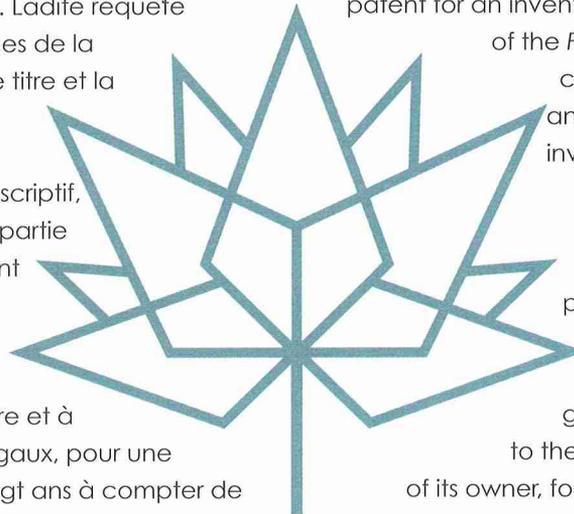




# Brevet canadien / Canadian Patent

Le commissaire aux brevets a reçu une demande de délivrance de brevet visant une invention. Ladite requête satisfait aux exigences de la *Loi sur les brevets*. Le titre et la description de l'invention figurent dans le mémoire descriptif, dont une copie fait partie intégrante du présent document.

Le présent brevet confère à son titulaire et à ses représentants légaux, pour une période expirant vingt ans à compter de la date du dépôt de la demande au Canada, le droit, la faculté et le privilège exclusif de fabriquer, construire, exploiter et vendre à d'autres, pour qu'ils l'exploitent, l'objet de l'invention, sauf jugement en l'espèce rendu par un tribunal compétent, et sous réserve du paiement des taxes périodiques.



**CANADA 150**

The Commissioner of Patents has received a petition for the grant of a patent for an invention. The requirements of the *Patent Act* have been complied with. The title and a description of the invention are contained in the specification, a copy of which forms an integral part of this document.

The present patent grants to its owner and to the legal representatives of its owner, for a term which expires twenty years from the filing date of the application in Canada, the exclusive right, privilege and liberty of making, constructing and using the invention and selling it to others to be used, subject to adjudication before any court of competent jurisdiction, and subject to the payment of maintenance fees.

BREVET CANADIEN	<b>2,863,249</b>	CANADIAN PATENT
Date à laquelle le brevet a été accordé et délivré	<b>2017/07/25</b>	Date on which the patent was granted and issued
Date du dépôt de la demande	<b>2014/09/12</b>	Filing date of the application
Date à laquelle la demande est devenue accessible au public pour consultation	<b>2016/03/12</b>	Date on which the application was made available for public inspection

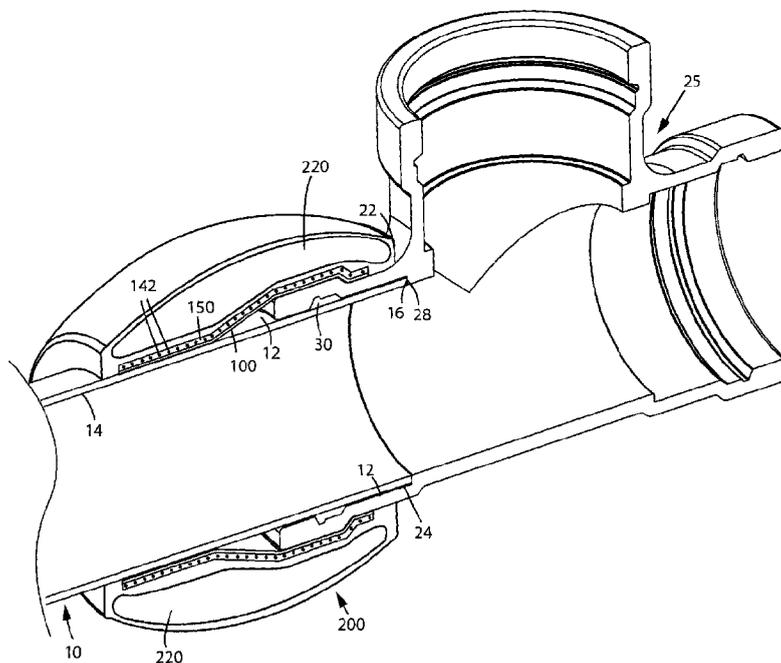
Commissaire aux brevets / Commissioner of Patents



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(54) Titre : APPAREIL DE CONTROLE DE QUALITE DE RACCORD DE TUYAU ET METHODES D'UTILISATION  
(54) Title: PIPE JOINING QUALITY CONTROL APPARATUS AND METHODS OF USE



(57) **Abrégé/Abstract:**

A pipe joining apparatus for joining a first conduit section with a second conduit section wherein a mechanical restraint member extends from an outer surface of the first conduit to an outer surface of the second conduit. The pipe joining apparatus includes: a) at least one of a heat producing member and a pressure applicator; b) a location monitoring member; and, c) a data recorder wherein the data recorder records for a location at which the apparatus is used the at least one of the temperature and pressure applied by the apparatus at the location.

**PIPE JOINING QUALITY CONTROL APPARATUS AND METHODS OF USE****INVENTORS: WAYNE CONRAD AND SCOTT CARD****FIELD**

[0001] This disclosure relates generally to the connection of pipes and fittings that  
5 are used to convey a fluid, and more particularly to a mechanical restraint member to  
secure components of a piping system to each other and methods for joining pipes and  
fittings that involves the application of the mechanical restraint member.

**INTRODUCTION**

[0002] Piping systems are used to convey liquids and/or gasses to, between, or  
10 within, residential, commercial, and/or industrial buildings. For example, most municipalities  
have a piping system for providing potable and/or non-potable water from one or more  
reservoirs, pumping stations, and/or water towers to one or more buildings (e.g. residential,  
commercial, or industrial) and/or other locations (e.g. fire hydrants). Other examples of  
municipal piping systems include sanitary sewers, storm sewers, and the like.

15 [0003] Typically, piping systems are made up of a number of components including  
straight or curved pipe sections, fittings (e.g. elbow fittings, T-junctions, straight connectors  
and the like), valves, etc. to provide an interior flow path for the liquid being conveyed. The  
pipe sections and fittings may be fabricated from concrete, ductile iron, plastics such as  
polyvinyl chloride (PVC), polyethylene or polypropylene, and/or a combination of these  
20 materials. Typically, a piping system (such as a system comprising thermoplastic pipes), is  
assembled such that the components are joined in a manner that provides a durable  
connection that prevents or inhibits the components from separating or cracking due to  
mechanical, thermal, and/or hydraulic stresses applied to the piping system. Separation of  
any of the components of the piping system or cracking of any element of the piping system  
25 may permit fluid to leak out of the piping system and, e.g., thereby damage the surrounding  
structure and/or pollute the ground water.

[0004] Municipal piping systems (e.g. potable water distribution systems) often  
operate with relatively high internal hydraulic pressures and flow rates. When coupling  
components of a piping system together (e.g. two lengths of pipe, a length of pipe to a  
30 fitting or a valve) the joint must resist both forces imposed by the internal hydraulic

pressure of the water (e.g. internal fluid pressure which tends to separate the coupled components) and those forces imposed by a flowing mass of liquid within the piping system when it changes direction. These combined forces tend to both separate the joint and to also force the liquid out of the joint. In addition, the joint must resist external forces that may be applied, such as by movement of the ground in which the piping system is located, e.g., due to settling of the soil and the like.

[0005] Joint architectures in general use include insertion fits, wherein one end of one part of a piping system is inserted into an open end of another part of the piping system. For example, in bell and spigot type couplings, an end of a pipe is inserted into a socket or bell of another pipe that receives the pipe end therein. To capture and hold or restrain the pipe end within the recess, a separate fitting may be used to secure the components of the piping system together. Types of fittings in general use today include push-on joint fittings and mechanical joint fittings.

[0006] A push-on joint fitting is exemplified by U.S. 3,963,298. As disclosed therein, a push-on joint fitting receives a pipe end and frictionally holds the pipe end within a bell of the push-on fitting. In use, a gasket is placed inside the bell in a gasket seat and the pipe is then inserted into the bell past the gasket. A considerable force is typically required to insert the pipe end past the gasket. Accordingly, a jacking mechanism may be attached to the pipe end and the bell in order to force the tapered end of the pipe past the gasket until the pipe bottoms out in the socket. The assembly of push-on fittings can be complicated and time consuming.

[0007] Typically, mechanical joint fittings utilize a flange provided on both components that are to be connected together, e.g., the end of a pipe and a bell of the fitting in which the pipe end is to be inserted. The flanges have axial bolt holes. In use, the pipe end may be inserted into the bell with minimal force until the pipe end bottoms out in the socket. The gasket may then be inserted into the gasket seat of the bell, where it is caulked or pounded into place as necessary. A gland may be brought into position touching the gasket. T-bolts may then be inserted into holes provided in the flanges and then tightened. The bolts are typically tightened in a star pattern. The use of external fittings requires care to ensure that the bolts are tightened to the required degree. A further issue

is that many fittings are installed in a trench, making access to the bolts on the bottom of the joint a problem.

[0008] Once an installation is complete (e.g. a piping system is buried under a road), accessing the piping system to repair a leak is typically time consuming and expensive.

## 5 SUMMARY

[0009] The following introduction is provided to introduce the reader to the more detailed discussion to follow. The introduction is not intended to limit or define any claimed or as yet unclaimed invention. One or more inventions may reside in any combination or sub-combination of the elements or process steps disclosed in any part of this document  
10 including its claims and figures.

[0010] This disclosure sets out methods for joining components of a piping system (e.g. pipes, fittings, and the like) utilizing a mechanical restraint member located directly on the exterior surface of the components that resists axial outward movement of the components. The disclosure also sets out a mechanical restraint member that may be  
15 utilized as well and a pipe securing apparatus that may be used and an apparatus for examining a joint so made.

[0011] In one broad aspect, the mechanical restraint member is positioned on the outer surface of the components so as to extend from one component to the other component to thereby inhibit or prevent axial outward movement of the components.  
20 Accordingly, once two piping system conduits have been joined together, such as by using an insertion fit, a restraint member extending in the axial direction is applied to the outer surface of the conduits to inhibit or prevent the conduits from moving away from each other wherein the restraint member is located essentially at the outer wall of the conduits.

[0012] In accordance with this aspect, the restraint member may be bonded or  
25 chemically adhered to the outer surface of the conduits. An advantage of this design is that a mechanical member is not physically secured to an outer wall of a conduit, such as by wedges that are inserted into an external groove of a pipe, or the like. An axially extending member that is bonded or chemically adhered to the outer surface enables the loading to be applied over a larger surface area and thereby reduces point stresses that may  
30 otherwise occur. Therefore, the area of contact between the restraint member and the

components is greater than in typical designs in common use today. This allows the restraining force to be distributed over a relatively large area, and thereby decreases the high load-per-unit-area on the components of the piping system that may be produced by typical designs in common use today. In particular, the area of contact between typical  
5 mechanical joint fittings and the components being restrained is relatively small (e.g. point contact loads where discrete mechanical fasteners such as wedges and the like press into the outer surface of the pipe). The axial restraint force provided by such typical mechanical joint fittings is transmitted through a relatively small area of the component's surface which may result in localized loading at these points of contact that can be quite high, imposing a  
10 relatively high load-per-unit-area. This requires that the portion of the wall of the conduit on which these point loads are applied have sufficient structural integrity to absorb the axial stresses so that a fluid tight seal is maintained at the joint. In addition, the point loads may also impose a relatively high inward radial stress on the wall of the component, in addition to the axial stresses resulting from the restraining forces being transferred to the  
15 components by the mechanical joint fittings.

[0013] Another advantage of this design is that the restraint member is radially located at (or directly adjacent) the position at which the outward axial forces (e.g., the hydrostatic pressure internal of the piping system once in use) are applied. In contrast, typical mechanical joint fittings use flanges or collars through which bolts to secure the  
20 components together. These bolts are located radially outwardly of the pipe as they are inserted into flanges that are applied to the components. Therefore, the axial restraint force provided by the bolts is transmitted radially inwardly by the flanges to the components. One problem with this design is that localized angular point loading is applied at the juncture of the flange and the axial wall of the component. In particular, a moment arm is created by  
25 the flange, and the wall of the component must be design to withstand the increased stress produced by the moment arm.

[0014] Another advantage of this design is that the restraint member does not mechanically penetrate the wall of the components being restrained. In contrast, typical mechanical joint fittings use mechanical attachment means that are inserted into grooves  
30 provided in the outer wall of the piping system component, or may otherwise penetrate at least a portion of the outer wall. One problem that this may create is that the effective

thickness of the wall of the piping system component is decreased, which leads to the component having a lower strength.

[0015] In accordance with this aspect, the restraint member may be bonded or chemically adhered to the outer surface of the conduits. An advantage of this design is that a mechanical member is not physically secured to an outer wall of a conduit, such as by wedges that are inserted into an external groove of a pipe, of the like. An axially extending member that is bonded or chemically adhered to the outer surface enables the loading to be applied over a larger surface area and thereby reduces point stresses that may otherwise occur.

10 [0016] Various types of mechanical restraint members may be used. Generally, a mechanical restraint member comprises a flexible substrate bonded by a bonding agent to the outer surface of each of the piping system components that are used to form a joint. The bonding agent may be selected based on the composition of the substrate and the components that are to be joined together. It will be appreciated that the type of flexible substrate and/or the type and amount of bonding agent used to secure a joint may vary, depending on the requirements of the joint to be restrained. For example, a mechanical restraint member may be provided around most or substantially all of the outer perimeter of the joint being restrained. Alternatively, the mechanical restraint member may only be applied to a portion of the perimeter of the joint. For example, multiple mechanical restraint members that are spaced apart may be applied around a joint.

25 [0017] In one embodiment, a mechanical restraint member suitable for use with a plastic piping system such as a thermoplastic piping system may comprise a woven or non-woven synthetic-fiber substrate, such as fiberglass or carbon fiber, bonded to the piping system components using a thermally activated bonding agent, such as a thermoplastic or thermoset resin.

[0018] The bonding agent may be any composition that may chemically secure the flexible substrate to a component of the piping system. The bonding agent may be in the nature of an adhesive (which may be a thermally activated or solvent based adhesive) or the same material or a material that is compatible with, the material from which the components are made. For example, if the components that are to be joined together are

made of polyvinylchloride (PVC), then the bonding agent may be PVC or a compatible plastic. Accordingly once the outer wall of the component and the bonding agent are heated, the PVC may blend together to form a unitary assembly (the substrate, the bonding agent and the component) once the PVC cools and solidifies. It will be appreciated that the method used to activate the bonding agent will vary depending upon the nature of the bonding agent.

[0019] It will be appreciated that if the components that are to be joined together are made of different materials, then the flexible substrate may contain two or more different bonding agents. For example, considered in the axial direction, one half may have a bonding agent suitable for the first component to which it will be applied and the other half may have a different bonding agent suitable for the second component to which it will be applied.

[0020] The mechanical restraint members described herein may be applied to a connected, but unrestrained joint in a piping system by wrapping or otherwise positioning a sheet or sheets of the flexible substrate comprising the bonding agent about the joint to be restrained, and then applying both heat (to activate the bonding agent) and pressure (to promote a good bond) to the sheet or sheets until the bonding agent has sufficiently cured.

[0021] In one method of application, a pressure cuff which may have an integrated heating element may be wrapped around the joint once the sheet(s) of flexible substrate are in position, and the pressure cuff may automatically apply the proper amount of temperature and pressure to provide a good quality bond.

[0022] An advantage over traditional methods of restraining piping system components is that by chemically – as opposed to mechanically – bonding the mechanical restraint member to the piping system components, the risk of deformation, cracking, or other structural damage to the piping system components during installation are significantly reduced (if not eliminated).

[0023] Another advantage is that since the area of bonded contact of mechanical restraint member with the piping system components will generally be much greater than in traditional methods, known structural issues relating to e.g. point loading may be alleviated or eliminated.

[0024] The mechanical restraint member may be used with piping system components may be made of concrete, metal, or plastic materials known in the piping arts. The plastic material may be a thermoplastic material and may be one or more of acrylonitrile butadiene styrene (ABS), PVC, chlorinated PVC (CPVC), ethylene vinyl acetate (EVA), polyethylene (PE), and the like. Preferred materials comprise PVC and/or CPVC.

[0025] In accordance with one broad aspect, there is provided a pipe joining apparatus for joining a first conduit section with a second conduit section wherein a mechanical restraint member extends from an outer surface of the first conduit to an outer surface of the second conduit, the pipe joining apparatus comprising: a) at least one of a heat producing member and a pressure applicator; b) a location monitoring member; and, c) a data recorder wherein the data recorder records for a location at which the apparatus is used the at least one of the temperature and pressure applied by the apparatus at the location.

[0026] In some embodiments, the apparatus applies at least heat or pressure for a period of time at the location and the data recorder records a duration of the period of time at the location.

[0027] In some embodiments, the apparatus comprises both a heat producing member and a pressure applicator.

[0028] In some embodiments, the apparatus applies both heat for a first period of time at the location and pressure for a second period of time at the location and the data recorder records a duration of the first and second periods of time at the location.

[0029] In some embodiments, the pressure comprises an inflatable member.

[0030] In some embodiments, the inflatable member comprises an inflatable annular member.

[0031] In some embodiments, the heat producing member comprises at least one of a resistive heating member, an exothermic reactive composition, an infrared producing member and a microwave producing member.

[0032] In some embodiments, the location monitoring member comprises a GPS locator.

[0033] In some embodiments, the apparatus comprises a body containing the at least one of a heat producing member and a pressure applicator and the location  
5 monitoring member and the body also contains the data recorder.

[0034] In some embodiments, the apparatus comprises a body containing the at least one of a heat producing member and a pressure applicator and the location monitoring member and the data recorder is located remote from the body.

[0035] In some embodiments, the body further comprises a transmitter whereby data  
10 is transmitted to the remotely located data recorder.

[0036] In some embodiments, the mechanical restraint member changes colour when a sufficient amount of heat has been applied to secure the mechanical restraint member to the conduits and the apparatus further comprises a colour sensor.

[0037] In some embodiments, the apparatus further comprises a signaling device  
15 and the signaling device produces a signal when the colour sensor fails to detect a predetermined colour.

[0038] In accordance with another broad aspect, there is provided a method of joining a first conduit section with a second conduit section wherein a mechanical restraint member is used that extends from an outer surface of the first conduit to an outer surface  
20 of the second conduit, the method comprising: a) applying at least one of heat and pressure at a location; and, b) recording at least one of the temperature and pressure applied at the location.

[0039] In some embodiments, the method further comprises recording a length of time during which the at least one of heat and pressure is applied at the location.

[0040] In some embodiments, the method further comprises: a) applying both heat  
25 and pressure at the location; and, b) recording both the temperature and pressure applied at the location.

[0041] In some embodiments, the method further comprises recording a length of time during which each of heat and pressure is applied at the location.

[0042] In some embodiments, the mechanical restraint member comprises a colour change member that changes colour when a sufficient amount of heat has been applied to secure the mechanical restraint member to the conduits and the method further comprises sensing the colour of the mechanical restraint member after the heat and pressure have been applied at the location.

[0043] In some embodiments, the method further comprises issuing a signal if a predetermined colour is not sensed after the heat and pressure have been applied at the location.

[0044] In some embodiments, a body comprises a transmitter and at least one of a heat producing member and a pressure applicator, and the method further comprises transmitting the heat and/or pressure applied at the location to a remotely located recorder

[0045] It will be appreciated by a person skilled in the art that a method or apparatus disclosed herein may embody any one or more of the features contained herein and that the features may be used in any particular combination or sub-combination.

[0046] These and other aspects and features of various embodiments will be described in greater detail below. The apparatus and methods described herein may be used to connect pipes and/or fittings of various materials (e.g. metallic pipes, thermoplastic pipes) to create piping systems for transporting various liquids or gasses. It will be appreciated that the piping system that uses the restraint member may be made from different materials (e.g., the pipes may be made of PVC and/or CPVC and the fittings may be made of metal). Alternatively, the piping system components (or at least their inner surfaces through which fluid is conveyed) may be made of the same material.

