, expansion loops require a large amount of space and large support platforms, which can be costly and/or disruptive to an LNG facility. Additionally, conventional bellows-type expansion joints, which only expand and contract in a spring-like manner, offer very little torsional strength and are also prone to fatigue, which may lead to catastrophic failure of the joint.

SUMMARY

[0003] In one embodiment, an in-line expansion joint includes an outer pipe having a first diameter and an inner pipe having a second diameter smaller than the first diameter, the inner pipe disposed at least partially within the outer pipe and forming an annular region between the inner pipe and the outer pipe. The in-line expansion joint further comprises a sealing assembly disposed within the annular gap. The sealing assembly includes at least one primary seal having a first packing ring adjacent the inner pipe and a first contraction ring disposed around the first packing ring, and a material of the first contraction ring having a higher thermal expansion

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coefficient than a material of the inner pipe. The sealing assembly further includes at least one biasing element, and the at least one biasing element applies a compressive force to the at least one primary seal to urge the first packing ring against the inner pipe.

[0004] In another embodiment, an in-line expansion joint includes an expansion element having a flexible portion, at least one attachment end coupled to the flexible portion and having a first diameter, and a first extension extending radially inwardly from an inner surface of the at least one attachment end and defining a portion of the expansion element having a second diameter smaller than the first diameter. The in-line expansion joint further comprises a pipe having a third diameter smaller than the first diameter and larger than the second diameter, and the pipe is disposed at least partially within the at least one attachment end of the expansion element to form an annular region between the pipe and the expansion element. The pipe includes at least one projection extending into the annular region, and a material of the expansion element has a higher thermal expansion coefficient than a material of the pipe. The in-line expansion joint further includes a sealing assembly disposed within the annular region. The sealing assembly includes at least one biasing element, a primary seal having a first packing ring adjacent the pipe, the primary seal disposed between the at least one projection and the first extension of the expansion element, and an outer seal having a second packing ring adjacent the pipe. The outer seal is disposed between the at least one biasing element and the primary seal, and the at least one biasing element applies a compressive force to the primary and secondary seals to urge the first and second packing rings against the pipe.

[0005] It should be appreciated that the foregoing concepts, and additional concepts discussed below, may be arranged in any suitable combination, as the present disclosure is not limited in this respect. Further, other advantages and novel features of the present disclosure will become apparent from the following detailed description of various non-limiting embodiments when considered in conjunction with the accompanying figures.

[0006] In cases where the present specification and a document incorporated by reference include conflicting and/or inconsistent disclosure, the present specification shall control. If two or more documents incorporated by reference include conflicting and/or inconsistent disclosure with respect to each other, then the document having the later effective date shall control.

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BRIEF DESCRIPTION OF DRAWINGS

[0007] The accompanying drawings are not intended to be drawn to scale. In the drawings, each identical or nearly identical component that is illustrated in various figures may be represented by a like numeral. For purposes of clarity, not every component may be labeled in every drawing. In the drawings:

[0008] Fig. 1 is a cross-sectional perspective view of one embodiment of an expansion joint;

[0009] Fig. 2 is a cross-sectional side view of the expansion joint of Fig. 1;

[0010] Fig. 3 is a cross-sectional axial view of a portion of the expansion joint of Fig. 1;

[0011] Fig. 4 is a cross-sectional axial view of another portion of the expansion joint of Fig. 1;

[0012] Fig. 5 is a detailed cross-sectional side view of a sealing assembly of the expansion joint of Fig. 1;

[0013] Fig. 6 is a cross-sectional side view of one embodiment of a primary seal of an expansion joint;

[0014] Fig. 7 is a cross-sectional axial view of the primary seal of Fig. 6;

[0015] Fig. 8 is cross-sectional side view of one embodiment of a secondary seal of an expansion joint;

[0016] Fig. 9 is a cross-sectional axial view of the secondary seal of Fig. 8;

[0017] Fig. 10 is a cross-sectional side view of one embodiment of an expansion joint including a bellows; and

[0018] Fig. 11 is a cross-sectional side view of a portion of the expansion joint of Fig. 10.

DETAILED DESCRIPTION

[0019] Aspects discussed herein relate to in-line expansion joints for use with cryogenic liquid systems such as pipelines and piping transporting cryogenic liquids (e.g., LNG). The expansion joints maintain a seal between two pipes over a wide temperature range (i.e., from ambient temperatures down to cryogenic temperatures) while also permitting rotational and/or

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translational movement of the pipes relative to one another, which may occur due to thermal expansion and contraction of the pipeline as it is exposed to various temperatures.

[0020] In some embodiments, an expansion joint includes an inner pipe and an outer pipe arranged telescopically. Specifically, the inner pipe has a first diameter and the outer pipe has a second, larger diameter, such that at least a portion of the inner pipe may be received into the outer pipe. The expansion joint is installed in-line within the pipeline; in particular, the inner pipe is attached to a first end of a pipeline, and the outer pipe is attached to a second end of the pipeline. The telescopic arrangement of the expansion joint allows the inner pipe to slide within the outer pipe to accommodate rotational and/or translational movement which may occur during thermal expansion and/or contraction of the pipeline. For example, the inner pipe may translate axially relative to the outer pipe to accommodate a length change of the pipeline as it is exposed to different temperatures.

[0021] Depending on the particular embodiment, the amount of axial translation that an expansion joint can accommodate may depend on the length of the inner pipe that is received within the outer pipe. The inner pipe may be free to rotate relative to the outer pipe in response to torsional forces which may result from thermal expansion and/or contraction of various components of the pipeline.

[0022] In further embodiments, an expansion joint includes two pipes connected in-line with an expansion element such as a flexible bellows or a flexible hose. As described in more detail below, the attachment of the expansion element to the pipeline permits rotation of the pipes relative to the expansion element. For example, in one embodiment in which the expansion element is a flexible bellows, the two pipes may be inner pipes having a first diameter that is smaller than a second diameter of the bellows, and a portion of each of the inner pipes may be received within opposing ends of the bellows. Similar to the embodiments described above, an expansion joint including a flexible bellows (or other suitable expansion element) may be installed in-line within a pipeline, and may be arranged to accommodate rotational and/or translational movement which may occur during thermal expansion and/or contraction of the pipeline. For example, the expansion element may expand and/or contract to accommodate

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changes in length of the pipeline (i.e., translational movement), and one or both of the two pipes may rotate relative to the bellows to accommodate rotational movement of the pipeline.

[0023] According to some aspects of the current disclosure, an expansion joint includes a sealing assembly comprising one or more seals disposed within an annular region between an inner pipe and an outer pipe or portion of expansion element such as a bellows. For example, the one or more seals may include one or more rings of packing material (i.e., packing rings) that extend circumferentially around the annular region between the inner and outer pipes or expansion element, and the packing rings may be compressed against the inner pipes and outer pipes or expansion element to provide a fluid tight seal. As discussed in more detail below, the sealing assembly is constructed and arranged to maintain a fluid-tight seal between the inner pipes and outer pipes or expansion element over a wide temperature range (i.e., between ambient temperatures and cryogenic temperatures), while still permitting the above-described rotational and/or translational movement in response to thermal expansion and/or contraction of the pipeline.

[0024] According to one aspect of the current disclosure, a sealing assembly includes one or more biasing elements associated with the one or more seals that aid in maintaining a fluid-tight seal when the expansion joint is exposed to ambient temperatures (i.e., non-cryogenic temperatures). For example, in one embodiment, the biasing elements may be arranged to apply a compressive force along a direction parallel to an axial direction of the telescoping pipes (or pipe and expansion element) to one or more sealing components of the seals, such as one or more packing rings. The packing rings may be at least partially constrained from moving along the axial direction, and consequently the compressive force applied by the biasing elements urges the packing material of the packing rings to expand in a radial direction. In this manner, the compressive force from the biasing elements may urge the packing rings into contact with the outer surface of the inner pipe and/or the inner surface of the outer pipe, thereby aiding in maintaining a fluid-tight seal in the annular region.

[0025] According to another aspect of the current disclosure, a seal in a sealing assembly of an expansion joint may include two or more components made from materials having different thermal expansion coefficients, and these components may contract and/or expand at different

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rates as the expansion joint is exposed to various temperatures. For example, in one embodiment, the seal includes a packing ring disposed around an inner pipe, and a contraction ring disposed around the packing ring. The contraction ring is formed of a material having a higher thermal expansion coefficient than both the packing material of the packing ring and the material of the inner pipe. Accordingly, when the expansion joint is exposed to cryogenic temperatures (e.g., when a cryogenic fluid such as LNG flows through the expansion joint), the contraction ring contracts radially inward to a greater degree than the packing ring and inner pipe, and consequently, the contraction ring presses the packing ring against the inner pipe to maintain a fluid-tight seal. In another embodiment, a seal may include a packing ring adjacent the inner surface of the outer pipe of the expansion joint, and the packing ring may extend around a support ring. In this embodiment, the support ring may be formed from a material having a lower thermal expansion coefficient than the outer pipe and packing ring. Accordingly, when the expansion joint is exposed to cryogenic temperatures, the outer pipe contracts more than the support ring, thereby compressing the packing ring against the inner surface of the outer pipe.

[0026] In further embodiments, such as those that include two inner pipes connected by an expansion element, a seal may include one or more packing rings disposed between an inner pipe and an inner surface of the expansion element. The expansion element may be formed from a material having a higher thermal expansion coefficient than both the packing material of the packing ring and the material of the inner pipe. Similar to the embodiments described above, when the expansion joint is exposed to cryogenic temperatures, the expansion element contracts radially inward to a greater degree than the packing ring and inner pipe, and consequently, the expansion element presses the packing ring against the inner pipe to maintain a fluid-tight seal.

[0027] In certain embodiments, the expansion element may further include first extensions spaced from the ends of the expansion element to define portions of the expansion element that have an inner diameter that is smaller than the diameter of inner pipes. In such embodiments, the inner surface of the inner pipes may contact these first extensions. Accordingly, thermal contraction of the expansion element may result in the ends of the inner pipes being compressed between the first extensions and a packing ring, thereby further aiding in forming a seal under cryogenic conditions. Moreover, in some embodiments, the inner pipes may include second

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extensions located at the ends of the inner pipes and positioned radially inwardly relative to the first extensions of the expansion element. The first and second extensions may define an annular gap in which additional packing material may be placed to further enhance the seal between the inner pipes and expansion element when the expansion joint is exposed to cryogenic temperatures.

