



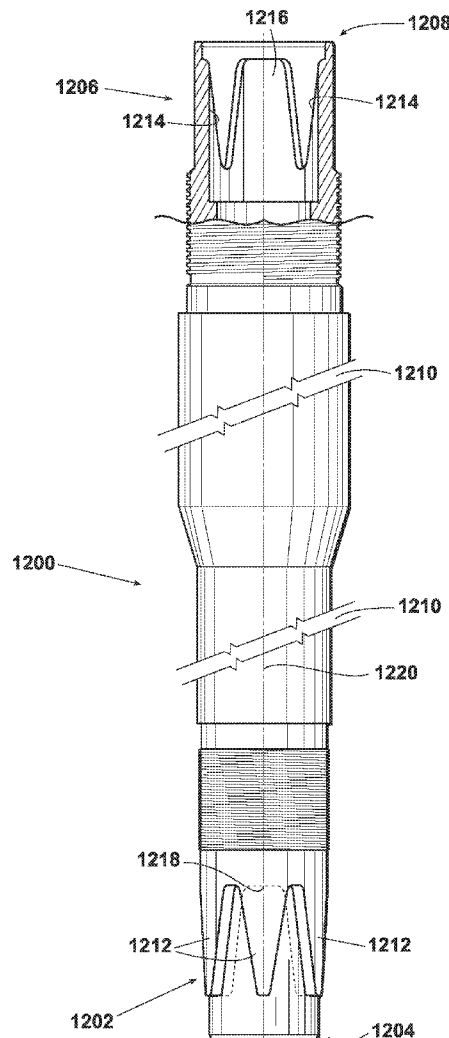
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(19) **United States**(12) **Patent Application Publication**
Hughes et al.(10) **Pub. No.: US 2015/0176341 A1**(43) **Pub. Date: Jun. 25, 2015**(54) **TAPERED SPLINE CONNECTION FOR
DRILL PIPE, CASING, AND TUBING***E21B 17/042* (2006.01)*E21B 17/00* (2006.01)(71) Applicant: **Sunstone Technologies, LLC**,
Oklahoma City, OK (US)(52) **U.S. Cl.**CPC *E21B 17/046* (2013.01); *E21B 17/003*
(2013.01); *E21B 17/028* (2013.01); *E21B*
17/042 (2013.01)(72) Inventors: **William James Hughes**, Highlands
Ranch, CO (US); **Bryan Lane**, Houston,
TX (US)

(57)

ABSTRACT(21) Appl. No.: **14/636,592**(22) Filed: **Mar. 3, 2015****Related U.S. Application Data**(63) Continuation-in-part of application No. 12/695,569,
filed on Jan. 28, 2010.**Publication Classification**(51) **Int. Cl.***E21B 17/046* (2006.01)*E21B 17/02* (2006.01)

An apparatus comprises a first number of splines located near a first end of a first joint section and a second number of splines located near a second end of a second joint section. The first number of splines extends in an axial direction of the first joint section and spans a circumferential surface of the first joint section. Each of the first number of splines has a base, a tip, and a pair of flanks that extends from the base to the tip and forms an acute angle. Each of the first number of splines are configured to be received between adjacent pairs of splines in the second number of splines as the first end of the first joint section and the second end of the second joint section are joined.



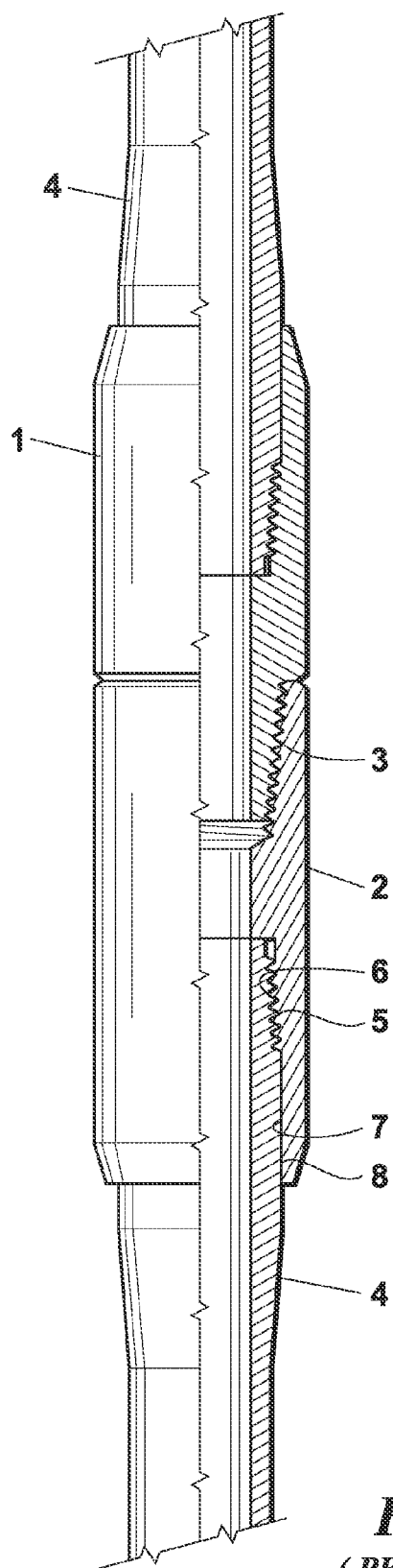
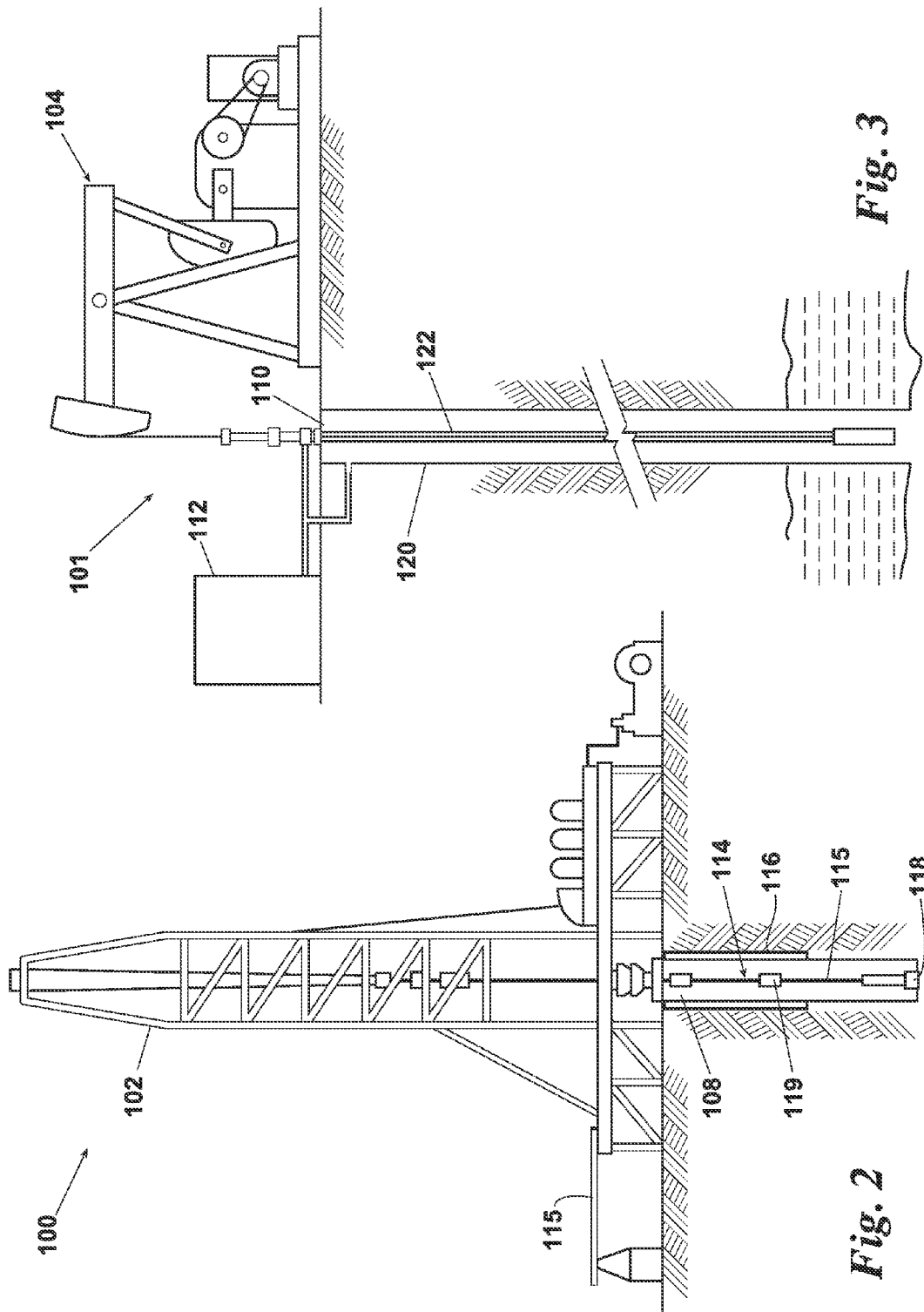


Fig. 1
(PRIOR ART)



