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(54) **Title**: FLUSH JOINT PIPE

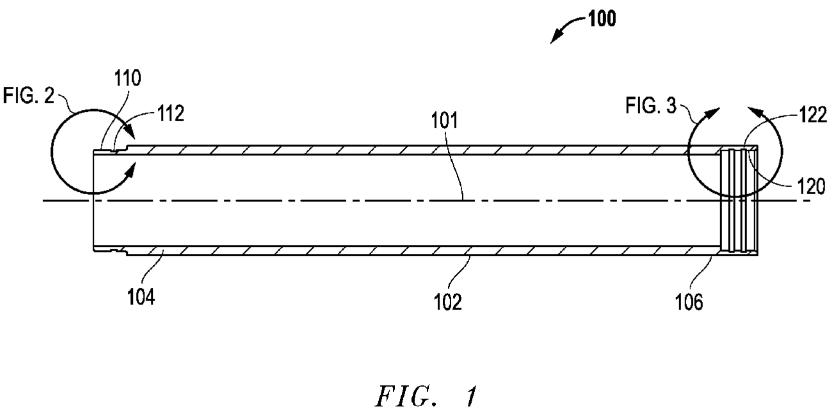

FIG. 1

(57) **Abstract**: A pipe has a tubular body with a male end and a female end. The male end has an external surface with a first engagement groove. The female end has an internal surface with a second engagement groove, and an aperture extending from an outer surface of the tubular body to the second engagement groove. The female end receives the male end of another pipe such that the first engagement groove of the male end axially aligns with the second engagement groove of the female end to establish a spline engagement groove having a groove length, LG. A flexible spline is located in the spline engagement groove to lock the pipes together and establish a pipe assembly. The flexible spline has a spline length, L_S, and $L_S \leq L_G$.

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FLUSH JOINT PIPE

BACKGROUND

Field of the Disclosure

The present disclosure is directed generally to pipes and more particularly to polymeric pipes and their installation.

Description of the Related Art

In recent years, the use of micro-boring or micro-tunneling has become more prevalent for installing underground pipes. The tunneling or boring machines can allow pipes to be installed under highways or freeways without having to break the road surface and disrupt traffic. Moreover, these machines can be used to install pipes under rivers and other small bodies of water.

The types of pipe that can be installed using these methods vary, but include water pipe and sewer pipes. As the industry is evolving, the types of pipes that can be installed using these methods also is changing. Other applications include pipes for municipal infrastructure improvements, residential utility delivery, water transfer, irrigation pipe and fluid transfer for mining operations, and even electrical conduit and temporary bypass systems.

Accordingly, the industry continues to need improvements in pipes, particularly improvements to pipes that can be installed using a micro-tunneling or micro-boring machine.

SUMMARY

Embodiments of a flush joint pipe and method of installation are disclosed. For example, a method of installing pipe in a subterranean location may include forming a bore in the subterranean location. The bore can include an inner wall at least partially comprising subterranean material. The method may further include moving a first polymeric pipe segment into the bore; coupling a second polymeric pipe segment to the first polymeric pipe segment using a mechanical restraint. The coupled first and second polymeric pipe segments can have a cross-sectional shape that is essentially uniform along the length of the first and second polymeric pipe segments. The method may include moving the first and second polymeric pipe segments into the subterranean location. The first and second polymeric pipe segments can be at least partially in direct contact with the inner wall of the bore.

BRIEF DESCRIPTION OF THE DRAWINGS

The present disclosure can be better understood, and its numerous features and advantages made apparent to those skilled in the art by referencing the accompanying drawings.

FIG. 1 includes a sectional side view of an embodiment of a pipe.

FIG. 2 includes an enlarged sectional side view of an embodiment of the pipe at Circle 2 in FIG. 1.

FIG. 3 includes an enlarged sectional view of an embodiment of the pipe at Circle 3 in FIG. 1.

FIGS. 4A and 4B include end and plan views, respectively, of an embodiment of a spline.

FIG. 5 includes a sectional side view of an embodiment of a portion of a pipe joint.

FIG. 6 includes a sectional side view of an embodiment of a pipe.

FIG. 7 includes an exploded side view of an embodiment of a pipe assembly.

FIG. 8 includes an isometric view of an embodiment of pipe segments prior to forming a joint.

FIGS. 9A and 9B are enlarged sectional side views of an embodiment of a spline groove shown without and with a spline, respectively.

FIG. 10 is an axial end view of an embodiment of a pipe in an earthen formation.

The use of the same reference symbols in different drawings indicates similar or identical items.

DETAILED DESCRIPTION

The following description is directed to pipes, and particularly, to pipes that are configured to have flush joints that minimize resistance when being installed using a micro-boring or micro-tunneling operation.

A typical underground pipe includes a relatively large bell end that can snag and catch on dirt when being installed in such a manner. A string of pipes including the pipe disclosed herein can have a cross-sectional shape that is substantially uniform along the entire length of the string of pipes. Further, the string of pipes is free of protuberances extending beyond an outer wall of the pipe.

Referring to the drawings, a pipe is illustrated and is generally designated 100. Embodiments of the pipe 100 include a flush joint pipe 100 with an axis 101, and a generally a tubular body 102 having a male end 104 and a female end 106. Both the male end 104 and the female end 106 can have cylindrical butt ends. In one version, no chamfers or tapers on the male end 104 or female end 106 are required. The male end 104 can include an external surface 110 that can be formed with a first engagement groove 112. The first engagement groove 112 can be the only groove formed in the male end 104, such that two or more grooves are not required. The female end 106 can include an internal surface 120 that can be formed with a second engagement groove 122.

As illustrated in FIGS. 7 and 8, an aperture 124 can extend from an outer surface 126 of the tubular body 102 radially inward to the second engagement groove 122. Embodiments of the aperture 124 can be formed tangential to the first and second engagement grooves 112, 122. Such a tangential direction can reduce resistance to the entry of a flexible spline 132, as described elsewhere herein. The aperture 124 can be round (e.g., drilled), rectangular/square (e.g., milled), etc., and may be oriented for clock-wise or counter-clockwise spline installation. In addition, the aperture 124 may be formed as small as possible while still enabling a spline to pass therethrough. More than one aperture 124 may be provided, which can allow for the spline to be inserted at different angles and/or directions depending on how the pipe is laying during installation. Such a configuration can also allow a tool to be inserted to assist in the removal of an installed spline.

In a particular aspect, the female end 106 can be configured to receive a male end 104 of another pipe 100 such that a first engagement groove 112 of the male end 104 of the other pipe 100 aligns with the second engagement groove 122 of the female end 106 to collectively establish a spline engagement groove 130, as indicated in FIG. 5. In a particular aspect, the spline engagement groove 130 can have a groove length (i.e., circumferential length relative to the axis), L_G (FIG. 10), measured around the external surface 110 of the male end 104 of the pipe 100.

In addition, the pipe joint assembly may be configured to include an interference between the male end 104 and a seal 142 inside the female end 106. The male and female ends 104, 106 may be close-fitting, but are not necessarily overlapping. A compressive force may be required to assemble the male and female ends 104, 106, due to compression of the seal 142.

In other embodiments, a desired interference fit between the butt ends of two pipes 100 is provided. In a version, there is no axial gap between the butt ends and the shoulders they abut on the respective pipes. For example, inserting one pipe into another may require a selected compressive force to be exerted on the pipes to align the respective first and second engagement grooves 112, 122.

A spline 132, illustrated in FIGS. 4 and 5, can be provided. The spline 132 can be flexible and configured to be inserted and fit through the aperture 124 and entirely into the spline engagement groove 130. The spline 132 can prevent the male end 104 of the other pipe 100 from withdrawing from the female end 106 to establish a pipe joint assembly of two pipes 100. The spline 132 may be formed from different types of materials, such as a polymer (e.g., nylon), glass-reinforced plastics, etc. The material may be chosen to meet the structural, strength and chemical resistance requirements for the intended application. The spline 132 may be extruded, molded, etc.