[0047] Furthermore, the apparatus and methods may be applied to different sizes of piping, and/or piping systems made of the same or different materials, and therefore may be applicable to piping systems for domestic or commercial uses, such as conveying potable water, non-potable or waste water, or other liquids and/or gasses.

#### **BRIEF DESCRIPTION OF THE DRAWINGS**

[0048] For a better understanding of the described embodiments and to show more clearly how they may be carried into effect, reference will now be made, by way of example, to the accompanying drawings in which:

[0049] Figure 1a is a perspective view of a pipe end positioned for installation within a T-fitting as is known in the prior art;

[0050] Figure 1b is a perspective view of a pipe end positioned for installation within a straight conduit as is known in the prior art;

5 [0051] Figure 1c is a perspective view of a pipe end positioned for installation within an elbow joint as is known in the prior art;

[0052] Figure 2 is a perspective cross-section view of Figure 1;

[0053] Figure 3 is a perspective cross-section view of the pipe end and T-fitting of Figure 1, with the pipe end inserted into the T-fitting;

10 [0054] Figure 4 is a perspective view of the pipe end and T-fitting of Figure 3 secured using a traditional bolt-on collar;

[0055] Figure 5 is a cross-section view of Figure 4;

[0056] Figure 6 is a perspective view of the pipe end and T-fitting of Figure 3 secured with a mechanical restraint member in accordance with one embodiment of this  
15 disclosure;

[0057] Figure 7 is a perspective cross-section view of Figure 6;

[0058] Figure 8 is a perspective view of the pipe end and T-fitting of Figure 3 secured with two or more mechanical restraint members in accordance with another embodiment;

20 [0059] Figure 9 is a perspective cross-section view of Figure 8;

[0060] Figure 10 is a cross-section view of a pipe end and a fitting secured in accordance with another embodiment, with a transition collar positioned at the end face of the fitting;

[0061] Figure 11 is a cross-section view of a pipe end and a fitting secured in  
25 accordance with one embodiment, where the end face of the fitting is beveled;

[0062] Figure 12 is a cross-section view of a mechanical restraint member bonded to a pipe surface in accordance with one embodiment;

[0063] Figure 13 is a cross-section view of another a mechanical restraint member with an outer protective layer bonded to a pipe surface;

[0064] Figure 14 is a cross-section view of another embodiment of a mechanical restraint member with an outer protective layer bonded to a pipe surface;

5 [0065] Figure 15 is a cross-section view of another embodiment of a mechanical restraint member with an embedded heating element bonded to a pipe surface;

[0066] Figure 16 is a perspective cross-section view of the pipe end and T-fitting of Figure 3, with a flexible substrate being wrapped around the joint in accordance with one embodiment;

10 [0067] Figure 17 is a perspective cross-section view of the pipe end and T-fitting of Figure 3, with the flexible substrate of Figure 16 and a pressure cuff wrapped around the joint in accordance with one embodiment, wherein the pressure cuff is in an un-inflated state;

[0068] Figure 18 is a perspective cross-section view of Figure 17, with the pressure  
15 cuff in an inflated state;

[0069] Figure 19 is a perspective cross-section view of the pipe end and T-fitting of Figure 3, with a flexible substrate wrapped around the joint, the flexible substrate having an embedded resistive heating element in accordance with another embodiment;

[0070] Figure 20 is a perspective cross-section view of the pipe end and T-fitting of  
20 Figure 3, with the flexible substrate of Figure 19 and a pressure cuff wrapped around the joint in accordance with another embodiment, wherein the pressure cuff is in an un-inflated state;

[0071] Figure 21 is a perspective cross-section view of Figure 20, with the pressure cuff in an inflated state;

25 [0072] Figure 22 is a perspective cross-section view of the pipe end and T-fitting of Figure 3, with the flexible substrate of Figure 16 wrapped around the joint, and with a heating blanket being wrapped around the joint and the flexible substrate in accordance with another embodiment;

[0073] Figure 23 is a perspective cross-section view of the pipe end and T-fitting of Figure 3, with the flexible substrate and heating blanket of Figure 22 and a pressure cuff wrapped around the joint in accordance with another embodiment, wherein the pressure cuff is in an un-inflated state;

5 [0074] Figure 24 is a perspective cross-section view of Figure 23, with the pressure cuff in an inflated state;

[0075] Figure 25 is a perspective cross-section view of the pipe end and T-fitting of Figure 3, with the flexible substrate of Figure 16 wrapped around the joint, and with a heat shrink being wrapped around the joint and the flexible substrate in accordance with another  
10 embodiment;

[0076] Figure 26 is a perspective cross-section view of the pipe end and T-fitting of Figure 3, with the flexible substrate and heat shrink of Figure 25 and a pressure cuff wrapped around the joint in accordance with another embodiment, wherein the pressure cuff is in an un-inflated state;

15 [0077] Figure 27 is a perspective cross-section view of Figure 28;

[0078] Figure 28 is a perspective view of the pipe end and T-fitting of Figure 3 secured with a mechanical restraint member in accordance with another embodiment;

[0079] Figure 29 is a perspective cross-section view of the pipe end and T-fitting of Figure 3, with the flexible substrate and heat shrink of Figure 25 wrapped around the joint,  
20 and with a heating blanket wrapped around the heat shrink in accordance with another embodiment;

[0080] Figure 30 is a perspective cross-section view of the pipe end and T-fitting of Figure 3, with the flexible substrate, heat shrink, and heating blanket of Figure 29 and a pressure cuff wrapped around the joint, wherein the pressure cuff is in an un-inflated state;

25 [0081] Figure 31 is a perspective cross-section view of Figure 30, with the pressure cuff in an inflated state;

[0082] Figure 32 is a perspective cross-section view of the pipe end and T-fitting of Figure 3, with two layers of flexible substrate and a heat shrink being around the joint, and

a pressure cuff wrapped around the joint and in an inflated state in accordance with another embodiment;

[0083] Figure 33 is a perspective view of a sheet of flexible substrate with a first bonding agent applied to substantially all of the sheet in accordance with an embodiment;

5 [0084] Figure 34 is a perspective view of the sheet of flexible substrate of Figure 33, with strips of a temporary adhesive applied to the bonding agent in accordance with another embodiment;

[0085] Figure 35 is a perspective view of the sheet of flexible substrate of Figure 33, with a second bonding agent applied around the first bonding agent in accordance with  
10 another embodiment;

[0086] Figure 36 is a perspective view of a sheet of flexible substrate with a first bonding agent applied in discrete strips in accordance with another embodiment

[0087] Figure 37 is a perspective view of the sheet of flexible substrate of Figure 36, with a second bonding agent applied around the first bonding agent in accordance with  
15 another embodiment;

[0088] Figure 38 is a perspective view of a sheet of flexible substrate with a first bonding agent applied in a pattern of discontinuous dots in accordance with another embodiment;

[0089] Figure 39 is an end-section of a pipe end with the sheet of flexible substrate  
20 of Figure 33 bonded to the pipe end in accordance with another embodiment;

[0090] Figure 40 is an end-section of a pipe end with the sheet of flexible substrate of Figure 36 bonded to the pipe end in accordance with another embodiment;

[0091] Figure 41a is a top view of a sheet of the flexible substrate of Figure 36, with a plurality of cutouts provided at each end, in accordance with another embodiment;

25 [0092] Figure 41b is an end-section of a pipe end with the sheet of flexible substrate of Figure 41a bonded to the pipe end in accordance with another embodiment;

[0093] Figure 42 is a side view of a flexible substrate with an oriented component aligned with a pipe end and a fitting in accordance with another embodiment;

[0094] Figure 43 is a perspective view of the pipe end and T-fitting of Figure 3 secured with a mechanical restraint member, the mechanical restraint member having a visual pattern of thermochromic material in accordance with another embodiment;

[0095] Figure 44 is a schematic cross-section view of a pipe end and a fitting  
5 secured in accordance with another embodiment;

[0096] Figure 45 is a schematic cross-section view of a pipe end and a fitting being secured with an mechanical restraint member using a bonding apparatus in accordance with another embodiment;

[0097] Figure 46 is a perspective view of a pipe end and T-fitting, with the flexible  
10 substrate of Figure 16 wrapped around the joint, and a pipe securing apparatus in accordance with one embodiment;

[0098] Figure 47 is a perspective view of the pipe end and T-fitting of Figure 46, with the pipe securing apparatus positioned over the flexible substrate wherein the pipe securing apparatus is in an un-inflated state;

[0099] Figure 48 is a perspective view of the pipe end and T-fitting of Figure 46, with  
15 the pipe securing apparatus positioned over the flexible substrate wherein the pipe securing apparatus is in an inflated state;

[00100] Figure 49 is a perspective view of a pipe end and T-fitting, with the flexible  
20 substrate of Figure 16 wrapped around the joint, and a pipe securing apparatus in accordance with another embodiment;

[00101] Figure 50 is a perspective view of the pipe end and T-fitting of Figure 49, with the pipe securing apparatus wrapped around the flexible substrate and coupled to itself;

[00102] Figure 51 is a perspective cross-section view of the pipe end and T-fitting of  
25 Figure 3, with the flexible substrate of Figure 16 and a pipe securing apparatus wrapped around the joint, with the pipe securing apparatus coupled to a source of pressure and to a source of power in accordance with one embodiment, wherein the pipe securing apparatus is in an un-inflated state;

[00103] Figure 52 is a perspective cross-section view of Figure 51, with the pipe  
securing apparatus in an inflated state;

- [00104] Figure 53 is a perspective cross-section view of the pipe end and T-fitting of Figure 3, with the flexible substrate of Figure 16 and a pipe securing apparatus wrapped around the joint, the pipe securing apparatus having a plurality of infrared energy sources in accordance with another embodiment;
- 5 [00105] Figure 54 is a perspective cross-section view of the pipe end and T-fitting of Figure 3, with the flexible substrate of Figure 16 and a pipe securing apparatus wrapped around the joint, the pipe securing apparatus having a plurality of microwave energy sources in accordance with another embodiment;
- [00106] Figure 55 is a perspective cross-section view of the pipe end and T-fitting of  
10 Figure 3, with the flexible substrate of Figure 19 and a pipe securing apparatus wrapped around the joint in accordance with another embodiment, wherein heating element in the flexible substrate is coupled to a power source via the pipe securing apparatus;
- [00107] Figure 56 is a perspective view of a pipe end and T-fitting, with the flexible  
15 substrate of Figure 16 wrapped around the joint, and a pipe securing apparatus with a quality control module in accordance with another embodiment;
- [00108] Figure 57 is a perspective view of the pipe end and T-fitting of Figure 56, with the pipe securing apparatus wrapped around the flexible substrate and coupled to itself, with the pipe securing apparatus coupled to a source of pressure and to a source of power in accordance with one embodiment;
- 20 [00109] Figure 58 is an end view of Figure 57, viewed along the axis of the joined conduits;
- [00110] Figure 59 is a cross-section view of the pipe end and T-fitting of Figure 3, with the flexible substrate of Figure 16 and pipe securing apparatus of Figure 56 wrapped around the joint;
- 25 [00111] Figure 60 is a schematic block diagram of control electronics for a pipe securing apparatus with a quality control module in accordance with at least one embodiment; and,

[00112] Figure 61 is a flow diagram illustrating a sequence of events for using a pipe securing apparatus with a quality control module to apply a mechanical restraint member in accordance with at least one embodiment.

[00113] The drawings included herewith are for illustrating various examples of articles, methods, and apparatuses of the teaching of the present specification and are not intended to limit the scope of what is taught in any way.

#### **DESCRIPTION OF EXAMPLE EMBODIMENTS**

[00114] Various apparatuses, methods and compositions are described below to provide an example of an embodiment of each claimed invention. No embodiment described below limits any claimed invention and any claimed invention may cover apparatuses and methods that differ from those described below. The claimed inventions are not limited to apparatuses, methods and compositions having all of the features of any one apparatus, method or composition described below or to features common to multiple or all of the apparatuses, methods or compositions described below. It is possible that an apparatus, method or composition described below is not an embodiment of any claimed invention. Any invention disclosed in an apparatus, method or composition described below that is not claimed in this document may be the subject matter of another protective instrument, for example, a continuing patent application, and the applicant(s), inventor(s) and/or owner(s) do not intend to abandon, disclaim, or dedicate to the public any such invention by its disclosure in this document.

[00115] The apparatuses, methods and compositions may be used with piping systems made of various materials. The piping system components, e.g. the pipes and/or fittings to be connected, may be made of concrete, fiberglass, a metal such as cast iron, steel, copper, stainless steel, titanium, zirconium and the like, and/or a plastic material (including a thermoplastic material), such as polypropylene, polystyrene, nylon, polycarbonate, acrylonitrile butadiene styrene (ABS), PVC, CPVC, ethylene vinyl acetate (EVA), polyethylene (PE), high density polyethylene, ultrahigh molecular weight polyethylene or the like. In one particular embodiment, the piping system components are made of plastic. In one particular embodiment, the plastic is a thermoplastic material.

[00116] The drawings exemplify the use of the restraint member to connect a section of pipe to a T-junction. It will be appreciated that the same restraint member may be used to connect any parts of a piping system together. For example, the restraint member may be used to connect two sections of pipe to each other, to connect a pipe with a fitting such as a valve, tees, couplers, elbows and the like, or to connect one fitting with another fitting.

[00117] The drawings exemplify the use of the restraint member with piping system components that are engaged using an insertion fit. It will be appreciated that other engagement systems, such as a butt joint, may be used

### **Typical Mechanical Joint Fitting**

10 [00118] Figures 1a to 3 illustrate an insertion fit, i.e., one end of one part of a piping system (e.g. pipe 10) is inserted into an open end of another part of the piping system (e.g. fitting 25). As exemplified, end 16 of the pipe 10 is inserted into opening 20 of fitting 25, which may be a T-junction as exemplified in Figure 1a, a straight conduit as exemplified in Figure 1b, an elbow joint as exemplified in Figure 1c, or any other fitting.

15 [00119] Preferably, pipe end 16 and opening 20 are dimensioned so that there is sufficient clearance between the outer surface 12 of pipe end 10 and the inner surface 24 of opening 20 to allow the pipe end to be inserted without requiring the application of undue axial force to pipe 10 and/or fitting 25. Typically clearances are provided in the American Society for Testing and Materials (ASTM) standards.

20 [00120] One or more annular gaskets 30 (e.g. O-rings) may be provided between outer surface 12 of pipe 10 and inner surface 24 of opening 20 to ensure a fluid-tight seal is provided. As shown in Figures 2 and 3, an annular groove 23 may be provided on inner surface 24 of opening 20 to receive gasket 30 and to restrain the axial movement of gasket 30 during insertion of pipe 10. It will be appreciated that other alternative configurations for providing a gasket between pipe 10 and fitting 25 may be used. For example, a groove or other surface feature may be provided on the outer surface 12 of pipe 10, and gasket 30 may be positioned around pipe 10 prior to its insertion into opening 20.

[00121] Fitting 25 may be configured such that an end 16 of a pipe 10 may be inserted only up to a predetermined distance into fitting 25. This may assist in aligning one or more features (e.g. grooves, gaskets) of the fitting and/or the pipe end with each other.

Therefore, a stop member may be provided inside fitting 25. For example, as exemplified in Figure 2, in some embodiments fitting 25 may comprise an interior ridge 28 that provides an abutment surface against which a pipe end inserted into opening 20 will abut when inserted a predetermined distance, to assist in coupling fitting 25 to a pipe end, as shown in Figure 3. It will be appreciated that interior ridge 28 may have a height that is similar to or the same as the thickness of the pipe 10 inserted into opening 20. Accordingly, the cross sectional area of flow through the pipe and the fitting is generally the same.

[00122] If a liquid at a sufficiently high internal hydraulic pressures and/or sufficiently high flow rates is conveyed through pipe 10 and fitting 25, the joint must resist both forces imposed by the internal hydraulic pressure of the liquid (e.g. internal fluid pressure which tends to separate the coupled components) and those forces imposed by a flowing mass of liquid within the piping system when it changes direction. These combined forces tend to both separate the joint and to also force the liquid out of the joint. Thus, the components of the piping system (e.g. pipe 10 and fitting 25) should be restrained relative to each other to prevent their separation, and to maintain the integrity of the joint.

[00123] Figures 4 and 5 exemplify a mechanical joint fitting apparatus 40 for securing two components of a piping system, according to a known method. Generally, a ring-shaped member 41, 42 is secured to each of the components (in this case fitting 25 and pipe 10, respectively), and then the ring-shaped-members are secured to each other to prevent the piping system components from separating.

[00124] In the illustrated example, ring-shaped member 41 is formed by securing two semi-circular portions 41a, 41b to each other about fitting 25 using one or more fastener 43, while ring-shaped member 42 is a unitary ring that is slid over pipe 10. The ring-shaped members 41, 42 are secured to fitting 25 and pipe 10, respectively, using a plurality of fasteners 44. Grooves or other recesses may be present on the outer surfaces 22, 12 of the fitting 25 and pipe 10, respectively at the points of contact 46 between the fasteners 44 and the piping system components. It will be appreciated that ring-shaped members 41, 42 may be flanges that are integrally formed with fitting 25 and pipe 10. Finally, bolts 48 and nuts 49 are used to restrain the relative position of the ring-shaped members 41, 42 to each other, and thus secure the relative position of pipe 10 and fitting 25.

[00125] While such an apparatus may be effective in securing the pipe and fitting (i.e. restraining the components from being separated), such an apparatus (and/or its method of installation) may have one or more disadvantages as discussed previously.

### **Construction of a Mechanical Restraint Member**

5 [00126] Reference is now made to Figures 6 to 15, which exemplify different embodiments of a mechanical restraint member 100, each of which may be made by (or used with) the methods disclosed herein. Mechanical restraint member 100 may be used by itself or with one or more of: the application method, the pipe securing apparatus 200, and the quality control module 300 disclosed herein.

10 [00127] Mechanical restraint member 100 includes a flexible substrate, referred to generally as 110, and a bonding agent 120 for securing the flexible substrate 110 to components of the piping system that are to be secured to each other (i.e. restrained from separating), as will be discussed further subsequently.

[00128] Flexible substrate 110 may be made from any suitable material that has  
15 sufficient tensile strength to restrain the piping system components from separating due the anticipated outward axial forces imposed during operation of the piping system. For example, the tensile strength of flexible substrate 110 should be at least equal to the expected load (e.g. the total expected static and dynamic pressure in the piping system during operation of the piping system, multiplied by the internal cross sectional pipe area).  
20 Preferably, the tensile strength of flexible substrate 110 is between 1 to 5, 1.5 to 5, 1 to 1.5, or 3 to 5 times the expected load, to provide an acceptable safety margin.

[00129] It will be appreciated that the flexible substrate may be made of one or more  
25 of metal (e.g. a metal foil, a sheet of perforated metal, a metal mesh, and the like), a woven fabric, and a non-woven fabric. The woven fabric and non-woven fabrics may comprise a natural or synthetic fiber.

[00130] If the flexible substrate is made of a solid member, e.g., a sheet of metal, then  
the sheet may be perforated so as to provide openings through which the bonding agent  
may pass. Accordingly, the perforations or other openings provide locations through which  
the bonding agent may flow so as to increase the axial loads that may be restrained by the  
30 restraint member. For example, the bonding agent may flow through the openings and

surround or encase both axially extending sides of the sheet, thereby essentially immersing the sheet in the bonding agent. Once the bonding agent solidifies (e.g. sets) or cures, the bonding agent may be secured to both axially extending sides of the sheet and also provide a solid member that extends through the openings to provide an additional portion that  
5 inhibits axial movement.

[00131] Alternatively, the flexible substrate may be porous, such as a porous material or a mesh material (e.g., woven metal wires or fibers, a plastic mesh, or the like). Once again, the bonding agent may flow through the pores or openings provided in the material.

[00132] In some cases, the bonding agent may not be able to flow through the  
10 substrate (e.g., the substrate is solid, or may have pores or openings that are too small to permit the bonding agent to enter into the substrate). In such a case, the adhesion between the inner surface of the substrate and the bonding agent provides the required mechanical strength to enable the mechanical restraint member to function.

