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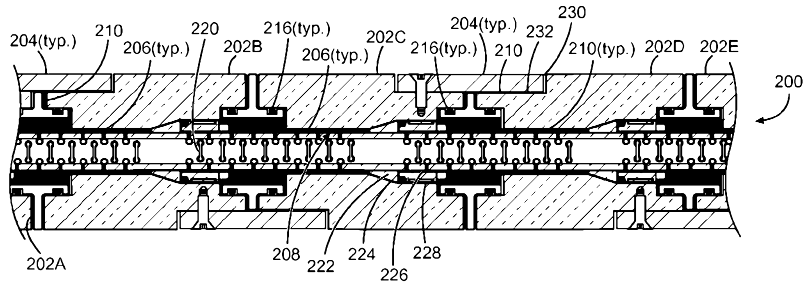

Fig. 2B

(57) **Abstract**: The disclosure addresses multiple embodiments of an acoustic isolator, and an acoustic logging tool which incorporates the acoustic isolator. The acoustic isolator is configured to minimize acoustic transmissions which could otherwise adversely affect acoustical measurements being made by an acoustic receiver. The described acoustic isolators include a plurality of longitudinally arranged mass members coupled to a central supporting structure, in a configuration to reduce acoustic transmissions in at least selected frequency ranges.

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ACOUSTIC ISOLATOR FOR DOWNHOLE TOOLS

CLAIM OF PRIORITY

This application claims the benefit of U.S. Provisional Application Serial No. 61/806,092, filed on March 28, 2013 which application is incorporated by reference herein in its entirety.

TECHNICAL FIELD

The present application relates generally to methods and apparatus for providing acoustic isolation between components in downhole tools.

BACKGROUND

A wide variety of logging tools are often used to evaluate parameters of that a wellbore being drilled, the formation surrounding that wellbore, and/or the fluids within the wellbore. Where such logging tools rely upon acoustical measurements, there is often a need to isolate the sensors of acoustical signals from other components within the logging system. One clear example of such tools are acoustic logging tools which generate acoustic signals through a transmitter at one location on the tool (or in the tool string) and which travel through the formation to a receiver at a spaced location on the tool. Depending on the tool, the receiver may be spaced a few feet from the transmitter, or may be spaced 20 feet or more from the transmitter.

When such a system is operated, different types of waves propagate within the well and/or formation, including pressure waves (P-waves), shear waves (S waves), Rayleigh waves, mud waves and Stoneley waves. Of these wave types, P-waves and S-waves in particular, if unimpeded, can propagate along the body of the acoustic logging tool in a manner that would mask or otherwise adversely affect measurements by the acoustic receiver. Accordingly, there is a need to attenuate and/or slow down such propagation along the logging tool body so as to not adversely affect the measurements being made at the receiver. Additionally, the external contours of an acoustic isolator can couple acoustic energy between the logging tool and the formation surrounding the borehole, reducing the fidelity of the acoustic measurements. Accordingly, for some applications, an acoustic isolator having an external profile which approximates continuous and symmetrical surfaces would be advantageous.

BRIEF DESCRIPTION OF THE DRAWINGS

Some embodiments are illustrated by way of example and not limitation in the following figures, in which:

Figure 1 depicts a schematic representation of an acoustic logging tool on an example configuration that can benefit from the methods and apparatus described herein.

Figure 2A -2B depict an example acoustic isolation structure, depicted in Figure 2A from an external view; and depicted in Figure 2B in a cross-sectional view.

Figures 3A-B depict an alternative configuration of an acoustic isolation structure depicted in Figure 3A from an external view; and depicted in Figure 3B in a cross-sectional view.

DETAILED DESCRIPTION

The following detailed description describes example embodiments of the disclosure with reference to the accompanying drawings, which depict various details of examples that show how the disclosure may be practiced. The discussion addresses various examples of novel methods, systems and apparatuses in reference to these drawings, and describes the depicted embodiments in sufficient detail to enable those skilled in the art to practice the disclosed subject matter. Many embodiments other than the illustrative examples discussed herein may be used to practice these techniques. Structural and operational changes in addition to the alternatives specifically discussed herein may be made without departing from the scope of this disclosure.