In a particular aspect, the flexible spline 132 can include a spline length, L_S (FIGS. 4 and 10). L_S can be slightly shorter than L_G. For example, L_S can be $\leq$ 95% L_G, such as $\leq$ 90% L_G, $\leq$ 85% L_G, or even $\leq$ 80% L_G. In still other embodiments, L_S can be greater than about half the length of L_G. For example, L_S can be $\geq 50\%\ L_G$, such as $\geq 55\%\ L_G$, $\geq 60\%\ L_G$, $\geq 65\%\ L_G$, $\geq 70\%\ L_G$, or even $\geq 75\%\ L_G$. In another aspect, L_S can be within a range between and including any of the values described herein.

While a continuous spline 132 is illustrated, a multi-piece spline can be used. Further, multiple splines installed in different grooves may be used, depending on the application. The splines may be configured in a parallel orientation.

In a particular aspect, the spline engagement groove 130 can have a cross-sectional groove height (i.e., radial length relative to the axis 101), H_G (FIG. 9A). The spline 132 can include a cross-sectional spline height, H_S (FIGS. 4A and 9B). The spline height H_S can be greater than the groove height H_G. For example, H_S can be $\geq 50\%\ H_G$, such as $\geq 55\%\ H_G$, $\geq 60\%\ H_G$, $\geq 65\%\ H_G$, $\geq 70\%\ H_G$, or even $\geq 75\%\ H_G$. Further, the spline height H_S can be very similar to the groove height H_G. For example, H_S can be $\leq 100\%\ H_G$, such as $\leq 99\%\ H_G$, $\leq 98\%\ H_G$, $\leq 97\%\ H_G$, $\leq 96\%\ H_G$, or even $\leq 95\%\ H_G$. In another aspect, H_S can be within a range between and including any of the values described herein.

In another aspect, the spline engagement groove 130 may include a cross-sectional groove width (i.e., axial length relative to the axis 101), W_G (FIG. 9A). The spline can include a cross-sectional spline width, W_S (FIG. 4A and 9B). The spline width W_S can be smaller than the groove width W_G. For example, W_S can be $\geq 80\%\ W_G$, such as $\geq 85\%\ W_G$, $\geq 90\%\ W_G$, $\geq 95\%\ W_G$, $\geq 96\%\ W_G$, $\geq 97\%\ W_G$, $\geq 98\%\ W_G$, or even $\geq 99\%\ W_G$. Further, the spline width W_S can be almost identical to the groove width W_G. For example, W_S can be ≤ 100% W_G, such as ≤ 99.9% H_G, ≤ 98.8% H_G, ≤ 99.7% H_G, ≤ 99.6% H_G, or even ≤ 99.5% H_G. W_S can be within a range between and including any of the values described herein.

In a particular aspect, the tubular body 102 can include one or more polymers. For example, the tubular body 102 can include polyolefin. Further, the tubular body 102 can include polyethylene. Alternately, the tubular body 102 can include polyvinyl chloride (PVC). In other aspects, the tubular body 102 can include a composite material, such as fiberglass, carbon fiber, or other fiber reinforced plastic materials, or even a combination of the materials described herein. In one embodiment, the tubular body 102 may not include one or more of these materials. For example, the tubular body 102 may not comprise a polymer.

In another aspect, the pipe joint assembly established by the male 104 and female end 106 can have a tensile strength, TS. The TS can be ≥ 500 lbs/in^2 of cross-sectional area, A_{CS}, of the tubular body 102. Tensile strength may be measured by assembling a male/female joint of pipes together, clamping it in a tensile test machine (e.g., UTM), and pulling on the joint until it fails. Tensile strength also may be validated by performing a water pressure burst test through a joint of pipes. In this method, a joint of pipes may be assembled and capped on both ends. The sealed joint is filled with water and the internal pressure is increased until the system fails. The tensile loads applied to the joint may be calculated by multiplying the water pressure and the outside area of the pipe and caps.

Further, the tensile strength TS can be ≥ 750 lbs/in^2, such as ≥ 1000 lbs/in^2. In another aspect, TS can be ≤ 10,000 lbs/in^2, such as ≤ 2250 lbs/in^2, ≤ 2000 lbs/in^2, ≤ 1750 lbs/in^2, or even ≤ 1500 lbs/in^2. Further, TS can be within a range between and including any of the values described herein. Moreover, the assembled pipes can have an outer cross-sectional shape that is substantially uniform along the entire length of the pipe assembly.

In another aspect, the pipe joint assembly can include a compressive strength, CS. The CS may be measure like the TS, but in a reverse direction. For example, the CS can be ≥ 2500 lbs/in^2 of cross-sectional area, A, of the tubular body 102. In other examples, CS can be ≥ 3000 lbs/in^2, or even ≥ 4000lbs/in^2. Moreover, CS can be ≤ 35,000 lbs/in^2, such as ≤ 25,000 lbs/in^2, ≤ 20,000 lbs/in^2, ≤ 15,000 lbs/in^2, or even ≤ 10,000 lbs/in^2. CS can also be within a range between and including any of the values described herein.

The pipe joint assembly can include a leak pressure, P_L. The P_L may include at least one or vacuum testing and pressure testing. The P_L may be tested by forming a pipe joint of at least two pipes, capping the ends, filling the joint with a fluid, and then vacuum and/or pressure testing the system. In one example, the leak pressure P_L can be ≥ -10 lbs/in^2 of surface area, A_S, of an inner wall of the tubular body. In other examples, P_L can be ≥ -5 lbs/in^2, ≥ -3 lbs/in^2, or even ≥ -1 lbs/in^2. Further, P_L can be ≤ 1000 lbs/in^2, such as ≤ 955 lbs/in^2, ≤ 755 lbs/in^2, or even ≤ 100 lbs/in^2. P_L can also be within a range between and including any of the values described herein.

As indicated in FIG. 3, the pipe 100 can also include a seal groove or sealing member groove 140 that can be formed in the internal wall 120 of the female end 106 of the tubular body 102. Moreover, a seal or sealing member 142 (FIGS. 5 and 8) can be disposed within the sealing member groove 140. The seal 142 may be formed from a variety of materials, such as elastomers, rubber, etc. In one version, the seal may have a selected hardness. For example, the seal hardness can be in a range of about 35 Shore A to about 115 Shore A. The seal 142 can compress and/or deform against the smooth exterior surface of the first engagement groove 112. There can be a clearance between outer surface 110 and inner surface 120 in a joint of pipes. The seal 142 can deform into the clearance to fill it. Thus, in an embodiment, there is no expansion or deformation of female end 106 when male end 104 is joined thereto.

In a particular aspect, the sealing member 142 is configured to deform as the male end 104 of one pipe 100 is inserted within the female end 106 of another pipe 100. Specifically, the sealing member 142 can be configured to engage the external wall 110 of the male end 104 of the tubular body 102 and form a sealed joint between the female end 106 and the male end 104 of the respective pipes 100.

In some versions, the sealing member 142 can include an elastic material. Moreover, the sealing member 142 can include rubber. In a particular aspect, the sealing member 142 can include a composite structure that includes a support structure and a sealing member.

In a particular aspect, the tubular body 102 can include an outer diameter, OD_{TB} (FIG. 10). The pipe joint assembly can include an outer diameter, OD_{PJA}. In one version, $OD_{PJA} = OD_{TB}$, or they can be substantially equal. Further, the tubular body can include a wall thickness, T_W. A ratio of $T_W:OD_{TB}$ can be < 1:20, such as ≤ 1:19, ≤ 1:18, ≤ 1:17, ≤ 1:16, or even ≤ 1:15. Further, $T_W:OD_{TB}$ can be ≥ 1:10, or ≥ 1:11, or ≥ 1:12.

In yet another aspect, the pipe joint assembly can include a flexural strength, FS. The FS can be measured at the pipe joint assembly using a three point flexural test. Flexural testing may be performed by assembling a pipe joint, capping the ends of the system, filling it with water at a nominal pressure, and then bending the system in a three-point press until leakage is noted at the joint. FS can be ≥ 2500psi, such as ≥ 3500psi, ≥ 5000psi, or even ≥7500psi. Further, FS can be ≤ 50,000psi, such as ≤ 35,000psi, ≤ 25,000psi, or even ≤ 15,000psi. The FS can be in a range between any of these values.