[00133] If flexible substrate 110 is provided as a woven fabric, the weave may or may  
15 not have an oriented component to provide enhanced tensile strength of the flexible substrate 110 in one or more directions. This would allow the flexible substrate 110 to be bonded to the joint with a direction of relatively high strength aligned with the direction of the highest expected loading. For example, as illustrated in Figure 42, flexible substrate 110 may have a first linear density, or linear mass density,  $LD_r$  in the radial direction, and a  
20 second linear density, or linear mass density,  $LD_a$  in the axial direction. This would allow the flexible substrate 110 to be bonded to the joint with a direction of relatively high strength (e.g. higher linear density) aligned with the direction of the highest expected loading (e.g. axially).

[00134] Examples of suitable materials include metals (e.g., steel, stainless steel,  
25 aluminum, brass, copper, and the like), fiberglass (e.g. E-glass, S-glass, E-CR-glass), carbon fiber, aramid fiber (e.g. Kevlar™, Twaron), ultra-high-molecular-weight polyethylene (UHMWPE) (e.g. Spectra®, Dyneema®), polycarbonate, polypropylene, polyethylene, PVC, CPVC, Teflon™, and the like.

[00135] The fabric may have a thickness that provides sufficient tensile strength  
30 based on the expected loading, while maintaining sufficient flexibility. For example, if the

flexible substrate 110 comprises S-glass, it may have a weight density in the range of 9-64 oz/ft<sup>2</sup>, or 18-36 oz/ft<sup>2</sup>.

[00136] Flexible substrate 110 is provided with a first bonding agent 120. The bonding agent may be applied to a surface of the flexible substrate or it may be impregnated therein. The bonding agent comprises a chemical or thermal bonding agent that is compatible with the first and second conduits.

[00137] Bonding agent 120 may be a thermoplastic or a thermoset material, such as polyurethanes (PUR), or reactive urethanes, polyesters, polyacrylates, methyl acrylates (solvented or unsolvented), latex-based, or gelatin-based adhesives.

[00138] Bonding agent 120 may be a thermally activated bonding agent. Such bonding agents may be a plastic (e.g. a thermoplastic or a thermoset material). Accordingly, the bonding agent may be a plastic that will melt, at least partially, and adhere to the respective conduit. Accordingly, a thermally activated bonding agent may have the same composition as the conduit. Alternatively, it may be an adhesive that is activated when heated so as to adhere to the conduit. The bonding agent may comprise a thermal plastic urethane. Testing using the Polyurethane Reactive (PUR) EZ 250150 adhesive available from 3M showed acceptable performance.

[00139] Bonding agent 120 may alternatively be a chemically activated bonding agent (e.g. a multi-component adhesive that forms an adhesive when the components are combined), such as polyester resin / polyurethane resin, polyols / polyurethane resin, and acrylic polymers / polyurethane resin combinations, and the like.

[00140] It will be appreciated that some bonding agents may be activated or catalyzed at least partly by modes other than thermal or chemical activation (e.g. at room temperature). For example, bonding agent 120 may be a light curing adhesive, such as a UV curing adhesive, or a moisture curing adhesive, which may begin to cure in the presence of moist air. Accordingly, bonding agent 120 may be applied to flexible substrate 110 in a controlled environment, such as a dry air environment, and packaged in a moisture and/or light impermeable container, such as a sealed foil bag. Flexible substrate 110 may be transported and stored in such packaging, and only removed shortly or immediately before use. For example, the bonding agent may be activated by exposure to the ambient.

For example, the bonding agent may be a solvent based adhesive which bonds to the conduit when the solvent evaporates. In such a case, the bonding agent may be maintained in an air tight container until use.

[00141] Bonding agent 120 may be provided as a thin layer of material. For example, bonding agent 120 may have a thickness of from 0.002 to 0.250 inches, more preferably from 0.005 to 0.080 inches, more preferably from 0.010 to 0.040 inches, and most preferably from 0.015 to 0.025 inches. An advantage of this design is that a relatively small amount of heat may be required to melt or activate the bonding agent and accordingly only the outer portion of the wall of the conduit may be melted.

[00142] In some embodiments, bonding agent 120 may have a melting or activation temperature that is proximate that, and optionally less than, the melting temperature of the conduit to which it is applied. For example, the bonding agent may have a melting or activation temperature that is approximately equal to, or from 100% to 110%, from 100% to 105%, or from 100% to 102% of the melting temperature of the conduit to which it is to be attached (wherein the percentage is a percentage of the melting temperature of the conduit). An advantage of this design is that only the outermost portion of the conduit will undergo slight melting and this will limit the extent to which the pipe may be degraded by heating. For example, the conduit may have a wall thickness of, e.g., 0.5-1.5 inches and only the outmost 25%, or 20%, or 15%, or 10%, or 2-5% of the wall may be heated above its melting point during bonding of the flexible substrate 110 to the conduit.

[00143] Alternatively, the bonding agent may have a melting or activation temperature that is below the melting temperature of the conduit to which it is to be attached, from 99% to 95%, from 95% to 90%, from 90% to 80%, or from 80% to 70% of the melting temperature of the conduit to which it is to be attached. An advantage of this design is that the outer surface of the conduit may not undergo melting during the bonding process. It will be appreciated that, in other cases, the melting or activation temperature may be substantially below the melting temperature of the conduit to which it is to be attached.

[00144] While the bonding agent may be provided on all portions of the inner surface of flexible substrate 110, it will be appreciated that, as will be discussed further

subsequently with respect to Figures 33-40, in some embodiments, bonding agent 120 may be provided only on portions of the inner surface of flexible substrate 110.

[00145] As shown in Figures 6 and 7, mechanical restraint member 100 may be applied to the outer surfaces 12, 22 of two components of a piping system (e.g., wrapped  
5 around the circumference of a joint between the two components), in this case pipe 10 and fitting 25, and bonded to a portion of the outer surfaces 12, 22 of each of the piping system components. More specifically, flexible substrate 110 has an outer side 112, an inner side 114, and first and second ends 116, 118. All or a portion of the inner side 114 at the first end 116 is bonded to an outer surface of one of the components of the piping system (in  
10 this case, to outer surface 22 of fitting 25), and all or a portion of the inner side 114 at the second end 118 is bonded to an outer surface of the other component (in this case, to outer surface 12 of pipe 10). In this way, mechanical restraint member 100 prevents the components from separating from each other.

[00146] As exemplified, a single sheet of mechanical restraint member 100 may be  
15 wrapped circumferentially around the joint. Accordingly, mechanical restraint member 100 may overlie all of the outer surfaces 12, 22 of pipe 10 and fitting 25 at the location of the joint. It will be appreciated that in some embodiments, mechanical restraint member 100 may be wrapped around the joint in more than one layer (e.g. 2 or 3 layers) so that mechanical restraint member 100 will also overlie itself. In such a case, the same bonding  
20 agent as is used to secure the mechanical restraint member to the conduit may be used. Alternatively, multiple layers of the substrate may be used (e.g., wrapped around a conduit). In such a case, substrate with bonding agent on an inner surface may be provided and wrapped around the joint. A layer of substrate that has or is provided with a bonding  
25 agent suitable for securing one layer of the substrate to another layer of the substrate may then be wrapped around the joint on top of the existing substrate. Multiple such layers may be provided. It will be appreciated that the substrate of each layer may be the same or different.

[00147] Alternatively, as shown in Figures 8 and 9, mechanical restraint member 100 may comprise one or more axially extending strips of flexible substrate 110, each strip  
30 having a first end 116 bonded to an outer surface of one of the components of the piping

system and a second end 118 bonded to an outer surface of the other component. For example, 3, 4, or more strips that are circumferentially spaced apart may be applied in the axial direction.

5 [00148] It will be appreciated that the one or more gaskets 30 positioned between outer surface 12 of pipe 10 and inner surface 24 of opening 20 provide the water-tight seal, while mechanical restraint member 100 acts to restrain the pie system components from separating, and not necessarily to provide any sealing capabilities. Thus, while in some embodiments a continuous sheet of flexible substrate 110 may be wrapped around – and bonded to – all (or substantially all) of the circumference of the joint, the primary function of  
10 the flexible substrate 110 is to prevent the joint from separating, although in some embodiments it may provide a back-up seal should a gasket 30 leak.

[00149] Since mechanical restraint member 100 is chemically bonded to the piping system components, this significantly reduces (if not eliminates) the risk of plastic deformation, cracking, or other structural damage to the piping system components during  
15 installation, as compared to, e.g. the apparatus illustrated in Figures 4 and 5.

[00150] Also, since the area of bonded contact of mechanical restraint member 100 with the piping system components will generally be much greater than in prior art systems – c.f. the points of contact 46 in Figure 5 with the area of contact in Figure 7 between inner surface 114 of flexible substrate 110 and the outer surface 12 of pipe 10 – structural issues  
20 relating to e.g. point loading may be substantially reduced or eliminated.

[00151] Optionally, a transition surface may be provided between the outer surfaces 12, 22, of the components 10, 25 being secured using mechanical restraint member 100. For example, Figure 10 shows an example of a transition ring 90 positioned about pipe 10 and against end face 26 of opening 20. Transition ring 90 has an outer transition surface 92  
25 that extends between outer surface 12 of pipe 10 and outer surface 22 of opening 20. This outer transition surface 92 provides a less abrupt transition between the piping system components, which may facilitate securing and bonding flexible substrate 110 to surfaces 12, 22. For example, outer transition surface 92 may provide a continuous angled or curved surface from outer surface 12 of pipe 10 to outer surface 22 of fitting 25. Alternately, it may  
30 provide one or more step changes that is more gradual than the single step change from

outer surface 12 of pipe 10 to outer surface 22 of fitting 25. An advantage of this design is that the juncture of end face 26 and outer surface 22 will not provide a sharp corner or transition that may cut into or fray substrate 110 over time. The geometry provided by transition surface 92 may also reduce the shear forces on the bonding agent when the piping system components try to move apart, as the force will be more parallel to, rather than perpendicular to, the bonded flexible substrate 110, which may reduce the tendency for flexible substrate 110 to peel free of the components to which it is bonded. It will be appreciated that outer surface 92 may have a variety of profiles and need not extend all the way to the radial outer position of outer surface 12 of pipe 10 and/or all the way to the radial outer position of outer surface 22 of fitting 25. Alternatively or additionally, as exemplified in Figure 11, all (or at least a portion of) the end face 26 of opening 20 may be beveled to provide all or a portion of a transition surface 92 between outer surface 12 of pipe 10 and outer surface 22 of opening 20 and accordingly a separate transition ring may not be provided.

[00152] Flexible substrate 110 may extend axially for a length L (see Figure 7) along each conduit to which it is applied for any desired length. It will be appreciated that the stronger the bond between flexible substrate 110 and the conduit, the smaller the overlap (length L) may be. For example, the axial length of the bonded portion of the flexible substrate 110 to a piping system component may be approximately equal to the diameter of the piping system component (diameter D in Figure 7) being restrained. It will be appreciated that this ratio may vary based on changes in various parameters, e.g. the required tensile load performance, shear strength per unit area of the bonding agent, and the material of the outer surface of the piping system components being restrained. The ratio of the length of substrate secured to a conduit in the axial direction (L) to the diameter of the conduit (D) may be about 1:10 (i.e.  $L = 0.1 \times D$ ) or more, or about 1:5 or more, or from about 3:10 to 1:2, or from 1:2 to 1:1.

[00153] Figures 12-15 illustrate various examples of possible configurations of mechanical restraint member 100. Each example includes at least one layer of flexible substrate 110 and a bonding agent 120. It will be appreciated that other variants are possible, depending on the application requirements (e.g. required tensile strength, expected installation environment, etc.).

[00154] In one embodiment, the flexible substrate may be embedded in the bonding agent. Such an embodiment is exemplified in Figure 12. As exemplified therein, a sheet of flexible substrate 110 is bonded to a pipe 10 using bonding agent 120. In the illustrated example, the flexible substrate 110 is fully saturated/embedded in the bonding agent 120, so that the cured bonding agent may also act as a protective layer for the individual fibers in the flexible substrate 110.

[00155] In some embodiments, a protective outer layer may be provided. This protective layer is preferably environmentally inert, and protects flexible substrate 110 and/or bonding agent 120 by providing a barrier to one or more environmental contaminants (e.g. ground water, acid rain, UV radiation, and the like). Accordingly, the protective layer may be selected to prevent or inhibit contact between the restraint member and groundwater. Alternatively, or in addition, the protective layer may be a flexible protective polymer that has been impregnated with  $\text{TiO}_2$  to protect flexible substrate 110 and/or flexible protective polymer 130a from ultra-violet (UV) radiation). Exemplary protective layers may comprise one or more of PVC, polyvinylidene difluoride (PVDF), polytetrafluoroethylene (PTFE), and the like.

[00156] The protective layer may be provided as part of the restraint member, or it may be a separate layer. For example, the protective layer may be formed on an outer surface of the flexible substrate. It may be applied to the outer surface of the substrate prior to the application of the bonding agent (e.g. it may be poured or coated thereon, or it may have an inner adhesive side that is securable to the outer side of the flexible substrate). Alternatively, it could be a separate member that is applied after the restraint member has been applied to the joint. One such embodiment is exemplified in Figure 13. As exemplified therein, the flexible substrate 110 is fully saturated/embedded in a flexible protective polymer 130, and the polymer-saturated flexible substrate 110 is bonded to a pipe 10 using bonding agent 120. The protective layer may extend beyond one or some or all of edges of flexible substrate 110 and contact (or be bonded to) the outer surface of one or both components being joined.

[00157] Alternatively, as exemplified in Figure 14, the outer side 112 of flexible substrate 110 may be partially saturated/embedded in a flexible protective polymer 130a,

such as PVC, PVDF, PTFE, and the like, and the inner side 114 of flexible substrate 110 may be partially saturated/embedded in the bonding agent 120, or had the bonding agent 120 applied thereto.

[00158] Also, as exemplified in Figure 14, an optional additional protective layer 130b  
5 may be provided on the outer side of flexible protective polymer 130a. Alternatively, optional additional protective layer 130b may be applied to the outer surface of flexible substrate 110 of any embodiment.

[00159] Optionally, a resistive heating member 142 (whose purpose will be discussed  
10 further subsequently) may be incorporated into mechanical restraint member 100. As exemplified in Figure 15, resistive heating member 142 may consist of electrically conductive fibers (e.g. Nichrome, Kanthal™, cupronickel, ceramic, carbon, and the like, and in some embodiments, may have a positive temperature coefficient (PTC)) interwoven into a sheet of flexible substrate 110, or one or more wire otherwise embedded therein. Alternatively, resistive heating member 142 may be provided adjacent, or at least near to,  
15 either side of flexible substrate 110. It will also be appreciated that in some embodiments, the flexible substrate 110 itself may be electrically conductive, allowing flexible substrate 110 to act as a resistive heating member 142.

### **Method of Securing Two Pipe Members**

[00160] Figures 16 to 40 exemplify methods and apparatus for securing piping system  
20 components using a mechanical restraint member. In general, the method includes connecting the piping system components using, e.g., an insertion fit (with a gasket positioned between the components to provide a water-tight seal), positioning a flexible substrate having a bonding agent provided on at least an inner side of the flexible substrate across the joint, and activating (e.g. heating) the bonding agent and applying pressure to  
25 the flexible substrate at least when the bonding agent is activated (e.g. at an elevated temperature) in order to bond the flexible substrate to the piping system components. It will be appreciated that the method may be used with any mechanical interface of two members of a piping system. The method may be used to apply a mechanical restraint member 100, and may be used with pipe securing apparatus 200 and/or the quality control  
30 module 300 disclosed herein.

[00161] It will also be appreciated that the activation (e.g. the application of heat) and the application of pressure may occur in any order provided that the bonding agent is activated (e.g. at a temperature required for bonding (a bonding temperature)) when a pressure required for bonding (a bonding pressure) is applied. Accordingly, the bonding agent may be raised to the bonding temperature, exposed to the ambient, formed by combining two or more components, etc. prior to, concurrently with, or subsequent to the bonding pressure being applied. Accordingly, various different constructs may be used to produce the bonding temperature and/or apply the bonding pressure.

[00162] Figures 16 to 19 exemplify one embodiment of a method of applying a mechanical restraint member to secure two components of a piping system utilizing a pipe securing apparatus, which is also referred to herein as a pressure cuff, that incorporates a heating member. First, as illustrated in Figure 16, the components are joined using an insertion fit, in this case by inserting pipe end 16 into opening 20 of fitting 25. One or more gaskets 30 may be provided to provide a fluid-tight seal between the components, as discussed above. Once the components are positioned as desired with any desired sealing system, a sheet of flexible substrate 110 is wrapped around all or a portion of the joint, so that all or a portion of inner surface 114 of flexible substrate 110 at a first end 116 is in contact with an outer surface 22 of one component (in this case fitting 25), and so that all or a portion of inner surface 114 of flexible substrate 110 at a second end 118 is in contact with an outer surface 12 of the other component (in this case pipe 10). In this example, a bonding agent 120 has been applied to at least a portion of the inner surface 114 of flexible substrate 110 at each of the first and second ends 116, 118 prior to wrapping flexible substrate 110 around the joint.

[00163] Flexible substrate 110 may be temporarily secured in position about the joint using any suitable means. For example, one or more pieces of tape or other fasteners (e.g. clamps, elastic bands, and the like) may be used to temporarily secure the sheet of flexible substrate 110 to the piping system components, e.g. by applying a tape to both the outer surface 112 of flexible substrate 110 and the outer surface 12 or 22 of the piping system components. Alternatively, or additionally, where the sheet of flexible substrate 110 is wrapped around substantially all of the perimeter of the joint, a tape or other fastener may be applied to the outer surface 112 of both longitudinal edges of the flexible substrate 110,

i.e. taping the flexible substrate 110 to itself. Other fasteners (e.g. clamps, elastic bands, and the like) may alternatively or additionally be used.

[00164] Alternatively, or additionally, an adhesive, which may be a temporary or releasable adhesive, may be applied to all or a portion of inner surface 114 of flexible substrate 110 (and/or to all or a portion of the bonding agent 120 applied to the inner surface 114 of flexible substrate 110) to secure flexible substrate 110 in position while heat and pressure are applied. Accordingly, the adhesive enables flexible substrate 110 to be placed on the outer surfaces 12, 22 of the piping system components and to then remain in position. The temporary adhesive may be a releasable adhesive. An advantage of a releasable adhesive is that flexible substrate 110 may be removed and repositioned (e.g., rewrapped) if needed. Such a temporary adhesive may comprise a low-tack pressure-sensitive adhesive, such as an elastomer (e.g. acrylic, butyl rubber, EVA, natural rubber, nitrile, silicone rubber, styrene block copolymer (SBC), or vinyl ether and the like) compounded with a suitable tackifier.

[00165] Next, as illustrated in Figure 17, a pressure cuff 200 (examples of which will be discussed further subsequently) is positioned around the sheet of flexible substrate 110 and, accordingly, around the perimeter of the joint. Pressure cuff 200 may be of any construct that enables pressure to be applied to the outer surface of flexible substrate 110. It will be appreciated that, as exemplified, pressure cuff 200 may be positioned directly over (i.e., in contact with) flexible substrate 110. Alternatively, an intermediary member or members that will transmit pressure may be positioned between pressure cuff 200 and flexible substrate 110, such as protective material 160 (e.g. a heat shrink and/or environmentally inert material) or the like. As exemplified, pressure cuff 200 includes one or more inflatable pockets. For example, pressure cuff 200 may be an annular cuff having a singular continuous annular inflatable pocket that may be brought into position by sliding pressure cuff 200 over a free end of one component being joined (e.g. pipe 10) and then along the component until it overlies flexible substrate 110. Alternatively, pressure cuff 200 may be a linear cuff that has one or more inflatable pockets; the linear cuff is wrapped around the joint and secured to itself to form an annular cuff. In the illustrated embodiment, pressure cuff 200 includes a heating element 210 and a single annular inflatable pocket or pressure chamber s.

[00166] Once pressure cuff 200 is in position, it may be used to apply heat and/or pressure to flexible substrate 110 and bonding agent 120. As illustrated in Figure 18, pressure chamber 220 may be inflated to exert pressure on flexible substrate 110, and heating element 210 may be energized to apply sufficient heat to activate bonding agent 120. It will be appreciated that the heat and pressure may be provided concurrently, or in any order (i.e. heat then pressure, or pressure then heat).