In this description, references to “one embodiment” or “an embodiment,” or to “one example” or “an example” in this description are not intended necessarily to refer to the same embodiment or example; however, neither are such embodiments mutually exclusive, unless so stated or as will be readily apparent to those of ordinary skill in the art having the benefit of this disclosure. Thus, a variety of combinations and/or integrations of the embodiments and examples described herein may be included, as well as further embodiments and examples as defined within the scope of all claims based on this disclosure, as well as all legal equivalents of such claims.

The present disclosure addresses multiple embodiments of an acoustic isolator, and an acoustic logging tool which incorporates the acoustic isolator. The acoustic isolator is configured to minimize acoustic transmissions which could otherwise adversely affect acoustical measurements being made by acoustic receiver. The described acoustic isolators include a plurality of longitudinally arranged mass members coupled to a central supporting structure. In the depicted examples, both the central supporting structure and the mass members are configured to allow the acoustic isolator to provide some degree movement or deflection within the isolator, such as relative longitudinal movement between adjacent mass blocks and/or some degree of axial deflection over a range of motion. In the depicted examples this movement or deflection is facilitated in part by cooperative configuration of the structures used to couple each mass member to another mass member.

Figure 1 depicts a schematic representation of an acoustic logging tool 100. Logging tool 100 is suspended from a wireline 102 through use of a cable head assembly 108, in one example operating configuration well-known in the art. Acoustic logging tool 100 is suspended within a borehole 112 penetrating a formation 114. In other examples, acoustic logging tool 100 might be incorporated into a tubular string, which may be for example, in a logging while drilling (LWD) drillstring disposed within a wellbore to perform drilling or reaming operations. In either configuration or form of operation, the various mechanisms and methods for providing power and/or signals to the logging tool, and for processing of signals received by the logging tool are well known to those skilled in the art.

Acoustic logging tool 100 includes a transmitter section, indicated generally at 104, housing acoustic transmitters 116 and 118. While in the depicted tool two transmitters are shown, either only a single transmitter or more than two transmitters may be utilized. Such transmitters may be constructed similarly to one another, or different configurations of transmitters known to those in the art may be utilized. In some example systems, one or more of the provided transmitters may be configured to emit acoustic signals essentially around the circumference of the transmitter section 104.

Acoustic logging tool 100 also includes a receiver section, indicated generally at 106; which in this example includes only a single receiver, indicated generally at 120. As with transmitters, either a greater or lesser number of receivers may be provided, and such receivers can either be a single configuration or of multiple configurations. In some example systems, multiple receivers will be angularly disposed around the lateral periphery of the receiver section. For example, a group of eight receivers might be disposed in essentially a single plane that extends generally perpendicular to the longitudinal axis through acoustic logging tool 100, with the receivers oriented at essentially 45° increments around the tool periphery.

As can be seen from the schematic representation of Figure 1, transmitter section 104 is retained in spaced relation relative to receiver section 106 through an acoustic isolation section, indicated generally at 110. Acoustic isolation section 110 can be constructed, for example, in accordance with the example embodiment as will be discussed with respect to Figures 2A-B. Acoustic isolation section 110 does not need to be entirely of a structure providing acoustic isolation along its entire length; as once an acoustical path is defined which is sufficiently disrupted, or which sufficiently retards or attenuates the problematic acoustic signals, then additional structures may be provided as needed for other purposes, for example to establish the desired spacing between the transmitter section 104 and receiver section 106. As will be apparent to those skilled in the art, there can be two sources of energy propagating through an acoustic logging tool: energy resulting directly from the transmitter(s) or other components and propagating directly through the tool string; and energy external to the tool recoupling to the logging tool through the borehole fluid.

Referring now to Figures 2A-B, the figures depict a portion of an acoustic isolator 200 such as could advantageously be used in logging tool 100 of Figure 1. Acoustic isolator 200 has an exterior surface formed of a plurality of mass blocks 202A-E, which are coupled together by “dog-bone”-shaped connectors, as indicated at 204. Each mass block 202 is a structural element which may be formed of a suitable, relatively higher mass, material. For example metal or metallic compounds, such as stainless steel, Iconel alloys, or tungsten, can be used, as well as many other comparable materials providing appropriate strength and weight which will be apparent to those skilled in the art having the benefit of this disclosure.