The flush pipe joint can include average outside diameter, OD_A (FIG. 10). The OD_A can be a relatively small diameter. In addition, the OD_A can have a tight tolerance. For example, OD_A can be ≥ 2.375"±0.011, such as OD_A ≥ 6.275"±0.011", ≥ 8.400"±0.012", ≥ 9.440"±0.014", ≥ 10.500"±0.015", ≥ 12.500"±0.018", or even ≥ 15.300"±0.023". In other examples, OD_A can be a relatively larger diameter, such as ≤ 36.300" ±0.054", ≤ 30.300" ±0.045", or even ≤ 24.300" ±0.036". In other embodiments, the ODA can be ±0.100". The OD_A can be within a range between and including any of the values described herein.

Other embodiments of the flush pipe joint can include an OD_A (FIG. 10), that is very consistent. For example, OD_A can be about ±0.5%. In another version, the OD_A can be about ±0.4%, such as about ±0.3%, about ±0.2%, about ±0.19%, about ±0.18%, about ±0.17%, about ±0.16%, about ±0.15%, or even about ±0.14%. The OD_A can be within a range between and including any of the values described herein.

Similarly, the flush pipe joint can include an average inside diameter, ID_A, that is also very consistent. For example, ID_A can be about ±0.5%. In another version, the ID_A can be about ±0.4%, such as about ±0.3%, about ±0.2%, about ±0.19%, about ±0.18%, about ±0.17%, about ±0.16%, about ±0.15%, or even about ±0.14%. The ID_A can be within a range between and including any of these values described herein.

Accordingly, the pipe joint assembly comprises two or more pipes that can have a very consistent outer diameter, a very consistent inner diameter, or both. Thus, the pipe joint assembly has an unusually high level of concentricity between the pipes (e.g., at the ID, the OD and/or at the interfaces therebetween) that make up the joint. For example, the pipe can include a concentricity relative to a pipe axis, wherein the concentricity at an outside diameter, an inside diameter and an interface between pipe segments is about ±0.5%. Such consistency in all pipes in the pipe joint assembly enables easier installation of a pipeline, as well as ease of fluid flow through the interior of the pipeline in operation.

In a particular aspect, the tubular body 102 can include an inner diameter, ID_{TB}. The pipe joint assembly can include an inner diameter, ID_{PJA}. In one version, $ID_{PJA} = ID_{TB}$. Further, the tubular body 102 can include a wall thickness, T_W. A ratio of $T_W:ID_{TB}$ can be < 1:20, such as ≤ 1:19, ≤ 1:18, ≤ 1:17, ≤ 1:16, or even ≤ 1:15. Further, $T_W:ID_{TB}$ can be ≥ 1:10, or ≥ 1:11, or ≥ 1:12. The ratio also can be in a range between any of these values.

Embodiments of the pipe 100 can have a diameter ratio (DR). Pipe DR (or SDR), as defined by Uni-Bell, help classify various thicknesses of nominally sized pipe. The terms "dimension ratio" and "standard dimension ratio" are widely used in the pipe industry (abbreviated DR and SDR). Both terms refer to the same ratio, which is a dimensionless term that is obtained by dividing the average outside diameter of the pipe by the minimum pipe wall thickness.

$SDR = DR = OD_A / t$

where: OD_A = average outside diameter

t = minimum wall thickness

DR classifications may be characterized by:

(a) the lower the DR number, the thicker the pipe wall;

(b) the pressure capacity of a particular DR is constant regardless of diameter; and

(c) the structural strength of a particular DR is constant regardless of diameter. In the definition of a pipe's pressure rating, the hydrostatic design stress (S), rather than the hydrostatic design basis, is used in calculations. The design stress is the value obtained when HDB is divided by a desired factor of safety (F).

In a particular embodiment, DR can be > 7, > 13, or > 15. Further, DR can be ≤ 32, such as ≤ 26, or even ≤ 21. DR can be within a range between and including any of the values described herein.

In another aspect, the pipe 100 can include an impact strength, S. The impact strength S can be measured in a number of industry standard ways. For base material, notches, izod or charpy testing is performed. For pipe impact test (from Uni-Bell), pipe samples are placed on a specified holder and are subjected to impact by a metal tip of defined geometry and weight falling from a specified height. Impact resistance by PVC pipe may be reported in foot-pounds (Joules) of energy. Impact resistance testing is conducted in accordance with ASTM D 2444.

In some embodiments, the impact strength S, at 23 °C, can be ≥ 284 J (210 ft•lbs), such as ≥ 299 J (220 ft•lbs). Further, S, at 23 °C can be ≤ 2000 J (1475 ft•lbs), such as ≤ 1750 J (1290 ft•lbs), ≤ 1500 J (1106 ft•lbs), ≤ 1250 J (921 ft•lbs), or ≤ 1000 J (737 ft•lbs). The impact strength can be in a range between any of these values.

The flush joint pipe 100 can be installed within a bore that is formed by a micro-boring or micro-tunneling machine. As shown in FIG. 10, the pipe 100 can include an outer diameter, OD_P, and the bore can include an inner diameter, ID_B. The OD_P can be very similar to the ID_B. For example, a ratio of ID_B:OD_P can be ≥ 1, such as ≥ 1.01, ≥ 1.02, ≥ 1.03, ≥ 1.04, or even ≥ 1.05. Moreover, ID_B:OD_P can be ≤ 1.25, such as ≤ 1.20, ≤ 1.15, or even ≤ 1.10.

In another aspect, the micro-tunneling machine can include an outer diameter, OD_{MTM}. For ease of illustration, OD_{MTM} is depicted as the inner diameter ID_B of an earthen bore in FIG. 10. However, in practice, OD_{MTM} would be slightly smaller than the inner diameter ID_B of the earthen bore shown. The OD_{MTM} can be very similar to the OD_P . For example, the ratio $OD_{MTM}:OD_P$ can be ≥ 1, such as ≥ 1.01, ≥ 1.02, ≥ 1.03, ≥ 1.04, or even ≥ 1.05. In other versions, $O_{MTM}:O_{DP}$ can be ≤ 1.25, such as ≤ 1.20, ≤ 1.15, or even ≤ 1.10.

In another embodiment, a method of installing a pipe can include a retrofit of existing or previously installed pipeline. For example, the method can include locating and exposing a previously installed pipeline in a bore hole; pulling a cutting head through the previously installed pipeline; breaking the previously installed pipeline with the cutting head and expanding the bore hole to a larger size by pushing pipe fragments of the previously installed pipeline into soil surrounding the bore hole; and then pulling a new pipe having a flush joint into the enlarged bore hole behind the cutting head. The cutting head can be static or dynamic, and can include at least one of hammering and turning cutters, and pneumatic systems.

With the configuration of structure described herein, the flush joint pipe 100 provides a pipe that can be installed using a micro-tunneling machine. The pipe can be pushed or pulled through a bore and can be installed directly in the earth in direct contact with the earth. The pipe can be a smooth walled pipe that is essentially free of protuberances. Further, the pipe is extremely strong in both compression and tension. Moreover, flexural strength of the pipe is relatively high and can allow the pipe to be installed over non-linear pathways.

One or more of the pipes can be installed by within a subterranean location by forming a bore in the subterranean location, e.g., using a micro-tunneling machine or a micro-boring machine. The bore can include an inner wall that at least partially includes subterranean material such as rocks, dirt, etc. A first polymeric pipe segment can be moved into the bore. Then, a second polymeric pipe segment can be coupled to the first polymeric pipe segment using a mechanical restraint, such as the spline described herein. The assembled or coupled first and second pipes can have a cross-sectional shape that is essentially uniform along the length of the first and second pipes. The first and second polymeric pipe segments can be moved into the subterranean location and the first and second polymeric pipes can be in direct contact with the inner wall of the earthen bore.