[0028] In some embodiments, a sealing assembly may include one or more different types of seals. For example, in one embodiment, a sealing assembly includes one or more primary seals and one or more secondary seals. Each primary seal includes a packing ring disposed circumferentially around the inner pipe and a contraction ring disposed around the packing ring and configured to compress the packing ring against the inner pipe when the expansion joint is exposed to cryogenic temperatures (as discussed above). The packing ring and contraction ring of the primary seal are secured in place around the inner pipe by a fixed ring attached to the inner surface of the outer pipe and a seal cover attached to the fixed ring. Similar to the primary seals, each of the secondary seals includes a first packing ring disposed circumferentially around the inner pipe and a contraction ring disposed around the first packing ring. The secondary seals also include a support ring disposed around the contraction ring and a second packing ring disposed between the support ring and the interior surface of the outer pipe.

[0029] Although primary and secondary seals including contraction and/or support rings are described above, it should be understood that other sealing arrangements also may be suitable. For example, as described above, an expansion joint including an expansion element such as a bellows may rely on a difference in thermal expansion coefficient between the bellows and an inner pipe such that the bellows contracts to compress a packing ring against the inner pipe when the expansion joint is exposed to cryogenic temperatures.

[0030] Depending on the particular embodiment, a sealing assembly may include any suitable number of primary and/or secondary seals, and the seals may be arranged in any suitable manner. For example, in one specific embodiment, a sealing assembly of an expansion joint includes two primary seals disposed at each end of the sealing assembly (along an axial direction of the expansion joint), and two secondary seals disposed between the primary seals. Further, the sealing assembly may include biasing elements to provide an axial compressive force to the

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sealing assembly (as discussed above), and the biasing elements may be positioned between one of the primary seals and one of the secondary seals. In some embodiments, the sealing assembly may further include one or more circumferential lantern rings positioned between the seals, which may aid in distributing axial forces, such as compressive forces from the biasing elements, within the sealing assembly. Alternatively or additionally, an inner pipe may include one or more protrusions extending radially outwardly from an outer surface of the inner pipe. The protrusions may be attached to the inner pipe in any suitable manner, such as by welding or forging. Similar to the lantern rings, the protrusions may aid in distributing axial forces, such as from one or more biasing elements, to packing rings which may form part of a seal,

[0031] In certain embodiments, it may be desirable for components of the sealing assembly to be easily accessible for maintenance and/or replacement. Accordingly, in some instances, the various components of the sealing assembly, such as the packing rings, contraction rings, support rings, and so on, may not extend entirely around the circumference of inner pipe, but may instead include one or more splits. In particular, these splits may allow those components to be removed from the sealing assembly in situ without requiring the various other components of the sealing assembly to be removed first by sliding them off of the inner pipe. However, it should be understood that the seal components may not include splits in some embodiments, as the disclosure is not limited in this regard.

[0032] In some embodiments, an expansion joint may be provided on one or more external support structures which may support the expansion joint within a pipeline (e.g., an LNG pipeline), also may aid in maintaining the expansion joint in a desired position and/or orientation. For example, in some instances, at least a portion of the expansion joint (e.g., an inner pipe of the expansion joint) may be supported on a rail that permits axial sliding movement of that portion of the expansion joint while restricting other movement, such as lateral or angular movement.

[0033] Depending on the particular embodiment, the various components of an expansion joint may be made from any suitable materials which have an operating temperature range that extends at least between ambient temperatures (e.g., about 40 °C) and cryogenic temperatures (e.g., about -170 °C to about -200 °C). For example, the inner pipes and outer pipes or expansion element, as well as other components of the expansion joint which are not intended to

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apply stresses in response to temperature changes (such as biasing elements and lantern rings provided between seals, seal covers and fixed rings which are attached to the inner and/or outer pipes and/or expansion element, and so on) may be made from a metals such as stainless steel. In some embodiments, these various components may be made from the same material such that they contract and/or expand together in response to varying temperatures (and thus do not create apply thermal stresses). For instance, in one particular embodiment, these components are made from stainless steel 314. Further, in some cases, metal components that may slide against the surface of the inner and/or outer pipes and/or expansion element (e.g., biasing elements and/or various seal components) also may include a coating, such as a soft and/or non-abrasive coating, which may aid in reducing wear.

[0034] Suitable materials for the packing rings, which are compressed against the inner and/or outer pipes, are generally those that can withstand large compressive forces. For example, in some embodiments, the packing rings may be formed from graphite.

[0035] Moreover, as noted above, contraction rings and support rings, which may be included within seals of a sealing assembly, are generally made from materials having a different thermal expansion coefficient than the other components of the expansion joint such that they can apply stresses to a packing material in response to temperature changes. In particular, the contraction rings have a larger thermal expansion coefficient than the inner pipes and outer pipes or expansion element, while the support rings have a smaller thermal expansion coefficient. Suitable materials for contraction rings which may be included in the sealing assembly have a higher thermal expansion coefficient than the materials of the inner pipes and outer pipes or expansion element, and also have an operating temperature range that extends to cryogenic temperatures. In some embodiments, the contraction rings may be formed from a Teflon PTFE fluoropolymer resin. Further, suitable materials for support rings of a sealing assembly generally have a lower thermal expansion coefficient than the materials of the inner pipes and outer pipes or expansion element, and also have an operating temperature that extends to cryogenic temperatures. For instance, in some embodiments the support rings may be formed from Invar 36.

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[0036] Although specific materials are described above for various components of an expansion joint, it should be understood that the current disclosure is not limited to these materials, and that other materials also may be suitable.

[0037] It should be understood that expansion joints according to the current disclosure are not limited to any particular size of pipes. In particular, an expansion joint may be constructed and arranged for use with a wide range of pipe diameters, such as from DN100 (100 mm) to DN1400 (1400 mm), or larger. In some cases, a single expansion joint may accommodate the longitudinal expansion and/or contraction of a section of pipeline having a length of up to 1000 m or longer.

[0038] For the sake of clarity, the presently disclosed embodiments are directed to expansion joints for use in pipelines for transporting cryogenic liquids such as LNG. However, the present disclosure is not limited to LNG pipelines or pipelines for transporting cryogenic liquids. Instead, the expansion joints could be used with other liquid pipelines, including those which are not exposed to extreme temperatures (e.g., cryogenic temperatures) during normal operation. Accordingly, it should be understood that the expansion joints described herein may be used in any suitable pipeline system.

[0039] Turning now to the figures, specific non-limiting embodiments of expansion joints and seals which may be included in an expansion joint are described in further detail. While specific embodiments are described below, it should be understood that the various components, systems, and methods of operation described herein may be combined in any suitable fashion as the current disclosure is not so limited.

[0040] FIGs. 1-2 depict a cross-sectional perspective view and a cross-sectional side view, respectively, of one embodiment of an expansion joint 100 which may connect two ends of a pipeline (e.g., an LNG pipeline). The expansion joint includes an inner pipe 102 that is attached to a first end of the pipeline, which in the depicted embodiment corresponds to an upstream end **A** of the pipeline. The inner pipe has a first diameter **D1** and is received within an outer pipe 104 having a second diameter **D2** that is larger than the diameter of the inner pipe. Accordingly, an annular region 106 is formed between the inner and outer pipes. The outer pipe attaches to a second, downstream end **B** of the pipeline, and in some cases, the size of the outer pipe includes a reducer 108 that reduces the diameter of the second pipe before attaching to the downstream

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end of the pipeline. In the depicted embodiment, the reducer 108 reduces the diameter of the second pipe 104 at the downstream end **B** to a diameter that is equal to the diameter of the inner pipe (i.e., from **D2** down to **D1**). In this manner, the expansion joint 100 may be installed in-line to attach two ends of a pipeline having the same diameter. Depending on the particular embodiment, the inner and outer pipes may be attached to the upstream and downstream ends of the pipeline in any suitable manner, including, but not limited to, by a welded attachment or a flanged attachment.

[0041] The expansion joint 100 is supported on three external supports. In particular, two anchor supports 110 extend circumferentially around the outer pipe 104 and are fixed to a base plate 112. A cross-sectional axial view of the expansion joint, including the anchor supports is depicted in Fig. 3. Further, the expansion joint includes a guide support 114 that extends circumferentially around the inner pipe 102 and is attached to a rail 116 disposed on the base plate 112 and parallel to an axial direction of the expansion joint. Accordingly, guide support 114 and rail 116 permit sliding movement of the inner pipe 102 along its axial direction, while substantially restricting lateral and/or angular movement of the inner pipe. In some instances, though, the guide support may permit rotational movement of the inner pipe about its longitudinal axis. A cross-sectional axial view of the expansion joint including the guide support is shown in Fig. 4. Although three external supports including two anchor supports and one guide support are depicted in the figures, it should be understood that the expansion joint may include any suitable number of external supports, as the current disclosure is not limited in this regard.

[0042] The expansion joint 100 further includes inner guides 118 attached to the end of the inner pipe 102, and configured to support the end of the inner pipe within the outer pipe 104. As best depicted in Fig. 3, the inner guides are distributed uniformly around the annular region 106 to aid in maintaining the inner and outer pipes in a parallel configuration. Each of the inner guides is attached with a bolt 120 to the inner pipe 102, though other means of attaching the inner guides to the inner pipe (such as welding) are also contemplated. Further, each of the inner guides 118 includes a coating 122 on the surface that contacts the inner surface of the outer pipe. As noted above, the coating may be formed from a soft and/or non-abrasive material, which may

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aid in reducing wear as the inner pipe 102 slides within the outer pipe 104. Further, while four inner guides are depicted in the figures and are shown as being uniformly distributed, it should be understood that the expansion joint may include any suitable number of inner guides, and that the inner guides may be arranged in any suitable manner.

[0043] As noted above, the inner pipe 102 is slidable along its axial direction relative to the outer pipe 104. Such sliding movement may allow the expansion joint 100 to accommodate changes in length of a pipeline arising from thermal contraction and/or expansion as the pipeline is exposed to various temperatures. In particular, the expansion joint is depicted in an expanded configuration, which may correspond to the configuration at ambient temperatures. As the temperature of the pipeline is reduced (e.g., from ambient down to cryogenic temperatures), the inner pipe may contract along its length and slide relative to the outer pipe towards the upstream end **A** of the expansion joint. Subsequently, when the temperature is raised from cryogenic temperatures to ambient temperatures, the inner pipe may expand and slide towards the downstream end **B**.