Each mass block 202 contains a respective central bore 206 which cooperatively form a central passageway, indicated generally at 208, when the mass blocks 202 are assembled as shown. Each mass block 202 also contains a plurality of appropriately configured recesses, as indicated typically at 210, proximate an external surface, each recess 210 configured to engage a respective portion of a dog bone connector 204. In most examples, even after coupling of the mass blocks together through a dog bone connector 210, the relative configuration of the dog bone connectors 204 and the recesses 210 provides some degree of longitudinal movement, and preferably also some degree of axial deflection, between adjacent mass blocks 202, The depicted “dog bone” shaped connector is only one example of a connector that may be utilized to enable the identified longitudinal movement and/or axial deflection over a range of motion. The function of this movement and/or deflection will be addressed later herein. In other examples, also as will be addressed later herein, the dog bone connectors may be coupled, such as through bolts, to both of two adjacent mass blocks. Other configurations of connectors can be envisioned. In many such alternative configurations, both space efficiency and secure limiting of the maximum motion will achieved through use of connector components that have regions of a relatively greater dimension that engage each mass block relative to the dimension of a central region that extends between the two mass blocks.

As can also be seen in Figures 2A-B in some examples, each dog bone connector 204 will be rigidly coupled to only one mass block 210. In most embodiments, each dog bone connector 204 is configured with a convex external profile such that when the connector is an operating configuration, as depicted in

Figures 2A-B, a generally uniform cylindrical surface is exposed. In many examples, the recess and dog bone connector will be cooperatively formed to facilitate the described longitudinal movement and axial deflection, while at the same time limiting torsional movement. For example, the dog bone connector and the recess may define both a longitudinally extending gap 232 and an axially extending gap 230 to accomplish such. The dimensions of these gaps (and the dimension of the space between joined mass blocks) may be configured to achieve a desired design balance between a maximum logging load limit (increased by relatively increased gap dimensions) and a maximum radius of curvature of the tool structure (restricted by relatively reduced gap dimensions).

Each mass block 202 is spaced from an adjacent mass block 202 by an elastomeric member 214 providing a resilient seal between the adjacent mass blocks 202. As can be seen in Figure 2B, in some configurations the elastomeric member 214 may have provisions for additional seals, such as o-ring seals, as indicated generally at 216. This resulting spacing between mass blocks avoids a vibration path between blocks. In some examples, the elastomeric members 214 might be constructed to enhance the acoustic isolation between the mass blocks.

Referring now particularly to Figure 2B, each mass block 202 is assembled in a respective fixed position relative to a slotted central tube 218, which extends through passageway 208 formed by individual bores 206 in each mass block 202. Central tube 218 is again formed of a structural material, such as an Iconel alloy, and includes a plurality of slots, as indicated typically at 220. As can be seen in the Figure, in this example, the slots are arranged in both longitudinally and radially spaced relation around all sides of the central tube, and each aperture radially overlaps with at least one longitudinally adjacent aperture. Thus, slots 220 are sized and arranged to define a nonlinear path for vibrations traversing central tube 218. For example, in the depicted example, slots are presented in pairs on opposing sides of central tube 218, and the next adjacent slots are also presented in pairs on opposing sides of central tube 218, but are positioned at a 90° offset from the preceding slots. Additionally, the slots are of dimensions such that they overlap one another so as to preclude a linear path for vibrations. Many other configurations and/or dimensions of slots, or other structural configurations to provide only a nonlinear vibrational path through central tube 218, might be utilized in place of the depicted structure. One advantage of the described slot configuration is that it also facilitates (and allows control of) the flexing of central tube 218, and thereby the relative deflection of the mass blocks secured to the tube.

Each mass block 202 is structurally secured to central tube 218 through a locking wedge 222 (which in many examples will have a discontinuity to facilitate compression of the wedge) which is compressed against an inclined shoulder 224 defining a portion of each mass block central bore 206. This compression is achieved through an annular locking nut 226 which threadably engages, at 228, a respective mass block 202. As will be apparent to those skilled in the art, increased threaded engagement of annular locking nut 226, causes wedge block 222 to compress against central tube 218, serving to both secure mass block 202 to central tube 218, and to also acoustically couple the mass block to the central tube.