In another aspect, the method can include coupling the first polymeric pipe segment to a micro-tunneling machine and running, or otherwise operating, a cutting head on the micro-tunneling machine while moving one or more polymeric pipe segments. Coupling the second polymeric pipe segment to the first polymeric pipe segment can include engaging an end of the second polymeric pipe segment with an end of the first polymeric pipe segment such that a spline engagement groove is established between the first pipe and the end of the second pipe and inserting a spline into the spline engagement groove to establish a polymeric pipe joint assembly.

In a particular aspect, the pipes can be deployed directly into the subterranean location without an outer casing around the one or more polymeric pipe segments. Further, the one or more polymeric pipe segments can be pushed into the bore or pulled through the bore.

Items

1. A pipe, comprising:

a tubular body having a male end and a female end, the male end comprises an external surface having a first engagement groove, the female end comprises an internal surface having an second engagement groove and an aperture extending from an outer surface of the tubular body to the second engagement groove, the female end is configured to receive the male end of another pipe such that the first engagement groove of the male end of a first pipe aligns with the second engagement groove of the female end of a second pipe to establish a spline engagement groove; and

a flexible spline configured to fit through the aperture and into the engagement groove to engage the first engagement groove and the second engagement groove to prevent the male end of the first pipe from withdrawing from the female end of the second pipe to establish a pipe joint assembly.

2. A pipe assembly, comprising:

a first tubular body having a male end comprising an external surface having a first engagement groove;

a second tubular body having a female end comprising an internal surface having a second engagement groove and an aperture extending from an outer surface of the tubular body to the second engagement groove, wherein the female end of the second tubular body is configured to receive the male end of the first tubular body such that the first engagement groove aligns with the second engagement groove to establish a spline engagement groove; and

a flexible spline configured to fit through the aperture into the engagement groove to engage the first engagement groove and the second engagement groove to establish the pipe assembly and to prevent the male end of the first tubular body from withdrawing from the female end of the second tubular body, wherein the pipe assembly comprises an outer cross-sectional shape that is substantially uniform along an entire length of the pipe assembly.

3. A method of installing pipe in a subterranean location, the method comprising:

moving a first polymeric pipe segment into a bore in a subterranean location, wherein the bore includes an inner wall at least partially comprising subterranean material;

coupling a second polymeric pipe segment to the first polymeric pipe segment using a mechanical restraint to form a pipe assembly, and wherein the coupled first and second polymeric pipe segments have a diameter that is substantially uniform along a length thereof; and

moving the pipe assembly into the subterranean location, wherein the first and second polymeric pipe segments are at least partially in direct contact with the inner wall of the bore.

4. The pipe of any one of claims 1-3, further comprising a tensile strength, TS, and the TS $\geq$ 500 lbs/in^2 of cross-sectional area, A_{CS}, of the pipe.

5. The pipe of any one of claims 1-3, wherein a spline engagement groove has a groove length, L_G; and

a flexible spline has a spline length, L_S, and $L_S \leq L_G$.

6. The pipe of claim 5, wherein $L_S \leq 95\%\ L_G$.

7. The pipe of claim 5, wherein $L_S \geq 50\%\ L_G$.

8. The pipe of any one of the preceding claims, wherein a spline engagement groove comprises a cross-sectional groove height, H_G, and a flexible spline comprises a cross-sectional spline height, H_S, wherein $H_S \geq 50\%\ H_G$.

9. The pipe of claim 8, wherein $H_S \leq 100\%\ H_G$.

10. The pipe of any one of the preceding claims, wherein a spline engagement groove comprises a cross-sectional groove width, W_G, and a spline comprises a cross-sectional spline width, W_S, wherein $W_S \geq 80\%\ W_G$.

11. The pipe of claim 10, wherein $W_S \leq 100\%\ W_G$.

12. The pipe of any one of the preceding claims, wherein the pipe comprises at least one of a polymer, polyvinyl chloride (PVC), polyethylene, polyolefin, a composite material, fiberglass, carbon fiber, fiber reinforced plastic material or any combination thereof.

13. The pipe of any one of the preceding claims, further comprising a compressive strength, $CS \geq 2500$ lbs/in^2 of cross-sectional area, A, of the pipe.

14. The pipe of claim 13, wherein the $CS \leq 35{,}000$ lbs/in^2.

15. The pipe of any one of the preceding claims, wherein the pipe comprises a leak pressure, P_L, $\geq$ -10lbs/in^2 of surface area, A_S, of an inner wall of the pipe.

16. The pipe of claim 15, wherein P_L, $\leq$ 1000 lbs/in^2.

17. The pipe of any one of the preceding claims, further comprising a sealing member groove formed in an internal surface of a female end of the pipe.

18. The pipe of claim 17, further comprising a sealing member disposed within the sealing member groove.

19. The pipe of claim 18, wherein the sealing member is configured to deform as a male end of a first pipe is inserted within a female end of a second pipe.

20. The pipe of claim 18 or 19, wherein the sealing member is configured to engage an outer wall of a male end of a first pipe and form a sealed joint with the female end of a second pipe.

21. The pipe of any one of claims 18-20, wherein the sealing member comprises at least one of an elastic material, rubber, a composite structure having a support structure and a sealing member, or any combination thereof.

22. The pipe of any one of the preceding claims, wherein the pipe comprises an outer cross-sectional shape that is substantially uniform along an entire length of the pipe.

23. The pipe of any one of the preceding claims, wherein the pipe comprises an outer diameter, OD_{TB}, and a pipe assembly comprises an outer diameter, OD_{PJA}, wherein OD_{PJA} is substantially equal to OD_{TB}.

24. The pipe of any one of the preceding claims, wherein the pipe comprises an outer diameter, OD_{TB}, and a wall thickness, T_W, wherein a $T_W:OD_{TB} < 1:20$.

25. The pipe of claim 24, wherein $T_W:OD_{TB} \geq 1:10$.

26. The pipe of any one of the preceding claims, wherein the pipe comprises a flexural strength, FS, and the FS $\geq$ 2500 psi.

27. The pipe of claim 26, wherein the FS $\leq$ 50,000 psi.

28. The pipe assembly of claim 4, wherein the TS $\geq$ 750 lbs/in^2.

29. The pipe assembly of claim 4, wherein the TS $\leq$ 10,000 lbs/in^2.

30. The pipe of any one of the preceding claims, further comprising forming a bore in a subterranean location prior to moving the pipe into the subterranean location.

31. The pipe of any one of the preceding claims, wherein the comprises an average outside diameter, OD_A is about ±0.5%.

32. The pipe of claim 31, wherein OD_A is about ±0.2%.

33. The pipe of any one of the preceding claims, wherein the pipe comprises a diameter ratio (DR) that is > 7.

34. The pipe of any one of the preceding claims, wherein the pipe comprises a diameter ratio (DR) that is DR ≤ 32.

35. The pipe of any one of the preceding claims, wherein the pipe comprises an impact strength, S, at 23 °C ≥ 284 J (210 ft•lbs).

36. The pipe of any one of the preceding claims, wherein the pipe comprises an impact strength, S, at 23 °C ≤ 2000 J (1475 ft•lbs).

37. The pipe of any one of the preceding claims, further comprising:

coupling the pipe to a micro-tunneling machine.

38. The pipe of claim 37, further comprising:

running a cutting head on the micro-tunneling machine while moving the pipe.

39. The pipe of any one of the preceding claims, further comprising:

engaging a second pipe with a first pipe such that a spline engagement groove is established between the first and second pipes; and

inserting a spline into the spline engagement groove to establish the pipe assembly.

40. The pipe of any one of the preceding claims, wherein the pipe is deployed directly into a subterranean location without an outer casing around the pipe.

41. The pipe of any one of the preceding claims, wherein the pipe is pushed or pulled through a bore.

42. The pipe of any one of the preceding claims, wherein the pipe comprises an outer diameter, OD_P, and a bore comprises an inner diameter, ID_B, and a ratio of $ID_B:OD_P$ is ≥ 1.