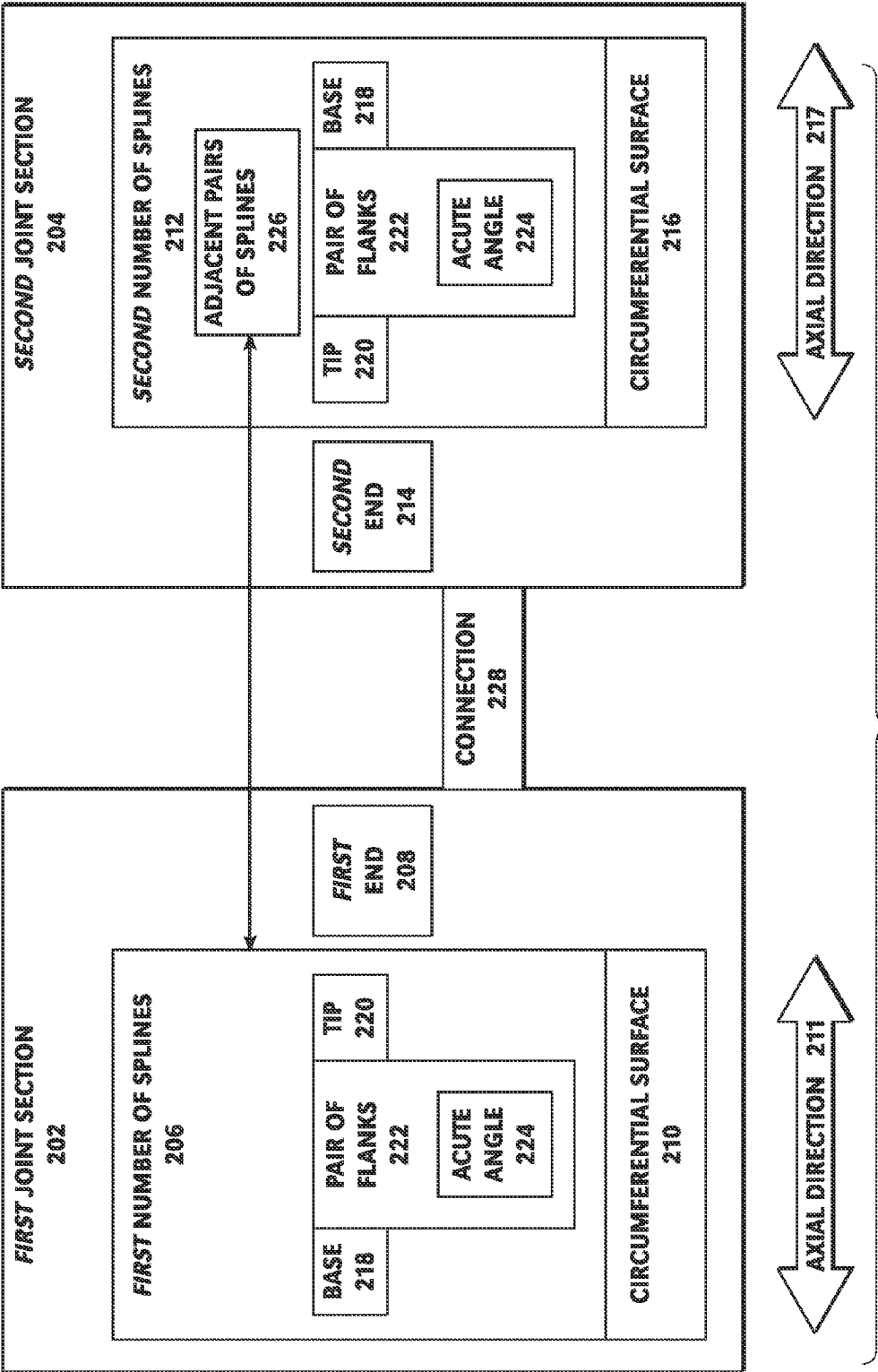


Fig. 4

200

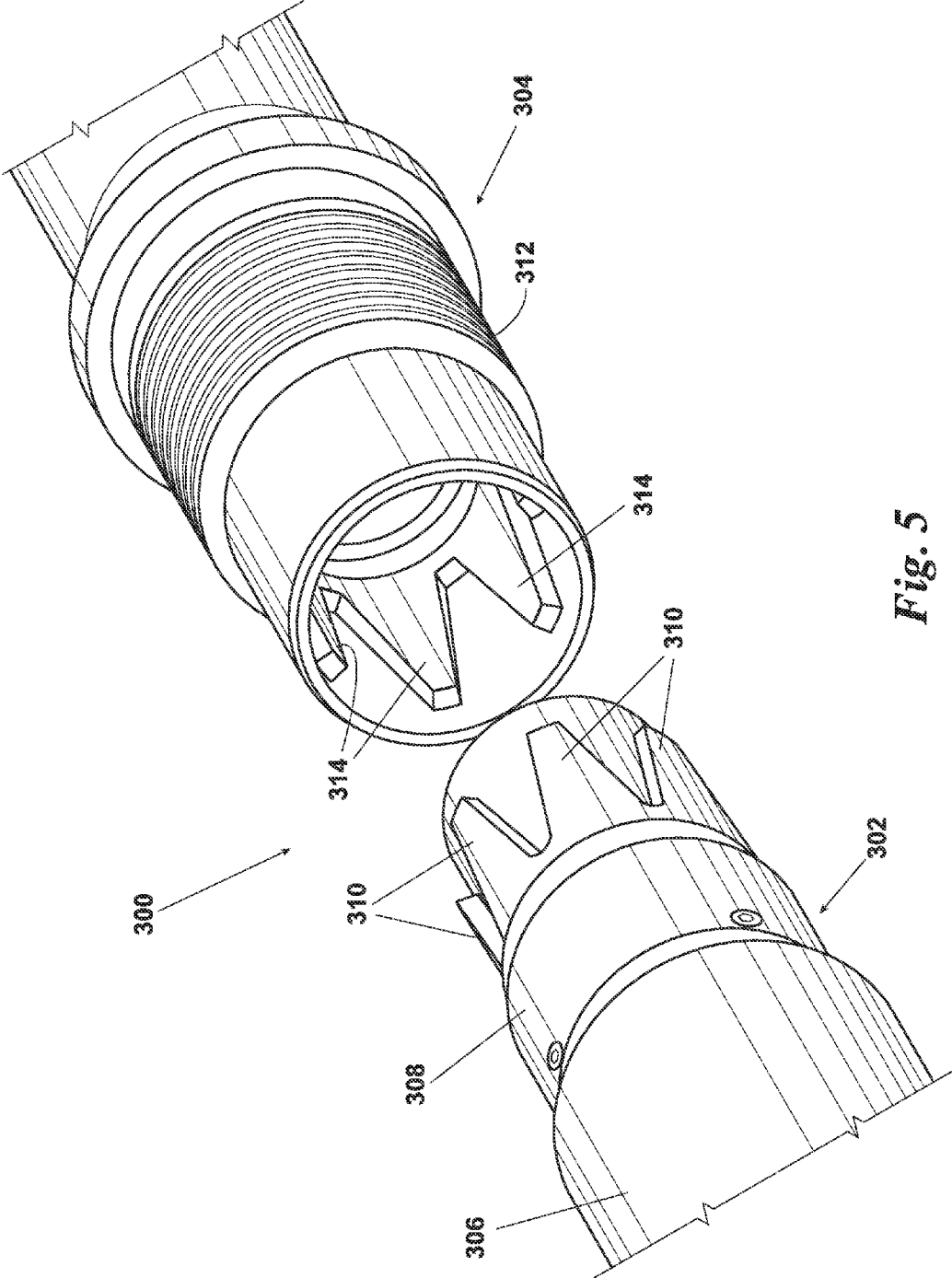


Fig. 5

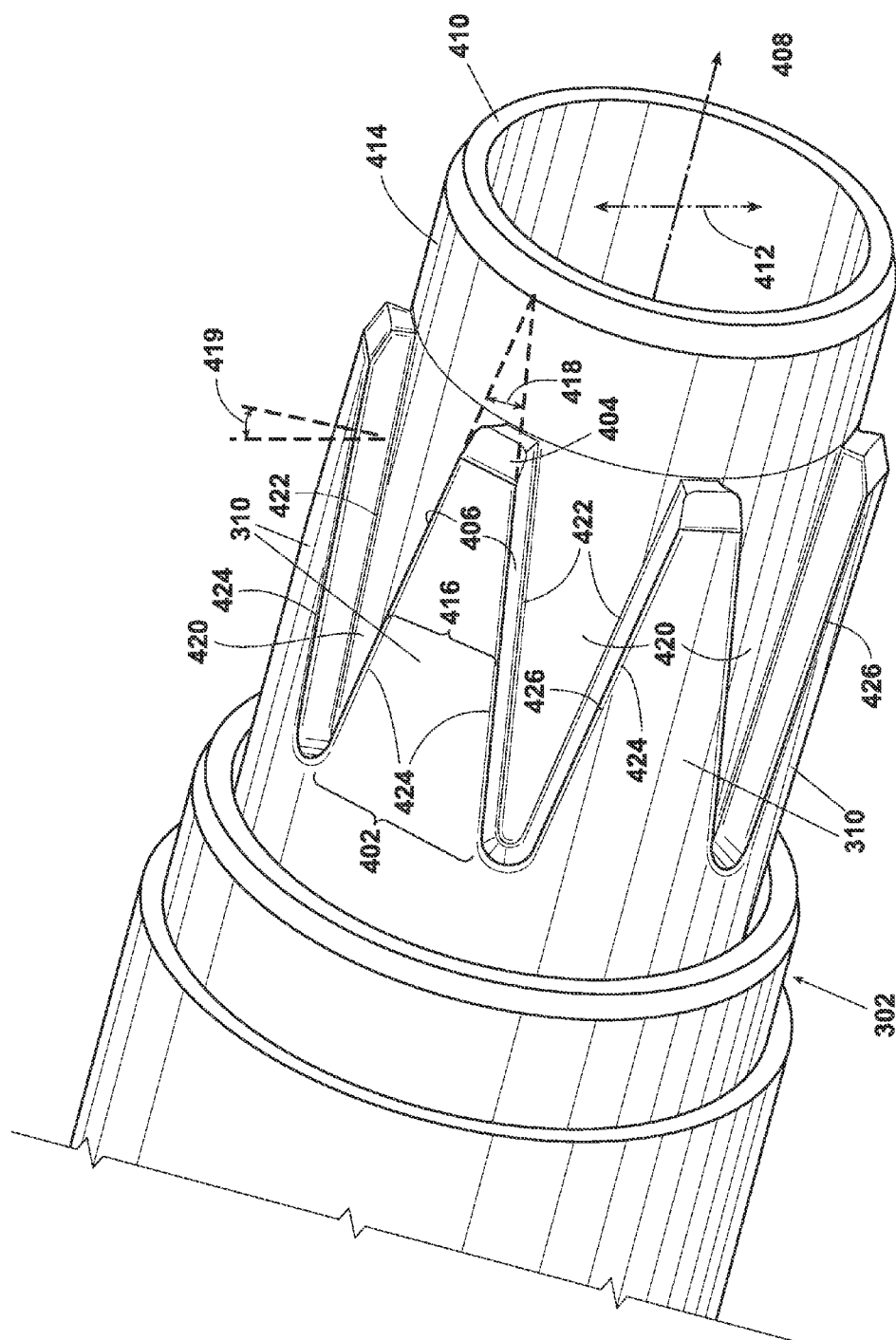


Fig. 6

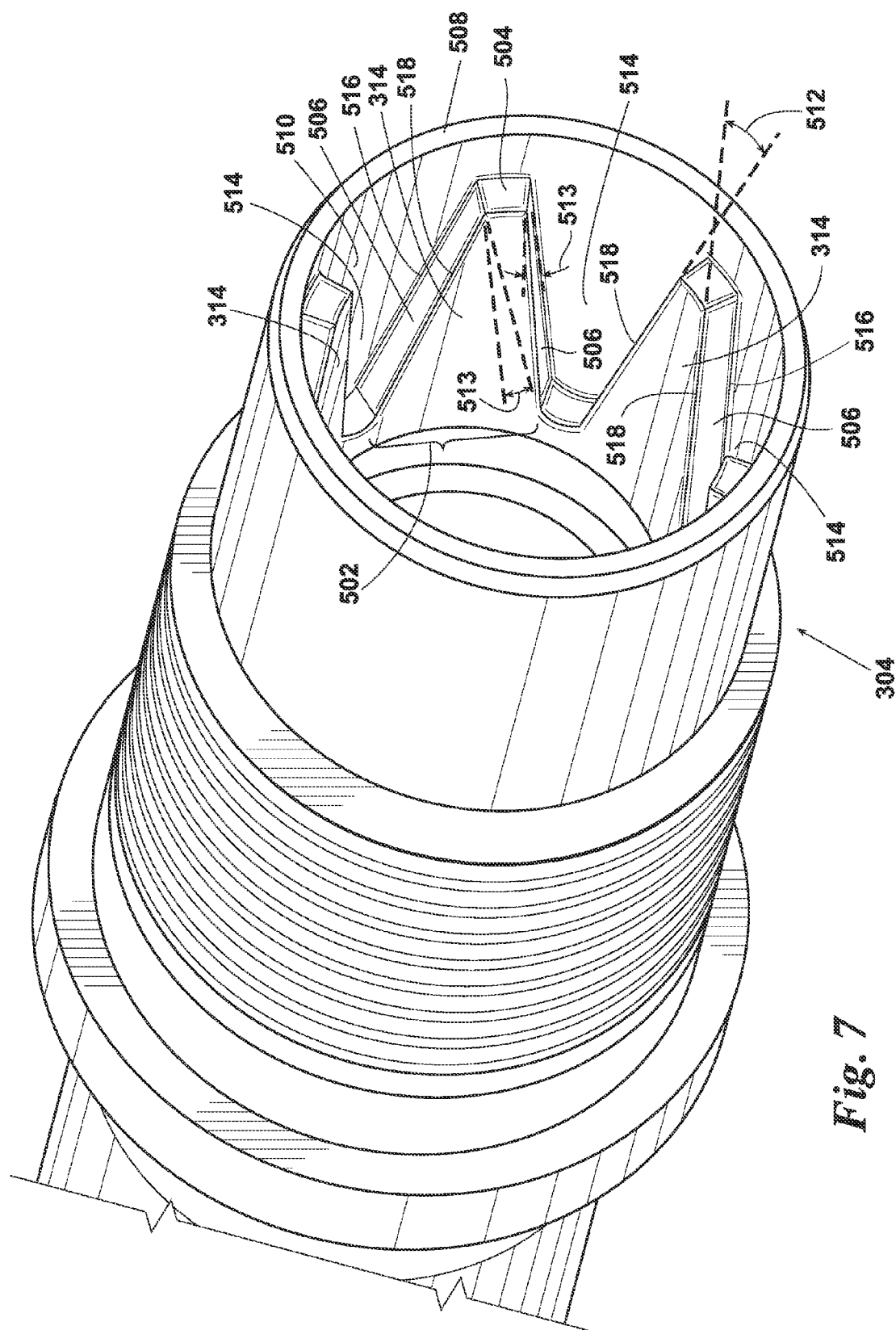
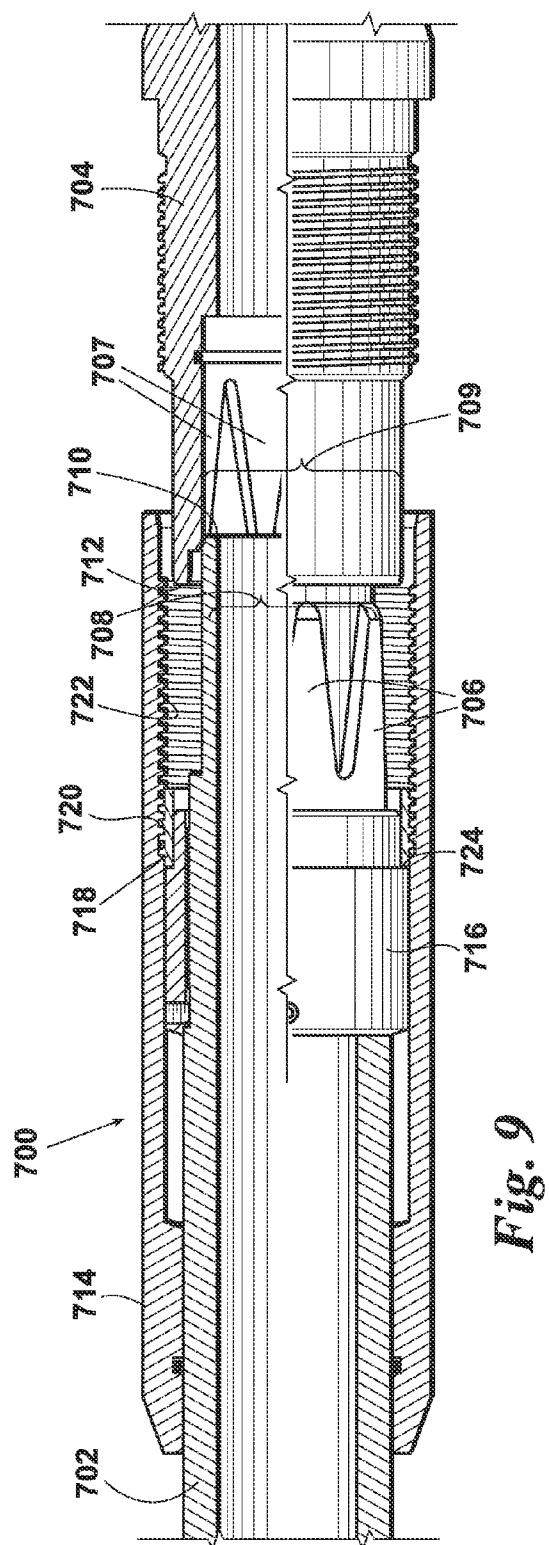
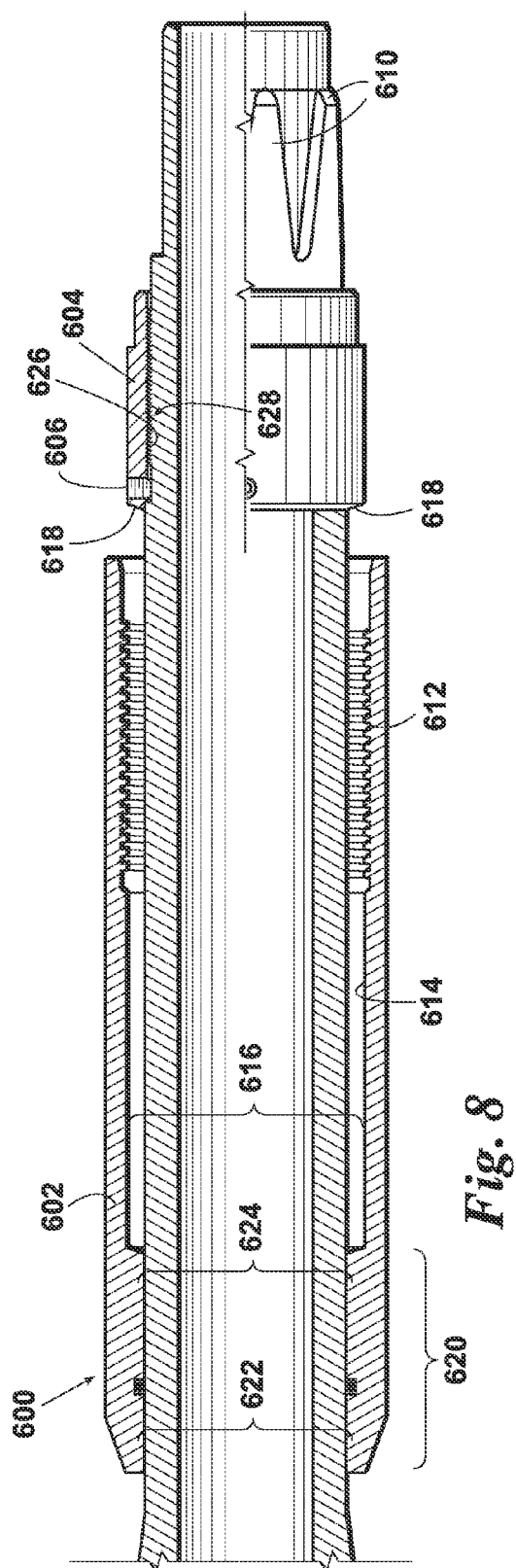