As a result of the above-described structure, the only direct acoustic path through the acoustic isolator 200 is along the slotted central tube 218. In this configuration of acoustic isolator 200, the flexural slowness is a function of the transverse motion of the mass and of the spring structure provided by the described structure. Some example configurations in accordance with the example structure described herein should be able to achieve a flexural wave slowness of at least 2500 microseconds per foot. Additionally, the mass and spring structure achieved by acoustically isolated mass blocks coupled to a flexible central tube defining a nonlinear acoustic path can be configured to mechanically filter out high-frequency flexural tool wave components, and to allow essentially only low flexural tool wave frequencies, for example below 200 Hz, to propagate along the spacer.

In other examples, dampening of the center tube and/or of the central fluid path there through may be provided. For example, a dampening member may be placed to engage the center tube, such as a coating or sleeve of tungsten rubber may be provided on either the interior or exterior surface of the central tube (218), to further attenuate any waves traveling down the tube. In some examples, it may also be desirable to attenuate any Stonely wave energy in the fluid channel within the central tube, or in other passageways in the system. Sintered metal may be provided in the central tube (or in any other passageway in the tool) to allow fluid and pressure communication while attenuating such energy. The permeability of such sintered metal may be selected in a manner known to those skilled in the art.

As noted previously, the configuration of the dog bone connectors with the respective recesses 210 in each mass block 204 allow acoustic isolator 204 to deflect over a range of motion to a selected point. Once the flexing between two adjacent mass blocks reaches that selected point, each dog bone connector will engage surfaces defining the recess of the respective mass blocks, and the system will then become more rigid. In one example configuration, the central tube 218 can be configured to accept over 2300 pound loads, and the flexing that comes therewith, before the dog bone connectors and mass blocks fully engage one another to significantly increase the stiffness, tensile strength, and torsional strength of the acoustic isolator.

In the depicted example, a plurality of mass blocks are provided at each of a plurality of longitudinal positions along the acoustic isolator, in this example, at a first longitudinal location, three dog bone connectors (and the associated structures) are provided at 120 degree circumferential spacing. And also in this example, at the next longitudinal location, there are again three dog bone connectors (and associated structures) at 120 degree circumferential spacing, but the orientation is offset 60 degrees from the connectors each of the longitudinally adjacent longitudinal locations (i.e., those next "above" and "below"). Of course other distributions of connectors may be used in different examples.

Referring now to Figures 3A-B, therein is depicted an alternative construction for an acoustic isolator 300. Acoustic isolator 300 functions in accordance with the basic principles described above relative to acoustic isolator 200. Accordingly, this description will address the two primary differences between acoustic isolator 300 and previously described acoustic isolator 200, i.e., the solid mounting of each dog bone connector, indicated generally at 304, to both respective mass blocks, indicated typically at 302; and a bolted compression assembly mechanically and acoustically coupling each mass block 302 to central tube 306.

In this example, wherein at least a first bolt 308A will secure a dog bone connector 304 to a first mass block 302, and a second bolt 308B will connect that dog bone connector 304 to another mass block 302, the dog bone connector will preferably be configured with appropriate spaces surrounding each bolt such that flexural loads will result in flexing of one mass block relative to another in a manner similar to that described relative to acoustic isolator 200. In some cases, the spacing provided to facilitate this relative movement between the bolts 308 and a respective dog bone connector 304 may be filled with an elastomer or other substance to preclude entry of contaminants and to thereby preserve the described movable relationships.

Acoustic isolator 300 also includes bolts which extend from the outside directly to engage apertures 312 in central tube 306 to both physically attach and acoustically couple each mass block 302 to central tube 306. In one example configuration, as depicted, such coupling bolts 308 may be provided around the periphery of the respective mass block, such as at 90° intervals around the periphery and arranged in a common plane perpendicular to the longitudinal axis of the longitudinal isolator.

In the foregoing Detailed Description, it can be seen that various features are grouped together in a single embodiment for the purpose of streamlining the disclosure. This method of disclosure is not to be interpreted as reflecting an intention that embodiments of the invention necessarily require all or even multiple of such features.

CLAIMS

What is claimed is:

1. An acoustic isolator for use in a downhole environment, comprising:

a linear central structure defining a non-linear acoustic path along at least a portion of its length;

a plurality of mass members coupled to the central structure along at least a portion of its length, each mass member coupled in spaced relation to an adjacent mass member, and physically and acoustically coupled to the central structure; and

a plurality of coupling mechanisms, each coupling mechanism coupling a respective mass member to a respective adjacent mass member, wherein each coupling mechanism facilitates relative movement between the respective coupled mass members within a range of motion, and precludes relative movement beyond such range of motion.