43. The pipe of claim 42, wherein $ID_B:OD_P$ is ≤ 1.25.

44. The pipe of any one of the preceding claims, wherein the pipe comprises an outer diameter, OD_P, and a micro-tunneling machine comprises an outer diameter, OD_{MTM}, and a ratio of $OD_{MTM}:OD_P$ is ≥ 1.

45. The pipe of claim 44, wherein $OD_{MTM}:OD_P$ is ≤ 1.25.

46. The pipe of any one of the preceding claims, wherein the pipe comprises a concentricity relative to a pipe axis, wherein the concentricity at an outside diameter, an inside diameter and an interface between pipe segments is about ±0.5%.

Those of ordinary skill in the art will recognize that there may be other applications that can utilize a pipe having one or more of the characteristics described herein.

The above-disclosed subject matter is to be considered illustrative, and not restrictive, and the appended claims are intended to cover all such modifications, enhancements, and other embodiments, which fall within the true scope of the present invention. Thus, to the maximum extent allowed by law, the scope of the present invention is to be determined by the broadest permissible interpretation of the following claims and their equivalents, and shall not be restricted or limited by the foregoing detailed description.

In addition, in the foregoing Detailed Description, various features can be grouped together or described in a single embodiment for the purpose of streamlining the disclosure. This disclosure is not to be interpreted as reflecting an intention that the claimed embodiments require more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive subject matter can be directed to less than all features of any of the disclosed embodiments. Thus, the following claims are incorporated into the Detailed Description, with each claim standing on its own as defining separately claimed subject matter.

WHAT IS CLAIMED IS:

1. A pipe, comprising:

a tubular body having a male end and a female end, the male end comprises an external surface having a first engagement groove, the female end comprises an internal surface having an second engagement groove and an aperture extending from an outer surface of the tubular body to the second engagement groove, the female end is configured to receive the male end of another pipe such that the first engagement groove of the male end of a first pipe aligns with the second engagement groove of the female end of a second pipe to establish a spline engagement groove; and

a flexible spline configured to fit through the aperture and into the engagement groove to engage the first engagement groove and the second engagement groove to prevent the male end of the first pipe from withdrawing from the female end of the second pipe to establish a pipe joint assembly.

2. A pipe assembly, comprising:

a first tubular body having a male end comprising an external surface having a first engagement groove;

a second tubular body having a female end comprising an internal surface having a second engagement groove and an aperture extending from an outer surface of the tubular body to the second engagement groove, wherein the female end of the second tubular body is configured to receive the male end of the first tubular body such that the first engagement groove aligns with the second engagement groove to establish a spline engagement groove; and

a flexible spline configured to fit through the aperture into the engagement groove to engage the first engagement groove and the second engagement groove to establish the pipe assembly and to prevent the male end of the first tubular body from withdrawing from the female end of the second tubular body, wherein the pipe assembly comprises an outer cross-sectional shape that is substantially uniform along an entire length of the pipe assembly.

3. A method of installing pipe in a subterranean location, the method comprising:

moving a first polymeric pipe segment into a bore in a subterranean location, wherein the bore includes an inner wall at least partially comprising subterranean material;

coupling a second polymeric pipe segment to the first polymeric pipe segment using a mechanical restraint to form a pipe assembly, and wherein the coupled first and second polymeric pipe segments have a diameter that is substantially uniform along a length thereof; and

moving the pipe assembly into the subterranean location, wherein the first and second polymeric pipe segments are at least partially in direct contact with the inner wall of the bore.

4. The pipe of any one of claims 1-3, further comprising a tensile strength, TS, and the TS $\geq$ 500 lbs/in^2 of cross-sectional area, A_{CS}, of the pipe.

5. The pipe of any one of claims 1-3, wherein a spline engagement groove has a groove length, L_G; and

a flexible spline has a spline length, L_S, and $L_S \leq L_G$.

6. The pipe of claim 5, wherein $L_S \leq 95\% \ L_G$.

7. The pipe of claim 5, wherein $L_S \geq 50\% \ L_G$.

8. The pipe of any one of the preceding claims, wherein a spline engagement groove comprises a cross-sectional groove height, H_G, and a flexible spline comprises a cross-sectional spline height, H_S, wherein $H_S \geq 50\% \ H_G$.

9. The pipe of claim 8, wherein $H_S \leq 100\% \ H_G$.

10. The pipe of any one of the preceding claims, wherein a spline engagement groove comprises a cross-sectional groove width, W_G, and a spline comprises a cross-sectional spline width, W_S, wherein $W_S \geq 80\% \ W_G$.

11. The pipe of claim 10, wherein $W_S \leq 100\% \ W_G$.

12. The pipe of any one of the preceding claims, wherein the pipe comprises at least one of a polymer, polyvinyl chloride (PVC), polyethylene, polyolefin, a composite

material, fiberglass, carbon fiber, fiber reinforced plastic material or any combination thereof.

13. The pipe of any one of the preceding claims, further comprising a compressive strength, $CS \geq 2500$ lbs/in^2 of cross-sectional area, A, of the pipe.

14. The pipe of claim 13, wherein the $CS \leq 35{,}000$ lbs/in^2.

15. The pipe of any one of the preceding claims, wherein the pipe comprises a leak pressure, P_L, $\geq$ -10lbs/in^2 of surface area, A_S, of an inner wall of the pipe.

16. The pipe of claim 15, wherein P_L, $\leq$ 1000 lbs/in^2.

17. The pipe of any one of the preceding claims, further comprising a sealing member groove formed in an internal surface of a female end of the pipe.

18. The pipe of claim 17, further comprising a sealing member disposed within the sealing member groove.

19. The pipe of claim 18, wherein the sealing member is configured to deform as a male end of a first pipe is inserted within a female end of a second pipe.

20. The pipe of claim 18 or 19, wherein the sealing member is configured to engage an outer wall of a male end of a first pipe and form a sealed joint with the female end of a second pipe.

21. The pipe of any one of claims 18-20, wherein the sealing member comprises at least one of an elastic material, rubber, a composite structure having a support structure and a sealing member, or any combination thereof.

22. The pipe of any one of the preceding claims, wherein the pipe comprises an outer cross-sectional shape that is substantially uniform along an entire length of the pipe.

23. The pipe of any one of the preceding claims, wherein the pipe comprises an outer diameter, OD_{TB}, and a pipe assembly comprises an outer diameter, OD_{PJA}, wherein OD_{PJA} is substantially equal to OD_{TB}.

24. The pipe of any one of the preceding claims, wherein the pipe comprises an outer diameter, OD_{TB}, and a wall thickness, T_W, wherein a $T_W:OD_{TB} < 1:20$.

25. The pipe of claim 24, wherein $T_W:OD_{TB} \geq 1:10$.

26. The pipe of any one of the preceding claims, wherein the pipe comprises a flexural strength, FS, and the FS $\geq$ 2500 psi.

27. The pipe of claim 26, wherein the FS $\leq$ 50,000 psi.

28. The pipe assembly of claim 4, wherein the TS $\geq$ 750 lbs/in^2.

29. The pipe assembly of claim 4, wherein the TS $\leq$ 10,000 lbs/in^2.

30. The pipe of any one of the preceding claims, further comprising forming a bore in a subterranean location prior to moving the pipe into the subterranean location.

31. The pipe of any one of the preceding claims, wherein the comprises an average outside diameter, OD_A is about ±0.5%.

32. The pipe of claim 31, wherein OD_A is about ±0.2%.

33. The pipe of any one of the preceding claims, wherein the pipe comprises a diameter ratio (DR) that is > 7.

34. The pipe of any one of the preceding claims, wherein the pipe comprises a diameter ratio (DR) that is DR $\leq$ 32.

35. The pipe of any one of the preceding claims, wherein the pipe comprises an impact strength, S, at 23 °C $\geq$ 284 J (210 ft•lbs).

36. The pipe of any one of the preceding claims, wherein the pipe comprises an impact strength, S, at 23 °C ≤ 2000 J (1475 ft•lbs).