Fig. 7



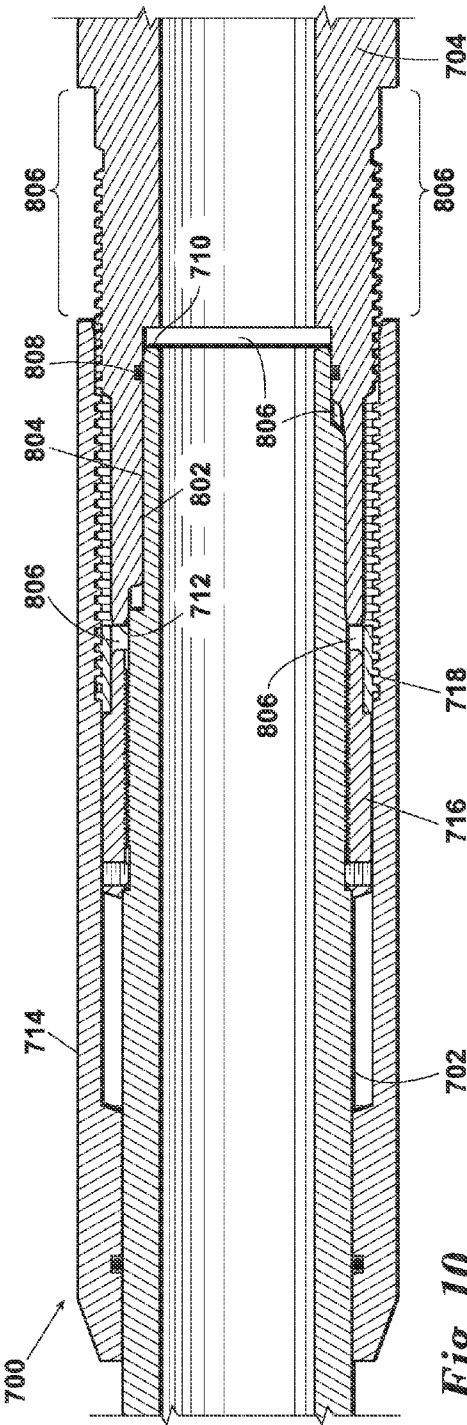


Fig. 10

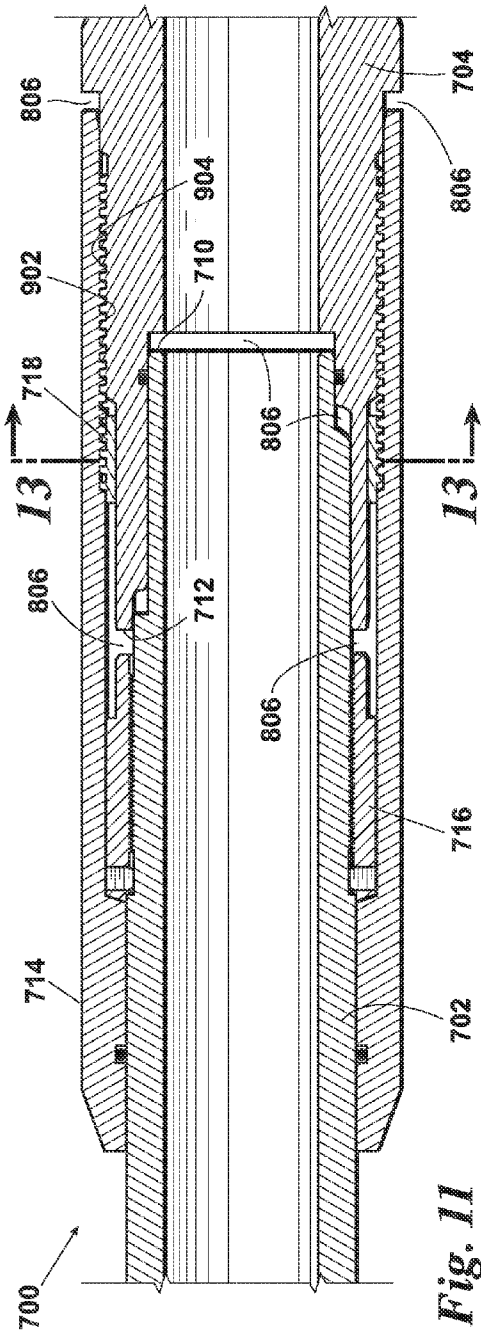


Fig. 11

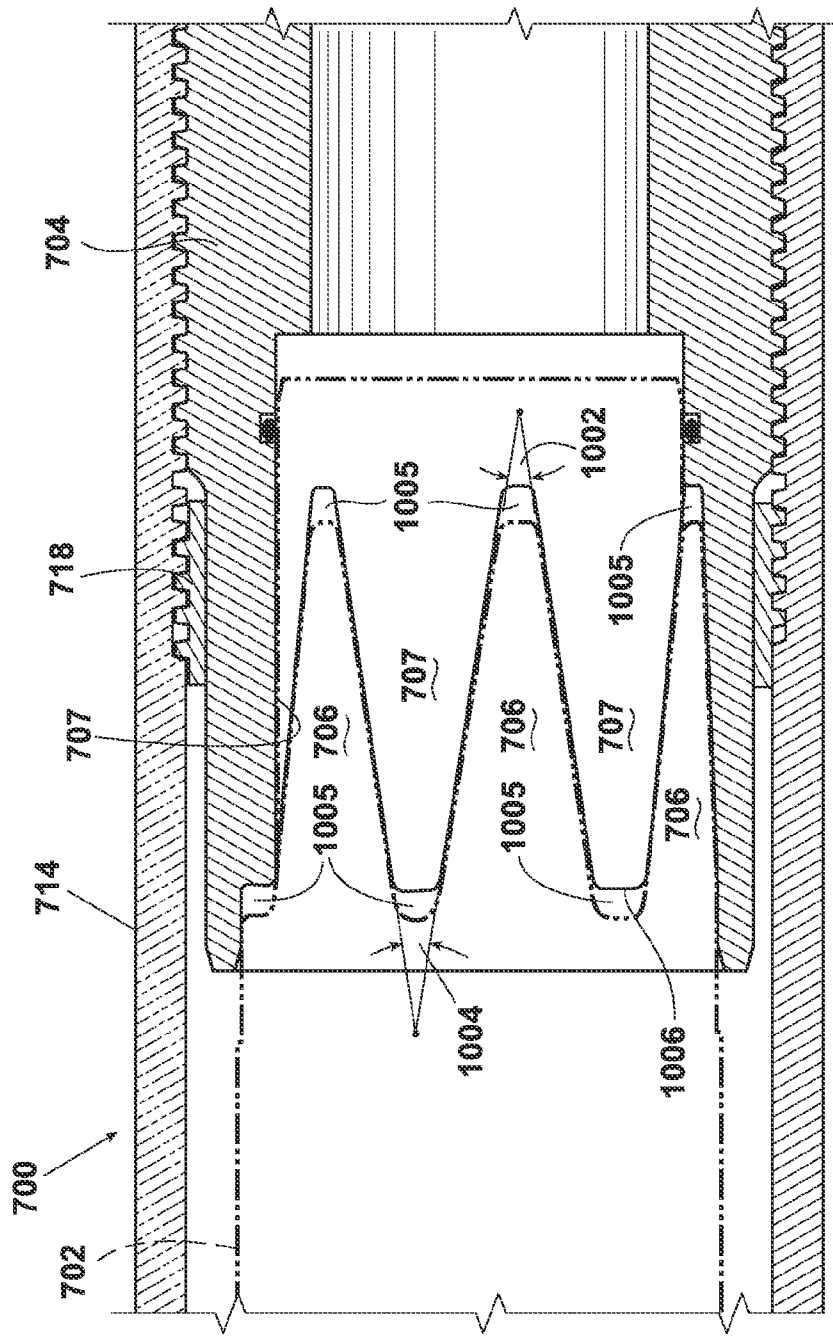


Fig. 12

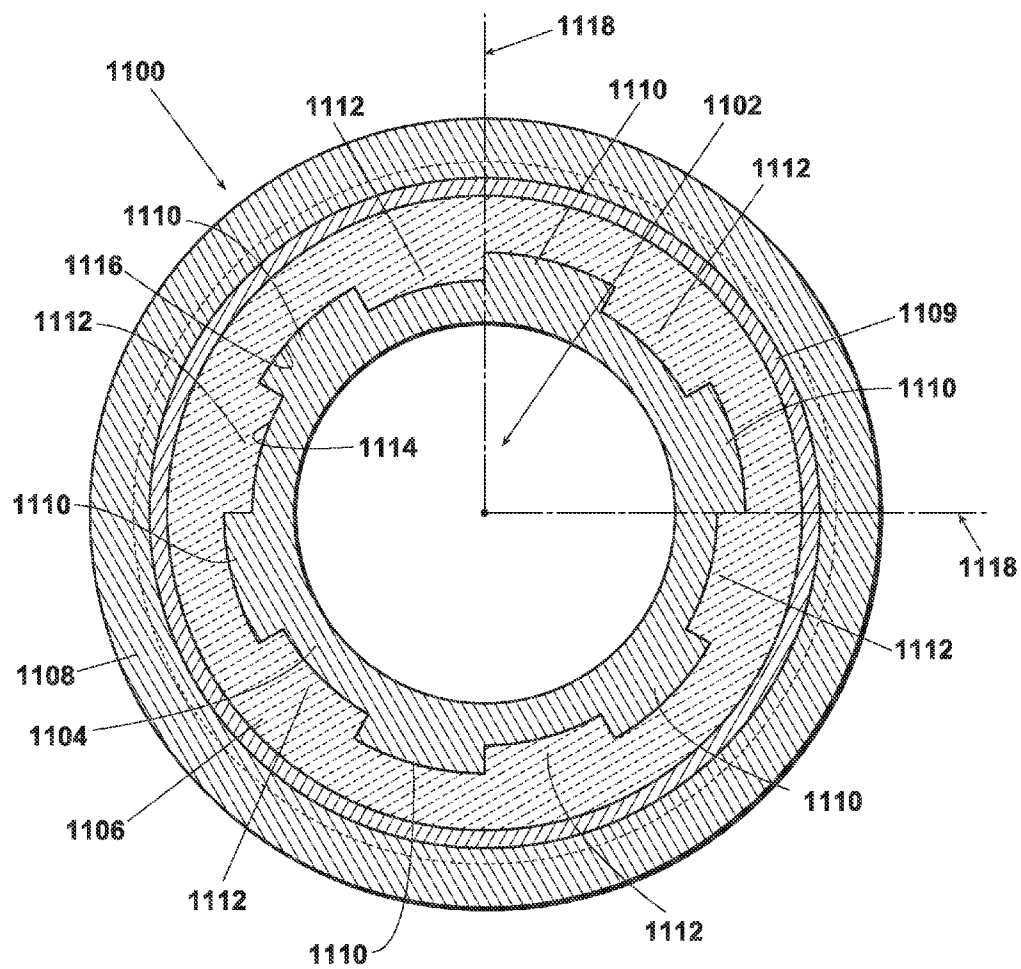


Fig. 13

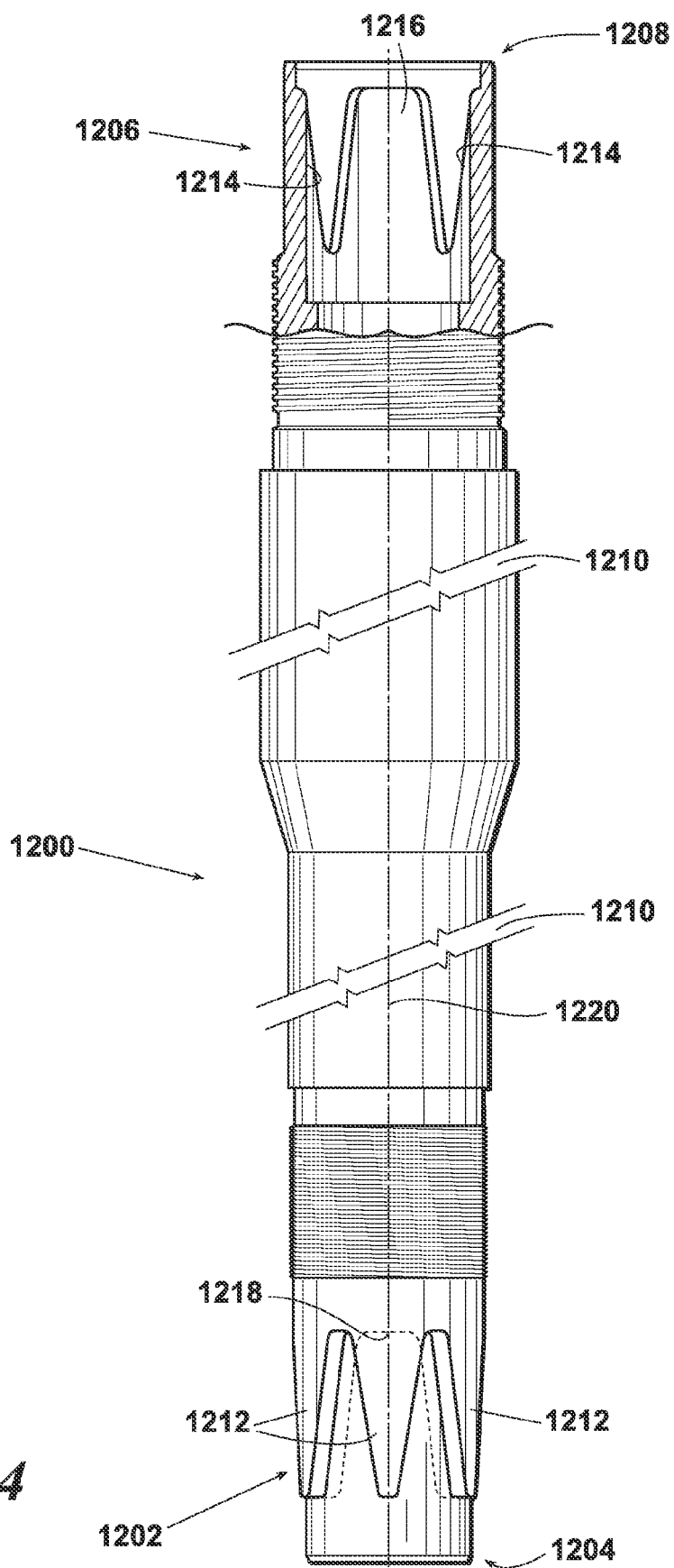


Fig. 14

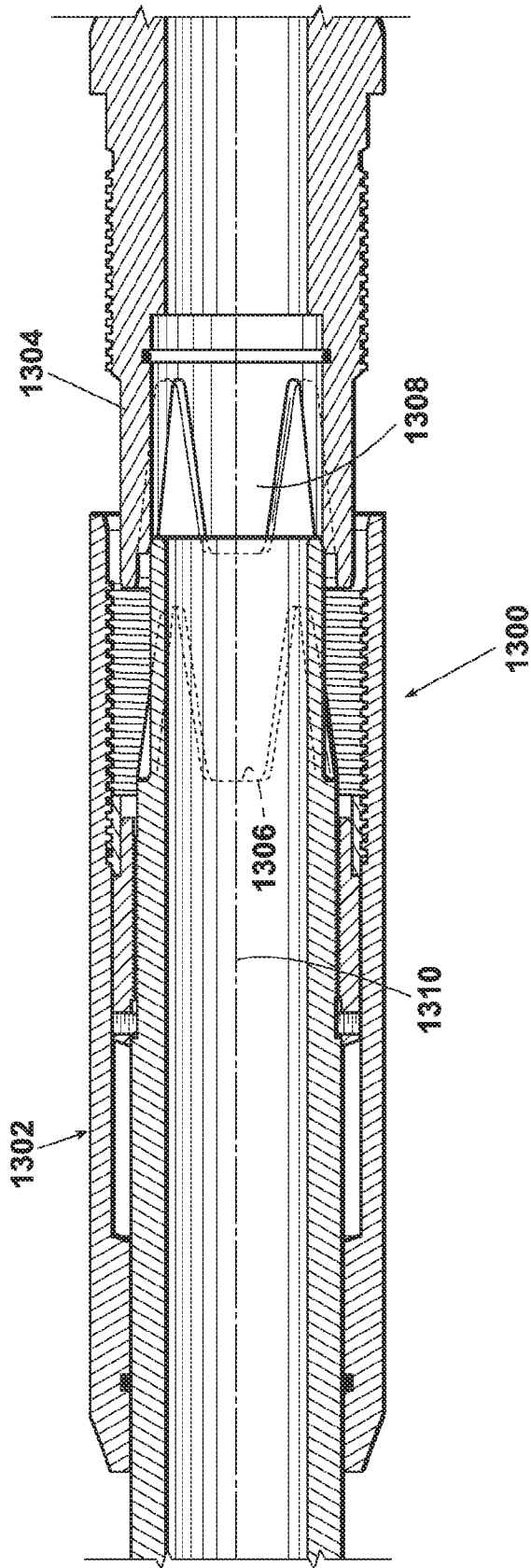


Fig. 15

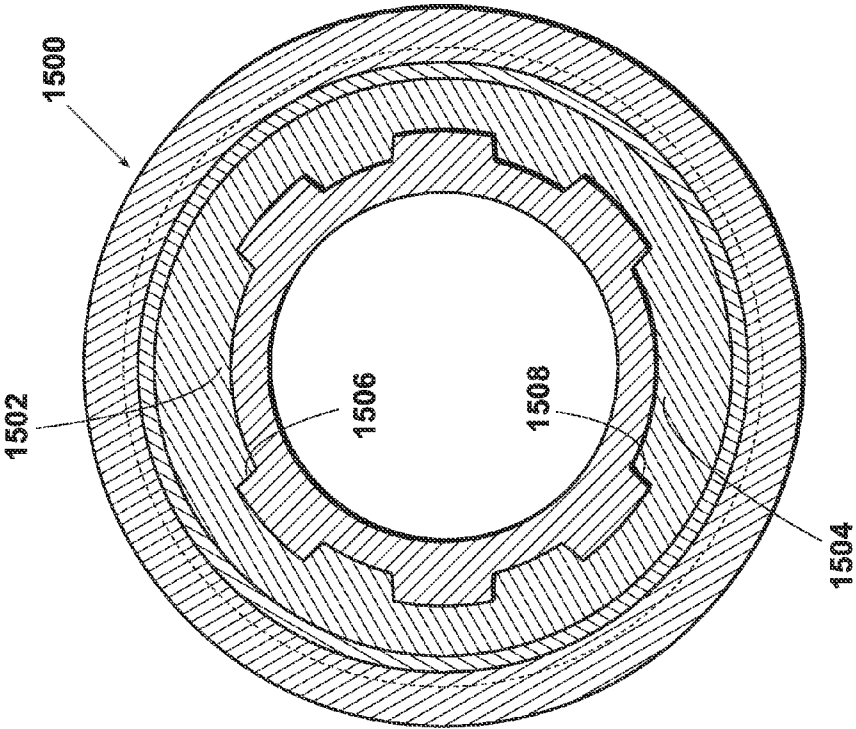


Fig. 17

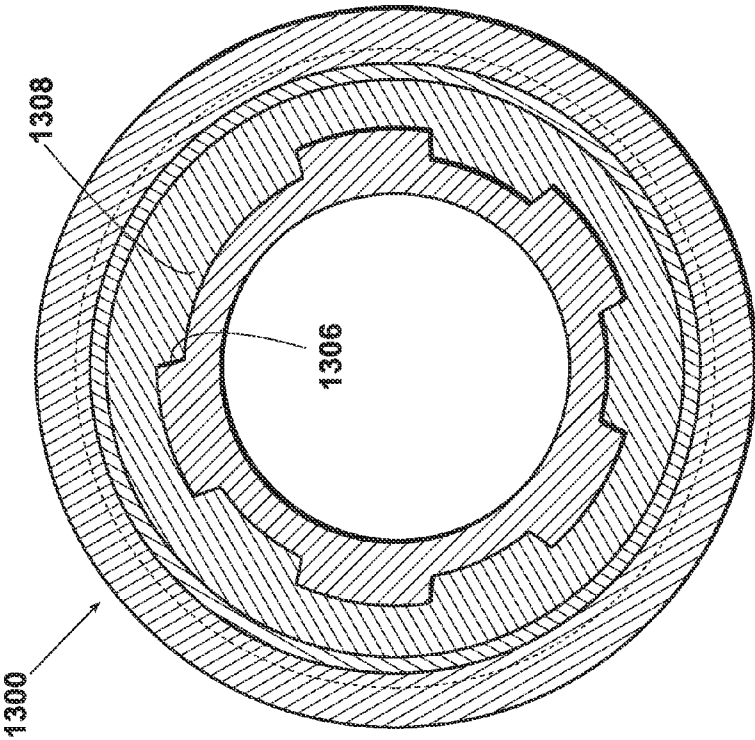


Fig. 16