[00167] Pressure chamber 220 may be inflated by any means known in the art. For example, pressure chamber may have one or more fluid inlet ports. Accordingly, a pressure source, such as a compressor, a tank of pressurized gas, or the like, may be connected to the inlet port. It will be appreciated that the inlet port may be used to subsequently depressurize the pressure cuff 200 and/or one or more fluid outlet ports may be provided. Pressure chamber 220 may also be inflated by, e.g., gas released by a chemical reaction, or the like.

[00168] Heating element 210 may be any member that is capable of raising the bonding agent to the bonding temperature. As exemplified, heating element 210 comprises a resistive heating element 142. Resistive heating element 142 may be heated by an on-board power source (e.g., batteries that are provided in pressure cuff 200) or it may be connectable to an external source of current, such as by electrical contacts that may be provided on pressure cuff 200 (similar to leads 144 shown in Figure 19). In other embodiments, heating element 210 may comprise one or more of: an exothermic reactive composition; an infrared heat source; or other radiant energy source (e.g. a microwave source) and the like. For example, pressure cuff 200 may incorporate one or more radiant energy sources (e.g., IR emitters). These may be positioned around pressure cuff 200 so as to provide the required degree of heating. Alternatively, one or more radiant energy sources may be provided on only a portion of pressure cuff 200, and pressure cuff 200 may be constructed to permit the radiant energy sources to rotate around the joint to provide the required degree of heating to all portions of the bonding agent.

[00169] Once activated by the application of heat by pressure cuff 200, bonding agent 120 begins forming a bond between flexible substrate 110 and the components of the piping system 10, 25. Once bonding agent 120 has cured to provide a sufficient bond

strength, pressure cuff 200 may be removed, leaving mechanical restraint member 100 in place to prevent components 10, 25 from separating. It will be appreciated that while bonding agent 120 may provide an initial bond strength (e.g. sufficient to allow the removal of pressure cuff 200 without disturbing or displacing mechanical restraint member 100) after a relatively short period of time (e.g. from 10, 20 or 30 minutes up to 1 or 2 hours and may be 10 to 30 minutes or 20 to 30 minutes) the strength of bonding agent 120 may increase as the bonding agent continues to cure. For example, bonding agent 120 may take from between 12 hours to 1 week. For example, Polyurethane Reactive (PUR) EZ 250150 achieves 50% of its strength within 30 minutes, about 75% of its strength after 12 hours, and 100% of its strength in about 7 days.

[00170] Figures 19 to 21 exemplify another example of a method of applying a mechanical restraint member to secure two components of a piping system. In this example, flexible substrate 110 has a resistive heating element 142 woven into it. Resistive heating element 142 may be energized by applying an electrical current to two or more leads 144. Otherwise, this method is similar to the method described with respect to Figures 16 to 18. In accordance with this embodiment, pressure cuff 200 need not have a heating element. However, pressure cuff 200 may have a heating element 210 as a backup, in case resistive heating element 142 of flexible substrate 110 does not function correctly.

[00171] First, as illustrated in Figure 19, the components are joined using an insertion fit, with one or more gaskets 30 provided between the components. Next, a sheet of flexible substrate 110 with an incorporated resistive heating element 142 is wrapped around all or a portion of the joint. As in the previous example, a bonding agent 120 has been applied to at least a portion of the inner surface 114 of flexible substrate 110 at each of the first and second ends 116, 118 prior to wrapping flexible substrate 110 around the joint. Flexible substrate 110 may be temporarily secured in position about the joint as discussed above.

[00172] Next, as illustrated in Figure 20, a pressure cuff 200 is positioned around the sheet of flexible substrate 110 and around the perimeter of the joint. In the illustrated embodiment, pressure cuff 200 includes a pressure chamber 220, but does not include a heating element. Once pressure cuff 200 is in position, it may be used to apply pressure to

flexible substrate 110 and bonding agent 120, while heating element 142 may be energized to apply sufficient heat to activate bonding agent 120. As will be discussed further subsequently, heating element 142 may be energized via pressure cuff 200. For example, leads 144 may be coupled to one or more electrical sockets or connectors located on  
5 pressure cuff 200.

[00173] As above, once bonding agent 120 has cured to provide a sufficient bond strength, pressure cuff 200 may be removed, leaving mechanical restraint member 100 in place to prevent components 10, 25 from separating.

[00174] Figures 22 to 24 exemplify another example of a method of applying a  
10 mechanical restraint member to secure two components of a piping system. In this example, after flexible substrate 110 has been positioned about the joint between piping system components 10, 25, a heating blanket 150 having a heating member (e.g. resistive heating element 142) may be positioned against the outer surface 112 of flexible substrate 110. As illustrated in Figure 22, the components are joined using an insertion fit, a sheet of  
15 flexible substrate 110 having a bonding agent 120 applied to at least a portion of the inner surface 114 of flexible substrate 110 at each of the first and second ends 116, 118 is wrapped around all or a portion of the joint and may be temporarily secured in position about the joint as discussed previously.

[00175] Next, a flexible heating blanket 150 is wrapped around all or a portion of the  
20 joint, so that all or a portion of inner surface 154 of heating blanket 150 is in contact with the outer surface 112 of flexible substrate 110. Heating blanket 150 may be temporarily secured in position about the flexible substrate 110 using any suitable means. For example, heating blanket 150 may have one or more hook and loop (or other) fasteners so that once the heating blanket 150 is wrapped around substantially all of the flexible substrate 110, it  
25 may be secured to itself. Alternatively or additionally, any of the methods discussed previously with respect to temporarily securing flexible substrate 110 about the joint may be used with heating blanket 150.

[00176] Once heating blanket 150 is in position, as illustrated in Figure 23 a pressure cuff 200 is positioned around the heating blanket and around the perimeter of the joint. In  
30 the illustrated embodiment, pressure cuff 200 includes a pressure chamber 220, but does

not include a heating element. In accordance with this embodiment, pressure cuff 200 may have a heating element 210 as a backup, in case resistive heating element 142 of heating blanket 150 does not function correctly. Once pressure cuff 200 is in position, it may be inflated as shown in Figure 24 to apply pressure to flexible substrate 110 and bonding agent 120, while heating element 142 in heating blanket 150 may be energized to apply sufficient heat to activate bonding agent 120. As will be discussed further subsequently, heating element 142 may be energized via pressure cuff 200. For example, heating element 142 may be electrically coupled to a power source via pressure cuff 200.

5 [00177] As above, once bonding agent 120 has cured to provide a sufficient bond strength, pressure cuff 200 may be removed, leaving mechanical restraint member 100 in place to prevent components 10, 25 from separating.

[00178] As discussed previously, mechanical restraint member 100 may comprise one or more optional protective layers on the outer surface of flexible substrate 110. Figures 25 to 28 exemplify one example of a method of applying a mechanical restraint member with a protective layer. First, as illustrated in Figure 25, the components are joined using an insertion fit, a sheet of flexible substrate 110 having a bonding agent 120 applied to at least a portion of the inner surface 114 of flexible substrate 110 at each of the first and second ends 116, 118 is wrapped around all or a portion of the joint and temporarily secured in position about the joint as discussed above.

15 [00179] Next, a sheet of protective material 160 is applied to the outer surface 112 of flexible substrate 110. For example, a protective layer may comprise a heat shrink material, such as a thermoplastic material (e.g. polyolefin, fluoropolymer such as FEP, PTFE or the like, or PVC and the like) may be provided.

[00180] As shown in Figure 25, a sheet of a heat shrink material 160 may be wrapped around all or a portion of flexible substrate 110 so that all or a portion of inner surface 164 of heat shrink 160 is in contact with the outer surface 112 of flexible substrate 110. Heat shrink 160 may be temporarily secured in position about the flexible substrate 110 using any suitable means, examples of which were discussed previously.

25 [00181] Next, as illustrated in Figure 26, a pressure cuff 200 (examples of which will be discussed further subsequently) is positioned around the sheet of flexible substrate 110

30

and around the perimeter of the joint. In the illustrated embodiment, pressure cuff 200 includes a heating element 210 and a pressure chamber 220. It will be appreciated that pressure cuff 200 need not include a heating member is a heating member is provided using one of the other constructs disclosed herein.

5 [00182] Once pressure cuff 200 is in position, it may be used to apply heat and/or pressure to heat shrink 160, flexible substrate 110, and bonding agent 120. For example, pressure chamber 220 may be inflated to exert pressure on heat shrink 160 and flexible substrate 110, and heating element 210 may be energized to apply sufficient heat to activate heat shrink 160 and bonding agent 120.

10 [00183] As above, once bonding agent 120 has cured to provide a sufficient bond strength, and heat shrink 160 has shrunk to form a protective layer 130b, pressure cuff 200 may be removed, leaving the heat shrink-wrapped mechanical restraint member 100 in place to secure conduits 10, 25, as shown in Figures 27 and 28.

[00184] While in the methods described above, bonding agent 120 was thermally  
15 activated by an external heat source, in other embodiments the bonding agent may be heated using a heating member part or all of which is incorporated into flexible substrate 110. For example, flexible substrate 110 may have bonding agent 120 applied to its inner side 114, and another composition provided on, e.g., outer side 112, this other composition capable of being activated by applying a catalytic agent (e.g. as a spray, or as another  
20 sheet of material applied to the outer surface 112 of flexible substrate 110) to initiate an exothermic reaction. Alternatively, the exothermically reactive compositions may be placed in separate pockets which are rupturable to enable reagents to react and produce heat. For example, the pockets may be designed to rupture when pressure cuff 200 is inflated (e.g., the walls of the pockets may be sufficiently thin such that they will rupture when  
25 pressure is applied, or one or more piercing members may be provided to break an adjoining wall of the pockets when pressure is applied. Such an exothermic composition and catalyst may comprise components that achieve a Grignard reaction (an organo-metallic chemical reaction), iron metal powder and an oxidizer such as sodium chloride, and the like.

[00185] It will be appreciated that the features of mechanical restraint member 100 and methods of applying mechanical restraint member 100 to secure two component of a piping system may be used in any particular combination or sub-combination.

[00186] For example, as illustrated in Figure 29 to 31, a mechanical restraint member  
5 100 may be applied by layering a flexible substrate 110, a shrink wrap 160, and a heating blanket 150 about a joint, and using resistive heating elements 142 in heating blanket 150 to apply heat while applying pressure using pressure cuff 200.

[00187] Another example is shown in Figure 32, where mechanical restraint member  
10 100 is applied by layering two flexible substrates 110a, 110b impregnated with bonding agent 120, a layer of heat shrink 160, and then using a pressure cuff 200 having both a pressure cavity 220 and a heating element 210 to apply heat and pressure.

[00188] As previously noted, the bonding agent 120 of a mechanical restraint member  
15 100 may be provided on all or only on portions of the inner surface 114 of flexible substrate 110. Examples of various different configurations of bonding agent 120 and flexible substrate 110 are exemplified in Figures 33-40. It will be appreciated that other configurations may be possible, in variant embodiments.

[00189] In Figure 33, a contiguous area of bonding agent 120 has been applied to substantially all of the inner surface 114 of a flexible substrate 110. It will be appreciated that bonding agent may be applied to all of inner surface 114.

20 [00190] In Figure 34, a contiguous area of bonding agent 120 has been applied to substantially all of the inner surface 114 of a flexible substrate 110. Also, longitudinal strips of temporary adhesive 124 have been applied to the surface of bonding agent 120, to assist in temporarily positioning flexible substrate 110 about the piping system components, prior to activating the bonding agent 120.

25 [00191] In Figure 35, a contiguous area of a first bonding agent 120 has been applied to substantially all of the inner surface 114 of a flexible substrate 110. Also, a second bonding agent 122 has been applied around the perimeter of the area to which the first bonding agent 120 has been applied. This second bonding agent 122 may be selected to have different properties than first bonding agent 120. For example, be second bonding  
30 agent 122 may be more resistant to chemical degradation from water. The second bonding

agent 122 may comprise an adhesive compatible with the mechanical restraint member and the pipe system component and resistant to degradation from water such as one or more of a hot melt glue, any type of adhesive which is inert e.g., a silicon based adhesive including those that are acetic acid or platinum reaction curing, and the like.

5 [00192] An advantage of providing a second bonding agent 122 around the perimeter of bonding agent 120 is that when a flexible substrate 110 with this configuration of bonding agents is bonded to a piping system, the first bonding agent 120 may primarily provide the bond strength necessary to prevent the piping system components from separating, while second bonding agent 122 may form a protective barrier around the first bonding agent  
10 120, preventing water or other environmental contaminants from contacting and possibly degrading the bond formed by bonding agent 120. Accordingly, the second bonding agent need not provide any resistance to mechanical separation of the components of the joint.

[00193] As discussed previously, bonding agent 120 need not be applied continuously over inner surface 114. For example, as shown in Figure 36, strips of bonding agent 120  
15 have been applied to the inner surface 114 of a flexible substrate 110. In Figure 37, each strip of bonding agent 120 has been provided with a continuous perimeter of a second bonding agent 122. Figure 38 illustrates a pattern of discontinuous dots of bonding agent 120 that have been applied to the inner surface 114 of a flexible substrate 110.

[00194] Figure 39 illustrates an end section view of a pipe 10 to which a sheet of  
20 flexible substrate 110 has been bonded, where the bonding agent 120 was applied to substantially all of the inner surface 114 of flexible substrate 110 prior to bonding (e.g. as shown in Figure 33). As exemplified, a continuous band of bonding agent 120 is provided circumferentially around the joint. Figure 40 illustrates an end section view of a pipe 10 to which a sheet of flexible substrate 110 has been bonded, where the bonding agent 120  
25 was applied in discrete strips to the inner surface 114 of flexible substrate 110 prior to bonding (e.g. as shown in Figure 36). As exemplified, a discontinuous band of bonding agent 120 is provided circumferentially around the joint.

[00195] It will be appreciated that flexible substrate 110 may be provided in any  
suitable shape. For example, flexible substrate 110 may be a substantially planar sheet  
30 shaped so as to facilitate wrapping flexible substrate 110 around a joint between two piping

system conduits, where the joint has two or more different outer dimensions. For example, as illustrated in Figure 41a, one or more notches, grooves or the like may be provided at the ends 116, 118 of flexible substrate 110. Accordingly, when wrapped around a pipe, the substrate may overlap itself less, or optionally, there may be no overlap. In the illustrated example, the total width of first end 116 (i.e.  $W_{116a} + W_{116b} + W_{116c} + W_{116d}$ ) may be substantially equal to the outer circumferential length of one of the two piping system components being joined (e.g. junction 25) axially offset away from the widest part of the junction, the total width of flexible substrate 110 (i.e.  $W_{110}$ ) may be substantially equal to the outer circumferential length at the widest part of the junction, and the total linear width of second end 118 (i.e.  $W_{118a} + W_{118b} + W_{118c} + W_{118d}$ ) may be substantially equal to the outer circumferential length of the other of the two piping system components being joined (e.g. pipe 10) axially offset from the widest part of the junction. In this way, when flexible substrate 110 is wrapped around the joint between components 10, 25 (i.e., the flexible substrate is wrapped in the width direction circumferentially around a joint), most or preferably all of inner face 114 of flexible substrate 110 may lie substantially flush with the outer surface of the components to which it is being bonded, as illustrated in Figure 41b. It will be appreciated that notches may be provided at one end, at both ends, or at neither end.

[00196] Optionally, the outer surface of mechanical restraint member 100 may be provided with a material that undergoes a visually observable change when heated, e.g. a thermochromic substance such as leuco dyes, liquid crystals, and the like. The use of such a material may allow a visual indication that the outer surface of flexible substrate 110 was raised to a certain temperature (i.e. the transition temperature at which the thermochromic material changes colour), which may be used to infer that sufficient heat was applied to flexible substrate 110 during the bonding process to activate a thermally-activated bonding agent. It will be appreciated that the thermochromic material may be selected and/or modified to provide a colour change at predetermined temperature (e.g. 100%, or from 100% to 110%, or higher than 110% of the temperature required to activate bonding agent 120).

[00197] A thermochromic material may be applied to substantially all of the outer surface of flexible substrate 110. Thus, a colour change could be observed to confirm that

substantially all of flexible substrate 110 reached the predetermined. Alternatively, or additionally, a thermochromic substance 170 may be applied in a pattern such as the pattern exemplified in Figure 43, to reduce the amount of thermochromic material required and/or to locate the thermochromic material at areas of greater importance – for example, where discontinuous strips of bonding agent 120 are applied to the inner surface 114 of flexible substrate 110 (see e.g. Figure 36), thermochromic material 170 may only be applied at corresponding locations on outer surface 112.

[00198] As discussed previously, a mechanical restraint member 100 may be bonded to a portion of the outer surfaces 12, 22 of each of the piping system components, thereby restraining the components from separating (see e.g. the embodiments illustrated in Figures 6 to 9). In an alternative embodiment, two piping system components may be restrained by bonding one or more securement members to the outer surfaces of each of the piping system components using a bonding agent, and then mechanically coupling the securement member(s) bonded to one component to the securement member(s) bonded to the other component. For example, one or more mechanical restraint members according to any embodiment herein, each of which may have one or more securement members, may be bonded to one component and one or more mechanical restraint members according to any embodiment herein, each of which may have one or more securement members, may be bonded to the other component. Once bonded, the securement members may be mechanically coupled together thereby inhibiting the outward axial movement of one component with respect to the other component of the joint. The securement members act as an interface between the flexible substrate that has been bonded to the piping system component and a mechanical coupling mechanism that is used to mechanical couple two or more securement members to each other. Examples of securement members include eyelets, hooks, posts, and the like affixed to an outer surface of the flexible substrate, openings provided in the flexible substrate itself and the like. The securement members may be mechanically coupled or otherwise engaged to each other using any suitable means, such as using a flexible elongate tie member e.g., wire or rope made of metallic (e.g., steel, brass, copper and the like) or non-metallic members, which may be natural and/or synthetic fibers (such as glass fiber, aramid fiber, polypropylene fiber, carbon fiber), chains, and/or rigid tie members such as mechanical fasteners (e.g.

bolts, screws, and the like), turnbuckles, and the like. The tie members may optionally be tensioned during or after their coupling to the securement members. It will be appreciated that any suitable combination of securement member and mechanical fastener may be used.

5 [00199] In the example illustrated in Figure 44, components 10, 25 have been joined using an insertion fit, as discussed previously. A piece of flexible substrate 110 to which a securement member 180 is secured is bonded to the outer surface 22 of conduit 25, and another piece of flexible substrate 110 to which a securement member 180 is secured is bonded to the outer surface 12 of conduit 10. Securement members 180 are mechanically  
10 coupled to each other to restrain the securement members (and thereby the pipe system components to which they are bonded) in the axial direction. It will be appreciated that securement members 180 may be the same or different. For example, securement members bonded to one component may have a threaded bore for receiving the threaded end of a mechanical fastener 182 (e.g. a screw or bolt), while securement members  
15 bonded to the other component may have a plain bore. In this way, mechanical fastener 182 (e.g. a screw or bolt) may be inserted through one securement member, and threaded into another securement member.

[00200] It will be appreciated that the securement members may be attached to the flexible substrate prior to the flexible substrate being bonded to the component. However,  
20 in other embodiments, the securement members may be attached to the flexible substrate concurrently with the flexible substrate being bonded to the component or thereafter.

[00201] In another variant embodiment, mechanical restraint member 100 may be applied to the pipe system components to be restrained by positioning a flexible substrate across the joint, and injecting a bonding agent through or around the flexible substrate to  
25 bond the flexible substrate to the piping system components. In other words, a flexible substrate is positioned across the joint, and a bonding agent is injected *in situ*.

[00202] For example, as illustrated in Figure 45, components 10, 25 have been joined using an insertion fit, as discussed previously. Flexible substrate 110 is positioned on the outer surface of the components to overlie the joint between components 10, 25. Once  
30 flexible substrate 110 is in position, a bonding apparatus may be used to inject a bonding

agent through the flexible substrate 110 (e.g. through the openings in a perforated substrate or through the pores in a woven flexible substrate 110) so that the bonding agent is operable to bond flexible substrate 110 to the piping system components. For example, the bonding apparatus may have one or more heads 190 for applying pressure to flexible substrate 110 (e.g. to maintain flexible substrate 110 in position during the injection of bonding agent 120, and/or to act as a seal against the outer surface 112 of flexible substrate 110 to force bonding agent 120 into the flexible substrate 110). One or more injection passages 192 may be provided through heads 190 for delivering bonding agent 120 to flexible substrate 110. In some embodiments, one or more heads 190 may be incorporated into the inner surface of a pipe securing apparatus, as will be discussed subsequently.