37. The pipe of any one of the preceding claims, further comprising:

coupling the pipe to a micro-tunneling machine.

38. The pipe of claim 37, further comprising:

running a cutting head on the micro-tunneling machine while moving the pipe.

39. The pipe of any one of the preceding claims, further comprising:

engaging a second pipe with a first pipe such that a spline engagement groove is established between the first and second pipes; and

inserting a spline into the spline engagement groove to establish the pipe assembly.

40. The pipe of any one of the preceding claims, wherein the pipe is deployed directly into a subterranean location without an outer casing around the pipe.

41. The pipe of any one of the preceding claims, wherein the pipe is pushed or pulled through a bore.

42. The pipe of any one of the preceding claims, wherein the pipe comprises an outer diameter, OD_P, and a bore comprises an inner diameter, ID_B, and a ratio of $ID_B:OD_P$ is $\geq$ 1.

43. The pipe of claim 42, wherein $ID_B:OD_P$ is ≤ 1.25.

44. The pipe of any one of the preceding claims, wherein the pipe comprises an outer diameter, OD_P, and a micro-tunneling machine comprises an outer diameter, OD_{MTM}, and a ratio of $OD_{MTM}:OD_P$ is ≥ 1.

45. The pipe of claim 44, wherein $OD_{MTM}:OD_P$ is ≤ 1.25.

46. The pipe of any one of the preceding claims, wherein the pipe comprises a concentricity relative to a pipe axis, wherein the concentricity at an outside diameter, an inside diameter and an interface between pipe segments is about ±0.5%.

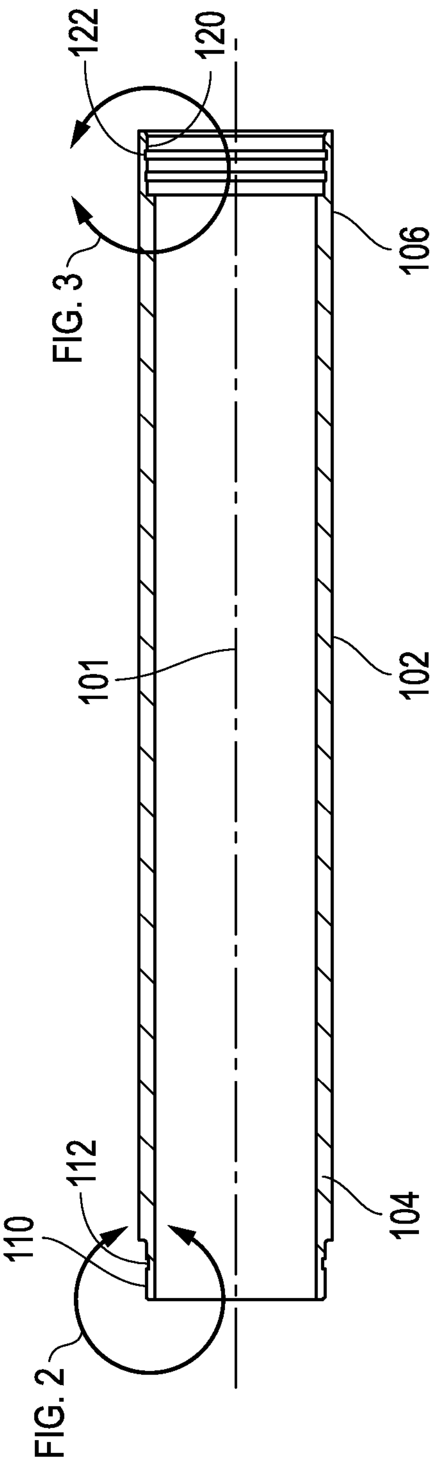


FIG. 1

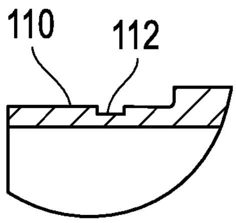


FIG. 2

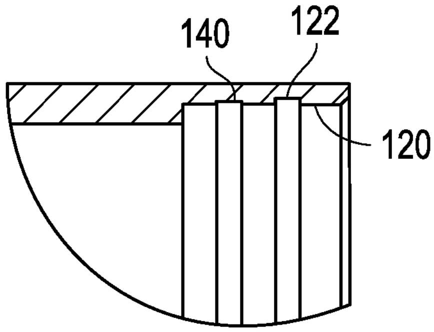


FIG. 3

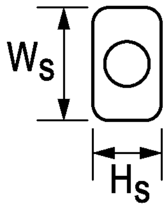


FIG. 4A

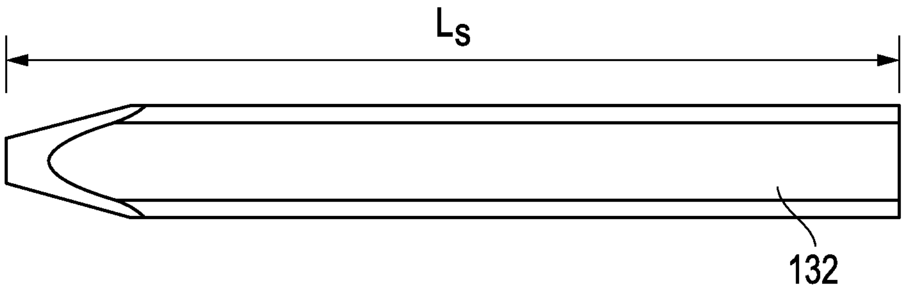


FIG. 4B

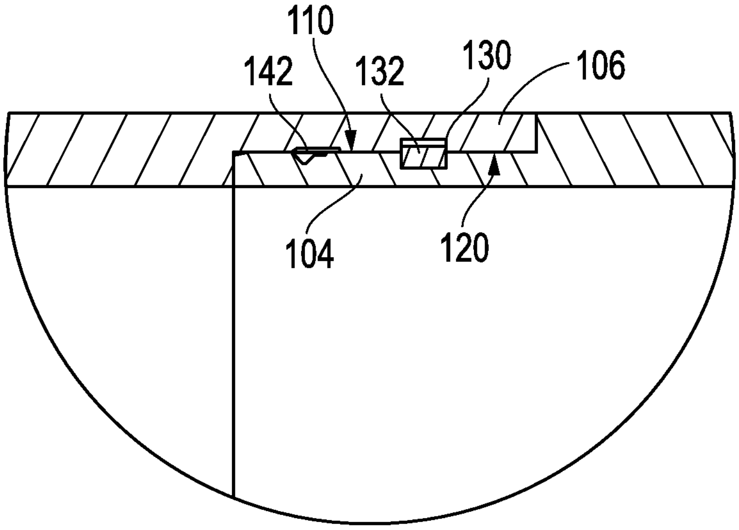
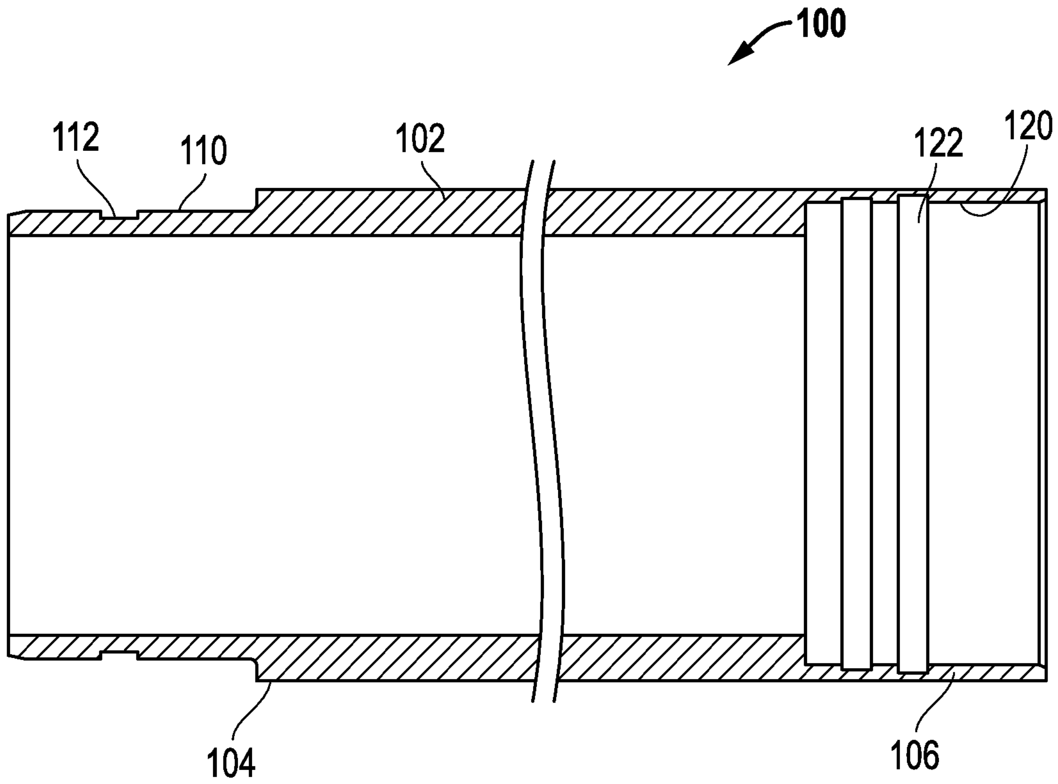