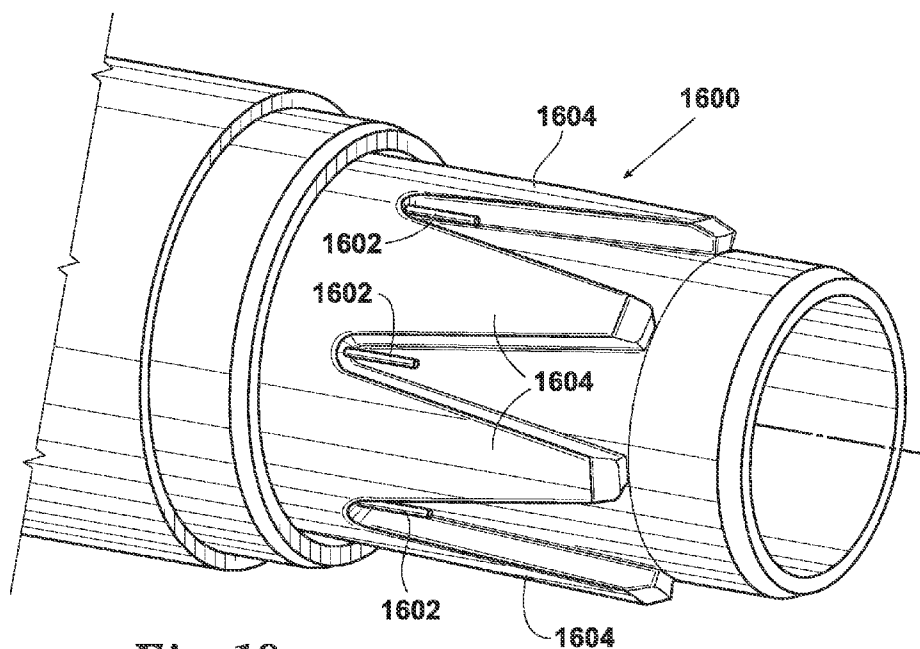


Fig. 18

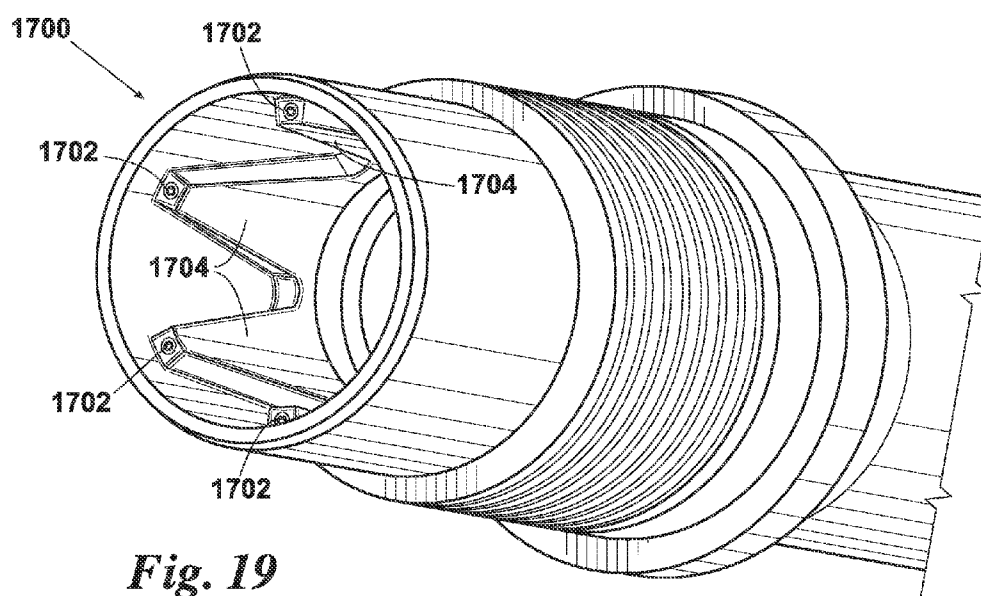


Fig. 19

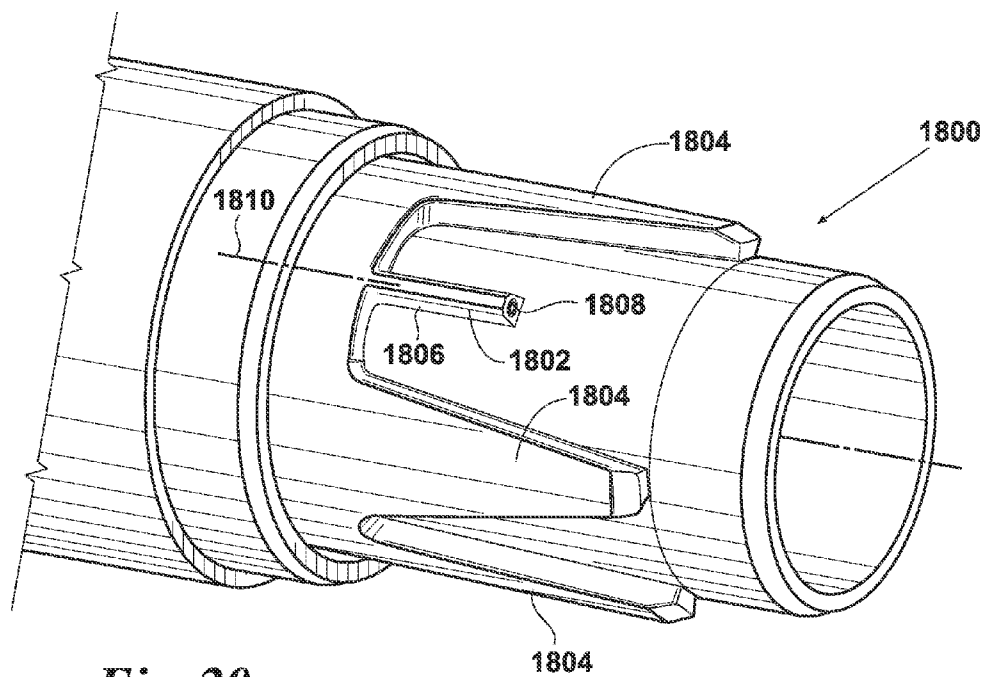


Fig. 20

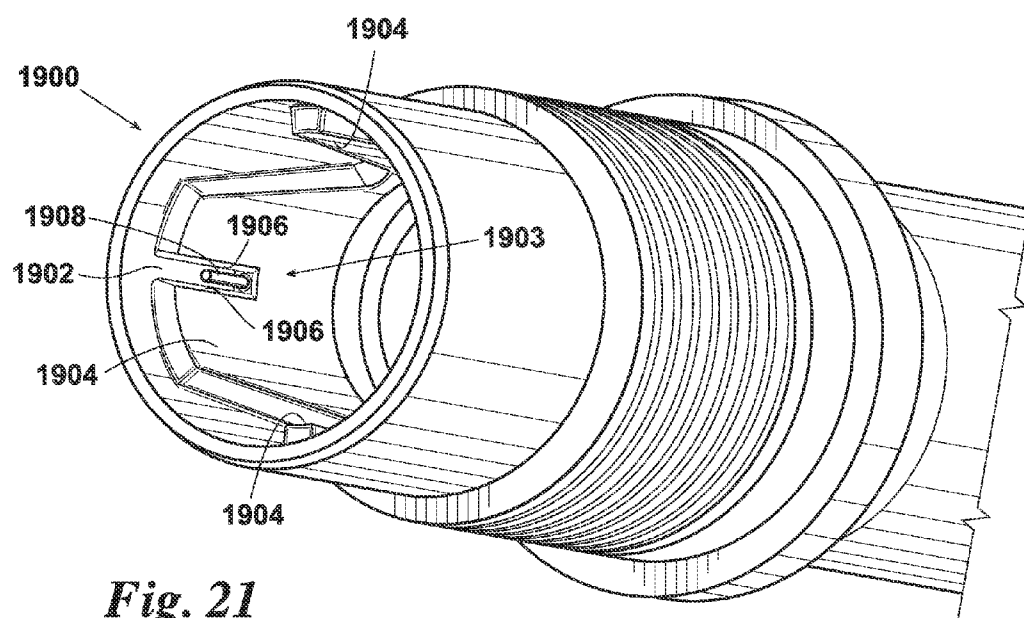


Fig. 21

TAPERED SPLINE CONNECTION FOR DRILL PIPE, CASING, AND TUBING

[0001] This application is a continuation-in-part of U.S. patent application Ser. No. 12/695,569, filed Jan. 28, 2010, the entire disclosure of which is incorporated by reference herein.