### **Pipe Securing Apparatus**

[00203] Reference is now made to Figures 46 to 55, which exemplify different embodiments of a pipe securing apparatus 200, each of which may be used with the methods disclosed herein. Pipe securing apparatus 200 may also be referred to as a pressure cuff. Pressure cuff 200 may be of any construct that enables pressure to be applied to the outer surface of flexible substrate 110. Pipe securing apparatus 200 includes one or more pressure chambers, referred to generally as 220, and may include one or more heat producing elements, referred to generally as 220, as will be discussed further subsequently. Pipe securing apparatus 200 may be used with one or more of mechanical restraint member 100, the application method, and the quality control module 300 disclosed herein.

[00204] Figures 46 to 48 exemplify one embodiment of a pipe securing apparatus that may be used in applying a mechanical restraint member to secure two components of a piping system. As exemplified in Figure 46, pressure cuff 200 is an annular cuff sized to fit over at least one end of a component to be joined, and having an outer surface 212 and an inner surface 214. Pressure cuff 200 may be brought into position by sliding pressure cuff 200 over a free end of one component being joined (e.g. pipe 10) and then along the component until it overlies flexible substrate 110 and, accordingly, around the perimeter of the joint. Once pressure cuff 200 is in position, as shown in Figure 47, it may be used to

apply pressure and/or heat to flexible substrate 110 and bonding agent 120. As illustrated in Figure 48, one or more pressure chambers – e.g. a singular continuous annular inflatable pocket (not shown) – may be inflated to exert pressure on flexible substrate 110, and a heating element may be energized to apply sufficient heat to activate bonding agent 120.

5 [00205] An alternate embodiment of a pipe securing apparatus that may be used in applying a mechanical restraint member to secure two components of a piping system is exemplified in Figures 49 and 50. As illustrated in Figure 49, pressure cuff 200 is a linear cuff having an outer surface 212, an inner surface 214, a first end 216, and a second end 218. This linear pressure cuff 200 may be brought into position by wrapping pressure cuff  
10 200 around flexible substrate 110 and, accordingly, around the perimeter of the joint, bringing at least a portion of inner surface 214 in contact with flexible substrate 110. Once pressure cuff 200 is in position, it may be secured to itself using one or more mechanical fasteners, which may be part of pressure cuff 200 or may be a separate member, examples of which include belts and corresponding buckles (including friction buckles), hook and loop  
15 fasteners, hook-and-eye closures, zippers, snap fasteners, lacing, the like. In the illustrated example, belts 242 located at first end 216 of pressure cuff 200 may cooperate with a buckle 240 located at the second end 218 to releasably couple the first and second ends to each other. It will be appreciated that mechanical fasteners may be provided at a plurality of locations at one or both ends 216, 218, so as to allow the ends to be connected to  
20 provide an open interior of varying diameters.

[00206] Once pressure cuff 200 is in position, it may be used to apply pressure to flexible substrate 110 and bonding agent 120. As illustrated in Figures 51 and 52, a pressure chamber 220 may be inflated to exert pressure on flexible substrate 110. Pressure chamber 220 may be inflated by any means known in the art. For example,  
25 pressure chamber may have one or more fluid inlet ports 222. Accordingly, a pressure source 280, such as a compressor, a tank of pressurized gas, or the like, may be connected to the inlet port 222. It will be appreciated that the inlet port may be used to subsequently depressurize the pressure cuff 200 and/or one or more fluid outlet ports may be provided. Pressure chamber 220 may also be inflated by, e.g., a fluid pumped into the  
30 pressure chamber 220, gas released by chemical reaction, or the like. The fluid may be a heated fluid. Accordingly, the fluid may supplement or be the heating member. For

example, the fluid (liquid and/or gas) may be continually circulated in a loop (e.g., into a heat exchanger and then into the pressure chamber prior to being returned to the heat exchanger) to continually supply heat to the pressure chamber 220. Alternately, a mechanical or electromechanical turnbuckle, electro- or magneto- constrictive wires or other exterior constriction member could be used to supplement or replace the pressure chamber 220.

[00207] In some embodiments, pressure cuff 200 may also include a heat producing member, such as a heating element 210 to apply heat to flexible substrate 110 and bonding agent 120, e.g. to raise the temperature of bonding agent to or past its activation temperature, thus initiating bonding between flexible substrate 110 and the piping conduits being joined. Heating element 210 may be any member that is capable of raising the bonding agent to the bonding temperature. As exemplified, heating element 210 comprises a resistive heating element 142. Resistive heating element 142 may be energized by an on-board power source (e.g., batteries that are provided in pressure cuff 200), or it may be connectable to an external power source 290, such as by electrical contacts or terminals that may be provided on pressure cuff 200 (similar to leads 144 shown in Figure 19). In other embodiments, heating element 210 may comprise a radiant energy source, such as an infrared (IR) source, a microwave source, and the like. For example, pressure cuff 200 may incorporate one or more IR emitters 146 (as shown in Figure 53), or one or more microwave emitters 148 (as shown in Figure 54), or a combination of radiant energy sources. These may be positioned around pressure cuff 200 so as to provide the required degree of heating. Preferably, radiant emitters are provided on (or proximate) inner surface 214 of pressure cuff 200, to facilitate energy transfer to flexible substrate 110. Alternatively, heating element 210 may comprise a chemical source of heat, such as chambers containing components that, when the chambers are ruptured and the components mixed, form an exothermic mixture, and the like.

[00208] Alternatively, pressure cuff 200 may not include a heating element 210, but may nonetheless be used to apply heat to flexible substrate 110 and bonding agent 120. For example, a pressure cuff 200 may lack an internal heating element, but may provide one or more electrical contacts to energize a resistive heating element located external to pressure cuff 200. As illustrated in Figure 55, such a pressure cuff may be used in

configurations where flexible substrate 110 has an embedded resistive heating element (see e.g. Figures 19 and 20). In such a configuration, the resistive heating element 142 may be coupled to a source of power, such as external power source 290, via wiring 211 located within pressure cuff 200. In other words, a resistive heating element 142 located in  
5 e.g. flexible substrate 110, heating blanket 150, or heat wrap 160, may be 'plugged in' to pressure cuff 200.

[00209] Pipe securing apparatus 200 may be made from any suitable material that has sufficient tensile strength to withstand the anticipated forces imposed by the inflation of the pressure chamber(s) 220 during operation of the pressure cuff. Preferably, the inner  
10 face of pressure cuff 200 (i.e. the surface that contacts flexible substrate 110 when used to apply heat and/or pressure to flexible substrate 110) comprises a material that bonding agent 120 does not bond to (or does not strongly bond to) to e.g. facilitate removal of pressure cuff 200. Examples of such anti-stick agents include Teflon, PVDF, ultrahigh molecular weight polyethylene, a fluropolymer, a mixture of titanium and ceramic and the  
15 like.

### **Quality Control Apparatus**

[00210] Reference is now made to Figures 56 to 59, which exemplify different embodiments of a pipe securing apparatus 200 having an optional quality control module 300. Such an apparatus may be used with the methods, mechanical restraint member 100,  
20 and/or pipe securing apparatus 200 disclosed herein. Quality control module 300 may be used to determine and/or record one or more physical parameters during or after the application of a mechanical restraint member 100 to a piping system, to provide data to an operator during or after operation of a pipe securing apparatus 200 so as to advise a user or allow a user to determine that the pipe securing apparatus 200 is operating correctly  
25 and/or that the pipe securing apparatus is or was used correctly, and/or to provide an auditable record of the use of pipe securing apparatus 200 and/or the application of one or more mechanical restraint members to a piping system. It will be appreciated that quality control module 300 need not be part of pipe securing apparatus 200 but may be a separate unit.

[00211] Quality control module 300 may include one or more sensors – such as a temperature sensor, pressure sensor, optical sensor, continuity sensor, force sensor, and/or location sensor – for determining one or more operational parameters before, during, and/or after the application of a mechanical restraint member 100.

5 [00212] For example, quality control module 300 may have one or more temperature sensors, such as an infra-red (IR) thermometer, a thermocouple, a thermistor and the like, that may be located, e.g., on the inner surface of a pipe securing apparatus 200, and configured to measure a surface temperature of an object (e.g. a pipe or a housing to which a mechanical restraint member 100 is being applied, a flexible substrate, a heating blanket,  
10 etc.). A signal representing the temperature of the object may be indicative of an adjacent object. For example, the temperature of the outer surface 112 of flexible substrate 110 may be indicative of the temperature of a bonding agent on the inner surface 114 of the flexible substrate 110.

[00213] Alternatively, or additionally, quality control module 300 may have one or  
15 more pressure sensors such as a pressure transducer, a piezoelectric transducer and the like, operable to measure the pressure being applied by a pipe securing apparatus 200 to a flexible substrate 110. For example, a pressure sensor may be located in fluid communication with one or more pressure chambers 220 of pipe securing apparatus 200. A signal representing an increase in the internal pressure of pressure chambers 220 may be  
20 indicative of the pressure being applied by pipe securing apparatus 200 to a flexible substrate 110. Other suitable pressure sensors may be used, such as or one or more strain gauges located on e.g. the inner surface of a pipe securing apparatus 200.

[00214] Alternatively, or additionally, quality control module 300 may have one or  
25 more optical sensors operable to determine a colour and/or a colour change of flexible substrate 110. For example, one or more optical sensors may be located on the inner surface of a pipe securing apparatus 200. A signal representing a colour and/or a change in colour of all or a portion of the outer surface 112 of flexible substrate 110 may be indicative of a thermochromic material applied thereon changing colour in response to flexible substrate 110 (and, by proxy, bonding agent 120) reaching a predetermined temperature,  
30 such as the activation temperature of bonding agent 120.

[00215] Alternatively, or additionally, quality control module 300 may have one or more location sensors such as a GPS (Global Positioning System) locator and the like, operable to determine a location of quality control module 300 and/or pipe securing apparatus 200. For example, a GPS may comprise a GPS receiver or transceiver for communicating with a GPS satellite network to determine a geographic location of quality control module 300. Accordingly, the location at which quality control module 300 and/or pipe securing apparatus 200 is used may be recorded along with the data provided by the other sensors.

[00216] Alternatively, or additionally, quality control module 300 may have one or more continuity sensors. Continuity sensor may be used, e.g., with a linear pressure cuff. Continuity sensors may be utilized to determine if, e.g., the pressure cuff has been wrapped around the pipe (e.g., the distal end of the linear pressure cuff may be looped or connected to the proximate end as exemplified in Figure 50). Alternately, or in addition, a continuity sensor may be used to determine if the pressure cuff is in sufficient contact with the conduits such that the pressure cuff will apply pressure to the conduits when used (e.g., by determining if an electric current will be conveyed around the pressure cuff).

[00217] Alternatively, or additionally, quality control module 300 may have one or more force sensors, such as a piezoelectric transducer, force sensing resistor and the like, to measure the force, e.g., applied by the pressure cuff at the outer surface 112 of the substrate.

[00218] Quality control module 300 preferably includes control electronics 310 operatively coupled to the sensors and/or other electrical components of pipe securing apparatus 200. For example, control electronics 310 may be coupled to heating element 210 and/or one or more temperature sensors (not shown) to regulate and/or record the heat being applied to flexible substrate 110, and/or the surface temperature of flexible substrate 110.

[00219] Control electronics 310 may also be operatively coupled to one or more signaling members to convey information to a user of pipe securing apparatus 200 regarding the status of one or more monitored conditions. For example, a display screen 350 may be provided to provide an indication that flexible substrate 110 has reached a

suitable temperature to activate bonding agent 120. Display screen 350 may also provide an indication that a sufficient amount of pressure is or has been applied to flexible substrate 110 to promote a good bond between flexible substrate 110 and the piping system components.

5 [00220] Display screen 350 may be any suitable display device, such as, for example, a liquid crystal display (LCD), a segment display, an Organic LED (OLED) display, a light emitting diode (LED) display, or an electrophoretic display. Display screen 350 may also be a touch screen display, capable of receiving input from a user.

[00221] Other signaling members may be provided as an alternative to, or in addition to, display screen 350. For example, an audio signalling member 352 such as an electroacoustic transducer (or speaker) may be configured to provide an audible tone in response to a sensor detecting that a predetermined temperature and/or pressure has been reached, and/or when otherwise directed by control electronics 310. As another example, one or more indicator lights (such as LEDs) may be provided on quality control  
10 module 300 and configured to emit a signal (e.g. illuminate, strobe, and/or change colour) in response to detecting that a predetermined temperature and/or pressure has been reached, and/or when otherwise directed by control electronics 310. For example, one or more power indicator lights (not shown) may be provided to convey information to a user regarding the status of a power source (e.g. a battery) coupled to pipe securing apparatus  
15 200.  
20

[00222] Control electronics 310 may also comprise a data logging module 320 for logging or recording data related to one or more sensors and/or operations of pipe securing apparatus 200. For example, the data logging module may record data corresponding to an amount of heat applied by heating element 210, a temperature reached by flexible  
25 substrate 110, a pressure applied by pressure chambers 220, a location of pipe securing apparatus 200 during use, and this information may be time stamped or otherwise tagged to provide an output, e.g., of the number of mechanical restraint member's applied per hour or per shift, and/or the locations at which they were applied. The data logging module may also record data corresponding to a number of signals issued by a signaling member.

[00223] The data logging module may also record operational parameters one or more components of pipe securing apparatus 200, such as temperature readings from heating element 210, electrical current draw by resistive heating element 142, pressure data from a pressure sensor within or in communication with pressure chamber 220, 5 temperature data from an IR thermometer, etc.

[00224] The data logging module may also include a timing module (not shown), and be configured to record data corresponding to the time(s) at which a pipe securing apparatus 200 was used to apply heat and/or pressure to a flexible substrate 110, which may be an absolute time (e.g. 12:00 am on May 24), and/or a relative time (e.g. 20 minutes 10 since the last time pipe securing apparatus was used, and/or a duration (i.e. a period of time, e.g. 8 minutes) of an application of heat and/or pressure by pipe securing apparatus 200). Time information may also be recorded for other operational parameters, such as when pipe securing apparatus 200 was turned on and off and/or the length of time of each step in the operation, such as the length of time that heat and/or pressure is applied.

[00225] In this way, the data logging module may be operable to record a detailed log 15 of the use of the tool throughout a predetermined time period, such as a working day, work week, or throughout a particular piping system installation project.

[00226] Control electronics 310 may be configured to display some or all of the logged data on display screen 350. Alternatively, or additionally, control electronics may comprise 20 a communications module 330 configured to establish a communication channel between the data logging module and remote device, e.g., a computing device, such as a laptop computer, tablet computing device, mobile communication device, remote server, etc. The communication channel may be established by the communication module using any suitable wired or wireless protocol, and may be configured as a personal area network 25 (PAN), a point-to-point network, or any other suitable network topology. Wired communication may be conducted in accordance with Universal Serial Bus (USB) standards, and pipe securing apparatus 200 may be provided with a Standard, Mini, or Micro USB port (not shown). Examples of wireless communication include standards developed by the Infrared Data Association (IrDA), Near Field Communication (NFC), and 30 the 803.11 family of standards developed by the Institute of Electrical and Electronics

Engineers (IEEE). In some embodiments, a relatively short-range wireless communications protocol such as Bluetooth® or Wireless USB may be used.

[00227] The communications module may be configured to transmit some or all of the recorded data to the computing device over the communication channel, as the data is recorded or subsequent thereto, so that data logged by pipe securing apparatus 200 may be reviewed, stored, and/or audited. For example, data logged by pipe securing apparatus 200 may be audited to confirm that one or more mechanical restraint members were applied correctly. The logged data may also be compared with an installation plan for a piping system being assembled, to confirm that the total number of mechanical restraint members actually applied using pipe securing apparatus 200 corresponds with the total number of mechanical restraint members required to be applied to correctly install the piping system and/or that the pipe securing apparatus 200 was used at the location of some or all of the joints.

[00228] Reference is next made to Figure 60 illustrating a block diagram of control electronics 310 in accordance with an example embodiment. Control electronics 310 are provided as an example and there can be other embodiments of control electronics 310 with different components or a different configuration of the components described herein.

[00229] Control electronics 310 comprises processing unit 302, display 350, user interface 340 (e.g. for receiving control instructions for the heating element 210 and/or pressure chamber 220), and other input/output (I/O) hardware 306, communications unit 308 (which may include wireless unit 309), power unit 312 and memory unit 314.

[00230] Processing unit 302 controls the operation of the pipe securing apparatus 200 and/or quality control module 300. Processing unit 302 can be any suitable processor, controller or digital signal processor that can provide sufficient processing power processor depending on the configuration, purposes and requirements of quality control module 300 as is known by those skilled in the art. For example, processing unit 302 may be a high performance general processor. In alternative embodiments, processing unit 302 can include more than one processor with each processor being configured to perform different dedicated tasks. In alternative embodiments, specialized hardware may be used to provide some of the functionality provided by processing unit 302.

[00231] Display 350 can be any suitable display that provides visual information depending on the configuration of quality control module 300. For instance, display 350 can be a display suitable for a laptop, tablet, or handheld device such as an LCD-based display and the like.

5 [00232] User interface 340 can include at least one of a keyboard, a touch screen, a thumbwheel, a track-pad, a track-ball, and the like again depending on the particular implementation of quality control module 300. In some cases, some of these components can be integrated with one another.

[00233] Communications unit 308 can be any interface that allows the quality control  
10 module 300 to communicate with other devices or computers. In some cases, the communications unit 308 can include at least one of a serial port, a parallel port or a USB port that provides USB connectivity. Wireless unit 309 is optional and can be a radio (e.g. a transceiver or a transmitter) that communicates utilizing CDMA, GSM, GPRS or Bluetooth protocol according to standards such as IEEE 802.11a, 802.11b, 802.11g, or 802.11n.  
15 Wireless unit 309 can be used by quality control module 300 to wirelessly communicate with other devices or computers.

[00234] I/O hardware 306 generally includes a temperature sensor, pressure sensor, optical sensor, and location sensor, or any other suitable sensor(s). I/O hardware 306 may optionally also include at least one of a microphone, a speaker, and a printer, for example.

20 [00235] Power unit 312 can be any suitable power source that provides power to pipe securing apparatus 200 and/or quality control module 300 such as a power adaptor or a rechargeable battery pack depending on the implementation of pipe securing apparatus 200 as is known by those skilled in the art.

[00236] Memory unit 314 can include RAM, ROM, one or more hard drives, one or  
25 more flash drives or some other suitable data storage elements such as disk drives, etc. Memory unit 314 may be used to store an operating system and programs as is commonly known by those skilled in the art. For instance, an operating system may provide various basic operational processes for pipe securing apparatus 200 and/or quality control module 300. Programs may include various user programs so that a user can interact with the pipe  
30 securing apparatus 200 and/or quality control module 300 to perform various functions

such as, but not limited to, inputting controls, viewing and manipulating data as well as sending messages as the case may be.

[00237] Memory unit 314 may also accept data from one of the input devices, communications module 308, and I/O hardware 306. Memory unit 314 uses the received  
5 data to define and store, for example, at least a subset of recorded sensor data (e.g. temperature, pressure and/or location data) for one or more operations of pipe securing apparatus 200, as discussed above.

[00238] An example embodiment for a method for applying a mechanical restraint member 100 using a pipe securing apparatus 200 having a quality control module 300 will  
10 now be described with reference to Figure 61 and is shown generally as 500.

[00239] The method starts at 502. At 504, after joining the two components together, using, for example, an insertion fit, and positioning a flexible substrate 110 about the joint, a user positions a pipe securing apparatus 200 about the joint and the flexible substrate 110. If the pipe securing apparatus 200 is an annular cuff, it may be slid over one end of one of  
15 the piping system components. If the pipe securing apparatus 200 is a linear cuff, it may be wrapped around the joint and one end of the pipe cuff may be connected to the other end of the pipe cuff.

[00240] At 506, a user activates the controls for pipe securing apparatus 200 and/or quality control module 300, for example by interacting with touch screen display 350.  
20 During start-up, optionally at 508 the controller may confirm, for linear pipe cuffs, that the ends 216, 218 of the cuff are properly secured to each other by, for example, confirming that a circuit between them is complete, indicating that the pipe cuff has been connected to itself. If not, an error may be displayed at 510a. Otherwise, the method proceeds to 512.