[0044] The expansion joint 100 includes a sealing assembly 140 positioned within the annular region 106 between the inner pipe 102 and the outer pipe 104. As described in more detail below, the sealing assembly is constructed and arranged to seal the expansion joint and prevent liquid flowing through the pipeline (e.g., cryogenic liquids such as LNG) from escaping around the inner pipe or otherwise leaking out of the expansion joint. As best illustrated in Fig. 2, the total contraction length ΔL that the inner pipe 102 may slide in order to accommodate thermal contraction may depend on the specific positioning of the sealing assembly 140 relative to the end of the inner pipe. Depending on the particular embodiment, the positioning of the sealing assembly and/or the dimensions of the expansion joint may be chosen to provide a desired contraction length ΔL .

[0045] Fig. 5 shows a detailed cross-sectional side view of the sealing assembly 140. In this embodiment, the upstream end of the assembly is defined by an end ring 142 that is attached to a flange 144 with one or more bolts 146. The flange 144 is welded onto the outer surface of the outer pipe 104. In some instances, the end ring 142 does not contact the outer surface of the inner pipe 102, and a small gap (not depicted) may remain between the end ring and the inner

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pipe. In this particular embodiment, the sealing assembly 140 comprises two primary seals 160 on the upstream and downstream ends of the sealing assembly, and two secondary seals 180 disposed between the primary seals. Each of the primary and secondary seals is described in more detail below. Further, each of the primary and secondary seals is separated by a lantern ring 148, also discussed in more detail below. As viewed in Fig. 6, the downstream end of the sealing assembly 140 is defined by a fixed ring 162 of a primary seal 160 that is circumferentially welded to the inner surface of outer pipe 104. Although a sealing assembly including two primary seals and two secondary seals is depicted in the figures, it should be understood that the current disclosure is not limited in this regard. Accordingly, a sealing assembly may have any suitable number of primary and/or secondary seals arranged in any suitable manner.

[0046] As best illustrated in Fig. 5, the sealing assembly includes one or more biasing elements, such as springs 150. For example, in some embodiments, multiple compressed metal springs 150 are arranged evenly around the inner pipe 102 and between two circumferential rings 152. The springs 150 are configured to apply a compressive force along a direction parallel to the axial direction of expansion joint 100 (i.e., in a direction parallel to the direction of fluid flow). As discussed above, this axial compressive force may urge packing material within each of the seals (discussed in more detail below) to expand outwardly in a radial direction, thereby aiding in maintaining a fluid-tight seal. In particular, the sealing force provided by the biasing elements may aid in maintaining a seal at ambient temperatures, at which no additional sealing forces are provided by thermal stresses. In some instances, the outer surfaces of the rings 152, which contact the outer surface of the inner pipe 102 and the inner surface of the outer pipe 104, may be formed from a soft and/or non-abrasive material to reduce wear which may result from sliding of the rings 152 within the annular region 106.

[0047] As noted above, circumferential lantern rings 148 are provided between each of the primary seals 160 and secondary seals 180. These lantern rings may aid in evenly distributing the compressive forces applied by the biasing elements (i.e., springs 150) around the circumference of the sealing assembly 140. Each lantern ring 148 includes two larger diameter rings separated by a smaller diameter ring to form a generally H-shaped cross section. The

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lantern rings may be constructed of the same material as the inner and outer pipes, (e.g., stainless steel 314). Further, similar to the rings 152, the inner and outer surfaces of the lantern rings may include a soft and/or non-abrasive coating.

[0048] Figs. 6-7 show a cross-sectional side view and a cross-sectional axial view, respectively of one embodiment of a primary seal. In particular, the depicted embodiment corresponds to the downstream primary seal 160a of Fig. 5. In this embodiment, the primary seal includes a fixed ring 162 that is welded circumferentially to the inner surface of outer pipe 104. In other embodiments, such as the upstream primary seal of Fig. 5, the fixed ring may be replaced with a circumferential ring, such as ring 152 associated with the springs 150. Accordingly, it should be understood that an end of a primary seal, such as a downstream end, generally includes a circumferential ring that may, or may not, be fixedly attached to the outer pipe 104. Similarly, and depending on the particular embodiment, the opposing end of the primary seal may, or may not, be fixedly attached to the outer pipe. Specifically, in the embodiment depicted in Fig. 6, the upstream end of the seal 160a contacts a lantern ring 148 (see Fig. 5). In other embodiments, such as the primary seal 160b disposed at the upstream end of the sealing assembly 140, the upstream end of the seal is attached to the end plate 142, which is fixed to the outer pipe 104 via flange 144 and bolt 146

[0049] As best illustrated in Fig. 6, each primary seal 160a and 160b includes a circumferential packing ring 164 that is tightly packed within cut-outs formed in a seal cover 166 and the fixed ring 162 (or the end ring 142 in the case of primary seal 160b). The seal cover 166 is attached to the fixed ring (or end ring) with one or more bolts 172. The packing ring 164 and the seal cover 166 are arranged to provide a tight seal in the inward radial direction against the outer surface of the inner pipe 102. Additionally, a contraction ring 168 is disposed circumferentially around the packing material. The contraction ring is formed from a material having a higher thermal expansion coefficient than the inner pipe 102 and outer pipe 104. Accordingly, when the primary seal is cooled (e.g., via exposure to cryogenic liquids), the contraction ring 168 contracts in the radial direction to a greater extent than the inner pipe 102, and thus compresses the packing ring 164 in the radial direction to maintain maintaining a fluid-tight seal against the inner pipe. In this manner, the primary seal provides a liquid-tight from

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ambient temperatures down to cryogenic operating temperatures (e.g., about -160 °C to -200 °C). In some embodiments, the primary seal further includes two circumferential O-ring seals 170, which may be made from the same material as the contraction ring 168. The O-rings are disposed within cut-outs in the seal cover 166 and the fixed ring 162 (or, in the case of primary seal 160b, in the end ring 142) respectively, on either side of the contraction ring.

[0050] In some instances, the various components of the primary seal may include one or more split to allow for in situ replacement of the seal components. As best illustrated in Fig. 7, the packing ring 164 includes a single split 165, while each of the contraction ring 168 and O-rings 170 include two splits 169 and 171, respectively, such that they have generally semi-circular shapes. Further, in some embodiments, surfaces of the seal fixed ring 162, seal cover 166, and/or end ring 142 that contact the outer surface of the inner pipe 102 and/or the inner surface of the outer pipe 104 may include a soft and/or non-abrasive coating, as discussed above.

[0051] Referring now to Figs. 8-9, secondary seals 180 of the sealing assembly 140 are discussed in more detail. In particular, Figs. 8-9 show a cross-sectional side view and a cross-sectional axial view, respectively, of one embodiment of a secondary seal 180. The secondary seal includes two packing rings 182, and 188, a contraction ring 184, and a support ring 186, each of which extend around the inner pipe 102. Each of these rings are disposed between two end rings 190 along the axial direction, and the end rings are attached to one another by multiple bolts 192. In particular, the inner packing ring 182 is in contact with the outer surface of the inner pipe 102, and the outer packing ring is in contact with the inner surface of the outer pipe 104. When the expansion joint is exposed to ambient temperatures, the axial compressive force from the springs 150 pushes against the end rings 190, thereby pressing the packing rings inwardly and outwardly in the radial directions to maintain a fluid-tight seal. When the secondary seal 180 is cooled (e.g., via exposure to cryogenic liquids), the fluid-tight seal is maintained via application of thermal stresses to the packing rings by the contraction ring 184 and the support ring 186. Specifically, similar to the contraction ring 168 described above, the contraction ring 184 is formed from a material having a higher thermal expansion coefficient than the material of the inner and outer pipes. In contrast, the support ring 186 is formed from a material having a lower thermal expansion coefficient than the material of the inner and outer

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pipes. Consequently, when the expansion joint is cooled, the contraction ring 184 contracts inwardly in the radial direction to a greater extent than the inner pipe 102, thereby compressing the inner packing ring 182 against the inner pipe. Similarly, the outer pipe 104 contracts radially inwardly to a greater extent than the support ring 186 to compress the outer packing ring 188 against the outer pipe 104. In this manner, differing rates of thermal contraction allow the secondary seal 180 to maintain a fluid-tight seal between the inner and outer pipes through the cooling process.

[0052] In some instances, the specific dimensions of the packing rings 182 and 188, the contraction ring 184, and the support ring 186 may be chosen such that they form a fluid-tight seal at ambient temperatures. Further, similar to the various components of the primary seals 160a and 160b, the components of the secondary seals 180 may include one or more splits to facilitate in situ replacement. As best illustrated in Fig. 9, each of the packing rings 182 and 188 includes splits 183 and 189, respectively. Additionally, the contraction ring 184 and support ring 186 are split in semi-circles at points 185 and 187, respectively. Moreover, in some instances, the outer surfaces of the end rings 190 may include a soft and/or non-abrasive coating to aid in reducing wear during sliding and/or rotation of the inner pipe.

[0053] Figs. 10 depicts a cross-sectional side view of another embodiment of an expansion joint 200 which may connect two ends of a pipeline (e.g., an LNG pipeline) via an expansion element, which in this particular embodiment, is a flexible bellows 204. In particular, the expansion joint includes two inner pipes 202 attached to opposing attachment ends 211 of the bellows, with a flexible portion 205 of the bellows positioned between the ends of the inner pipes. Each of the inner pipes 202 has an inner diameter **D3** and is received in the bellows, which has an inner diameter **D4** larger than **D3**. In the depicted embodiment, the bellows includes a first extensions 207 extending inwardly from the inner surface of the bellows and defining a portion of the bellows that has an inner diameter **D5** that is smaller than **D3**. Further, the inner pipes 202 each have a second extensions 209 such that the inner pipes have an inner diameter **D6** at their ends that is smaller than the diameter of the first extension **D5**.

[0054] As best illustrated in Fig. 11, which depicts a detailed cross-sectional view of a portion of the expansion joint of Fig. 10, the relative dimensions of the inner pipe 202 and

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bellows 204 forms annular regions between portions of the inner pipe and bellows. In particular, a first annular region 206 is formed between the outer surface of the inner pipe 202 and the inner surface of the bellows 204, and a second annular region 209 is formed between the first extension 207 of the bellows and the second extension 209 of the inner pipe. In some portions of the expansion joint, though, no annular region is formed and inner pipe and bellows are in direct contact. For example, the inner surface of the inner pipe may contact the outer surface of the first extension 207 of the bellows. The expansion joint 200 includes a sealing assembly 240 which includes one or more seals disposed within the annular regions 206 and 209. As described in more detail below, the sealing assembly is constructed and arranged to seal the expansion joint and prevent liquid flowing through the pipeline (e.g., cryogenic liquids such as LNG) from escaping the inner pipes or bellows or otherwise leaking out of the expansion joint.