FIELD OF THE INVENTION

[0002] The present disclosure generally relates to drill pipe, casing, and tubing used to locate and produce hydrocarbons in a subterranean environment and more specifically to a connection for joining sections of one of drill pipe, casing, and tubing together.

BACKGROUND OF THE INVENTION

[0003] Large portions of hydrocarbon location and production activities involve drilling, pumping, and conduit installation beneath the earth's surface. Drilling, pumping, and conduit installation operations may include water location and distribution. Drilling, pumping, and conduit installation operations may also include sewage processing and distribution, or support installation of electrical power lines or telecommunications transmission lines. Drilling, pumping, and conduit installation activities often use lengths of pipes, which may be joined together in a variety of different manners. There are several considerations associated with joining pipes. For example, drilling activities may require torque to be transmitted across numerous pipes. Thus a joint may need to be strong enough to transmit torque and resist failure.

[0004] Additionally, some industry standards exist related to pipe section diameters. For example, internal pipe diameters are often standardized so expected flow and capacity of the drill string can be achieved. Standards also exist concerning pipe outer diameters that dictate clearances between the outer pipe surface and a wellbore casing, for example. Thus there are often limits on material sizes and thicknesses that can be used for drill pipe segments.

[0005] Currently, pipe segments are joined with threaded connections. Although a threaded connection will adequately join pipe segments, a threaded connection does not transfer torque effectively while rotating both to the left and to the right. That is, threads may loosen or disengage when the pipe segments are rotated in a direction opposite the direction used to tighten to pipe segments together. Some have addressed this issue by adding teeth to the ends of threaded joint sections. Teeth may be capable of transferring torque interconnected pipe segments, even if the pipe segments are rotated in a direction counter the tightening direction. But teeth are often ineffective and result in a weakened joint.

[0006] Drill pipe segments of the prior art are often made of steel alloy, such as 4140 steel or other steel alloys. As one of ordinary skill in the art will appreciate, such pipe segments are heavy and difficult to manage. As described in U.S. Pat. No. 3,126,214 to Wong, previous attempts to reduce drill pipe weight entailed providing an aluminum drill pipe with stainless steel joints adapted to interconnect two or more drill pipe segments together. For example, FIG. 1 shows interconnected drill pipe segment of the prior art comprising a male joint section 1 and a female joint section 2. The male joint section 1 and the female joint section 2 are connected to the aluminum drill pipe section 4 via threads provided on each of the male and female joint sections and the aluminum pipe section 4. In the example shown, the aluminum pipe section 4 pos-

sesses outer threads 6 and the male and female joint section includes internal threads 5. The outer diameter 8 of the drill pipe section 4 is larger than the internal diameter 7 of the male and female joint sections. Thus, to interconnect the male and female joint sections to the aluminum drill pipe section, the joint sections must be heated to approximately 650° F., which expands the joint sections so they can be threadingly received on the aluminum drill pipe section. After the threaded connections are engaged, the male and female joint sections are allowed to cool, or forcibly cooled by water spray, which bonds the joint sections to the aluminum pipe section.

[0007] One of ordinary skill in the art will appreciate that one drawback of the current method of joining stainless steel joint sections 2 and aluminum drill pipe section is that premature joint section cooling will prevent complete integration of the joint section to the pipe section. If the interconnection of joint section to pipe section is not ideal, the joint section cannot simply be removed by re-heating, as the heat required for joint section expansion will adversely affect the aluminum drill pipe section.

[0008] It is appreciated that one may postulate that further weight reductions can be achieved if both the drill pipe section and the joint sections are made of aluminum. The use of an aluminum drill pipe with threaded end interconnections as found in the prior art would weaken the drill string because under the conditions normally experienced in drilling operations, the threads of interconnected aluminum drill pipe joint segments would adhere and gall. Galling may lead to catastrophic failure. Further, even if an anti-galling coating is used, aluminum threads are weak and, thus, are not ideal to transfer torque.

[0009] Those of ordinary skill in the art will also appreciate that because steel joints are the widest portion of the drill pipe segment and, thus, the drill string; they often contact cement and casing walls or the stone wellbore. Abrasive contact between joint sections and the wellbore tends to wear the joint sections. Accordingly, hard bands are often integrated into the steel joint sections before they are connected to the aluminum pipe section. Hard bands are designed as a sacrificial surface that bears the brunt of the frictional interaction between the drill string and the wellbore. Thus the joint members must be re-banded from time to time which is done by removing the existing band and welding a new band onto the joint section. The excess heat required by this process will degrade the interconnected aluminum pipe.

[0010] Accordingly, a need exists for a method and apparatus, which takes into account one or more of the issues discussed above as well as possibly other issues.

SUMMARY OF THE INVENTION

[0011] One embodiment of the present invention is a drill pipe segment comprising: 1) a pipe section; 2) a first, male joint section; and 3) a second, female joint section. Those of skill in the art will appreciate that drill pipe segments are often referred to as "joints," wherein a drill string is comprised of a plurality of interconnected joints. Further, a "joint" of the prior art comprises a drill pipe having "tool joints," e.g., male and female connecting members, at each end. The first joint section includes a first number of splines, and the second joint section includes a second number of splines. The drill pipe segment has a circumferential outer surface that defines a longitudinal axis. The first number of splines extend in a direction generally parallel to the longitudinal axis and span a circumferential outer surface of the first joint section. Like-

wise, the second number of splines extend in a direction generally parallel to the longitudinal axis and span a circumferential outer surface of the second joint section. Each of the first number of splines and the second number of splines have a base, a tip, and a pair of flanks that extend from the base to the tip. The pair of flanks may form an acute angle. Each of the first number of splines is configured to be received between pairs of splines in the second number of splines of another drill pipe segment to form a connection between two drill pipe segments.

[0012] It is a further aspect of embodiments of the present invention described above to provide a coupling for securing the first joint section to the second joint section. More specifically, the coupling may be associated with the first joint section of the drill pipe segment. The second joint section includes a plurality of external threads that selectively interface with the internal threads of the coupling. The first joint section also has external threads that selectively interconnected to threads of a load ring. In operation, the coupling is moved away from the first joint section to expose the external threads of the first joint section, and the load ring is interconnected to the first joint section. The splines of the first joint section and the splines of the second joint section of another drill pipe segment are intermesh as the two drill pipe segments are interconnected. Finally, the coupling is threadingly interconnected to the second joint section, wherein excess movement of the coupling along the longitudinal axis is prevented by the load ring. Thus a rigid connection of two drill pipe segments is provided that can accommodate torque and axial loads often encountered during drilling operations.

[0013] It is yet another aspect of embodiments of the present invention to provide a drill string that is formed of a plurality of aluminum drill pipe segments joined by steel couplings. Those of ordinary skill the art will appreciate that “aluminum” means aluminum, aluminum alloys, or any other material that exhibits the properties of aluminum, such as corrosion resistance, reduced weight, strength, toughness, etc. Those of ordinary skill the art will also appreciate that “steel” means steel, stainless steel, and other alloys of steel, or any other material that exhibits the properties of steel, such as strength and durability.

[0014] The aluminum drill pipe segment of embodiments of the present invention does not require hard banding. More specifically, as the hard band wears, the coupler can be removed from the drill pipe segment by slipping it over the second joint section. A new coupler can then be added to the drill pipe segment and the old coupler can be discarded, recycled, or repaired/reused. Of course, the coupler can be hard banded, and the hard band can be repaired away from the aluminum drill pipe section wherein the increase heat required for such repair will not affect the aluminum drill pipe section.

[0015] The Summary of the Invention is neither intended nor should it be construed as being representative of the full extent and scope of the present invention. Moreover, references made herein to “the present invention” or aspects thereof should be understood to mean certain embodiments of the present invention and should not necessarily be construed as limiting all embodiments to a particular description. The present invention is set forth in various levels of detail in the Summary of the Invention as well as in the attached drawings and the Detailed Description of the Invention and no limitation as to the scope of the present invention is intended by either the inclusion or non-inclusion of elements, compo-

nents, etc. in this Summary of the Invention. Additional aspects of the present invention will become more readily apparent from the Detail Description, particularly when taken together with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The novel features believed characteristic of the illustrative embodiments are set forth in the appended claims. The illustrative embodiments, however, as well as a preferred mode of use, further objectives and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment of the present invention when read in conjunction with the accompanying drawings, wherein:

[0017] FIG. 1 shows a prior art method of joining drill pipe segments;

[0018] FIG. 2 shows a hydrocarbon drilling environment in accordance with an illustrative embodiment;

[0019] FIG. 3 shows a hydrocarbon production environment in accordance with an illustrative embodiment;

[0020] FIG. 4 is a block diagram of connection in accordance with an illustrative environment;

[0021] FIG. 5 is a perspective view of two pipe segments to be joined together in accordance with an illustrative embodiment;

[0022] FIG. 6 is a detailed view of a male joint section of a pipe segment in accordance with an illustrative embodiment;

[0023] FIG. 7 is a detailed view of a female joint section of a pipe segment in accordance with an illustrative embodiment;

[0024] FIG. 8 is a cross-sectional view of a male joint section of an upper pipe segment in accordance with an illustrative embodiment;

[0025] FIG. 9 is a cross-sectional view of male and female joint sections at an initial engagement stage in accordance with an illustrative embodiment;

[0026] FIG. 10 is a cross-sectional view of male and female joint sections at an intermediate engagement stage in accordance with an illustrative embodiment;

[0027] FIG. 11 is a cross-sectional view of male and female joint sections at a fully engaged stage in accordance with an illustrative embodiment;

[0028] FIG. 12 is a cross-sectional view of male and female joint sections at a fully engaged stage in accordance with an illustrative embodiment;

[0029] FIG. 13 is a cross-sectional center view of FIG. 12;

[0030] FIG. 14 is a front elevation view of a length of pipe having an orientation in accordance with an illustrative embodiment;

[0031] FIG. 15 is a cross-sectional view of male and female joint sections having an orientation at an initial engagement stage in accordance with an illustrative embodiment;

[0032] FIG. 16 is a cross-sectional view of FIG. 15;

[0033] FIG. 17 is a cross-sectional view of FIG. 15 showing an alternative embodiment;

[0034] FIG. 18 is an illustration of a male joint section having wiring in accordance with an illustrative embodiment;

[0035] FIG. 19 is an illustration of a female joint section having wiring in accordance with an illustrative embodiment;

[0036] FIG. 20 is an illustration of a male joint section having wiring in accordance with an illustrative embodiment; and

[0037] FIG. 21 is an illustration of a female joint section having wiring in accordance with an illustrative embodiment.

[0038] It should be understood that the drawings are not necessarily to scale. In certain instances, details that are not necessary for an understanding of the invention or that render other details difficult to perceive may have been omitted. It should be understood, of course, that the invention is not necessarily limited to the particular embodiments illustrated herein.

DETAILED DESCRIPTION

[0039] FIG. 2 shows a common hydrocarbon drilling environment that employs one or more of the embodiments of the present invention described herein. In this illustrative example, hydrocarbon drilling environment 100 includes drilling derrick 102 that is used to create and access a borehole 108. The derrick 102 includes drill string 114, casing 116, and a drill bit 118 that forms the borehole 108. The drill string 114 may include any number of drill pipe segments 115 connected end to end using connectors 119. In one embodiment, the drill pipe segments 115 are made of aluminum and the connectors 119 are made of stainless steel.

[0040] FIG. 3 shows a common hydrocarbon production environment that employs one or more of the embodiments of the present invention described herein. The hydrocarbon production environment 101 includes a pump jack 104 and a storage center 112. The pump jack 104 uses tubing 112 to produce hydrocarbons such as oil and gas, for example, from the borehole 110.

[0041] FIG. 4 is a block diagram of a connection in accordance with one embodiment of the present invention. In this example, the connection 200 includes first joint section 202 and second joint section 204. For example, the first joint section 202 or second joint section 204 may be associated with a cylindrical object, e.g., a drill pipe segment. The first joint section 202 includes first number of splines 206 located near a first end 208 of the first joint section 202. The first number of splines 206 span a circumferential surface 210 of the first joint section 202. The first number of splines 206 also extend in an axial direction 211 of the first joint section 202. Similarly, the second joint section 204 includes a second number of splines 212 located near a second end 214 of the second joint section 204. The second number of splines 212 span circumferential surface 216 of the second joint section 204. The second number of splines 212 also extend in axial direction 217 of second joint section 204. As used herein, a circumferential surface, when referring to objects, is a surface of the object that bounds the object in a circular fashion. For example, a circumferential surface may be a surface corresponding to an inner circumference of a cylinder. A circumferential surface may also be a surface corresponding to an outer circumference of a cylinder. Also used herein, an axial direction when referring to cylindrically shaped objects means a direction substantially parallel to the center axis of the cylindrically shaped object.