[00241] At 512, the control electronics may actuate the pipe securing apparatus 200  
25 to apply pressure. For example, a fluid inlet port coupled to a source or pressurized gas may be opened to inflate one or more pressure chambers 220.

[00242] At 514, the control electronics may verify, using e.g. one or more pressure sensors, that a correct bonding pressure has been reached (e.g., a desired pressure has been achieved in the pressure chamber). In the exemplified method, the control software  
30 may continuously monitor (e.g. using a timeout subroutine 516a) the duration of time that

the pressure has been applied without reaching the specified bonding pressure. If subroutine 516a determines that pressure has been applied for a predetermined amount of time without reaching the specified bonding pressure, at 510b an error may be displayed.

[00243] Once the correct bonding pressure is determined to have been reached at 514, control electronics may direct the heating module 210 to apply heat to the flexible substrate 110, e.g. via one or more heating members 142 adjacent inner surface 214 of pressure cuff 200.

[00244] At 520, control electronics may monitor one or more temperature sensors to determine if a correct bonding temperature has been reached (e.g., the heating element has reached a desired temperature). Again, a time out subroutine 516b may be used to monitor the duration of time over which heat has been applied without reaching the correct bonding temperature. If a time out condition is reached, an error may be displayed at 510c, and the heat may be turned off at 524.

[00245] Once the control electronics determines at 520 that the correct bonding temperature has been reached, the method proceeds to 522, where one or more force sensors may be used to determine whether or not a correct bonding force has been reached (e.g., by determining if the pressure cuff has applied a desired pressure to the conduits). If a correct bonding force is not reached, an error may be displayed at 510d, and the heat may be turned off at 524. Otherwise, upon determining the correct bonding force has been reached, the control electronics may turn off the heat at 524 and begin a logging operation.

[00246] At 526, control electronics may optionally determine a geographical location of the pressure cuff 200 and/or quality control module 300, e.g. using a location sensor, and store this data to memory. At 528 control electronics may optionally use an optical sensor to determine a colour of, or colour change, or other visual change, of all or a portion of an outer surface of flexible substrate 110, as discussed previously. This GPS and/or optical data, along with any pressure, temperature, and force data collected earlier (e.g. during steps 512, 514, 518, 520, 522) may be transmitted to another computing device at 530, and/or internally stored to memory at 532. It will be appreciated that any of the data may also optionally be displayed at the device, e.g. via display 350.

[00247] At 534, after logging and storing the data, a label listing none, some, or all of the logged data may optionally be printed. The label may be affixed on or adjacent the joint that was checked to indicate that the application of the mechanical restraint member has been checked. It will be appreciated that the label may merely indicate that the application  
5 of the mechanical restraint member was checked and approved.

[00248] At 536, another temperature measurement may be taken. For example, one or more temperature sensors may be used to measure the surface temperature of the outer surface 112 of flexible substrate 110. If the temperature is determined to be too high for, e.g. safe removal of pipe securing apparatus 200, an optional cooling module may be  
10 turned on at 538 to cool the flexible substrate 110. If a cooling module is activated at 538, a timing subroutine 516c may be used to determine if the cooling has been on for a predetermined amount of time without reaching a predetermined temperature, and an error may optionally be displayed at 510e.

[00249] After optionally determining at 536 that the mechanical restraint member has  
15 sufficiently cooled, or after the errors at 510b-e, at 540 control electronics may reduce the pressure being applied (e.g. by deflating pressure chamber 220) in order to deflate the pressure cuff. At 542, the pressure may be monitored to confirm that the cuff has been sufficiently deflated to allow a safe removal. Again, a time out subroutine 516d may be used.

[00250] At 544, after determining that the pressure cuff has been sufficiently  
20 depressurized, a signal may be provided (e.g. either on display 350 or using some other mechanism, such as an indicator light) to confirm the application of mechanical restraint member 100 is complete.

[00251] At 546, a user may remove pipe securing apparatus 200 from its position  
25 about the joint, leaving behind one or more mechanical restraint members 100 secured in position.

[00252] As used herein, the wording "and/or" is intended to represent an inclusive - or. That is, "X and/or Y" is intended to mean X or Y or both, for example. As a further example, "X, Y, and/or Z" is intended to mean X or Y or Z or any combination thereof.

[00253] Although preferred embodiments of the invention have been disclosed for illustrative purposes, those skilled in the art will appreciate that many additions, modifications, and substitutions are possible and that the scope of the claims should not be limited by the embodiments set forth herein, but should be given the broadest interpretation  
5 consistent with the description as a whole.

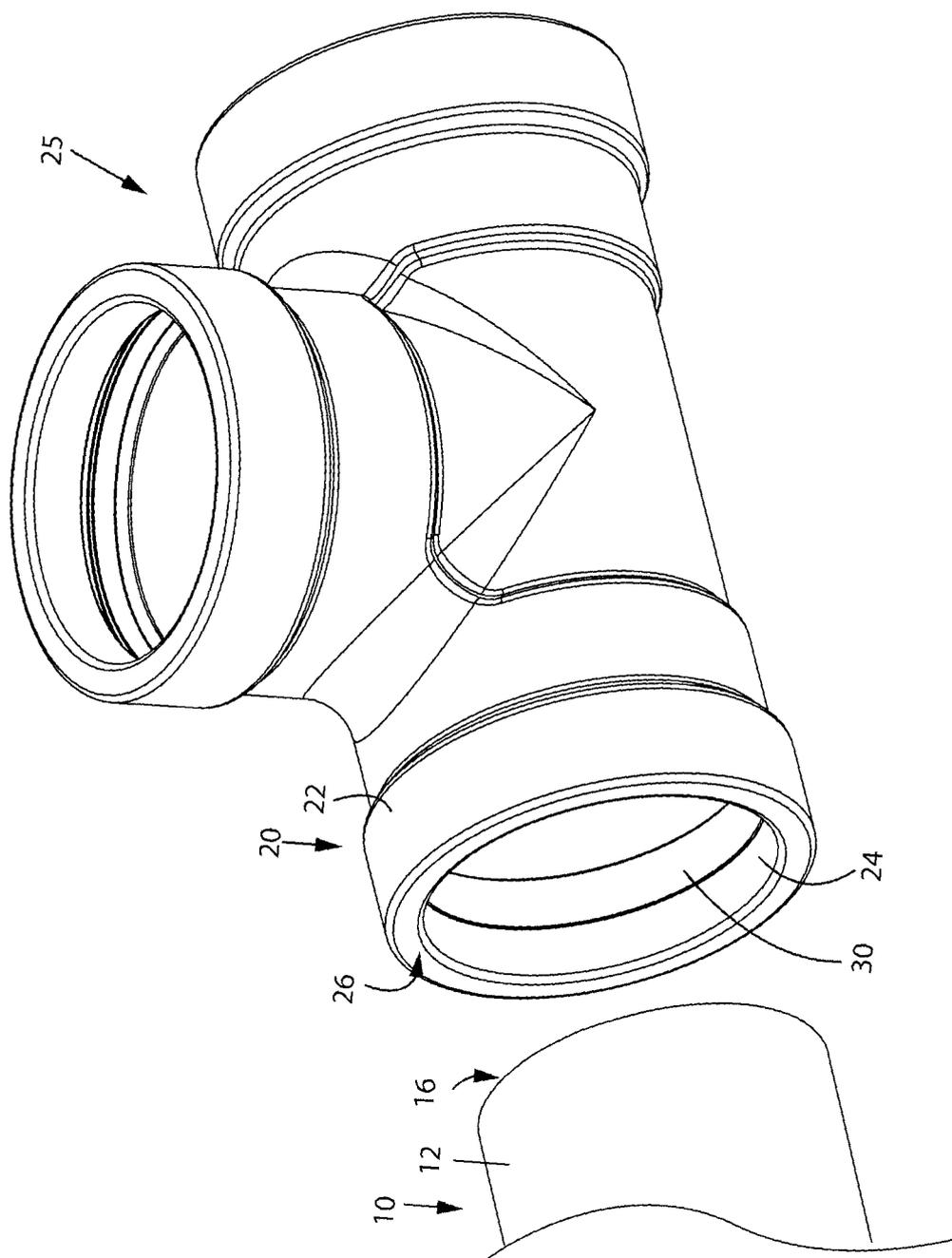
## CLAIMS:

1. A pipe joining apparatus for joining a first conduit section with a second conduit section wherein a mechanical restraint member extends from an outer surface of the first conduit to an outer surface of the second conduit, the pipe joining apparatus comprising:
  - a) a pressure applicator comprising an inflatable member;
  - b) a location monitoring member; and,
  - c) a data recorder wherein the data recorder records for a location at which the apparatus is used the at least one of the temperature and pressure applied by the apparatus at the location.
2. The pipe joining apparatus of claim 1 wherein the apparatus applies at least heat or pressure for a period of time at the location and the data recorder records a duration of the period of time at the location.
3. The pipe joining apparatus of claim 1 wherein the apparatus comprises both a heat producing member and a pressure applicator.
4. The pipe joining apparatus of claim 3 wherein the apparatus applies both heat for a first period of time at the location and pressure for a second period of time at the location and the data recorder records a duration of the first and second periods of time at the location.
5. The pipe joining apparatus of claim 1 wherein the inflatable member comprises an inflatable annular member.
6. The pipe joining apparatus of claim 1 wherein the heat producing member comprises at least one of a resistive heating member, an exothermic reactive composition, an infrared producing member and a microwave producing member.
7. The pipe joining apparatus of claim 1 wherein the location monitoring member comprises a GPS locator.

8. The pipe joining apparatus of claim 1 wherein the apparatus comprises a body containing the at least one of a heat producing member and a pressure applicator and the location monitoring member and the body also contains the data recorder.
9. The pipe joining apparatus of claim 1 wherein the apparatus comprises a body containing the at least one of a heat producing member and a pressure applicator and the location monitoring member and the data recorder is located remote from the body.
10. The pipe joining apparatus of claim 9 wherein the body further comprises a transmitter whereby data is transmitted to the remotely located data recorder.
11. A pipe joining apparatus for joining a first conduit section with a second conduit section wherein a mechanical restraint member extends from an outer surface of the first conduit to an outer surface of the second conduit, the pipe joining apparatus comprising:
  - a) a heat producing member;
  - b) a location monitoring member;
  - c) a data recorder wherein the data recorder records for a location at which the apparatus is used the at least one of the temperature and pressure applied by the apparatus at the location; and,
  - d) a colour sensorwherein the mechanical restraint member changes colour when a sufficient amount of heat has been applied to secure the mechanical restraint member to the conduits.
12. The pipe joining apparatus of claim 11 wherein the apparatus further comprises a signaling device and the signaling device produces a signal when the colour sensor fails to detect a predetermined colour.
13. A method of joining a first conduit section with a second conduit section wherein a mechanical restraint member is used that extends from an outer surface of the first conduit to an outer surface of the second conduit, the method comprising:
  - a) applying both heat and pressure at a location;

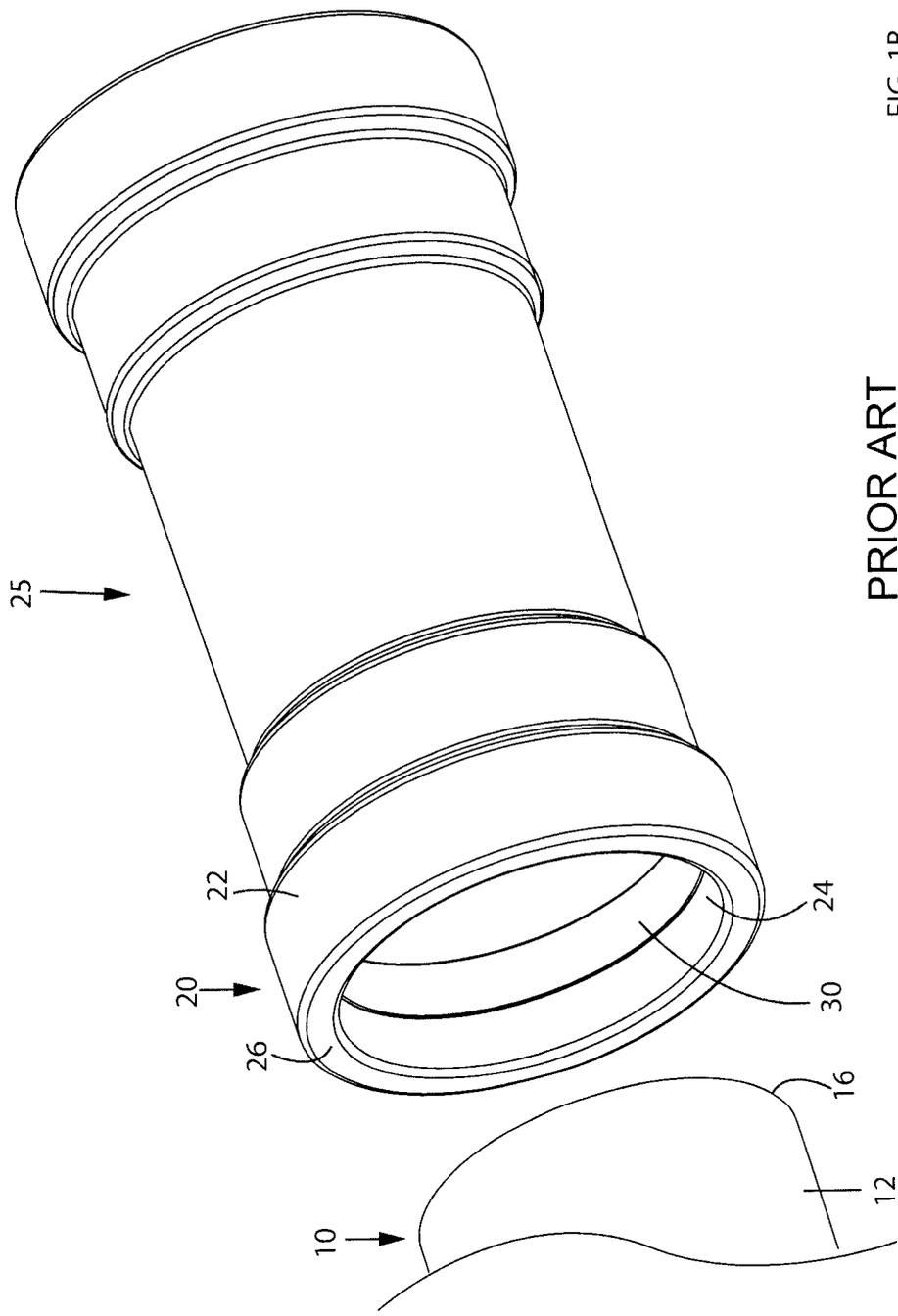
- b) recording both the temperature and pressure applied at the location; and,
- c) recording a length of time during which the at least one of heat and pressure is applied at the location.

14. The method of claim 13 further comprising recording a length of time during which each of heat and pressure is applied at the location.
15. The method of claim 13 wherein the mechanical restraint member comprises a colour change member that changes colour when a sufficient amount of heat has been applied to secure the mechanical restraint member to the conduits and the method further comprises sensing the colour of the mechanical restraint member after the heat and pressure have been applied at the location.
16. The method of claim 15 further comprising issuing a signal if a predetermined colour is not sensed after the heat and pressure have been applied at the location.
17. The method of claim 13 wherein a body comprises a transmitter and at least one of a heat producing member and a pressure applicator, and the method further comprises transmitting the heat and/or pressure applied at the location to a remotely located recorder.