FIG. 5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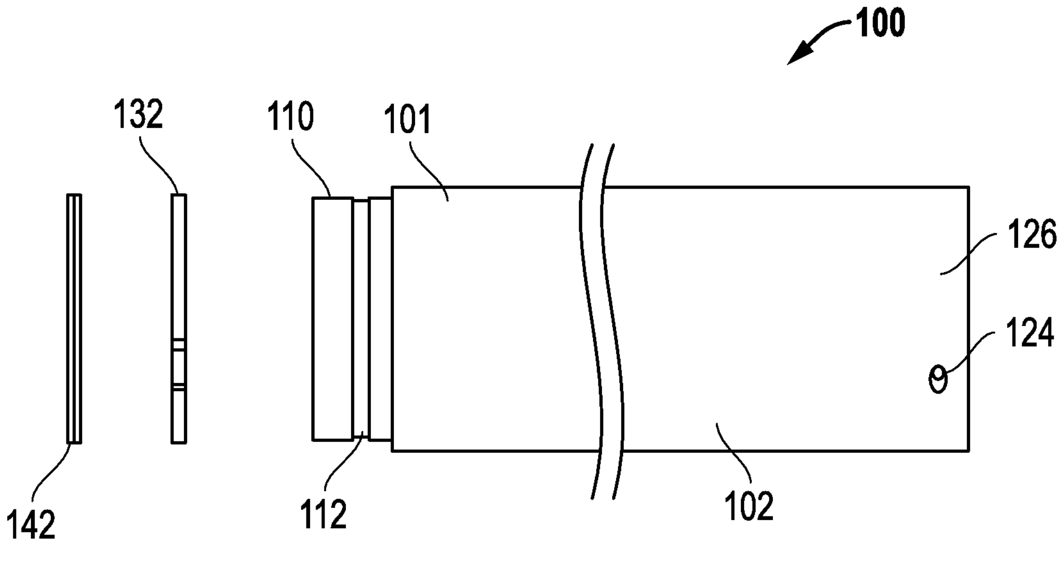
112
110
102
122
120
104
106

FIG. 6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101
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124
142
112
102