[0042] In this illustrative embodiment, splines in both the first joint section 202 and the second joint section 204 have a shape defined by base 218, tip 220, and pair of flanks 222 that extends from base 218 to tip 220. The pair of flanks also form acute angle 224. Each spline in first number of splines 206 is configured to be received between adjacent pairs of splines 226 in second number of splines 212 of another drill pipe segment as first end 208 of the first joint section 202 and second end 214 of the second joint section 204 are joined together to form connection 228 between the first joint section 202 and the second joint section 204. The illustration of

connection 200 in FIG. 4 is not meant to imply physical or architectural limitations to the manner in which different illustrative embodiments may be implemented. Other components in addition to, or in place of, the ones illustrated may be used. Some components may be unnecessary in some illustrative embodiments. Also, the blocks are presented to illustrate some functional components. One or more of these blocks may be combined and/or divided into different blocks when implemented in different illustrative embodiments.

[0043] As one of skill in the art will appreciate, the first joint section 202 and the second joint section 204 may be a tool joint. The first joint section 202 and the second joint section 204 may be secured to ends of drill pipes. The first joint section 202 and the second joint section 204 may also be formed on surfaces of drill pipes near the end of the drill pipes. The first joint section 202 and the second joint section 204 may have different inner diameters and outer diameters. For example, without limitation the first joint section 202 and the second joint section 204 may be a connection section for pipes having three and a half inch diameters, five inch diameters or any other sizes suitable for use in locating or producing hydrocarbons. In other embodiments, splines in the first number of splines 206 and the second number of splines 212 may be different sizes than each other. Splines in the first number of splines 206 and the second number of splines 212 may also have different spacing from each other to receive different sizes of splines.

[0044] FIG. 5 shows a connection for two drill pipe segments wherein a first male joint section 302 is shown spaced from the second female joint section. A coupling 306 and load ring 308 are associated with the first joint section 312. The coupling 306 is configured to slide over load ring 308 until it is stopped by the load ring 308, which will be described in further detail below. The coupling 306 also has threads on an inner surface, which cannot be seen in this particular illustration. The second pipe joint section 304 also includes threads 312. The threads 312 are configured to receive the threads on the inner surface of coupling 306. In this example, threads 312 are right hand threads, though left hand threads may be used in alternative embodiments. Both the first joint section and the second joint section include splines 310 and 314.

[0045] In one embodiment of the present invention, the first joint section 302 and the second joint section 304 are made of aluminum or an aluminum alloy, and the coupling 306 is made of steel, a steel alloy, or a variation thereof. The load ring 308 may also be made of aluminum or steel. In operation, the splines 310, 314 of adjoining drill pipe segments are interconnected as described below with regard to FIGS. 8-11. The coupling of the first joint section 302 is then fitted over the second joint section 304 and the threads of the coupling are interconnected to the threads 312 of the second joint section 304. The steel threads of the coupling 306 and the aluminum threads of the second joint section 304 are compatible and incidences of galling are greatly reduced. The splines 310, 314 of each joint section provide the ability for the drill pipe string to transfer torque, regardless of the drill string rotation direction, and the steel coupler 306 axially interconnects the pipe segments.

[0046] FIG. 6 is a detailed view of a drill pipe segment of a joint section of one embodiment of the invention. Here, the first joint section 302 and plurality of splines 310 are depicted with greater detail. Each of plurality of splines 310 have a base 402, a tip 404, and pair of flanks 406. In this example, each of plurality of splines 310 extend from the base 402 in

axial direction 408 towards end 410 of first joint section 302. Each of plurality of splines 310 also extends outwardly in radial direction 412 from outer surface 414 of first joint section 302. Also as used herein, a “radial direction” or “radial extension,” when referring to cylindrically shaped objects means a direction substantially perpendicular to the center axis of the cylindrically shaped object.

[0047] Plurality of splines 310 are also tapered, meaning that as plurality of splines extend from base 402 towards tip 404 width 416 of plurality of splines 310 decreases. For example, this decrease in width 416 is attributable to spline flank angle 418. Spline flank angle 418 is the angle between pair of flanks 406. Each flank in pair of flanks 406 form flank face angles 419 as each flank extends in radial direction 412 from outer surface 414. Additionally, the radial extension of plurality of splines 310 from outer surface 414 form recessed areas 420 between each of plurality of splines 310.

[0048] In this illustrative embodiment, plurality of splines 310 also includes root radii 422 as well as chamfers 424. Root radii 422 are the small edging portions near the interface between plurality of splines 310 and outer surface 414 of first joint section 302. Chamfers 424 are the rounding off or reduction of edge 426 of plurality of splines 310.

[0049] FIG. 7 shows the second joint section 304 and its plurality of splines 314. The shape of the plurality of splines 314 is similar to the shape of the plurality of splines 310 shown in FIG. 6. That is, each of plurality of splines 314 also have base 502, tip 504, and pair of flanks 506. Each of plurality of splines 314 extend from base 502 in an axial direction towards end 508 of the second joint section 304. However, each of plurality of splines 314 extends inwardly in a radial direction from inner surface 510 of the second joint section 304. Like the plurality of splines 310, the plurality of splines 314 are tapered and have spline flank angle 512 between pair of flanks 506. Each flank in pair of flanks 506 form flank face angles 513 as each flank extends in a radial direction from inner surface 510. Additionally, the radial extension of plurality of splines 314 from inner surface 510 form recessed areas 514 between each of plurality of splines 314.

[0050] In this illustrative embodiment, plurality of splines 314 also includes root radii 516 as well as chamfers 518. Root radii 516 and chamfers 518 may be another example of root radii 422 as well as chamfers 424 in FIG. 6. Root radii 516 provide additional support for plurality of splines 314. Chamfers 518 allow splines of opposing joint sections, such as plurality of splines 310 in FIG. 6 for example, to match with and be received between splines in plurality of splines 314. Root radii 516 as well as chamfers 518 may also reduce wear and deformation of the edges of the splines, such as edge 426 of plurality of splines 310 in FIG. 6. Root radii 516 and chamfers 518 may also reduce a tendency for edges of opposing splines to become stuck together during connection and separation stages.

[0051] FIG. 8 is a cross-sectional view of a first joint section that is integrated onto one end of a drill pipe segment 600. In this illustrative example, the first joint section 600 includes the coupling 602, load ring 604, set screws 606, and plurality of splines 610. The coupling 602 has set of threads 612 formed on inner surface 614. Inner surface 614 of coupling 602 has diameter 616 that is substantially equal to an outer diameter 618 of load ring 604. This configuration allows inner surface 614 of coupling 602 to slide in the axial direction around load ring 604. On the other hand, portion 620 of coupling 602 has inner diameter 622 that is substantially

smaller than diameter 616 of inner surface 614. Inner diameter 622 is also substantially equal to outer diameter 624 of the first joint section 600. The inner diameter 622 is substantially equal to outer diameter 624 of first joint section 600 allows coupling 602 to slide around the load ring 604 until the point where portion 620 of coupling 602 contacts load ring 604.

[0052] As depicted, the load ring 604 has set of inner threads 626 that are matched to threads 628 located on the first joint section 600. The set of inner threads 626 allow the load ring 604 to be rotated onto threads 628 located on the first joint section 600. Once in place, the load ring 604 may be secured to the first joint section 600 and secured using the set screws 606. Any number of set screws 606 may be used to lock the load ring 604 in place. In alternative embodiments, the load ring 604 may be formed on the first joint section 600. Thus, the load ring 604 and the first joint section 600 may be the same physical part.

[0053] Turning now to FIG. 9, an illustration of a side cross-sectional view of a pair of joint sections at an initial engagement stage is depicted in accordance with an illustrative embodiment. In this illustrative example, connection section 700 includes upper joint section 702 and lower joint section 704. Connection section 700 is an example of one embodiment of connection section 300 in FIG. 5, while upper joint section 702 and lower joint section 704 may be examples of first joint section 302 and second joint section 304 in FIG. 5, respectively. As depicted, upper joint section 702 includes plurality of splines 706 on an outer surface. Similarly, lower joint section 704 includes plurality of splines 707 on an inner surface. In this example, outer diameter 708 of the first joint section 702 is less than inner diameter 709 of the second joint section 704. The outer diameter 708 of the first joint section 702 being less than inner diameter 709 of the second joint section 704 allows end 710 of the first joint section 702 to be placed inside end 712 of the second joint section 704. The outer diameter 708 of the first joint section 702 being less than inner diameter 709 of the second joint section 704 also allows plurality of splines 706 to be received and positioned in recesses between plurality of splines 707. Connection section 700 further includes coupling 714, the load ring 716, and a retaining ring 718.

[0054] In this illustrative embodiment, the retaining ring 718 restricts the coupling 714 from sliding in an axial direction away from lower joint section 704. The retaining ring 718 is positioned in the coupling 714 by engaging threads 720 of the retainer ring 718 with threads 722 of the coupling 714 when it is slid over the load ring 716. Once engaged, the retaining ring 718 then contacts a shoulder 724 of the load ring 716 to restrict the coupling 714 from sliding away from the load ring 716 and the second joint section 704.

[0055] FIG. 10, is a side cross-sectional view of a pair of joint sections at an intermediate engagement stage. Here, the first joint section 702 inserted inside end 712 of the second joint section 704. The first joint section 702 and the second joint section 704 are mated together. As depicted, outer surface 802 of upper joint section 702 and inner surface 804 of lower joint section 704 have diameters of similar size. These diameters of similar size allow outer surface 802 of upper joint section 702 to connect with inner surface 804 of lower joint section 704. On the other hand, in this example, ends 710 and 712 do not contact surfaces of lower joint section 704 and upper joint section 702, respectively. Because ends 710 and 712 do not contact surfaces of lower joint section 704 and

upper joint section 702, ends 710 and 712 do not bottom out and gaps 806 exist. Gaps 806 extend in the axial direction between upper joint section 702 and lower joint section 704. [0056] In this example, connection section 700 also includes a seal 808. The seal 808 is configured to prevent any leakage of fluids from the connection formed between outer surface 802 of upper joint section 702 and inner surface 804 of lower joint section 704. Additionally, filler may be inserted in gap 806 between end 710 of upper joint section 702 and end 712 of lower joint section 704. The filler may be made from a compressible material, such as, for example, without limitation, polymer or urethane material. For example, the filler may be a polymer ring. Fluids may flow through connection section 700 at certain pressures causing possible wear or erosion of components in connection 700. Inserting a filler in gap 806 in connection section 700 may reduce an amount of wear or erosion on end 710 of upper joint section 702 and end 712 of lower joint section 704.

[0057] With reference now to FIG. 11, an illustration of a side cross-sectional view of a pair of joint sections at a fully engaged stage is depicted in accordance with an illustrative embodiment. In this illustrative example, connection section 700 is depicted at a fully engaged stage. Coupling 714 has been shifted in the axial direction around lower joint section 704. Threads 902 located on an inner surface of coupling 714 have been received by and rotated onto threads 904 located on an outer surface of lower joint section 704.

[0058] In this depicted embodiment, as coupling 714 is shifted axially towards lower joint section 704, a point is reached where load ring 716 begins to physically resist further axial movement of coupling 714 towards lower joint section 704. At this point, further tightening of coupling 714 on threads 904 begins to force upper joint section 702 and lower joint section 704 further together. Forcing upper joint section 702 and lower joint section 704 together may reduce the axial distance of gaps 806 between upper joint section 702 and lower joint section 704. However, in this example, ends 710 and 712 do not bottom out on surfaces of lower joint section 704 and upper joint section 702. Thus, gaps 806 extending in the axial direction between surfaces of upper joint section 702 and lower joint section 704 remain.

[0059] With reference now to FIG. 12, an illustration of an internal cross-sectional view of a pair of joint sections at a fully engaged stage is depicted in accordance with an illustrative embodiment. In this illustrative example, connection section 700 at an engaged stage, such as illustrated in FIG. 10 and FIG. 11 for example, is seen from an internal view. This internal view provides greater detail regarding the position of plurality of splines 706 and plurality of splines 707.

[0060] As depicted, each spline of plurality of splines 706 is matched with a recessed area, such as one of recessed areas 512 in FIG. 7, located between adjacent splines of plurality of splines 707. Likewise, each spline of plurality of splines 707 is matched with a recessed area, such as one of recessed areas 420 in FIG. 6, located between adjacent splines of plurality of splines 706. In this example, the degree of spline flank angle 1002 is substantially equal to the degree of spline flank angle 1004. Because the degree of spline flank angle 1002 is substantially equal to the degree of spline flank angle 1004, each flank of the splines of plurality of splines 706 will come in contact with and seat on an opposing flank of a spline in of plurality of splines 707. Tightening of coupling 714 forces plurality of splines 706 between and towards plurality of splines 707. In this example, plurality of splines 706 and 707

also do not bottom out on opposing surfaces of upper joint section 702 and lower joint section 704. Thus, gaps 1005 are formed between tips 1006 of each of plurality of splines 706 and 707 and portions of the flanks of opposing splines. In this example, gaps 1005 may have a length that ranges from about $\frac{3}{32}$ of an inch to about $\frac{9}{32}$ of an inch in the axial direction. However, in other examples the length of gaps 1005 may be increased or decreased based upon a tightening and/or gap size considerations.

[0061] In this depicted embodiment, tightening of coupling 714 forces plurality of splines 706 between and towards plurality of splines 707. Preload in the connection caused by tightening of coupling 714 is generated from the mechanical advantage created by the wedge shape of the flanks of each of plurality of splines 706 and 707. As used herein, preload, when referring to a joint connection, refers to the force in a tightened joint connection prior to using the joint connection for its primary function. Preload is a compressive force resulting from two or more surface pairs being forced together during the assembly of a connection. The surfaces in compression can be tightened by any mechanical forces up to the yield strength of the surfaces in contact.

[0062] Preload increases the connection stiffness of connection 700 between upper joint section 702 and lower joint section 704. Connection stiffness is the resistance of a connection section to deflecting when external loads are applied to the pipe string. Preload in a connection allows the connection section between pipe joints to respond to forces as if the connection is a continuous section of pipe, because the connection section does not deflect. In this example, preload is applied to connection section 700 as upper joint section 702 and lower joint section 704 are forced together in the axial direction. Additionally, this preload is applied to surfaces of flanks of opposing splines. As gaps 1005 exist, the splines in connection section 700 have not bottomed out. Thus, additional tightening of coupling 714 increases an amount of preload in both the axial and circumferential directions for connection section 700.

[0063] In this illustrated embodiment, the angle selected for spline flank angle 1002 and 1004 has a value of about 18 degrees. However, in other advantageous embodiments spline flank angle 1002 and 1004 may be selected from a range between an angle having a value of about 10 degrees and an angle having a value of about 50 degrees. One of ordinary skill in the art would understand that as a spline flank angle approaches 90 degrees the mechanical advantage between opposing splines is reduced. Correspondingly, as a spline flank angle approaches zero degrees, disassembly of the joint sections may become more difficult once forces have been applied to the connection.