[0055] Referring again to Fig. 11, a first end of the expansion joint includes an end ring 242 that is attached to a flange 244 with one or more bolts 246; the flange is welded to the outer surface of the bellows. As shown in Fig. 11, in some instances the end ring 242 may not contact the outer surface of the inner pipe 202, and a small gap may remain between the end ring and the inner pipe. In the depicted embodiment, the sealing assembly 240 includes a primary seal 262 positioned within the first annular gap 206 at an end of the inner pipe and located between a projection 266 of the inner pipe and a portion of the first extension 207 of the bellows 204. A secondary seal 263 is disposed within the second annular gap 209 between portions of the second extension 208 of the inner pipe and the first extension 207 of the bellows. The sealing assembly further includes an outer seal 260 disposed within the first annular gap 206 between a lantern ring 248 and a second projection 266, which are positioned between the primary seal 262 and the end ring 242. Each of the seals 262, 263, and 260 comprise a packing ring, which may be made from graphite packing material. Although a sealing assembly 240 including one primary seal 262, one secondary seal 263, one outer seal 260, and two projections 266 is depicted in Figs. 10-11, it should be understood that the current disclosure is not limited in this regard. Accordingly, a sealing assembly may have any suitable number of primary and/or secondary and/or other seals and may include any suitable number of protrusions arranged in any suitable configuration. Further, in the depicted embodiment, a space 264 is formed between the projections 266. In

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some instances, the sealing assembly may further include an additional seal disposed within this space. Alternatively, the space 264 may include a suitable interface (not depicted) to allow attachment of a pressure gauge or similar device for leak detection.

[0056] Similar to the embodiments described above with reference to Figs. 1-5, the sealing assembly 240 includes one or more biasing elements, such as springs 250. For example, in some embodiments, multiple compressed metal springs 250 are arranged around the inner pipe 202 and between two circumferential rings 252. The springs 250 are configured to apply a compressive force along a direction parallel to the axial direction of the expansion joint (i.e., in a direction parallel to the direction of fluid flow). As discussed above, this axial compressive force may urge packing material within each of the seals to expand outwardly in a radial direction, thereby aiding in maintaining a seal at ambient temperatures, at which no additional sealing forces are provided by thermal stresses. As the pipeline is exposed to cryogenic conditions, it contracts axially and pulls on the bellows towards the contracting pipeline, thereby applying an axial contraction force to the outer seal 260. This forms a tighter axial seal due to restrictions from the end ring 242, springs 250 and projections 266.

[0057] In some instances, the outer surfaces of the rings 252, which contact the outer surface of the inner pipe 202 and the inner surface of the bellows or equivalent 204, may be formed from a soft and/or non-abrasive material to reduce wear which may result from sliding of the rings 252 within the annular regions 206 and 209. Further, as noted above, circumferential lantern rings 248 may be provided between the rings 252 and outer seal 260. These lantern rings may aid in evenly distributing the compressive forces applied by the biasing elements (i.e., springs 250) around the circumference of the sealing assembly 240. Each lantern ring 248 includes two larger diameter rings separated by a smaller diameter ring to form a generally H-shaped cross section. The lantern rings may be constructed of the same material as the bellows 204 (e.g., stainless steel 304). Further, similar to the rings 252, the inner and outer surfaces of the lantern rings may include a soft and/or non-abrasive coating.

[0058] Referring again to Fig. 11, the projections 266 of the inner pipe 202 are described in more detail. The projections are forged or welded onto the inner pipe 202 to receive the compressive forces applied by the biasing elements (i.e., springs 250) around the circumference

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of the sealing assembly 240. This axial force aids in attaching the inner pipe 202 to the first extension 207 of the bellows without welding or bolting the connecting pieces together. In some embodiments, contraction rings 268 may be positioned in a space between the projections 266 and the inner surface of the bellows 204. The contraction rings may be formed from a Teflon PTFE fluoropolymer resin or other similar material which has a higher thermal coefficient of expansion than the inner pipe. Accordingly, these rings apply a radially inward force between the inner side of the inner pipe 202 and the upper side of the first extension 207 to aid in sealing under cryogenic conditions.

[0059] Although the embodiment described above with reference to Figs. 10-11 includes an expansion element in the form of a flexible bellows, it should be understood that the current disclosure is not limited to a bellows, and that other structures also may be suitable for the expansion element. For example, the expansion element may include a flexible hose, or any other suitable structure that can expand and/or contract, or otherwise accommodate length changes of a section of pipeline. Further, it should be understood that the materials of the pipeline may be the same as, or different than, the materials used in the various components of the expansion joint, including the inner pipes and the expansion element.

[0060] In certain embodiments, an expansion joint may further include one or more pressure gauges, which may be provided at each of the primary and/or secondary seals. The pressure gauges may allow for monitoring of the expansion joint, including detection of leaks within the sealing assembly.

[0061] While the present teachings have been described in conjunction with various embodiments and examples, it is not intended that the present teachings be limited to such embodiments or examples. On the contrary, the present teachings encompass various alternatives, modifications, and equivalents, as will be appreciated by those of skill in the art. Accordingly, the foregoing description and drawings are by way of example only.

[0062] What is claimed is:

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CLAIMS

1. An in-line expansion joint comprising:
 - an outer pipe having a first diameter;
 - an inner pipe having a second diameter smaller than the first diameter, the inner pipe disposed at least partially within the outer pipe and forming an annular region between the inner pipe and the outer pipe; and
 - a sealing assembly disposed within the annular region, the sealing assembly comprising:
 - at least one primary seal having a first packing ring adjacent the inner pipe and a first contraction ring disposed around the first packing ring, wherein a material of the first contraction ring has a higher thermal expansion coefficient than a material of the inner pipe; and
 - at least one biasing element, wherein the at least one biasing element applies a compressive force to the at least one primary seal to urge the first packing ring against the inner pipe.
2. The in-line expansion joint of claim 1, wherein the first contraction ring compresses the first packing ring against the inner pipe when the temperature of the expansion joint is reduced from a first temperature to a second temperature lower than the first temperature.
3. The in-line expansion joint of claim 1, wherein the sealing assembly further comprises at least one secondary seal having a second packing ring adjacent the inner pipe and a third packing ring adjacent the outer pipe.
4. The in-line expansion joint of claim 3, wherein the at least one biasing element applies a compressive force to the at least one secondary seal to urge the second packing ring against the inner pipe and the third packing ring against the outer pipe.

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5. The in-line expansion joint of claim 4, wherein the at least one secondary seal includes a second contraction ring disposed around the second packing ring, wherein a material of the second contraction ring has a higher thermal expansion coefficient than a material of the inner pipe.
6. The in-line expansion joint of claim 5, wherein the second contraction ring compresses the second packing ring against the inner pipe when the temperature of the expansion joint is reduced from a first temperature to a second temperature lower than the first temperature.
7. The in-line expansion joint of claim 3, wherein the at least one secondary seal includes a support ring, wherein the third packing ring is disposed around the support ring, and wherein a material of the support ring has a lower thermal expansion coefficient than a material of the outer pipe.
8. The in-line expansion joint of claim 7, wherein the third packing ring is compressed between the outer pipe and the support ring when the temperature of the expansion joint is reduced from a first temperature to a second temperature lower than the first temperature.
9. The in-line expansion joint of claim 3, wherein the sealing assembly comprises at least two primary seals and at least two secondary seals.
10. The in-line expansion joint of claim 9, wherein each of secondary seals are disposed between two primary seals.
11. The in-line expansion joint of claim 1, wherein the at least one biasing element comprises one or more springs.

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12. The in-line expansion joint of claim 1, wherein the sealing assembly maintains a seal between the inner pipe and the outer pipe or bellows or equivalent over an operating temperature range of 40°C to -200 °C.
13. The in-line expansion joint of claim 1, wherein the inner pipe is axially slidable relative to the outer pipe.
14. The in-line expansion joint of claim 1, wherein the inner pipe is rotatable relative to the outer pipe about a longitudinal axis of the inner pipe.
15. The in-line expansion joint of claim 1, wherein the expansion joint is capable of accommodating longitudinal contraction and/or expansion of a section of pipeline having a length of up to 1000 m or longer.
16. The in-line expansion joint of claim 1, wherein the expansion joint is welded or flanged in-line with an associated pipeline.
17. The in-line expansion joint of claim 1, further comprising one or more supports associated with at least one of the outer pipe and the inner pipe, wherein the one or more supports are arranged to restrict lateral and/or angular movement of the inner pipe relative to the outer pipe.
18. An in-line expansion joint comprising:
 - an expansion element having a flexible portion, at least one attachment end coupled to the flexible portion and having a first diameter, and a first extension extending radially inwardly from an inner surface of the at least one attachment end and defining a portion of the expansion element having a second diameter smaller than the first diameter;

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a pipe having a third diameter smaller than the first diameter and larger than the second diameter, the pipe disposed at least partially within the at least one attachment end of the expansion element and forming an annular region between the pipe and the expansion element, the pipe including at least one projection extending into the annular region, wherein a material of the expansion element has a higher thermal expansion coefficient than a material of the pipe; and

a sealing assembly disposed within the annular region, the sealing assembly comprising:

at least one biasing element;

a primary seal having a first packing ring adjacent the pipe, the primary seal disposed between the at least one projection and the first extension of the expansion element; and

an outer seal having a second packing ring adjacent the pipe, the outer seal disposed between the at least one biasing element and the primary seal, wherein the at least one biasing element applies a compressive force to the primary and secondary seals to urge the first and second packing rings against the pipe.

19. The in-line expansion joint of claim 18, wherein the expansion element compresses the first and second packing rings against the pipe when the temperature of the expansion joint is reduced from a first temperature to a second temperature lower than the first temperature.
20. The in-line expansion joint of claim 18, wherein the pipe further comprises a second extension at an end of the pipe received in the expansion element, the second extension extending radially inwardly from an inner surface of the pipe and defining a portion of the pipe having a fourth diameter smaller than the second diameter of the expansion element such that the first and second extensions are separated by a second annular region.