2. The acoustic isolator of claim 1, wherein at least a portion of the plurality of coupling mechanisms each comprises a member which engages complementary recesses in a pair of adjacent mass members, and wherein the member has a greater width at a location where it engages the recesses then it has at a central portion extending between the coupled mass members.

3. The acoustic isolator of claim 2, wherein the complementary recesses are sized to provide a gap adjacent a coupling member to facilitate flexure of the acoustic isolator.

4. The acoustic isolator of claim 2, wherein each coupling mechanism is a generally dog bone-shaped member.

5. The acoustic isolator of claim 1, wherein the nonlinear acoustic path through the linear central structure is achieved by a series of apertures in the central structure, the apertures arranged to eliminate a linear acoustic path through at least a portion of the length of the central structure.

6. The acoustical isolator of claim 5, wherein the linear central structure is a tube.

7. The acoustic isolator of claim 6, wherein the apertures are generally linear and are arranged in spaced relation around all sides of the tube, and wherein each aperture radially overlaps with at least one longitudinally adjacent aperture.

8. An acoustic isolator for use in a downhole environment, comprising:

a generally linear central tube defining a non-linear acoustic path along at least a portion of its length;

a plurality of mass members, each mass member defining a central aperture engaging the central tube, with each mass member physically and acoustically coupled to the central tube, each mass member coupled in spaced relation to an adjacent mass member, each mass member including a plurality of radially offset coupling recesses;

a plurality of elastomeric members, each elastomeric member placed between longitudinally adjacent mass members; and

a plurality of coupling mechanisms, each coupling mechanism engaging the coupling recesses of a pair of longitudinally adjacent mass members, wherein each coupling mechanism facilitates relative movement between the respective coupled mass members within a range of motion, and precludes relative movement beyond such range of motion.

9. The acoustic isolator of claim 8, wherein the central tube comprises a plurality of generally linear apertures in at least a portion of the central tube, and wherein the apertures are arranged in both longitudinally and radially spaced relation around all sides of the central tube, and wherein each aperture radially overlaps with at least one longitudinally adjacent aperture.

10. The acoustic isolator of claim 8, further comprising a plurality of wedge assemblies, each wedge assembly mechanically engaging a respective mass

member and the central tube to establish the physical and acoustic coupling of the mass member to the central tube.

11. The acoustic isolator of claim 8, further comprising a dampening member engaging the central tube.

12. The acoustic isolator of claim 8, wherein the dampening member comprises tungsten rubber engaging the central tube.

13. The acoustic isolator of claim 8, further comprising sintered metal placed in the central tube.

14. The acoustic isolator of claim 8, wherein the coupling recesses are sized to provide a gap adjacent a coupling member engaging the recess to facilitate flexure of the acoustic isolator.

15. The acoustic isolator of claim 8, wherein each coupling mechanism comprises a coupling member which engages coupling recesses in a pair of longitudinally adjacent mass members, and wherein the coupling member has a greater width at a location where it engages the recesses than it has at a central portion extending between the coupled mass members.

16. The acoustic isolator of claim 8, wherein a coupling member is bolted only to one of the engaged mass members, and engages an adjacent mass member through engagement of the coupling recess.

17. The acoustic isolator of claim 15, wherein each coupling member is bolted to both engaged mass members, and wherein the bolted couplings allow deflection of one mass member relative to the other mass member.

18. The acoustic isolator of claim 8, wherein the isolator is configured to filter high-frequency flexural tool wave components, and to allow flexural wave frequencies below 200 Hz to propagate through the isolator.

19. The acoustic isolator of claim 8, further comprising a plurality of elastomeric seals, with each elastomeric seal placed between a respective pair of mass members to prevent a vibration path between adjacent mass members.

20. The acoustic isolator of claim 9, further comprising sintered metal placed in a passageway other than a passageway inside the central tube.