PRIOR ART

FIG. 1A



PRIOR ART

FIG. 1B



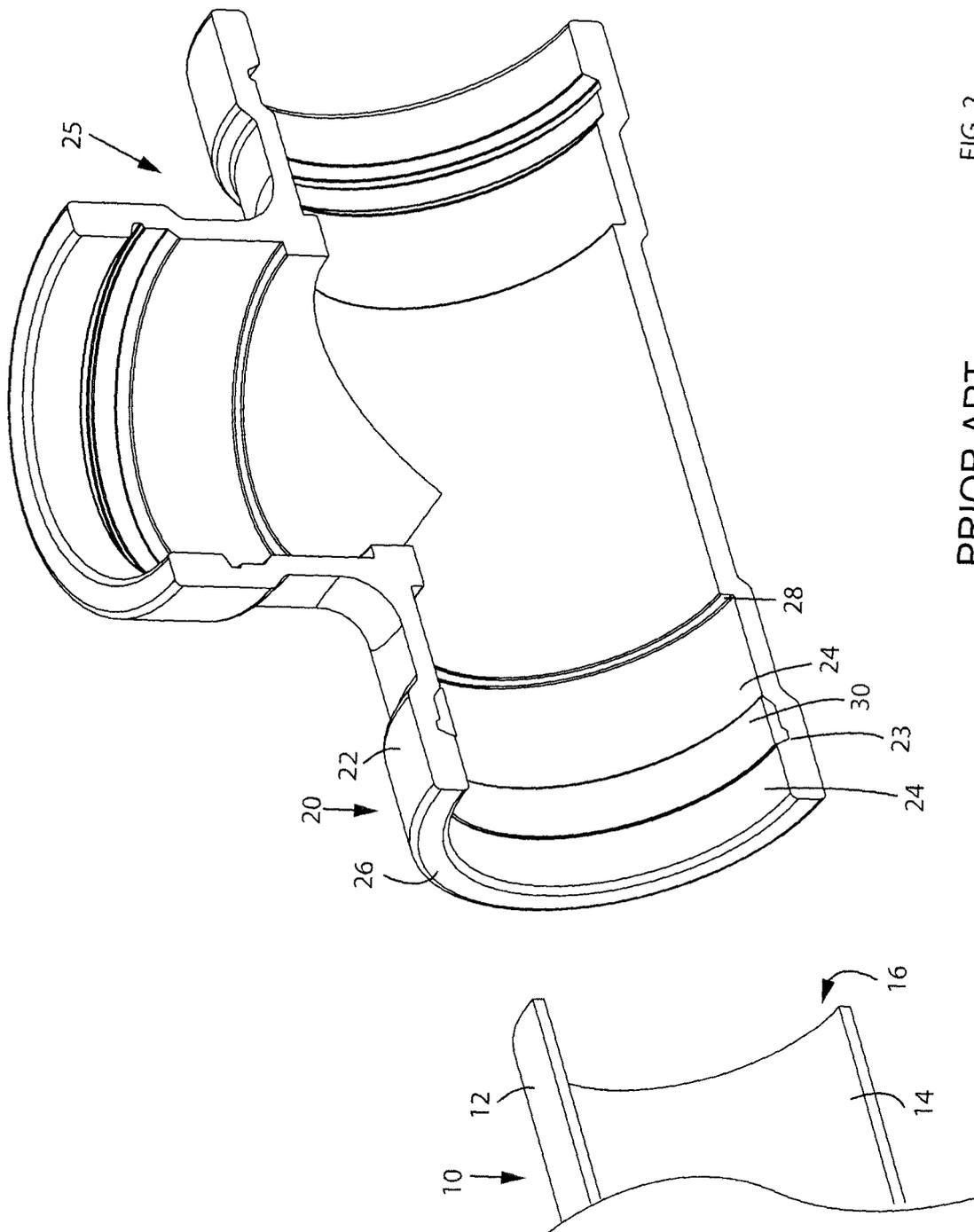


FIG.2

PRIOR ART

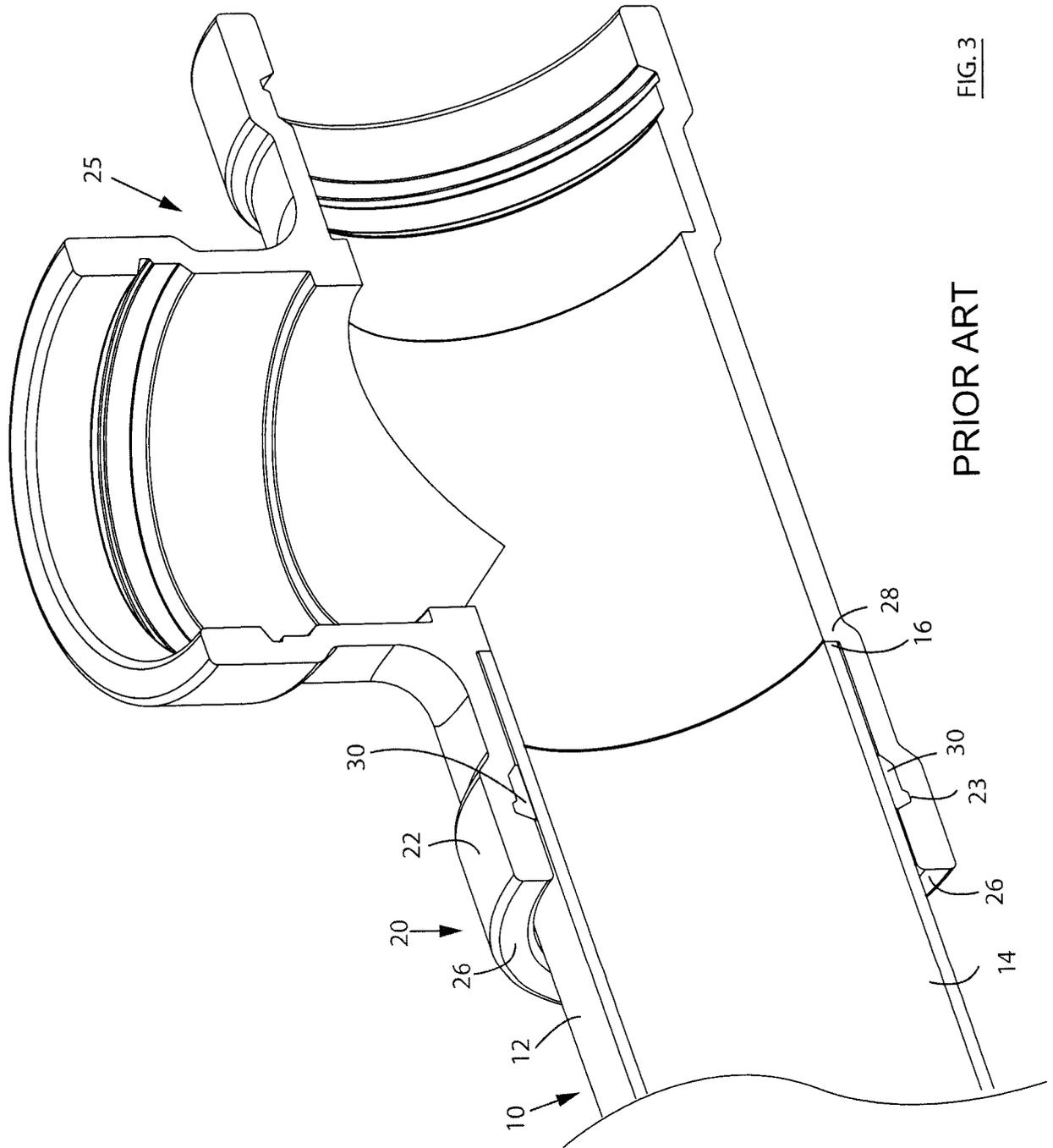
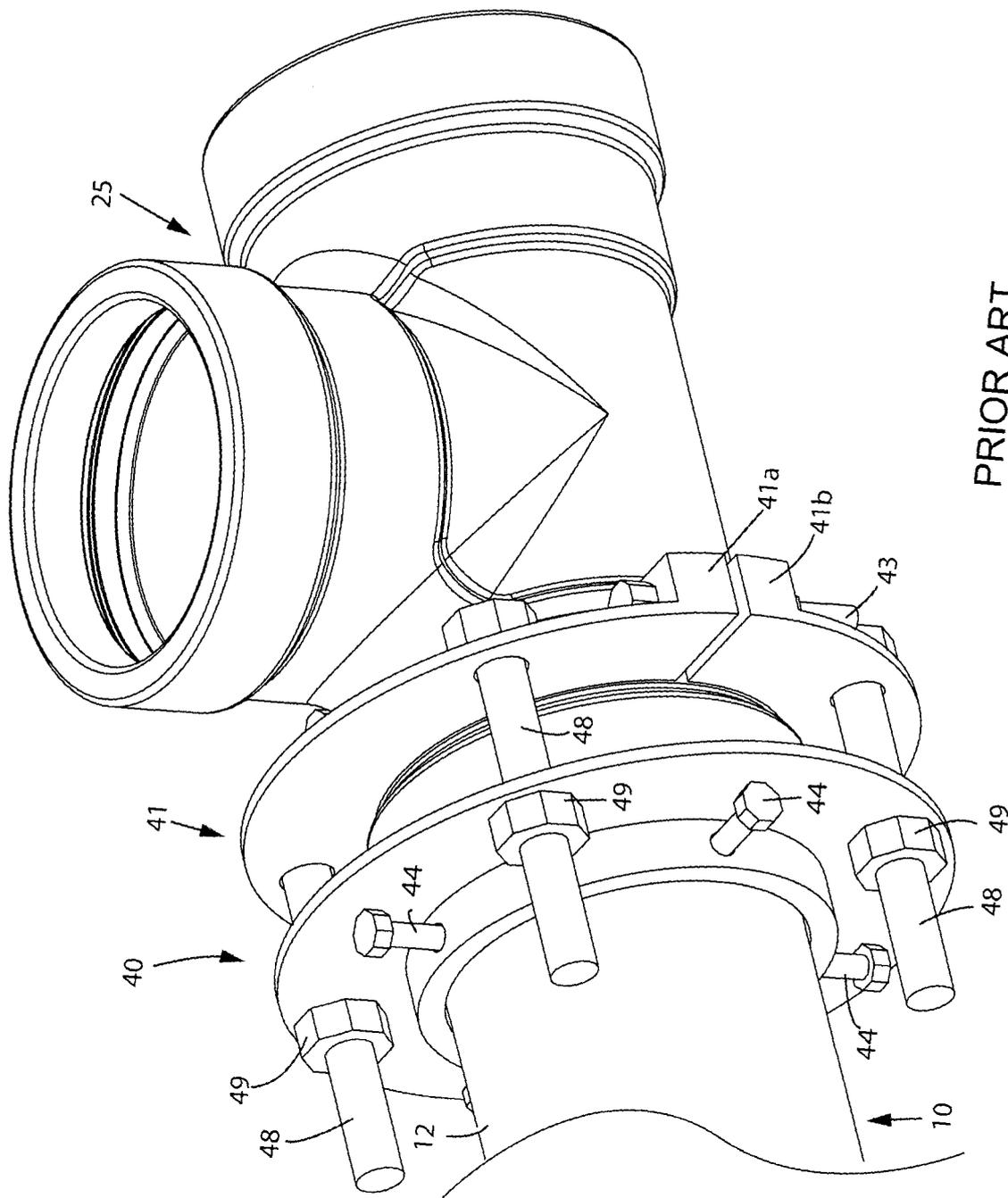