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21. The in-line expansion joint of claim 20, further comprising a secondary seal disposed within the second annular region, the secondary seal comprising a third packing ring.
22. The in-line expansion joint of claim 21, wherein a material of the third packing ring has a larger thermal expansion coefficient than a material of the pipe and a smaller thermal expansion coefficient than a material of the expansion element.
23. The in-line expansion joint of claim 22, wherein the third packing ring is compressed between the first and second extensions when the temperature of the expansion joint is reduced from a first temperature to a second temperature lower than the first temperature.
24. The in-line expansion joint of claim 18, further comprising a contraction ring disposed around the at least one projection of the pipe, wherein a material of the contraction ring has a larger thermal expansion coefficient than a material of the pipe.
25. The in-line expansion joint of claim 24, wherein the contraction ring compresses the pipe against the first extension when the temperature of the expansion joint is reduced from a first temperature to a second temperature lower than the first temperature.
26. The in-line expansion joint of claim 18, wherein the flexible portion of the expansion element is axially extensible relative to the pipe.
27. The in-line expansion joint of claim 18, wherein the pipe is rotatable relative to the expansion element.
28. The in-line expansion joint of claim 18, wherein the at least one biasing element comprises one or more springs.

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29. The in-line expansion joint of claim 18, wherein the sealing assembly maintains a seal between the inner pipe and the outer pipe or bellows or equivalent over an operating temperature range of 40°C to -200 °C.
30. The in-line expansion joint of claim 18, wherein the expansion joint is capable of accommodating longitudinal contraction and/or expansion of a section of pipeline having a length of up to 1000 m or longer.
31. The in-line expansion joint of claim 18, wherein the expansion joint is welded or flanged in-line with an associated pipeline.
32. The in-line expansion joint of claim 18, further comprising one or more supports associated with at least one of the expansion element and the pipe, wherein the one or more supports are arranged to restrict lateral and/or angular movement of the pipe relative to the expansion element.
33. The in-line expansion joint of claim 18, further comprising a second pipe coupled to the expansion element.
34. The in-line expansion joint of claim 33, wherein the expansion element includes first and second attachment ends positioned on opposing sides of the flexible portion, and wherein the second pipe is received in the second attachment end and defining a third annular region between the second pipe and the expansion element.
35. The in-line expansion joint of claim 34, further comprising a second sealing assembly disposed within the third annular region.
36. The in-line expansion joint of claim 18, wherein the expansion element comprises at least one of a flexible bellows and a flexible hose.