21. An acoustic logging tool, comprising:
at least one acoustic transmitter;
at least one acoustic receiver; and
an acoustic isolator placed between the acoustic transmitter and the acoustic receiver, the acoustic isolator including,
a linear central member defining a non-linear acoustic path along at least a portion of its length;
a plurality of mass members, each mass member defining a central aperture engaging the central tube, with each mass member physically and acoustically coupled to the central tube in spaced relation to an adjacent mass member; and
a plurality of coupling mechanisms, each such coupling mechanism coupling a respective mass member to a respective adjacent mass member, wherein each coupling mechanism facilitates relative movement between the respective coupled mass members within a range of motion, and precludes relative movement beyond such range of motion.

22. The acoustic logging tool of claim 21, wherein the acoustic logging tool is a wireline-conveyed logging tool.

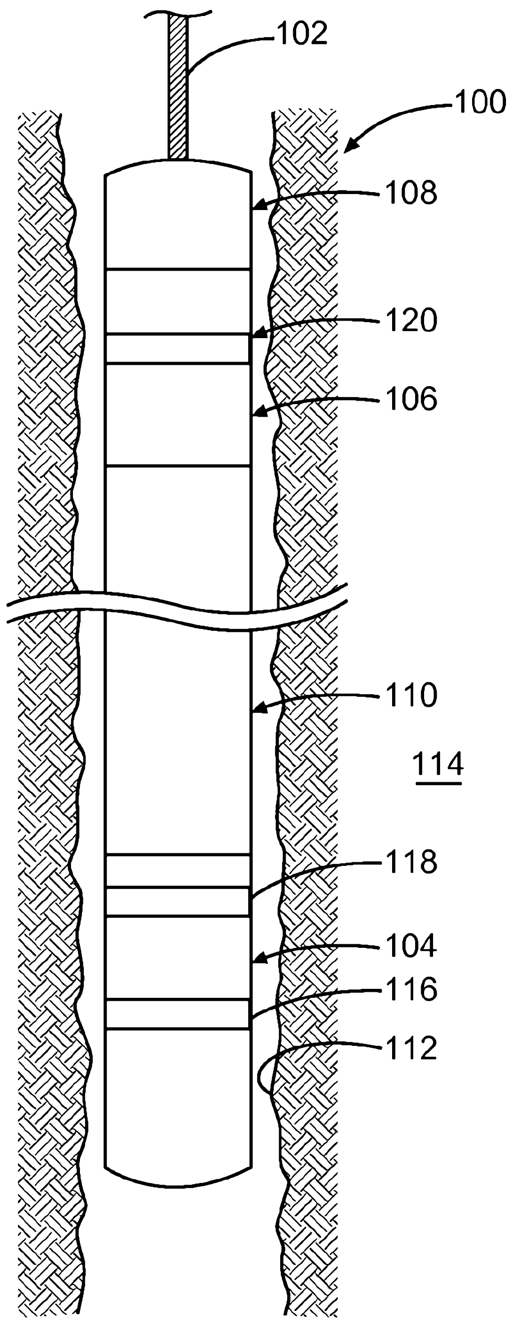

Fig. 1

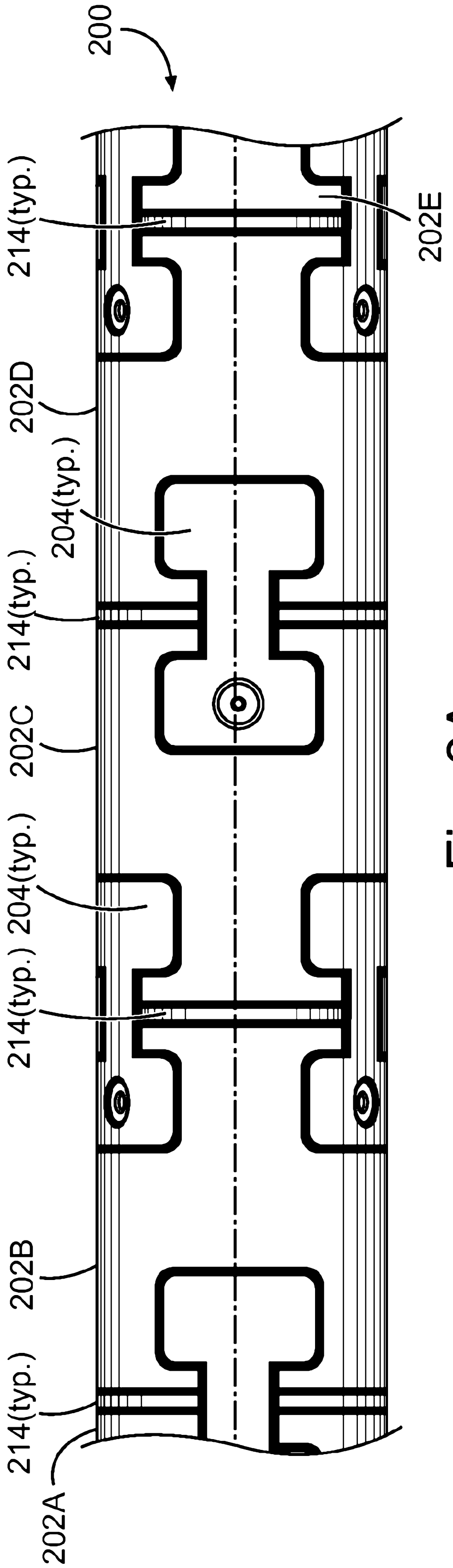
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Fig. 2A