FIG. 7

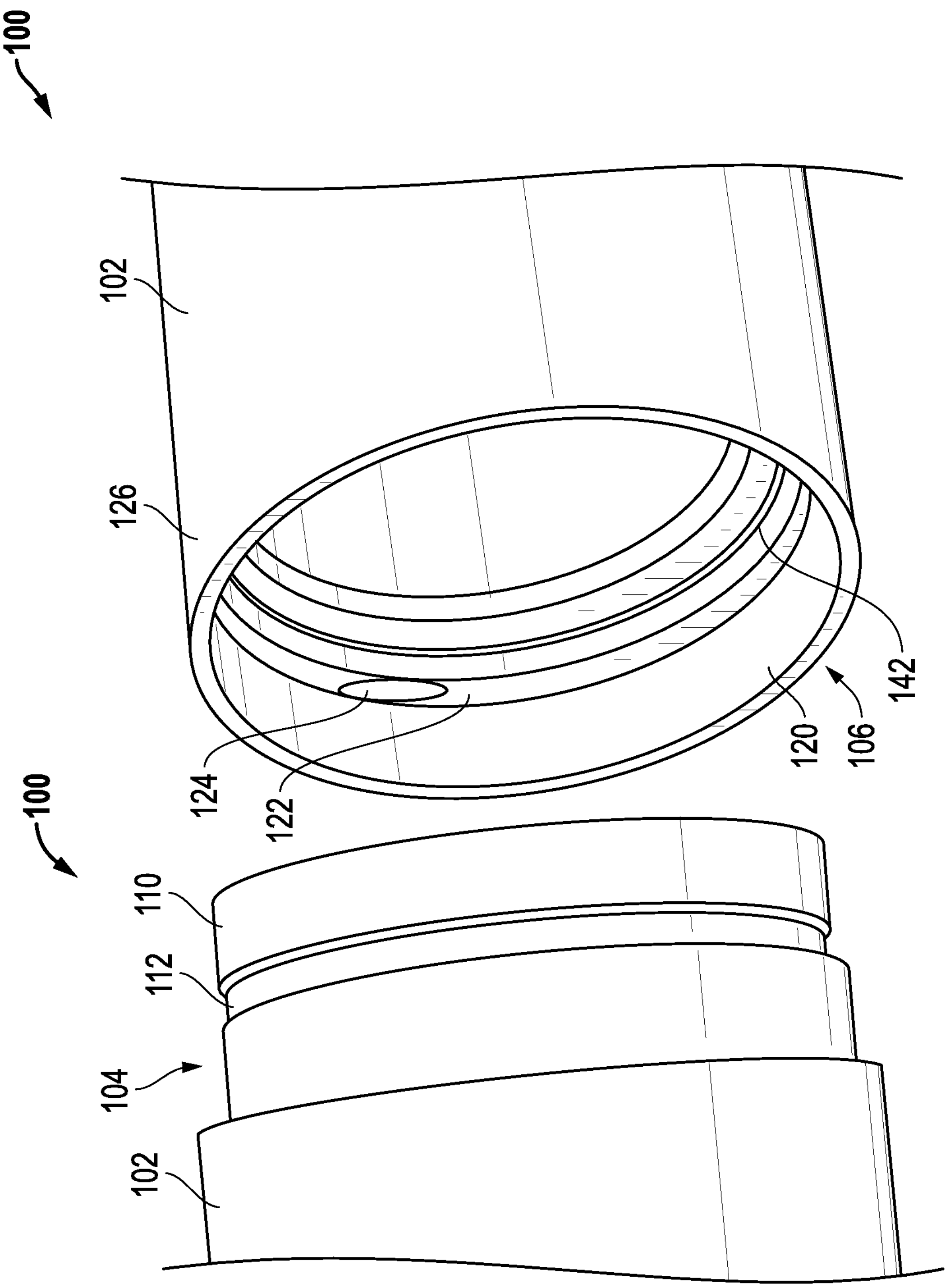


FIG. 8

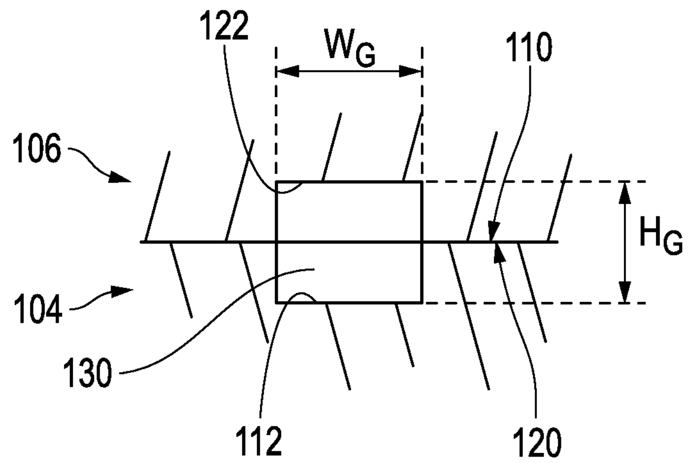
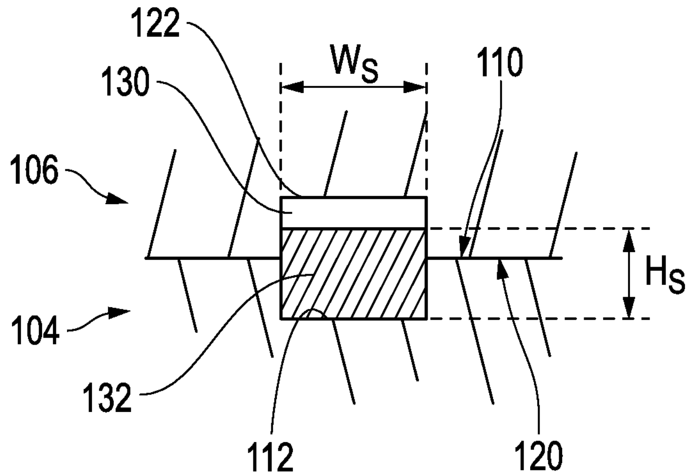

122
W_G
110
106
H_G
104
130
112
120

FIG. 9A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130
W_S
110
106
H_S
104
132
112
120

FIG. 9B

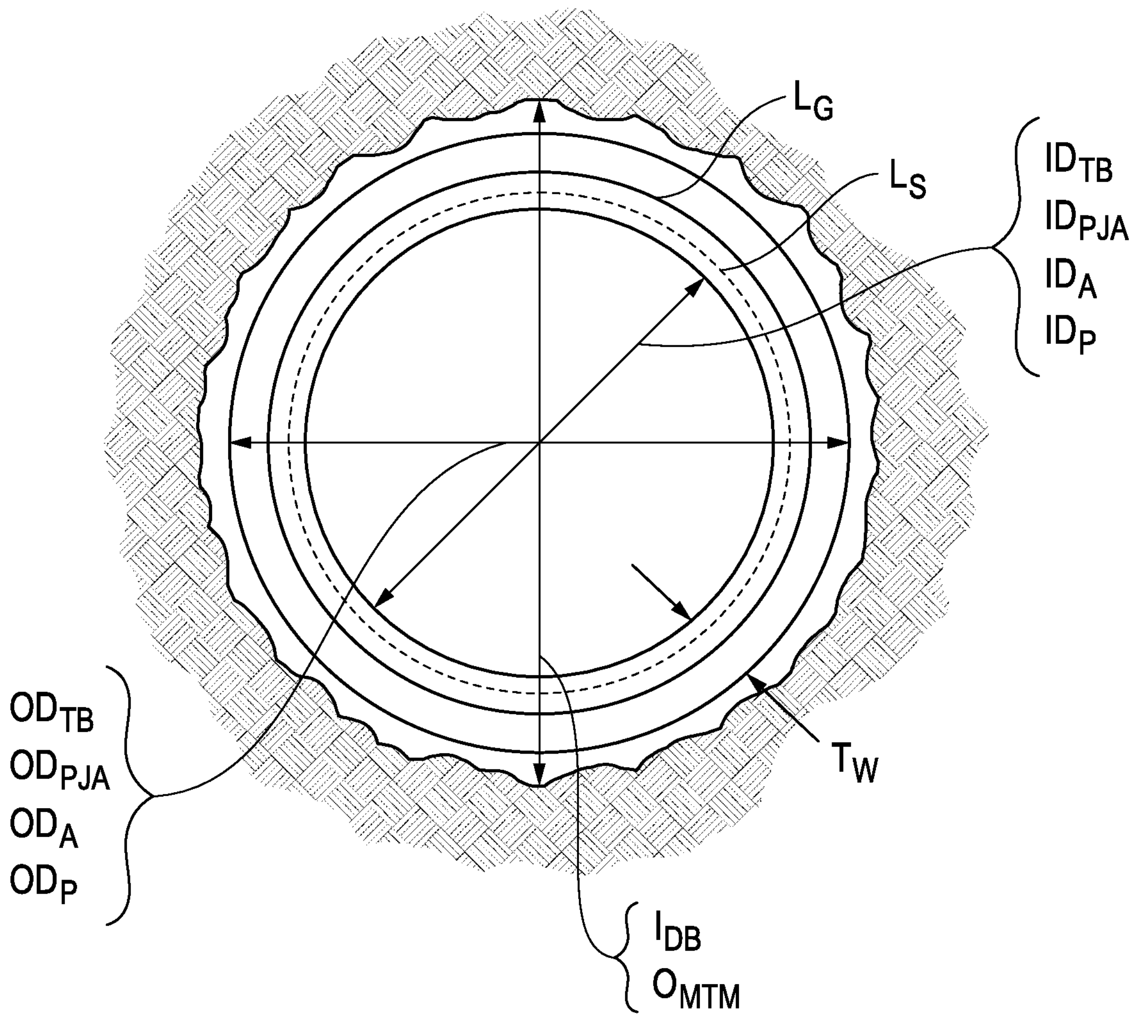

FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/057504

A. CLASSIFICATION OF SUBJECT MATTER

F16L 21/02(2006.01)i, F16L 21/06(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F16L 21/02; F16L 25/00; F16L 21/00; F16L 37/00; F16L 37/14; F16L 21/06

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & keywords: joint, pipe, tubular, engagement, groove, aperture, male, female, and spline

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5255945 A (TOON, DONALD A.) 26 October 1993 See abstract, column 4, line 58 - column 5, line 39; claim 1 and figures 2,6.	1-7,28-29
A	WO 99-40355 A1 (CERTAINTEED CORPORATION) 12 August 1999 See page 4, line 3 - page 5, line 3 and figures 1-2.	1-7,28-29
A	US 2012-0049513 A1 (HERRERA, DEREK F.) 01 March 2012 See paragraph 38 and figure 1.	1-7,28-29
A	US 6739630 B2 (RIEDY, CHARLES H.) 25 May 2004 See column 2, line 53 - column 3, line 8 and figures 3,6.	1-7,28-29
A	US 7108295 B1 (ZARYNOW, JOHN) 19 September 2006 See column 10, line 35 - column 11, line 3 and figures 1-3a.	1-7,28-29

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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

Date of the actual completion of the international search	Date of mailing of the international search report
25 November 2013 (25.11.2013)	**26 November 2013 (26.11.2013)**

Name and mailing address of the ISA/KR
Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-701, Republic of Korea
Facsimile No. +82-42-472-7140

Authorized officer
AHN, Jae Yul
Telephone No. +82-42-481-8525

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/057504

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos.: 9,11,14,16,18-19,25,27,32,38,43,45
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
Claims 9, 11, 14, 16, 18-19, 25, 27, 32, 38, 43 and 45 are unclear, because they refer to multiple dependent claims which do not comply with PCT Rule 6.4(a). (PCT Article 6)

3. ☒ Claims Nos.: 8,10,12-13,15,17,20-24,26,30-31,33-37,39-42,44,46
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required addtional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest
☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/US2013/057504

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5255945 A	26/10/1993	None	
WO 99-40355 A1	12/08/1999	AU 1999-27607 A1	23/08/1999
US 2012-0049513 A1	01/03/2012	GB 201014511 D0	13/10/2010
		GB 201305836 D0	15/05/2013
		GB 2497488 A	12/06/2013
		US 8474879 B2	02/07/2013
		WO 2012-028864 A2	08/03/2012
		WO 2012-028864 A3	26/04/2012
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		CA 2419198 C	08/08/2006
		US 2003-0230896 A1	18/12/2003
US 7108295 B1	19/09/2006	None	