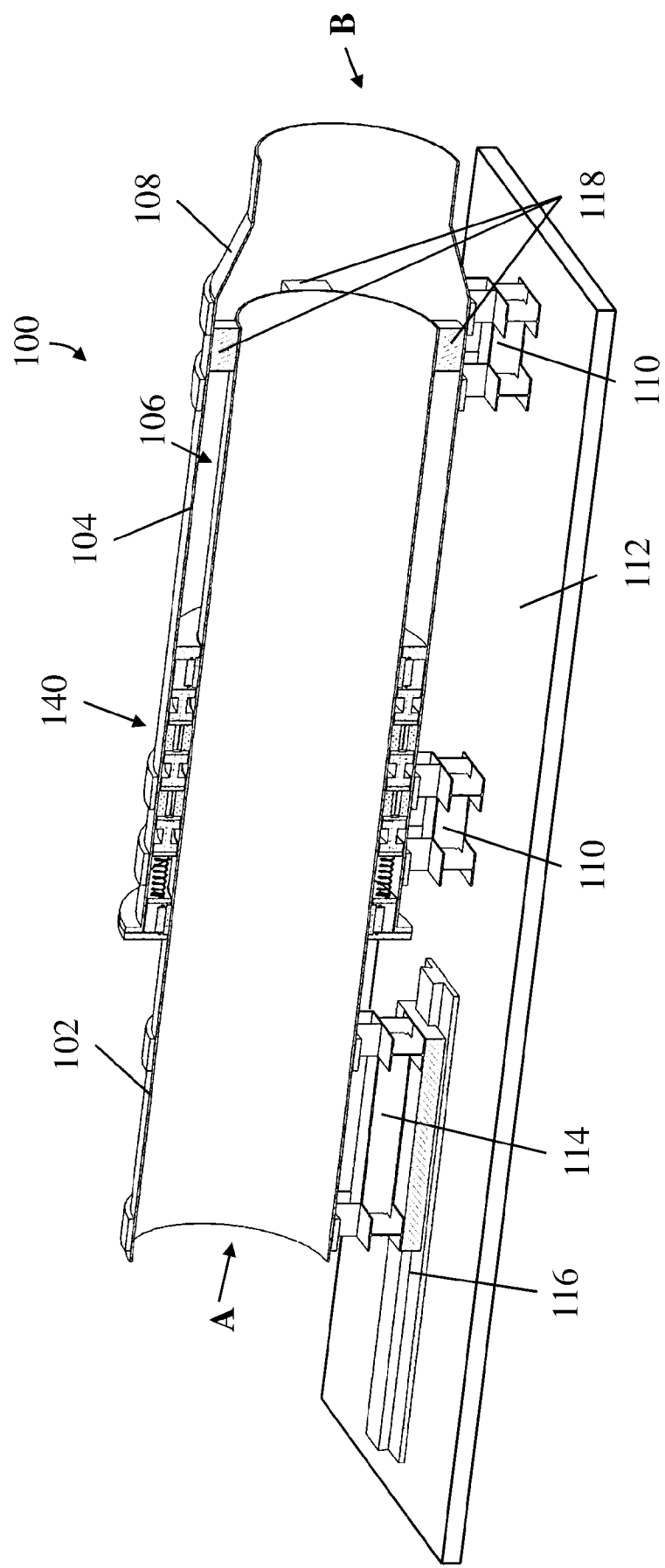


Fig. 1

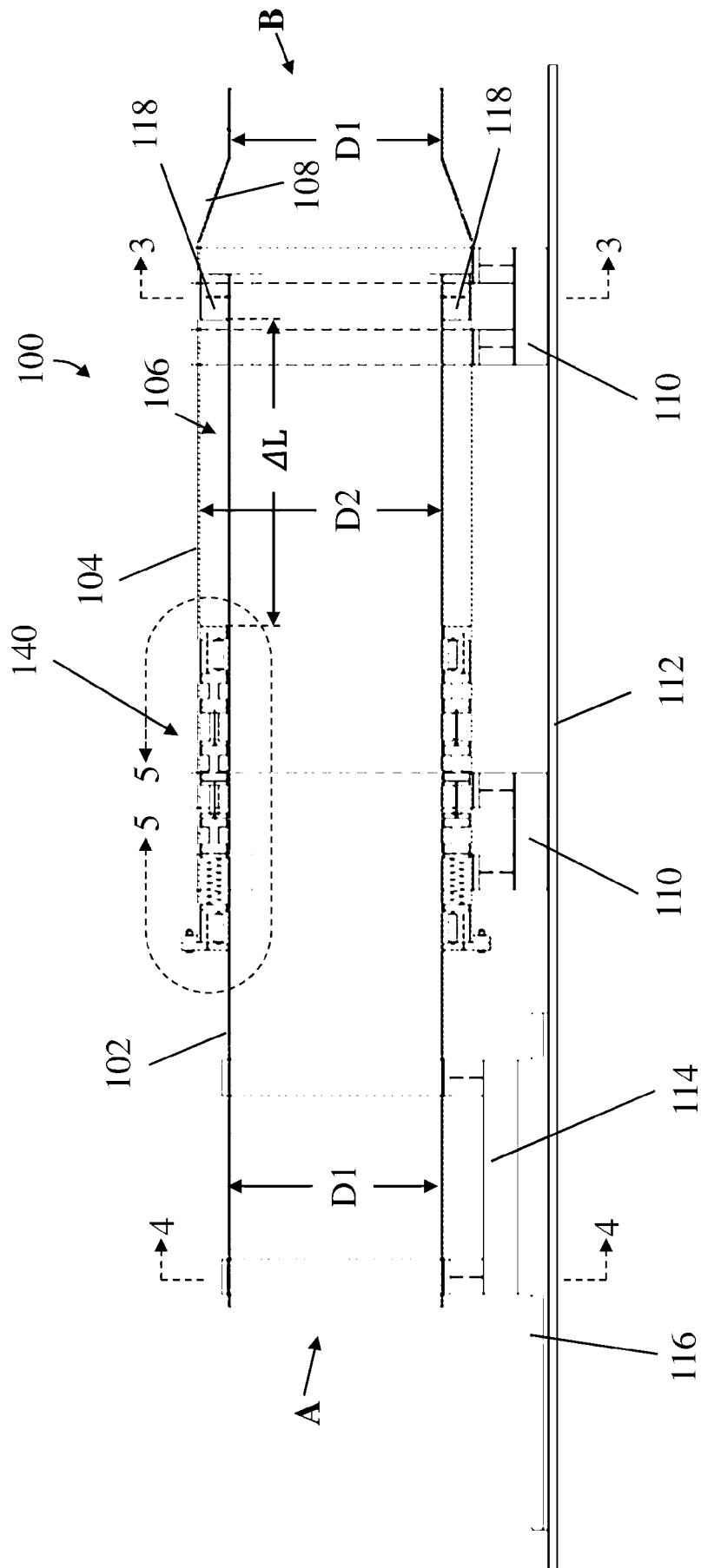


Fig. 2

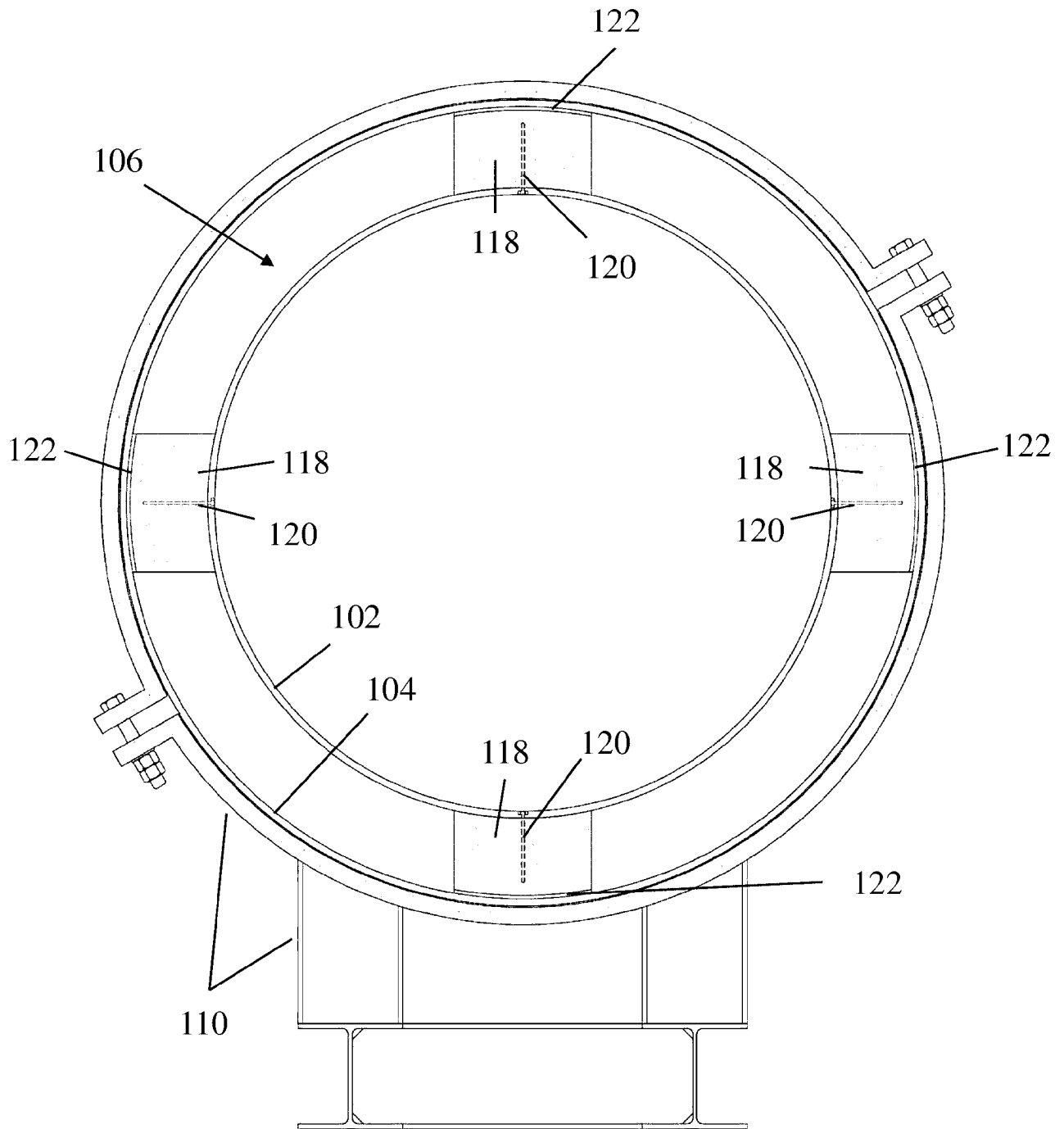


Fig. 3

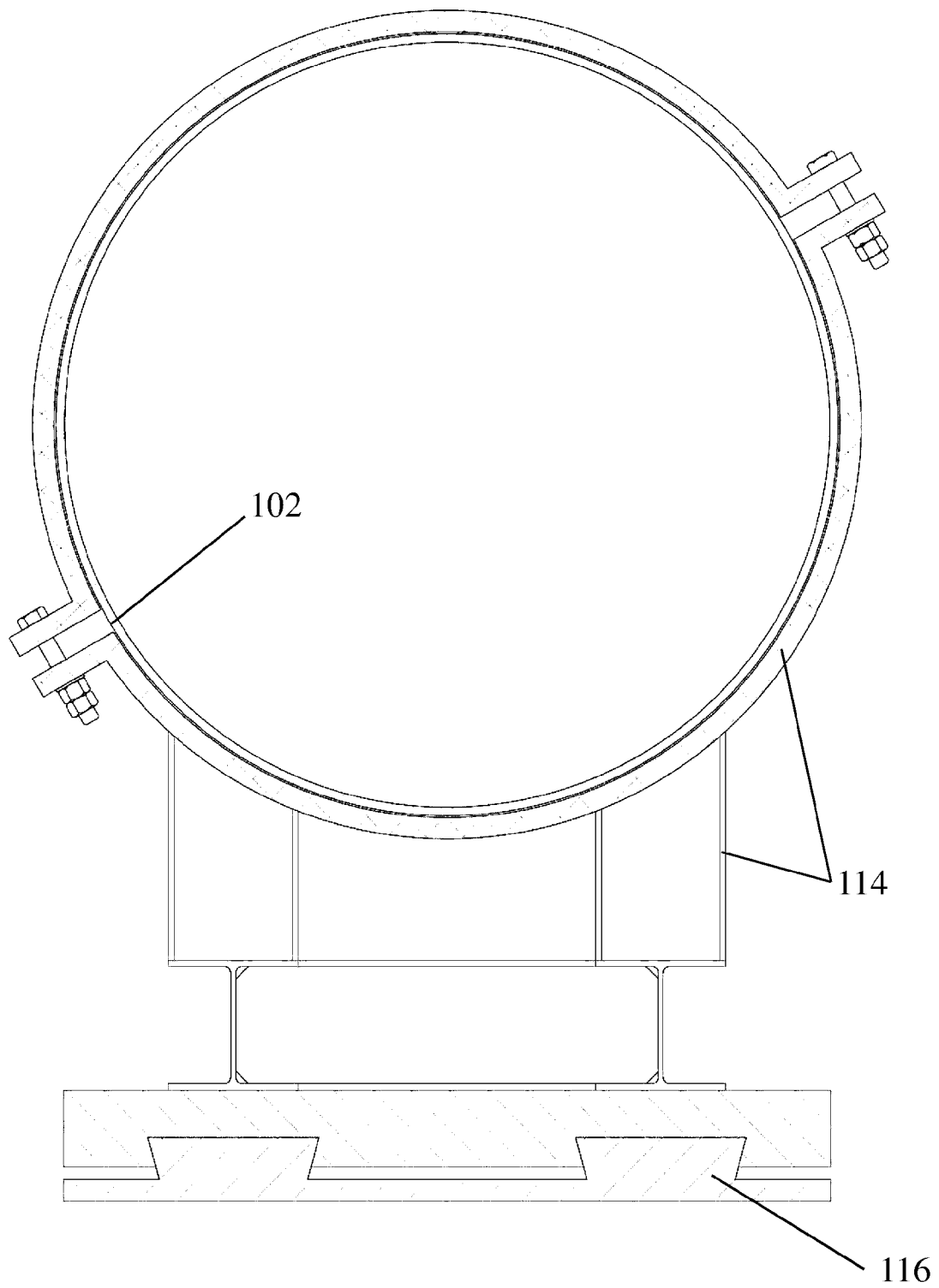


Fig. 4

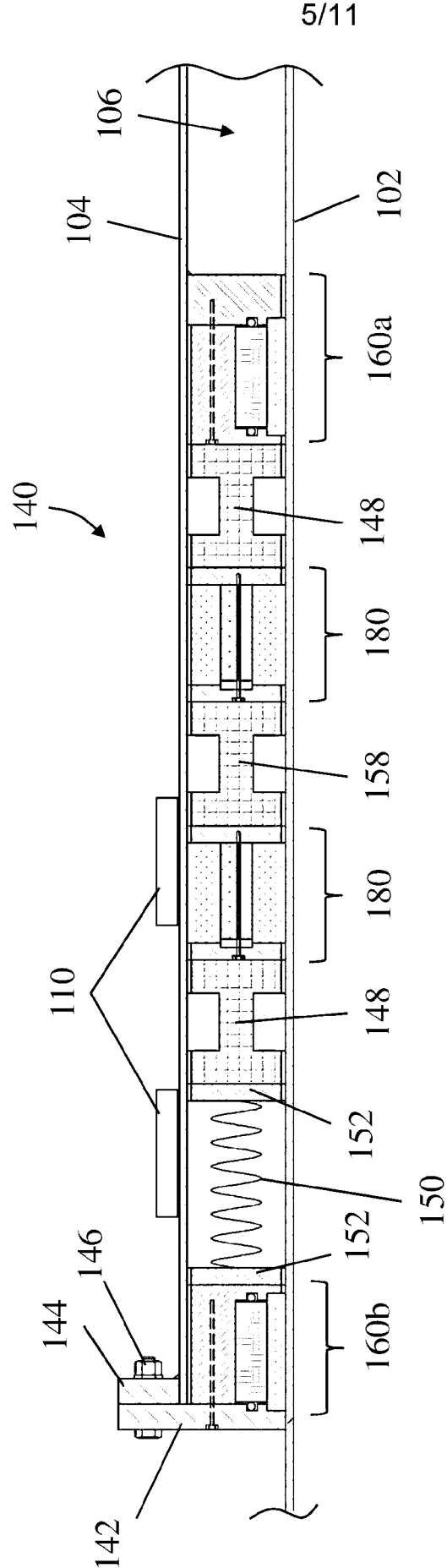


Fig. 5

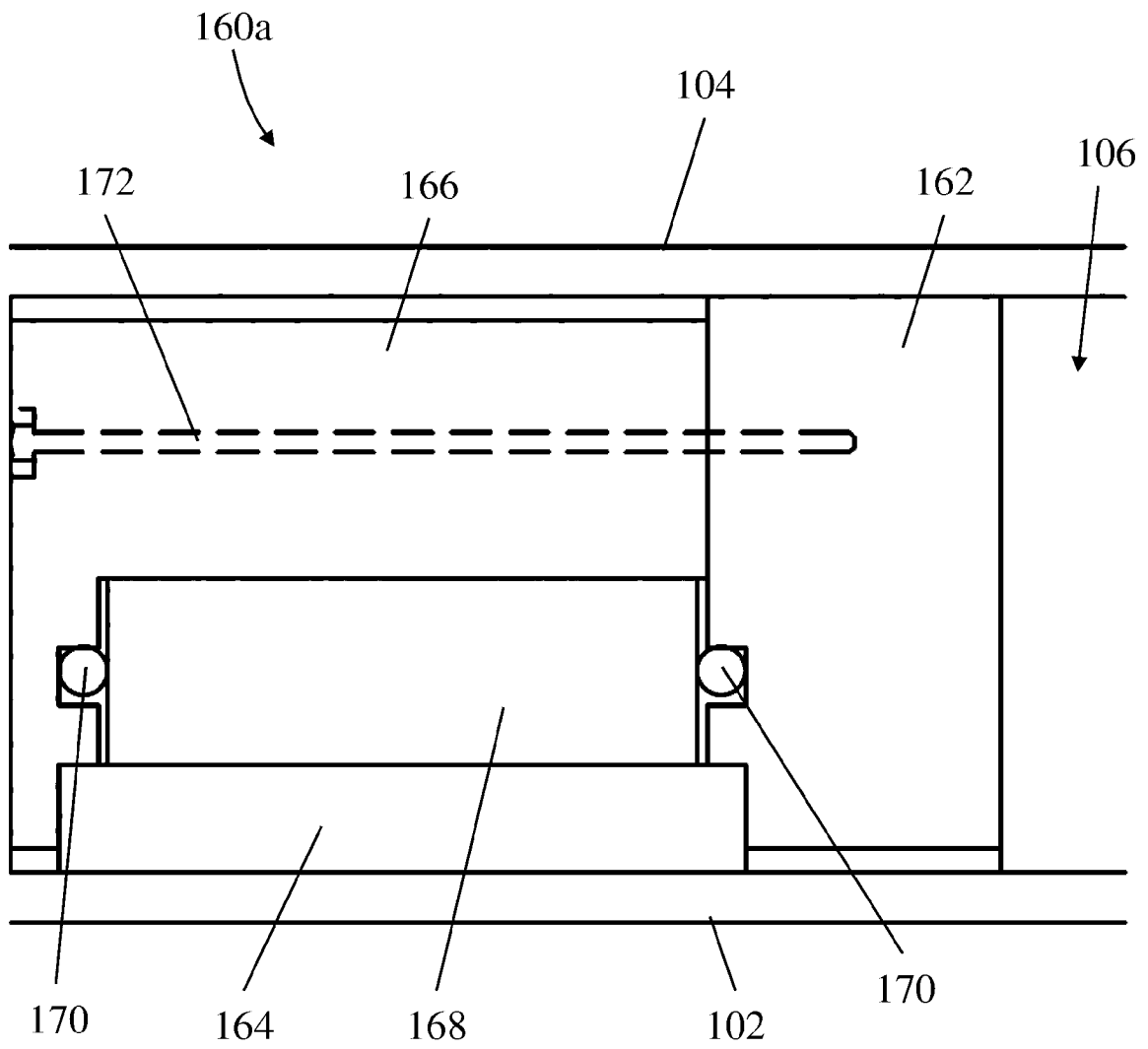


Fig. 6

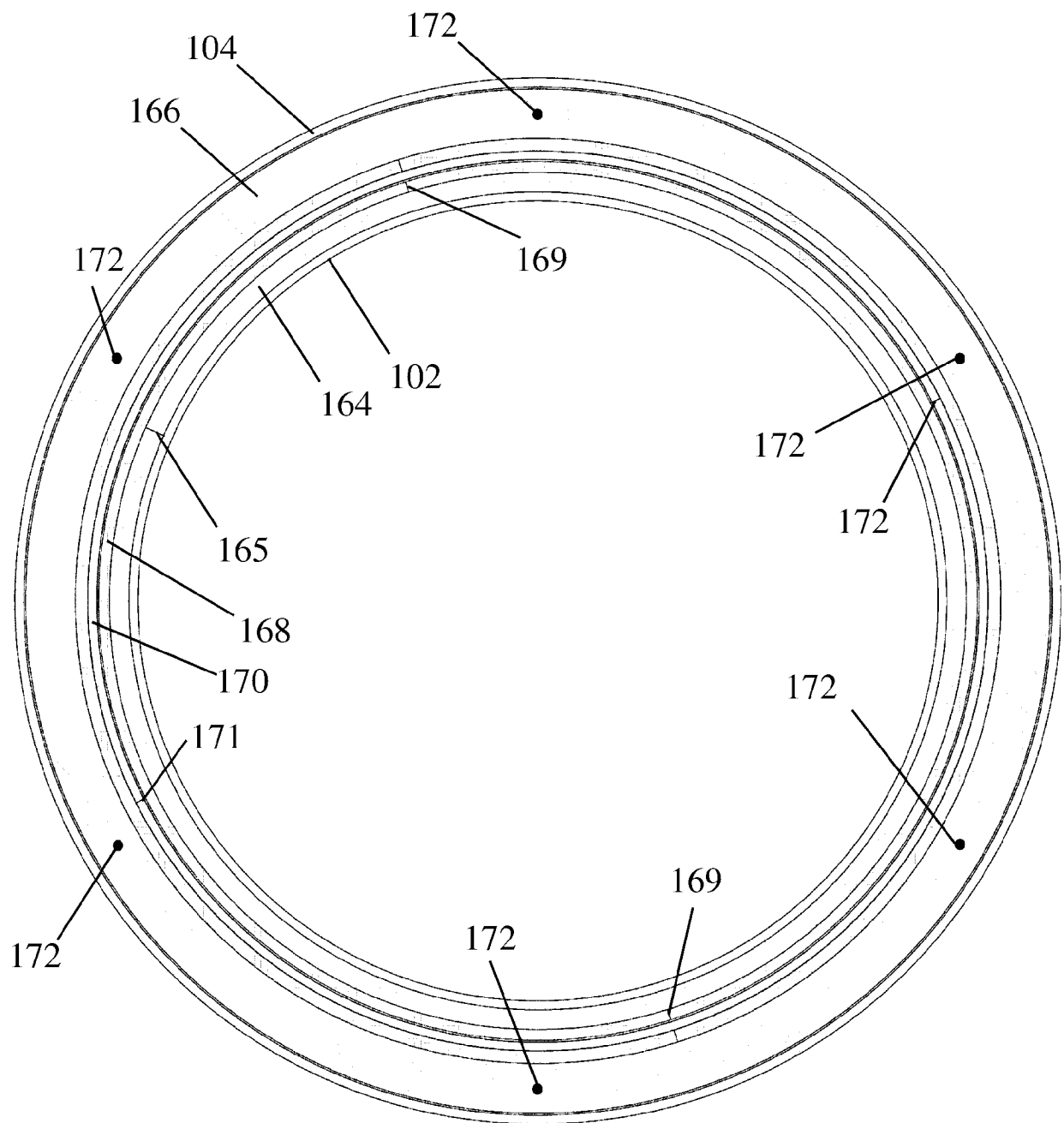


Fig. 7

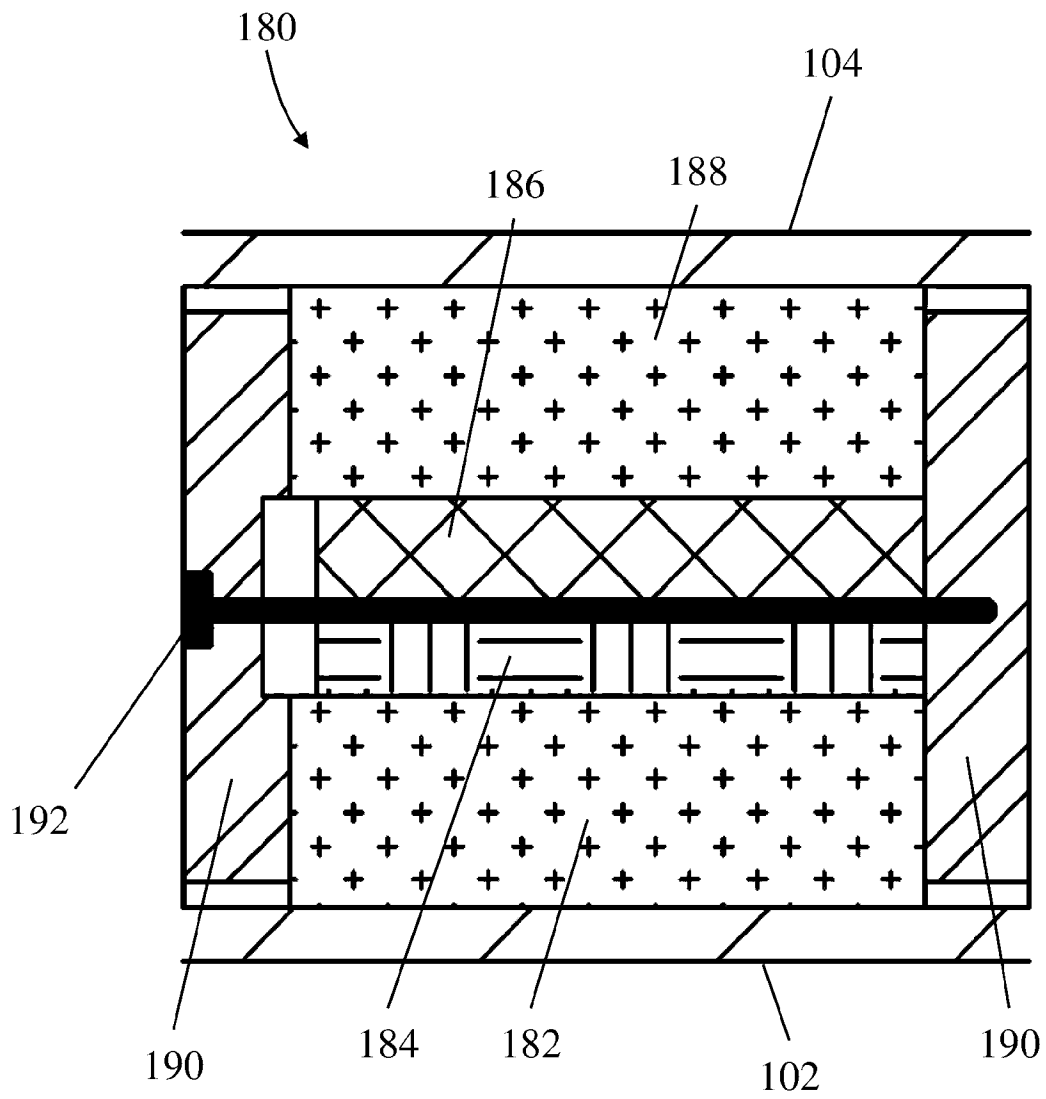


Fig. 8

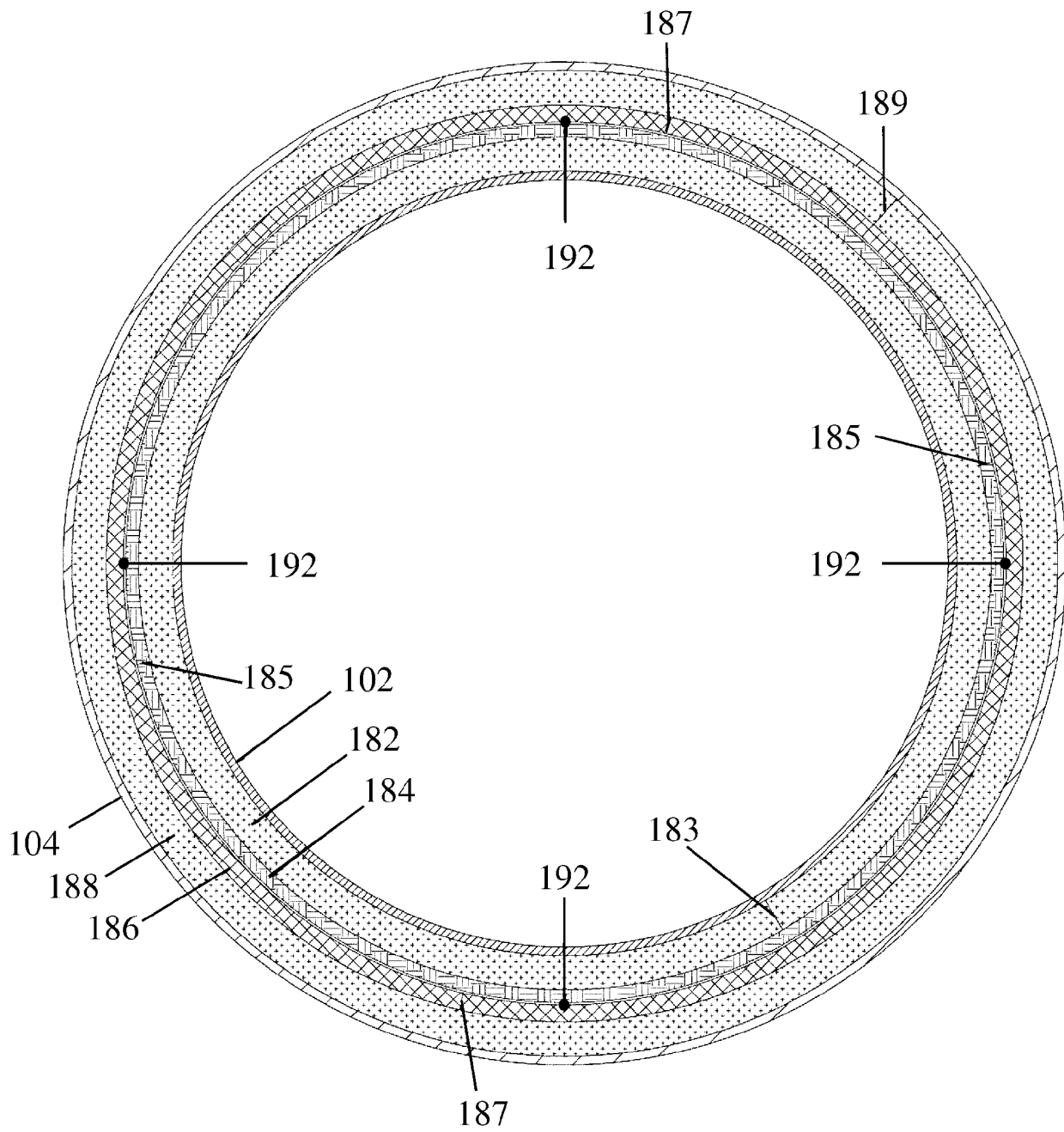


Fig. 9

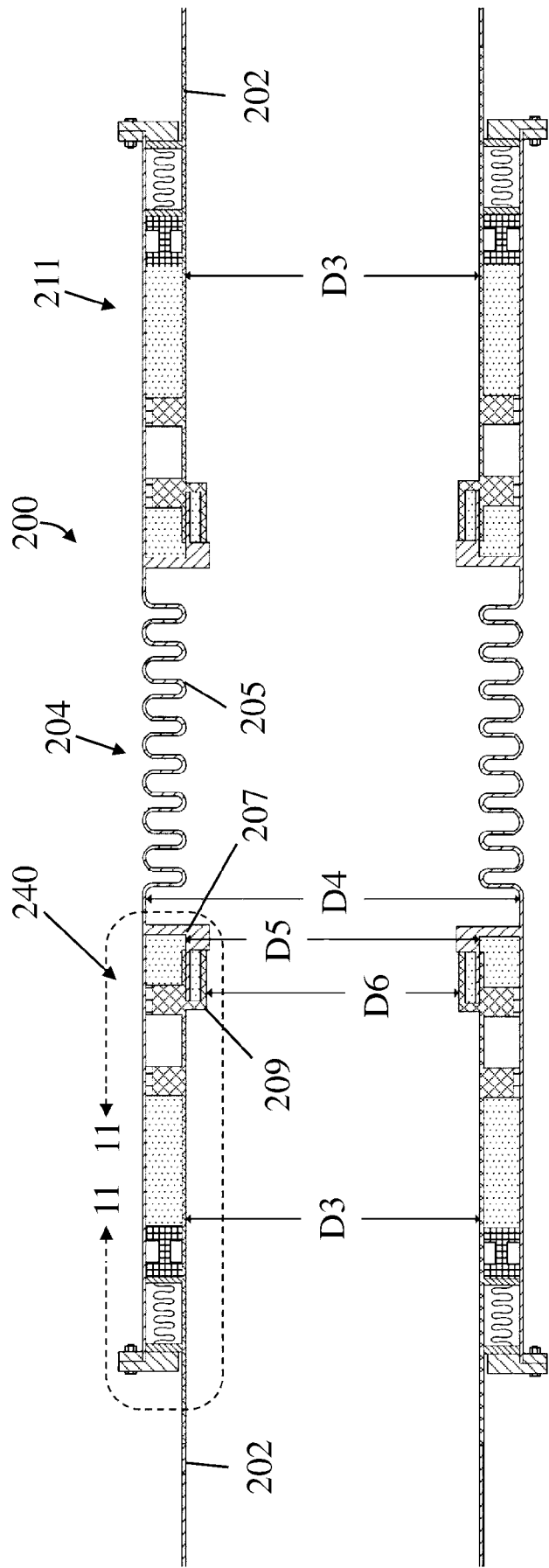


Fig. 10

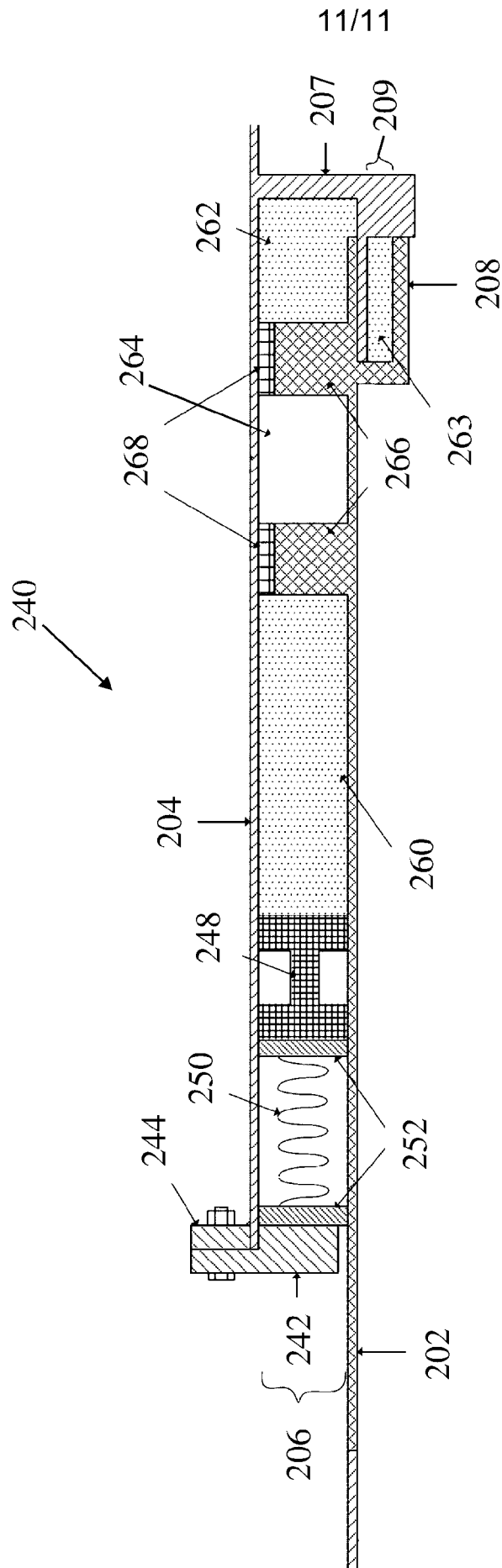


Fig. 11

INTERNATIONAL SEARCH REPORT

 International application No.
PCT/AU2017/000119

A. CLASSIFICATION OF SUBJECT MATTER

F16L 27/12 (2006.01) F16L 27/10 (2006.01)

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

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

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

EPODOC, WPIAP, TXTE, Espacenet, Google Patents, Google