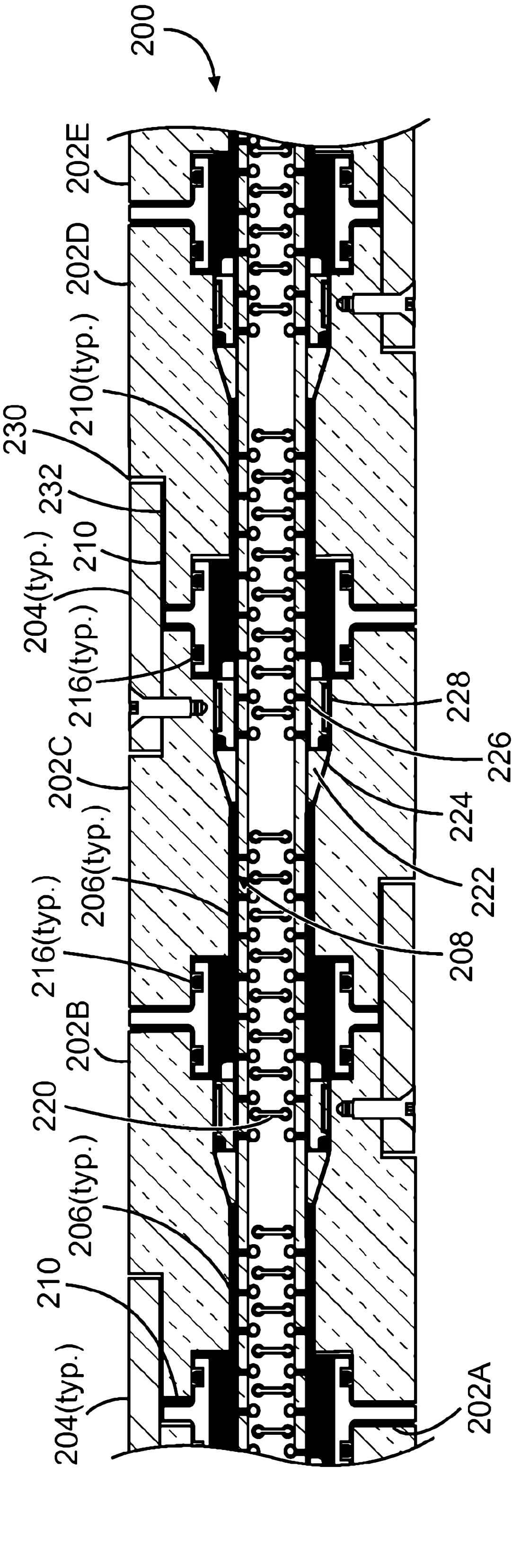
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Fig. 2B