[0064] The tapered shape of plurality of splines 706 and 707 supplies a number of advantages to connection section 700. First, the tip of each of the splines is narrower than the base of the spline. The narrower tip fits within the larger recessed areas between the splines at an initial engagement stage, such as depicted in FIG. 9, for example. At such an initial engagement stage, a clearance exists between the narrower tip of the splines and the larger recessed areas. The clearance allows the splines to intermesh without the need for precise alignment at the initial engagement stage. Second, the area of contact between the flanks of the opposing splines allows torque to be transferred between upper joint section 702 and lower joint section 704. Transfer of torque between the flanks allows pipes connected by connection section 700

to be rotated either to the right or to the left without becoming disconnected. Further, as plurality of splines 706 are forced between and towards plurality of splines 707, the splines are wedged together. Wedging plurality of splines 706 and plurality of splines 707 together reduces possible radial gaps, such as joint slop for example, that may exist between flanks of opposing splines. Joint slop in a connection section may be any undesired gaps and/or lack of connection between surfaces of opposing joint sections. Wedging plurality of splines 706 and plurality of splines 707 together also forms a strong connection between upper joint section 702 and lower joint section 704. For example, the connection may be capable of withstanding levels of torque of about 15% or greater than the base pipe and about 70% or greater than connections used in current drilling applications.

[0065] Another advantage which may be attributable to the tapered shape of plurality of splines 706 and 707 is a reduction in the demand for machine tolerances. For example, irregularities may exist in one of more of the splines. One of the flanks of a spline may not be completely planar or the spline flank angle for one of the splines may not be formed to the exact degree desired. As the opposing splines are wedged together, the forces exerted on the splines adjacent to the spline having an irregularity may cause the irregular spline to deform. This deformation of the irregularity as the splines are wedged together may reduce problems caused by the irregularities.

[0066] The illustration of connection section 700 in FIG. 12 is not meant to imply physical or architectural limitations to the manner in which different illustrative embodiments may be implemented. Other components in addition to, and/or in place of, the ones illustrated may be used. Some components may be unnecessary in some illustrative embodiments. For example, in different illustrative embodiments any number of splines may be used. In other examples, splines may be any number of different sizes. Further, different illustrative embodiments may include splines having any number of different spline flank angles including angles beyond any previously discussed ranges. Still further, the spline flanks may be curved. For example, the spline flanks may have a slope that may be approximated by a parabolic curve. The spline flank angle may be formed by lines that are tangential to points on each flank in the pair.

[0067] With reference now to FIG. 13, an illustration of a cross-sectional center view of a connection section at an engaged stage is depicted in accordance with an illustrative embodiment. In this illustrative example, connection section 1100 is seen from center view 1102. Connection section 1100 is an illustration of an example of one embodiment of connection section 700 in FIG. 9. Connection section 1100 includes male joint section 1104, female joint section 1106, coupling 1108, and retainer ring 1109. Male joint section 1104 includes plurality of splines 1110. Female joint section 1106 includes plurality of splines 1112. As can be seen, substantially no circumferential gaps occur between plurality of splines 1110 and 1112 because connection section 1100 is engaged.

[0068] In this illustrative embodiment, external forces applied to connection section 1100 are resisted by the connection stiffness of male joint section 1104 and female joint section 1106. Additionally, if torque were applied to connection section 1100, hoop stress and hoop tension would be experienced in connection section 1100. Hoop stress, in connection section 1100, is the resistance in male joint section

1104 that arrests retraction and the resistance in female joint section 1106 that arrests swelling as the two joint sections are compressed and/or rotated against each other. Hoop tension in connection section 1100 is the resisting force in the female joint section 1106 wall that provides support and counteracts the hoop stress in the male joint section 1104. For example, the thickness of inner wall 1114 of male joint section 1104 provides support for plurality of splines 1110. Support for plurality of splines 1110 provided by the thickness of inner wall 1114 of male joint section 1104 reduces the tendency for plurality of splines 1110 to retract. Inner wall 1114 also provides an area of support to reduce the exposure of plurality of splines 1110. The area of support provided by inner wall 1114 increases an amount of applied force that plurality of splines 1110 may withstand. In a similar manner, the thickness of outer wall 1116 of female joint section 1106 provides support for plurality of splines 1112. Support for plurality of splines 1112 provided by the thickness of outer wall 1116 of female joint section 1106 reduces the tendency for plurality of splines 1112 to expand. Outer wall 1116 also provides an area of support to reduce the exposure of plurality of splines 1112. The area of support provided by outer wall 1116 increases an amount of applied force that plurality of splines 1112 may withstand.

[0069] In addition, inner wall 1114 provides support in the area between the each spline in plurality of splines 1110. The support provided by inner wall 1114 reduces any tendency for splines of plurality of splines 1110 to shear inwardly. Similarly, outer wall 1116 provides support in the area between each spline in plurality of splines 1112. The support provided by outer wall 1116 reduces any tendency for splines of plurality of splines 1112 to shear outwardly. Thus, the cylindrical shape of inner wall 1114 and outer wall 1116 cause axial and torsional forces to be distributed evenly across plurality of splines 1110 and 1112 in connection section 1100. As torque is applied to one joint section, the torque is transferred to the other joint section through the plurality of splines 1110 and 1112 which are supported by the hoop stiffness caused by the cylindrically adjoined flanks. Thus, the overall torsional strength of the connection section 1100 is increased. As used herein, torsional strength, when referring to a connection section, means the amount of torsional forces the connection may withstand before the components of the connection section yield.

[0070] As depicted, both plurality of splines 1110 and 1112 have similar flank face angles 1118. In this illustrative embodiment, the angle of flank face angle 1118 is approximately 0 degrees. In this example, flank face angles 1118 are determined relative to the axis of the cylinder of connection section 1100. Flank face angles 1118 are an angle between a first line and a second line. The first line is perpendicular to the axis and intersects the spline flank at a point along the radial midpoint of the flank face. The second line is a line that is tangential to the point along the radial midpoint of the flank face that intersects with the first line. As depicted in FIG. 13 these two lines are substantially the same and thus the angle is approximately 0 degrees.

[0071] However, flank face angles 1118 may vary as the cross section of connection 1100 is shifted axially. For example, near the bases of splines in plurality of splines 1110 the flank face angle may be different than the flank face angle near the bases of splines in plurality of splines 1112. As depicted, in FIG. 13 flank face angles 1118 are zero degrees. The illustration of connection section 1100 in FIG. 13 may be

at an axial midpoint of connection section **1100**. The axial midpoint being the approximate midpoint between the bases of opposing splines in plurality of splines **1110** and **1112**. As a cross-sectional view of connection section **1100** is shifted axially flank face angles **1118** may increase or decrease. Thus, flank face angles **1118** may vary in connection section **1100**. Additionally, the flank face angle at a point on flanks in plurality of splines **1110** may be different than the flank face angle at a point on flanks in plurality of splines **1112**.

[0072] Overall, flank face angle **1118** may be selected from a range between an angle having a value of about negative 30 degrees and an angle having a value of about 30 degrees. Additionally, flank face angle **1118** may vary in connection section **1100** from a range between an angle having a value of about negative 30 degrees and an angle having a value of about 30 degrees. Persons skilled in the art recognize and take note that an angle approaching 90 degrees may cause male joint section **1104** and female joint section **1106** to slip rotationally as torque load increases **1100**. Persons skilled in the art recognize and take note that an angle approaching negative 30 degrees may cause the materials of the joint section to yield in response to certain levels of torque or other forces applied to connection section **1100**.

[0073] The illustration of connection section **1100** in FIG. **13** is not meant to imply physical or architectural limitations to the manner in which different illustrative embodiments may be implemented. Other components may be added or substituted for the illustrated components. Some components may be unnecessary in some illustrative embodiments. For example, in different illustrative embodiments any number of splines may be used. In other examples, splines may be any number of different sizes. Further, different illustrative embodiments may include splines having any number of different flank face angles including angles beyond any previously discussed ranges. Moreover, different illustrative embodiments may combine splines with different flank face angles. Still further, the faces of flanks of splines in plurality of splines **1110** and **1112** may be curved.

[0074] With reference now to FIG. **14**, an illustration of a front view of a length of pipe having an orientation is depicted in accordance with an illustrative embodiment. In this illustrative example, pipe **1200** has first joint section **1202** at first end **1204** and second joint section **1206** at second end **1208**. In this example, first joint section **1202** may be a male joint section, such as first joint section **302** in FIG. **5**, and second joint section **1204** may be a female joint section, such as second joint section **304** in FIG. **5**. Abbreviations **1210** are provided for illustrative purposes. Abbreviations **1210** allow greater detail of first joint section **1202** and second joint section **1206** to be seen on pipe **1200**. Accordingly, pipe **1200** may not be illustrated to scale and may be longer than depicted.

[0075] In this illustrative embodiment, first joint section **1202** has plurality of splines **1212**, while second joint section **1204** has plurality of splines **1214**. Plurality of splines **1214** includes at least one spline, spline **1216**, that is a different size than other splines in plurality of splines **1214**. On the other end of pipe **1200**, recessed area **1218** between splines in plurality of splines **1212** is larger than other recessed areas between splines in plurality of splines **1212**. As depicted, both spline **1216** and recessed area **1218** are substantially centered on scribe line **1220**. Scribe line **1220** is a reference line that extends from first end **1204** to second end **1208** on pipe **1200**.

In this example, centering both spline **1216** and recessed area **1218** along scribe line **1220** provides a particular orientation for pipe **1200**.

[0076] In this illustrated embodiment, spline **1216** is larger than other splines in plurality of splines **1214**. However, in other embodiments, splines **1216** may be smaller than other splines in plurality of splines **1214**. In another example, splines **1216** may be tapered at a different angle than other splines in plurality of splines **1214**. Still further, the different spline may be a part of one first joint section **1202** and any number of different sized splines may be used.

[0077] With reference now to FIG. **15**, an illustration of a pair of joint sections having an orientation at an initial engagement stage is depicted in accordance with an illustrative embodiment. In this illustrative example, connection section **1300** is shown at an initial engagement stage similar to connection section **700** in FIG. **9**, for example. In this example, connection section **1300** uses pipes that maintain a particular orientation, such as pipe **1200** in FIG. **14**. Connection section **1300** includes upper joint section **1302** and lower joint section **1304**. Upper joint section **1302** includes recessed area **1306** similar to recessed area **1218** in FIG. **14**. Lower joint section **1304** includes spline **1308** similar to spline **1216** in FIG. **14**.

[0078] Connection section **1300** is configured such that spline **1308** may only be fit into and be received by recessed area **1306** when upper joint section **1302** and lower joint section **1304** are fully engaged. Configuring connection section **1300** such that spline **1308** may only be fit into and be received by recessed area **1306** when upper joint section **1302** and lower joint section **1304** are fully engaged allows connection section **1300** to maintain a particular orientation as illustrated by scribe line **1310**. Further, maintaining this particular orientation of connection section **1300** may allow an entire string of drill pipe to maintain a selected and particular orientation. Additional methods and apparatuses for maintaining orientation of pipes are disclosed in U.S. Pat. No. 5,950,744 entitled "Method and Apparatus for Aligning Drill Pipe and Tubing," incorporated herein by reference.

[0079] With reference now to FIG. **16**, an illustration of a center view of a connection section having a particular orientation is depicted in accordance with an illustrative embodiment. In this depicted example, connection section **1300** is seen at a fully engaged stage. As illustrated, spline **1308** fits within and is received by recessed area **1306**. Spline **1308** is larger than other splines and, thus, a particular orientation may be selected and maintained.

[0080] With reference now to FIG. **17**, an illustration of a center view of a connection section having two particular orientations is depicted in accordance with an illustrative embodiment. In this depicted example, connection section **1500** is similar to connection section **1300** in FIG. **15**. However, spline **1502** and spline **1504** are similar in size. Spline **1502** and spline **1504** may be received by either of recessed area **1506** or recessed area **1508**. Thus, two particular orientations of connection section **1500** may be selected and maintained. In other embodiments, any number of orientations may be achieved.

[0081] With reference now to FIG. **18**, an illustration of a male joint section having wiring is depicted in accordance with an illustrative embodiment. In this illustrative example, male joint section **1600** includes electrical wires **1602** and plurality of splines **1604**. Male joint section **1600** may be an example of one embodiment of first joint section **302** in FIG.

6 including electrical wiring. As depicted, electrical wires **1602** are positioned between bases of adjacent splines in plurality of splines **1604**.

[0082] With reference now to FIG. 19, an illustration of a female joint section having wiring is depicted in accordance with an illustrative embodiment. In this illustrative example, female joint section **1700** includes electrical contacts **1702** and plurality of splines **1704**. Female joint section **1700** may be an example of one embodiment of second joint section **304** in FIG. 7 including electrical contacts. As depicted, electrical contacts **1702** are positioned at the tips of splines in plurality of splines **1704**. Female joint section **1700** may be joined with a male joint section, such as male joint section **1600** in FIG. 18, such as described in FIGS. 9-11 above, for example. In this embodiment, electrical contacts **1702** are configured to receive electrical wires, such as electrical wires **1602** in FIG. 18, as female joint section **1700** is joined with male joint section **1600** in FIG. 18. Thus, electrical wiring may be maintained through a connection of two pipes and/or as entire string of connected pipes. Additional methods and systems for including wiring in pipes are disclosed in U.S. Pat. No. 7,226,090 B2 entitled "Rod and Tubing Joint of Multiple Orientations Containing Electrical Wiring," incorporated herein by reference.

[0083] The illustrations of electrical wiring and electrical connections FIGS. 18-19 are not meant to imply physical or architectural limitations to the manner in which different illustrative embodiments may be implemented. Other components in addition to, and/or in place of, the ones illustrated may be used. Some components may be unnecessary in some illustrative embodiments. For example, in different illustrative embodiments any number of electrical wiring and electrical contacts may be used. Electrical wiring and/or electrical contacts may be inserted into any different configuration of male and/or female splines. Additionally, electrical wiring and contacts may be inserted into the walls of the pipes themselves.