IPC/CPC: F16L27/12, F16L27/107, F16L27/113, F16L27/10, F16L27, Y10S285/904, F16J15/164, F16J15, F17B1/08, F16L25/10, F16L21/03, F16L21/035, F16L21/04, F16L21/045, F16L21/002, F16L21/022

Keywords: cryogenic, cold, refrigeration, cool, seal, pack, retain, ring, band, gasket, bias, urge, spring, resilient, flexible, elastic, coefficient, thermal, temperature, expansion, expand, deform, vary, stress, compress, axial, longitudinal, length, along, concentric, telescopic, inner, outer, inside, outside, radial, hoop, contraction, annular, joint or the like and/or in combination, Applicant Name, Inventor names.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	



Further documents are listed in the continuation of Box C



See patent family annex

* "A"	Special categories of cited documents: document defining the general state of the art which is not considered to be of particular relevance	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E"	earlier application or patent but published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means	"&"	document member of the same patent family
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search 7 August 2017	Date of mailing of the international search report 07 August 2017
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA Email address: pct@ipaaustralia.gov.au	Authorised officer Andrew Schmidt AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No. +61399359621

INTERNATIONAL SEARCH REPORT		International application No.	
Information on patent family members		PCT/AU2017/000119	
This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.			
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		US 7883094 B2	08 Feb 2011
		EP 2157340 A1	24 Feb 2010
		EP 2157340 B1	09 Mar 2011
End of Annex			
Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.			