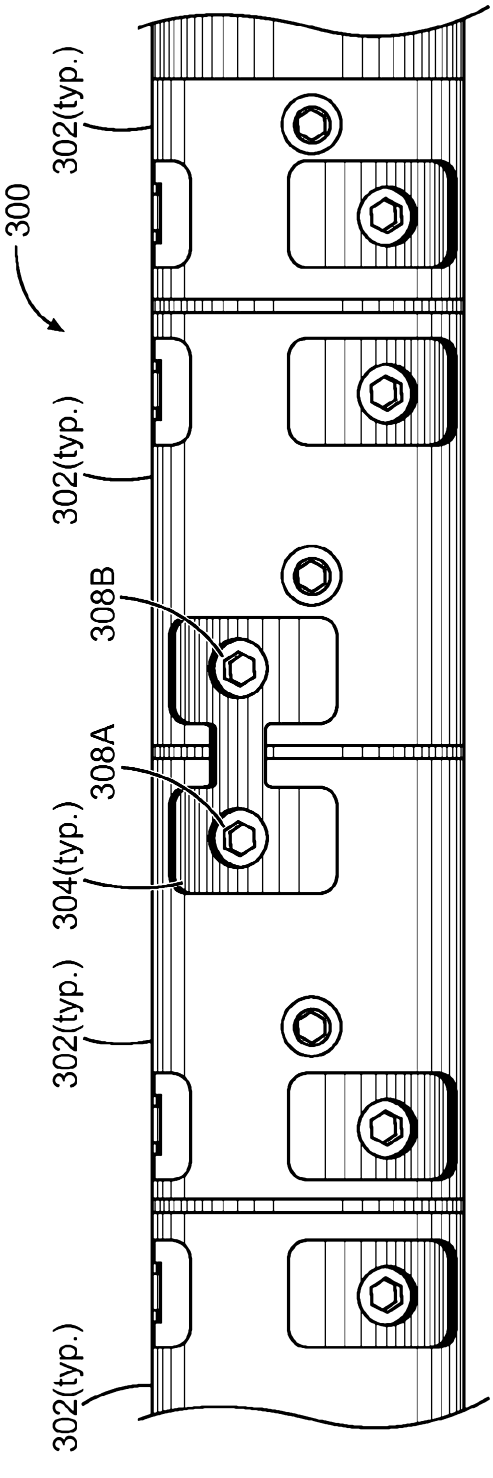
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Fig. 3A

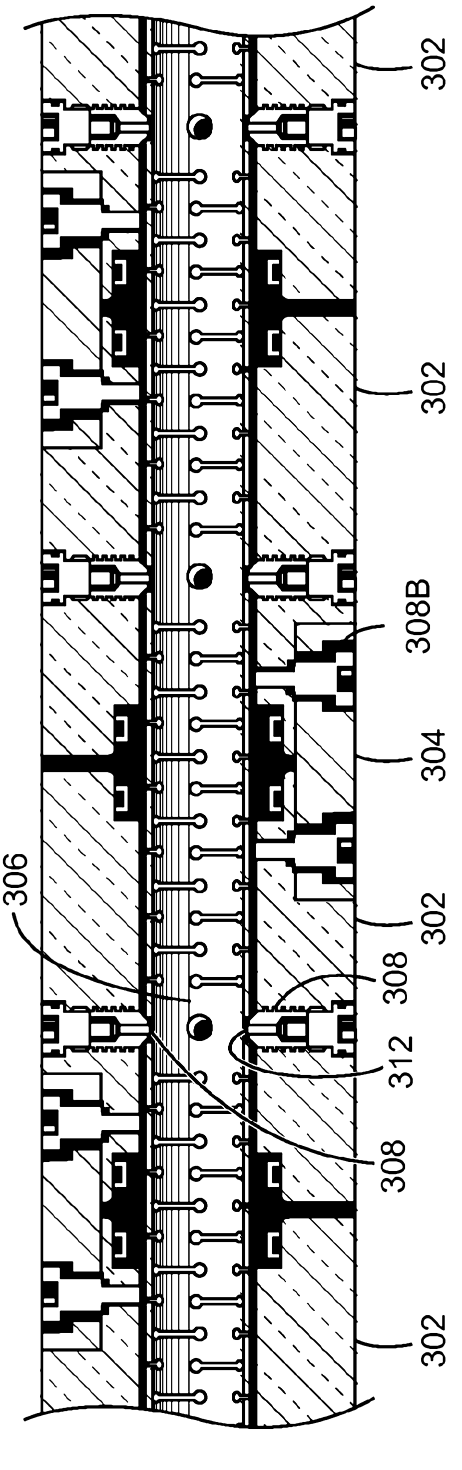
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Fig. 3B