[0084] With reference now to FIG. 20, an illustration of a male joint section having wiring is depicted in accordance with an illustrative embodiment. In this illustrative example, male joint section **1800** includes spline **1802** and plurality of tapered splines **1804**. Male joint section **1800** may be another example of an embodiment of first joint section **302** in FIG. 6 including a spline for electrical connections. Spline **1802** has flanks **1806** that are substantially parallel. Spline **1802** further includes electrical contact **1808** located at the tip of spline **1802**. In this example, spline **1802** and electrical contact are substantially centered on scribe line **1810**. Scribe line **1810** may be used to maintain a particular orientation for pipe connections such as described with respect to FIGS. 14-17 above, for example.

[0085] With reference now to FIG. 21, an illustration of a female joint section having wiring is depicted in accordance with an illustrative embodiment. In this illustrative example, female joint section **1900** includes recessed area **1902**, located inside of orientation spline **1903**, and plurality of tapered splines **1904**, which includes orientation spline **1903**. Female joint section **1900** may be another example of an embodiment of second joint section **304** in FIG. 7 including a recessed area for electrical connections. Recessed area **1902** has sides **1906** that are substantially parallel. Recessed area **1902** further includes electrical wire **1908** extending from the base of recessed area **1902**.

[0086] Female joint section **1900** may be joined with a male joint section, such as male joint section **1800** in FIG. 20. These sections may be joined as described in FIGS. 9-11 above, for example. Recessed area **1902** is adapted to receive spline **1802** in FIG. 20 as female joint section **1900** is joined with male joint section **1800** in FIG. 20. A substantially parallel configuration of recessed area **1902** and spline **1802** in FIG. 20 allows for electrical wire **1908** to be guided into electrical contacts **1808** in FIG. 20. Guiding of electrical wire **1908** by the substantially parallel configuration may allow for a connection between electrical contacts **1808** in FIG. 20 and **1908** without a need to manually align electrical connectors **1808** in FIG. 20 and **1908** themselves as male joint section **1800** in FIG. 20 and female joint section **1900** are joined together.

[0087] While spline **1802** in FIG. 20 and recessed area **1902** may aid in the connection of electrical wiring, spline **1802** in FIG. 20 may not be tapered similar to plurality of tapered splines **1804** in FIG. 20. Thus, spline **1802** in FIG. 20 and recessed area **1902** may not provide the same advantages of torque transmission described above with respect to FIG. 13. However, positioning recessed area **1902** inside orientation spline **1903** reduces any negative impact using non-tapered splines for electrical connections may have.

[0088] The illustrations of electrical connections and splines having substantially parallel sides in FIGS. 20-21 are not meant to imply physical or architectural limitations to the manner in which different illustrative embodiments may be implemented. Other components in addition to, and/or in place of, the ones illustrated may be used. Some components may be unnecessary in some illustrative embodiments. For example, in different illustrative embodiments any number of electrical wiring and electrical contacts may be used. Electrical wiring and/or electrical contacts may be inserted into any different configuration of male and/or female splines. Additionally, any number of splines having substantially parallel flanks may be located in or between any number of different splines.

[0089] The description of the different embodiments of the present invention has been presented for purposes of illustration and description, but is not intended to be exhaustive or limited to the invention in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art. The embodiment was chosen and described in order to best explain the principles of the invention the practical application to enable others of ordinary skill in the art to understand the invention for various embodiments with various modifications as are suited to the particular use contemplated.

What is claimed is:

1. A drill pipe segment, comprising:

- a first end comprising a first joint section, said first joint section having at least one electrical connector;
- a first number of splines located at said first joint section, the first number of splines disposed on a circumferential outer surface of the first joint section, and extending in a first axial direction towards the first end and outwardly in a first radial direction from the circumferential outer surface, each of the first number of splines having a base, a tip, and a pair of flanks extending from the base to the tip wherein the pair of flanks forms an acute angle, wherein the tips of the first number of splines are spaced from the first end of the first joint section, which defines a first cylindrical portion with an outer surface, and

wherein the first number of splines extend outwardly from the outer surface of the first cylindrical portion;

wherein one spline of the first number of splines is a different size than the other splines of the first number of splines;

a second end comprising a second joint section, said second joint section having at least one electrical contact;

a second number of splines located at said second joint section, the second number of splines disposed on a circumferential inner surface of the second joint section and extending in a second axial direction towards the second end and inwardly in a second radial direction from the circumferential inner surface, each of the second number of splines having a base, a tip, and a pair of flanks extending from the base to the tip wherein the pair of flanks forms an acute angle, wherein the tips of the second number of splines are spaced from the second end of the second joint section, which defines a second cylindrical portion with an inner surface, and wherein the second number of splines extend inwardly from the inner surface of the second cylindrical portion;

wherein each of the first number of splines is configured to be received between a plurality of recessed areas defined by corresponding splines of a second joint section of another drill pipe segment;

wherein one recessed area of the plurality of recessed areas is a different size than the other recessed areas of the plurality of splines, and wherein the recessed area of the different size accommodates the spline of a different size of the other drill pipe segment;

a length of pipe between the first joint section and said second joint section;

wherein said first joint section, said length of pipe, and said second joint section are made of aluminum or an aluminum alloy;

a load ring threadingly engaged to threads spaced from said first end;

a coupling operatively interconnected to said length and adapted to engage said load ring; and

wherein said load ring and coupling are made of steel or a steel alloy.

2. The drill pipe segment of claim 1, wherein the pair of flanks of said first number of splines forms a first spline angle; and

wherein said flanks of said second number of splines forms a second spline angle.

3. The drill pipe segment of claim 2, wherein the first spline angle and the second spline angle are about the same.

4. The drill pipe segment of claim 1, wherein the first spline angle and the second spline angle are different.

5. The drill pipe segment of claim 2, wherein the flanks of the first number of splines and the flanks of the second number of splines are curved.

6. The drill pipe segment of claim 2, wherein the flanks of the first number of splines and the flanks of the second number of splines are approximated by a parabolic curve.

7. The drill pipe segment of claim 1, wherein:

the at least one electrical connector is positioned between bases of splines of the first number of splines; and

wherein the at least one electrical contacts is positioned on tips of splines of the second number of splines.

8. The drill pipe segment of claim 1, wherein when the drill pipe segment is interconnected to another drill pipe segment, the tips located at the end of each of the first splines are spaced

from the intersection of adjacent flanks of a second number of splines of the other drill pipe segment, and wherein the tips located at the end of each of the second splines are spaced from the intersection of adjacent flanks of the drill pipe segment.

9. An apparatus, comprising:

a first drill pipe segment having a first end comprising a first joint section and a second end comprising a second joint segment;

a second drill pipe segment having a third end comprising a third joint section and a fourth end comprising a fourth joint segment;

a first number of splines located near the first end of a first joint section, the first number of splines disposed on a circumferential outer surface of the first joint section, and extending in a first axial direction towards the first end and outwardly in a first radial direction from the circumferential outer surface, each of the first number of splines having a base, a tip, and a pair of flanks extending from the base to the tip wherein the pair of flanks forms an acute angle, wherein the first number of splines have first root radii at first interfaces between the first number of splines and the circumferential outer surface, and wherein a number of first edges of the first number of splines have a first rounded off portion;

a second number of splines located near the second end of a second joint section, the second number of splines disposed on a circumferential inner surface of the second joint section and extending in a second axial direction towards the second end and inwardly in a second radial direction from the circumferential inner surface, each of the second number of splines having a base, a tip, and a pair of flanks extending from the base to the tip wherein the pair of flanks forms an acute angle, wherein the second number of splines have second root radii at second interfaces between the second number of splines and the circumferential outer surface, and wherein a number of second edges of the second number of splines have a second rounded off portion;

a third number of splines located near the third end of a third joint section, the third number of splines disposed on a circumferential outer surface of the third joint section, and extending in a third axial direction towards the third end and outwardly in a third radial direction from the circumferential outer surface, each of the third number of splines having a base, a tip, and a pair of flanks extending from the base to the tip wherein the pair of flanks forms an acute angle, wherein the third number of splines have third root radii at third interfaces between the third number of splines and the circumferential outer surface, and wherein a number of third edges of the third number of splines have a third rounded off portion;

a fourth number of splines located near the fourth end of a fourth joint section, the fourth number of splines disposed on a circumferential inner surface of the fourth joint section and extending in a fourth axial direction towards the fourth end and inwardly in a fourth radial direction from the circumferential inner surface, each of the fourth number of splines having a base, a tip, and a pair of flanks extending from the base to the tip wherein the pair of flanks forms an acute angle, wherein the fourth number of splines have fourth root radii at fourth interfaces between the fourth number of splines and the

circumferential outer surface, and wherein a number of fourth edges of the fourth number of splines have a fourth rounded off portion;

wherein each of the first number of splines is configured to be received between adjacent pairs of splines in the fourth number of splines as the first end of the first joint section and the fourth end of the second drill pipe segment are joined together to form a connection between the first joint section and the fourth joint section, wherein a gap remains between each tip of each of the first number of splines and corresponding portions of the flanks of the fourth number of splines when the first drill pipe segment and the second drill pipe segment are fully connected;

an orientation spline of the second number of splines having a size that is substantially different from other splines in the second number of splines wherein the size of the orientation spline is one of a wider size from other splines in the second number of splines; and a recessed area on the first joint section near the first end, the recessed area positioned between a pair of splines of the fourth number of splines, the recessed area adapted to receive the orientation spline, wherein the orientation spline and the recessed area maintain a particular orientation for the connection between the first drill pipe and the second drill pipe;

a first length of pipe between the first joint section and said second joint section;

a second length of pipe between the third joint section and said fourth joint section;

wherein said first joint section, said second joint section, said third joint section, and said fourth joint section, said first length of pipe, and said second length of pipe are made of aluminum or an aluminum alloy;

a load ring threadingly engaged to threads spaced from said first end;

a coupling operatively interconnected to said first length of pipe and adapted to engage said load ring; and

wherein said load ring and coupling are made of steel or a steel alloy.

10. The apparatus of claim 9, wherein the orientation spline is a first orientation spline and the recessed area is a first recessed area further comprising:

an additional orientation spline of the second number of splines having a size that is substantially different from other splines in the fourth number of splines; and

an additional recessed area on the first joint section near the first end, the additional recessed area positioned between a pair of splines of the fourth number of splines, the additional recessed area adapted to receive the orientation spline, wherein the additional orientation spline and the additional recessed area maintain a particular orientation for the connection between the first joint section and the fourth joint section.

11. The apparatus of claim 9, wherein said orientation spline includes a second recessed area associated with an electrical connector, and the recessed area of said first joint section includes a second spline that is associated with an electrical connector having a size that is substantially different from the first number of splines, the second recessed area having a profile that corresponds with the second spline.

12. An apparatus comprising:

a first drill pipe segment having a first end comprising a first joint section and a second end comprising a second joint segment;

a second drill pipe segment having a third end comprising a third joint section and a fourth end comprising a fourth joint segment;

a first number of splines located near a first end of a first joint section, the first number of splines disposed on a circumferential outer surface of the first joint section, and extending in a first axial direction towards the first end and outwardly in a first radial direction from the circumferential outer surface, each of the first number of splines having a base, a tip, and a pair of flanks extending from the base to the tip wherein the pair of flanks forms an acute angle, wherein the first number of splines have first root radii at first interfaces between the first number of splines and the circumferential outer surface;

a second number of splines located near a second end of a second joint section, the second number of splines disposed on a circumferential inner surface of the second joint section and extending in a second axial direction towards the second end and inwardly in a second radial direction from the circumferential inner surface, each of the second number of splines having a base, a tip, and a pair of flanks extending from the base to the tip wherein the pair of flanks forms an acute angle, wherein the second number of splines have second root radii at second interfaces between the second number of splines and the circumferential outer surface;

a third number of splines located near a third end of a third joint section, the third number of splines disposed on a circumferential outer surface of the third joint section, and extending in a third axial direction towards the third end and outwardly in a third radial direction from the circumferential outer surface, each of the third number of splines having a base, a tip, and a pair of flanks extending from the base to the tip wherein the pair of flanks forms an acute angle, wherein the third number of splines have third root radii at third interfaces between the third number of splines and the circumferential outer surface;

a fourth number of splines located near a fourth end of a fourth joint section, the fourth number of splines disposed on a circumferential inner surface of the fourth joint section and extending in a fourth axial direction towards the fourth end and inwardly in a fourth radial direction from the circumferential inner surface, each of the fourth number of splines having a base, a tip, and a pair of flanks extending from the base to the tip wherein the pair of flanks forms an acute angle, wherein the fourth number of splines have fourth root radii at fourth interfaces between the fourth number of splines and the circumferential outer surface;

wherein each of the first number of splines is configured to be received between adjacent pairs of splines in the fourth number of splines of the first joint section and fourth joint section are joined to form a connection between the first drill pipe segment and the second drill pipe segment, wherein a gap remains between each tip of each of the first number of splines and corresponding portions of the flanks of the fourth number of splines when the first joint section and the second joint section are fully connected;

a first length of pipe between the first joint section and said second joint section;
 a second length of pipe between the third joint section and said fourth joint section;
 wherein said first joint section, said second joint section, said third joint section, and said fourth joint section, said first length of pipe, and said second length of pipe are made of aluminum or an aluminum alloy;
 a load ring threadingly engaged to threads spaced from said first end;
 a coupling operatively interconnected to said first length of pipe and adapted to engage said load ring; and
 wherein said load ring and coupling are made of steel or a steel alloy.

13. The apparatus of claim **12**, wherein the pairs of flanks of each of the first number of splines are wedged between and seated on flanks of adjacent splines of the fourth number of splines as the first end of the first joint section and the fourth end of the fourth joint section are joined and wherein the coupling is tightened to wedge the first number of splines between adjacent pairs of splines in the fourth number of splines to a preconfigured force.

14. The apparatus of claim **12**, wherein each of the first number of splines and each of the fourth number of splines has a size that is substantially similar, so that the first joint

section and the fourth joint section may be connected in a number of different orientations.

15. The apparatus of claim **12**, further comprising:

- a first number of electrical connectors positioned between bases of splines of the first number of splines;
- a second number of electrical connectors positioned on tips of splines of the second number of splines, wherein the second number of electrical connectors are adapted to connect to the first number of electrical connectors when the first joint section and the second joint section are joined
- a third number of electrical connectors positioned between bases of splines of the third number of splines;
- a fourth number of electrical connectors positioned on tips of splines of the fourth number of splines, wherein the fourth number of electrical connectors are adapted to connect to the first number of electrical connectors when the first joint section and the fourth joint section are joined.

16. The apparatus of claim **12**, further comprising a filler positioned within the gap.

17. The apparatus of claim **12**, wherein the gaps have a length from about $\frac{3}{32}$ in. to about $\frac{9}{32}$ in.

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