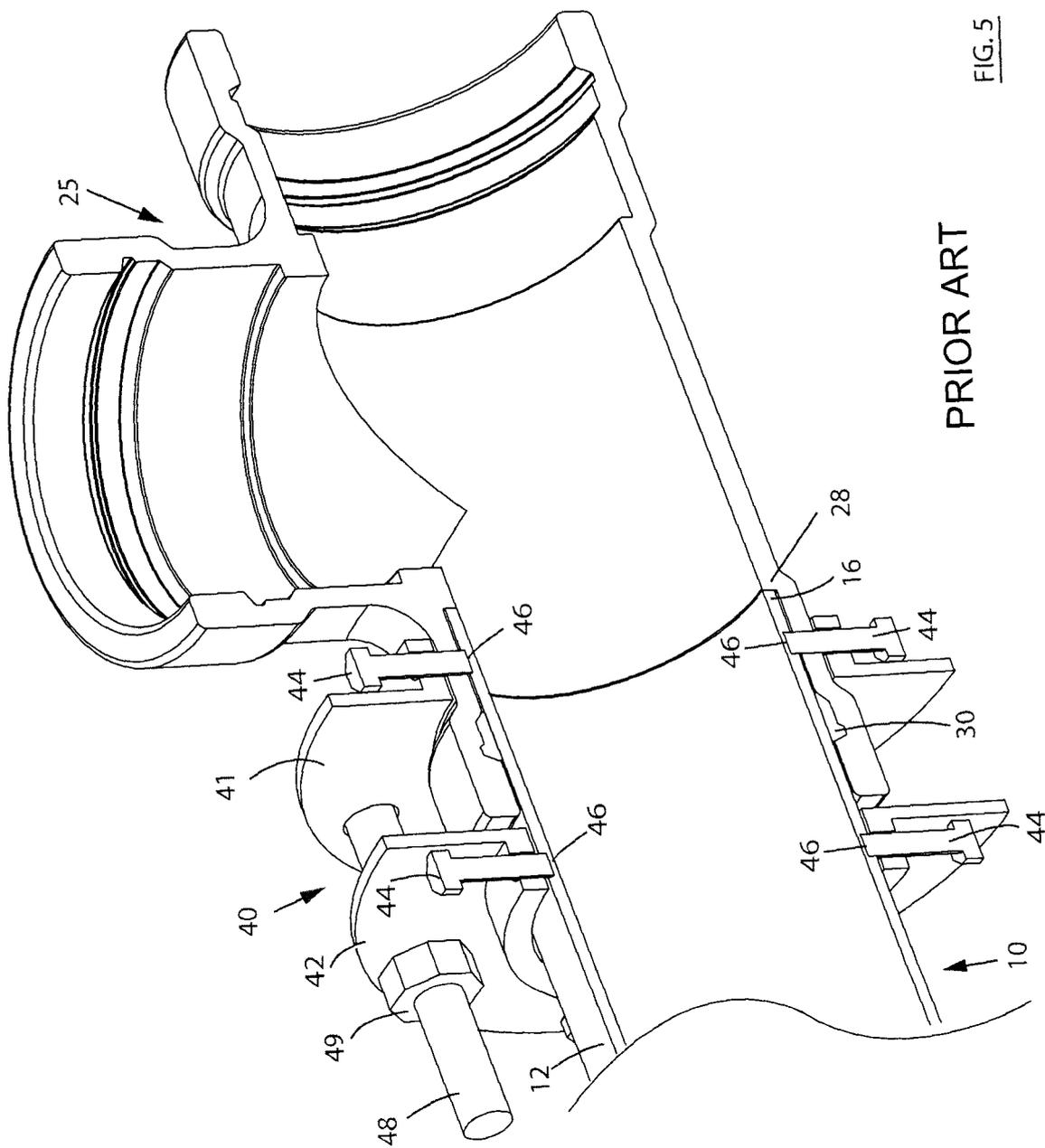
FIG. 3

PRIOR ART



PRIOR ART

FIG. 4



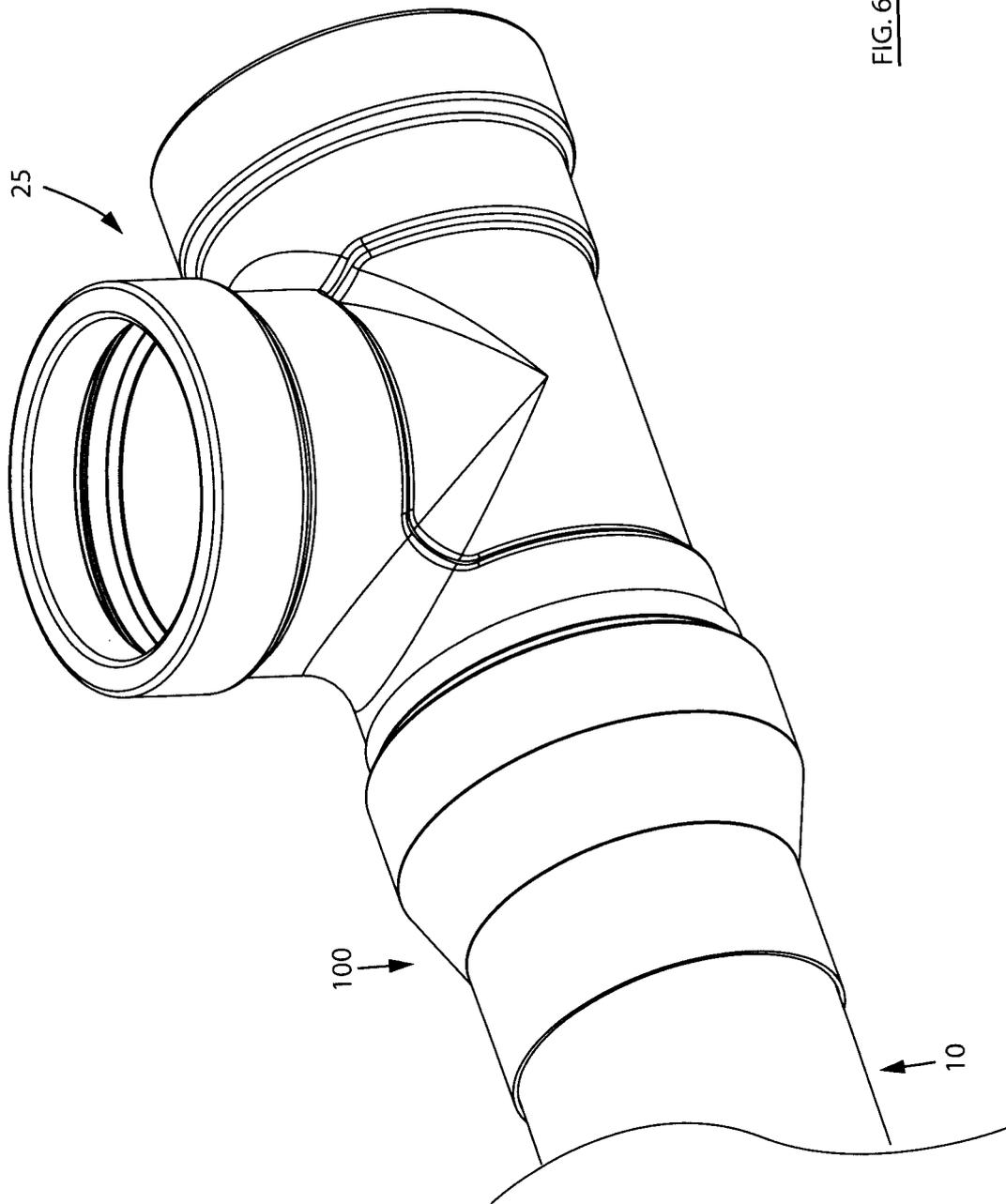


FIG. 6



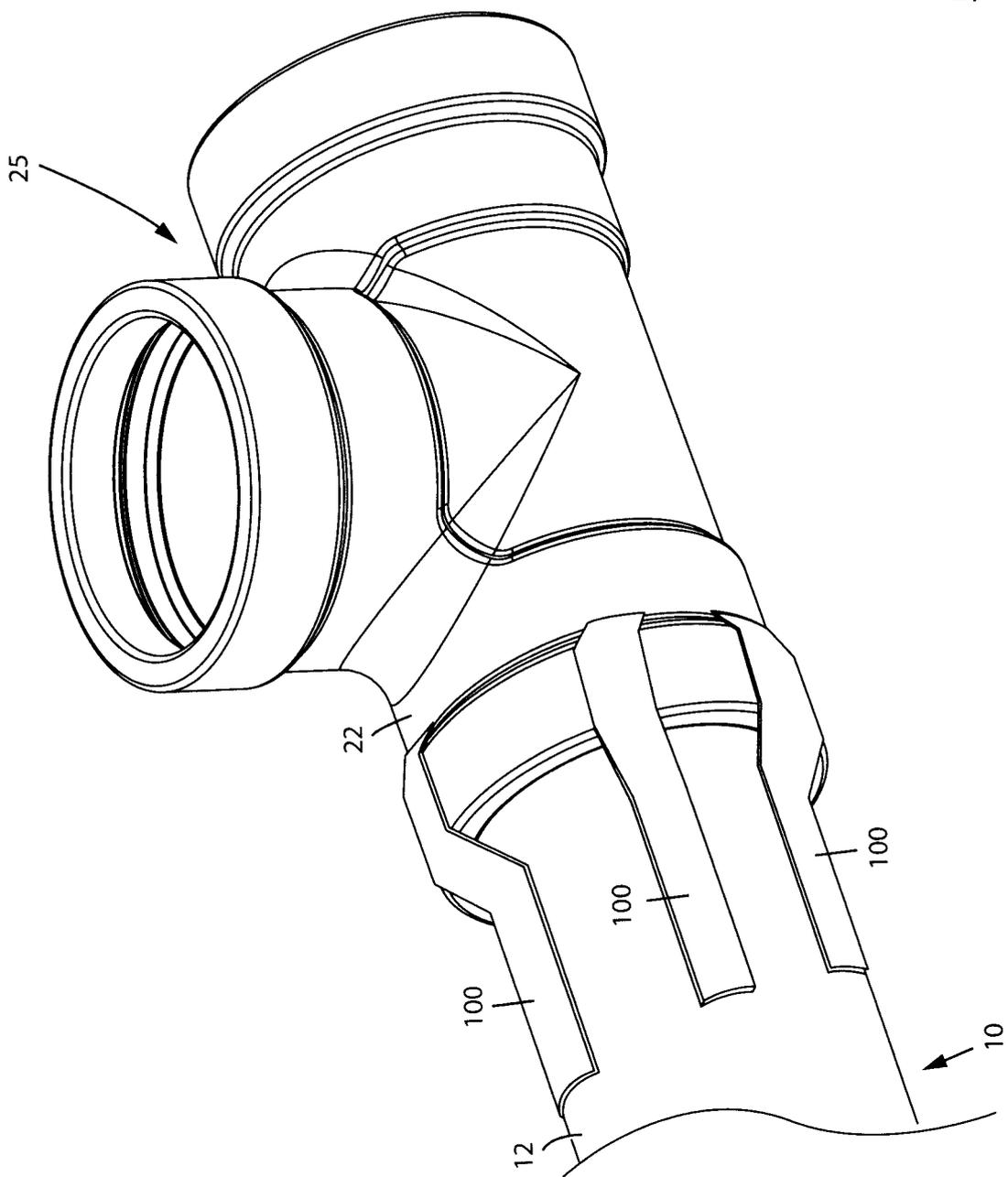


FIG. 8



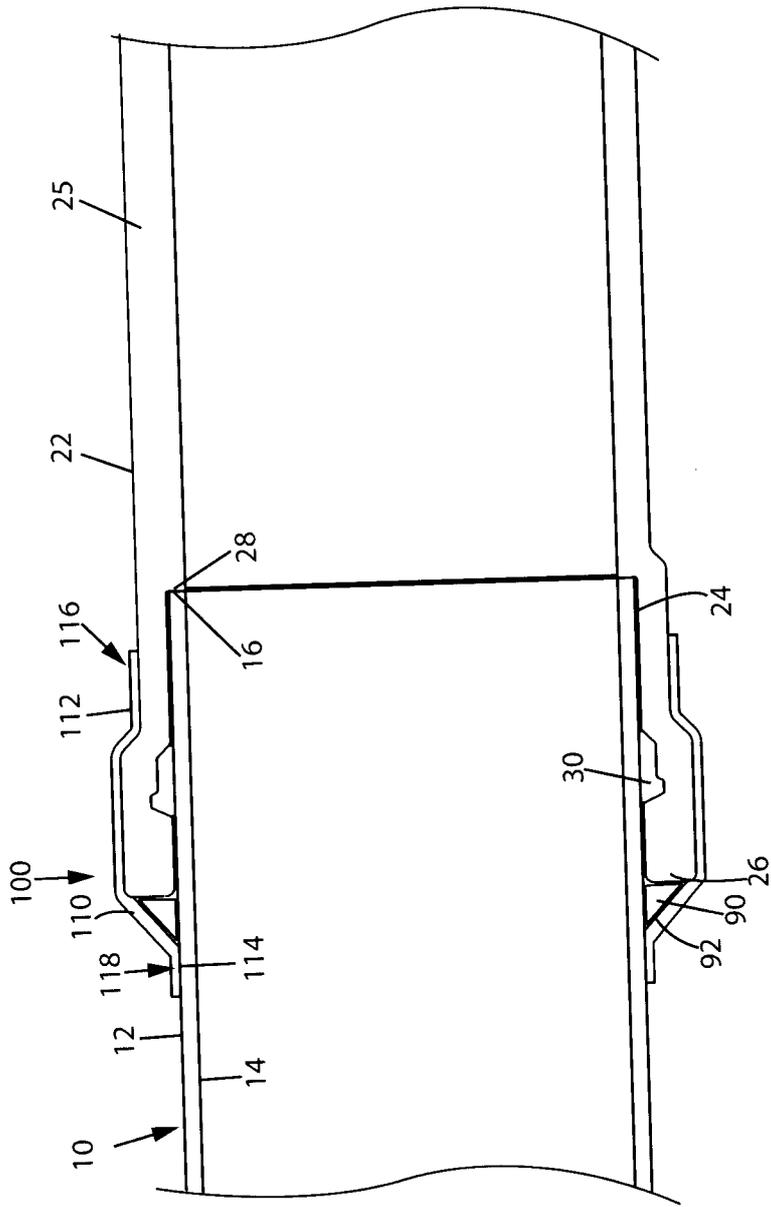


FIG. 10

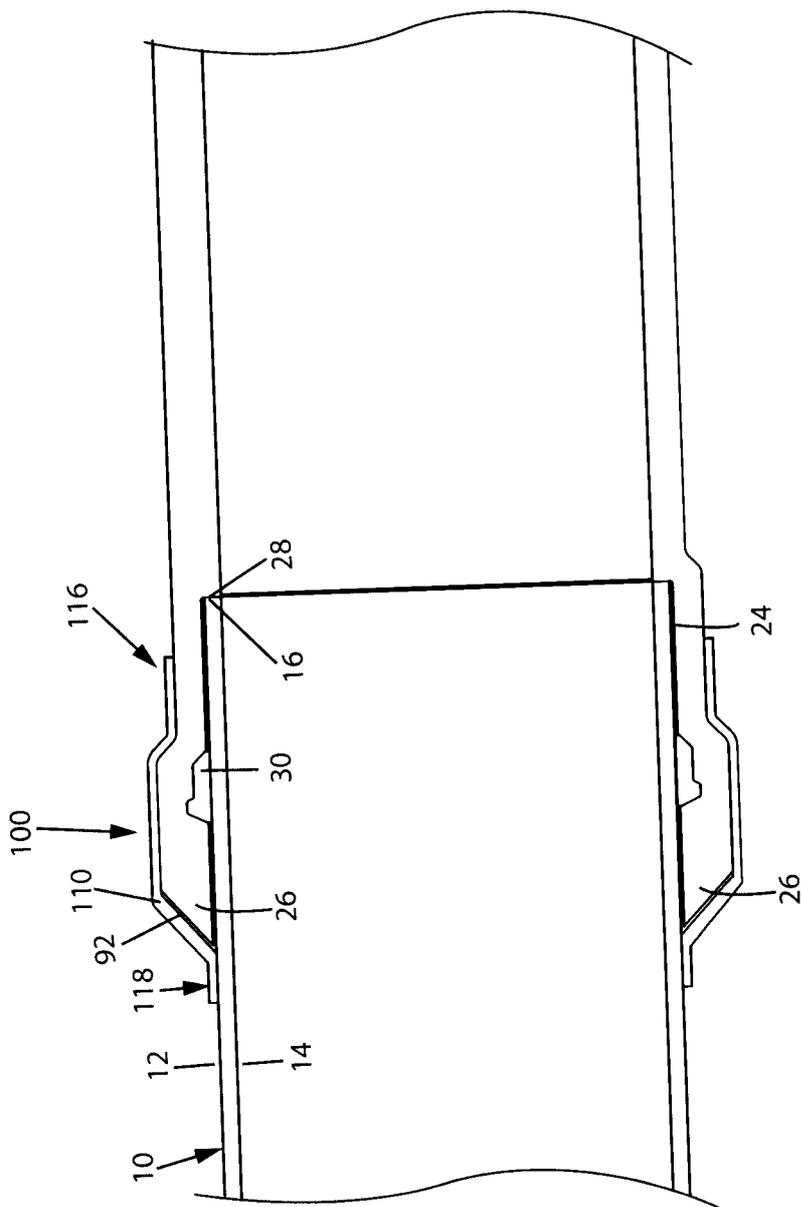


FIG. 11

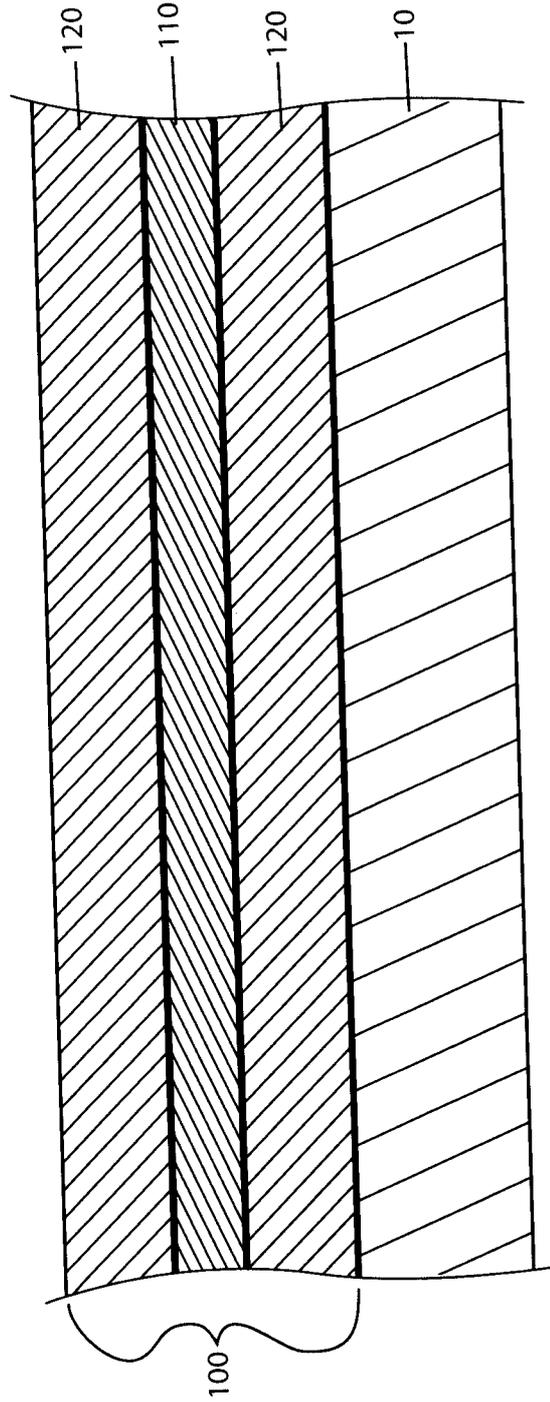


FIG. 12

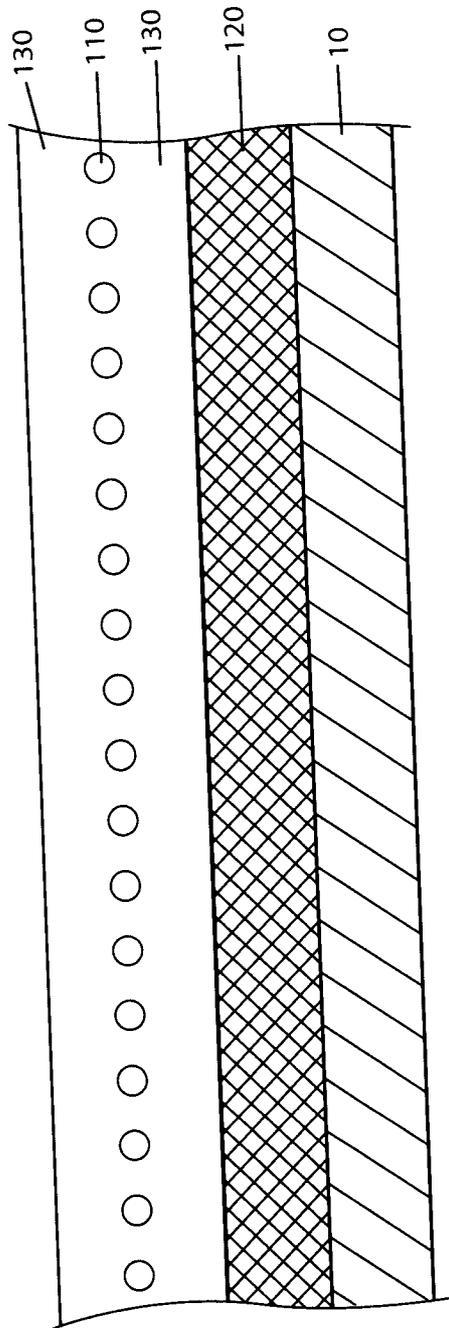


FIG. 13

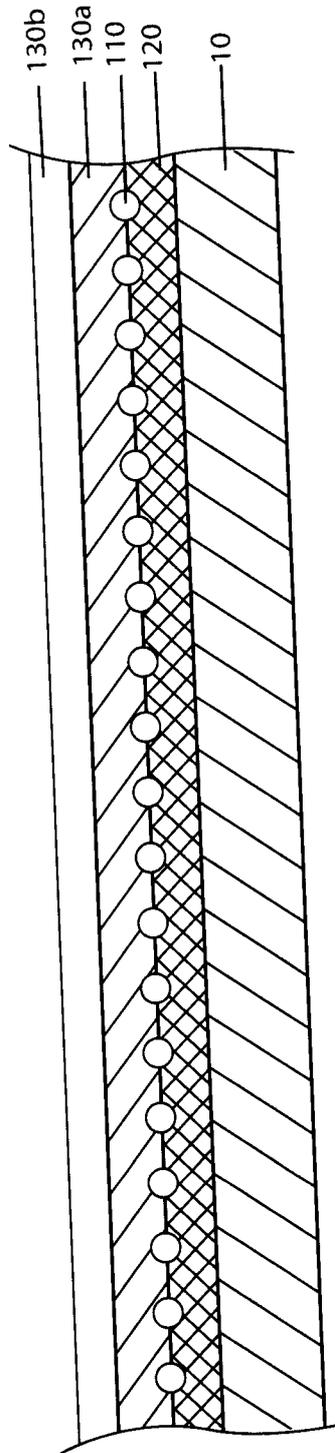


FIG. 14

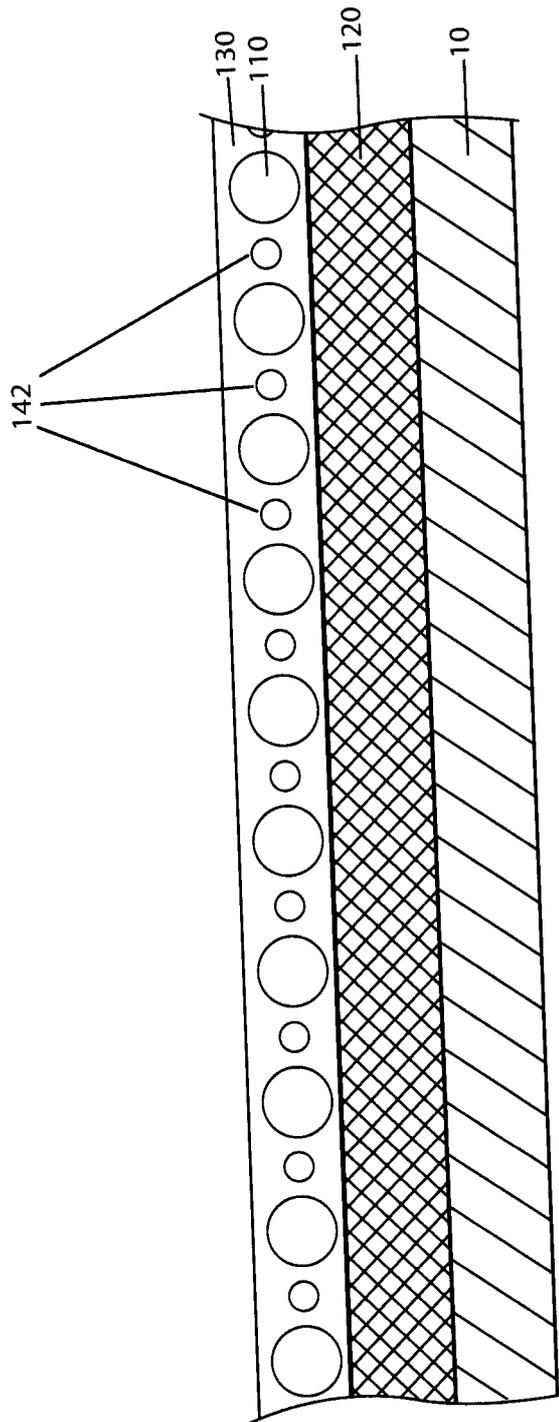


FIG. 15

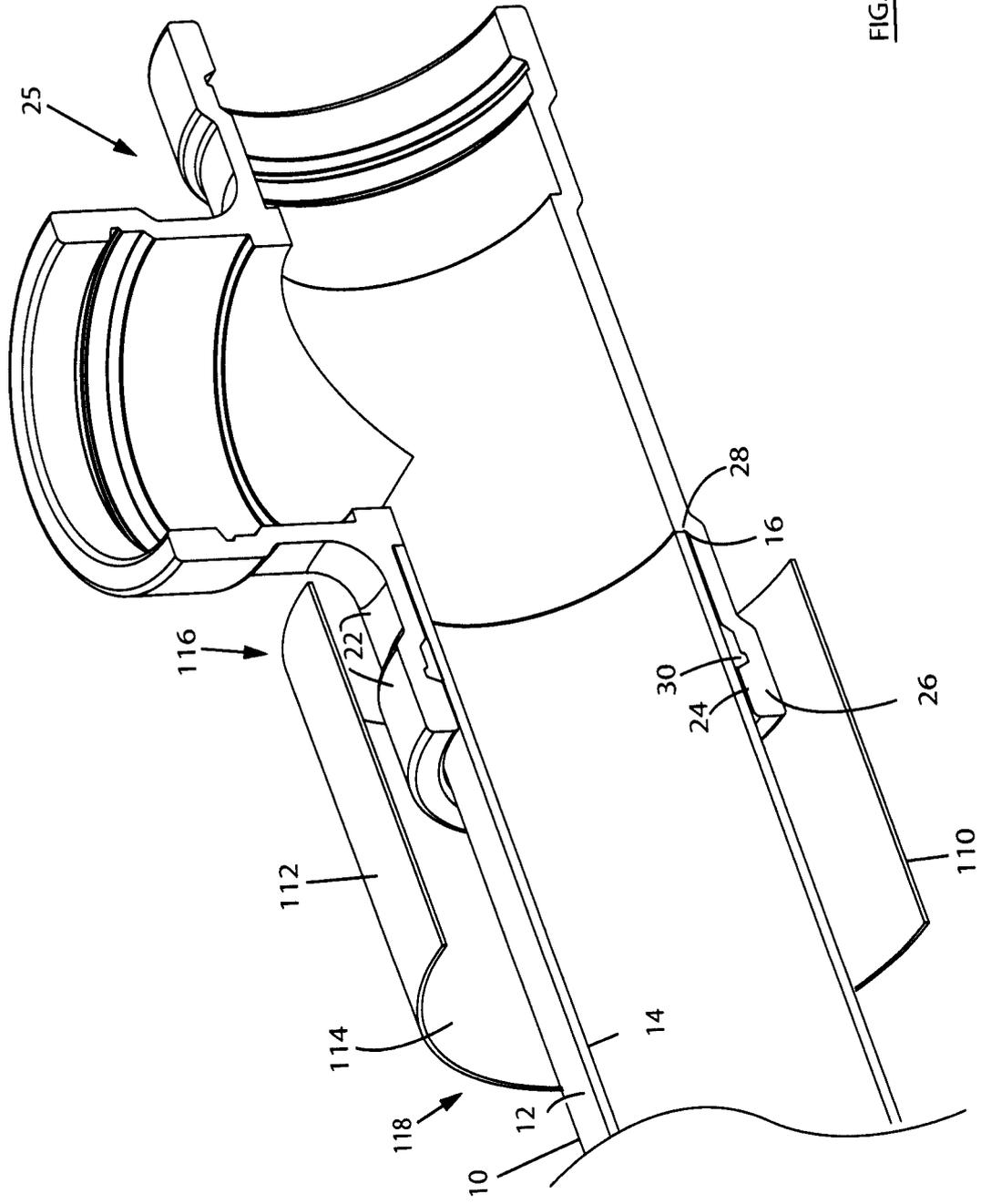
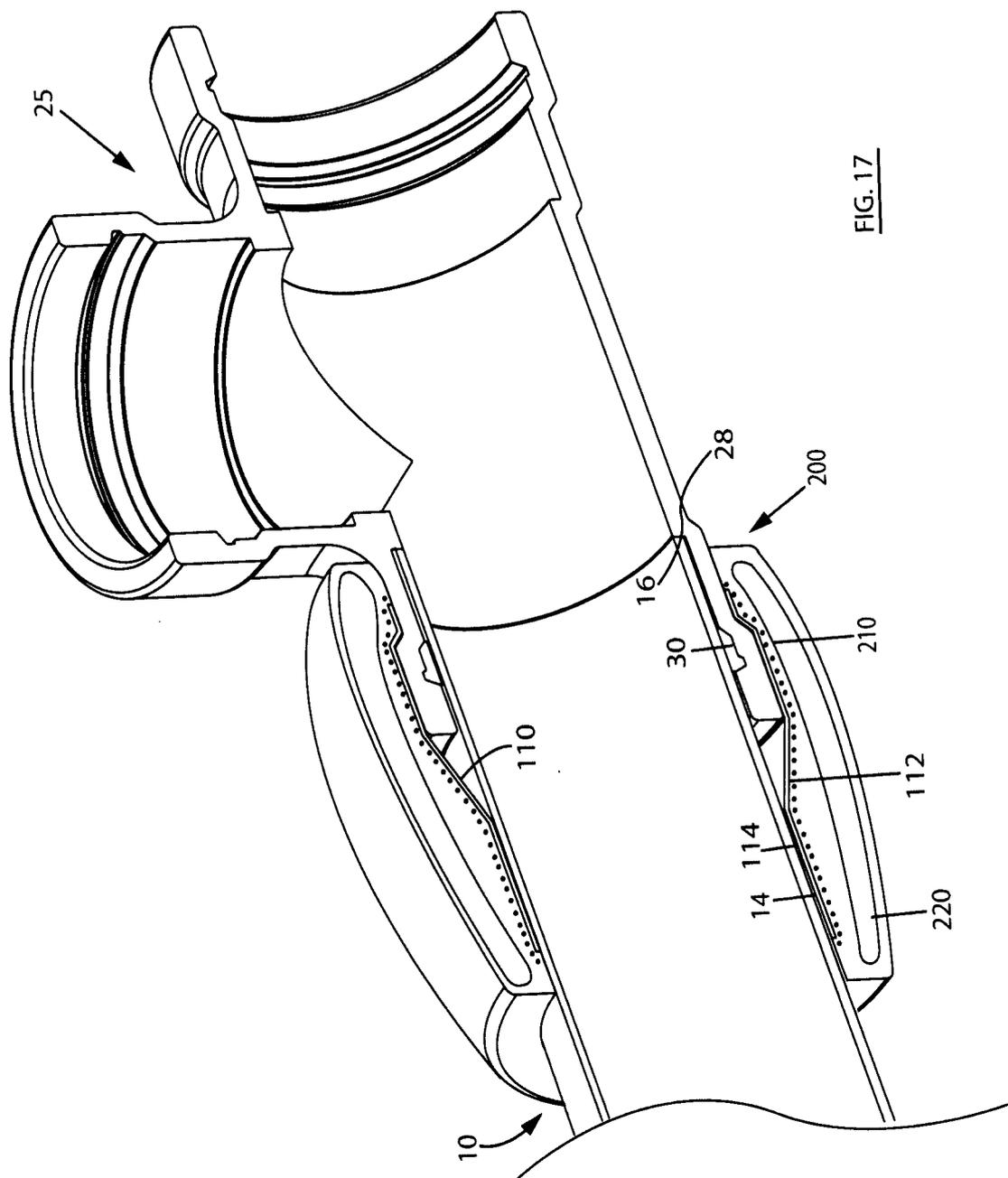


FIG. 16



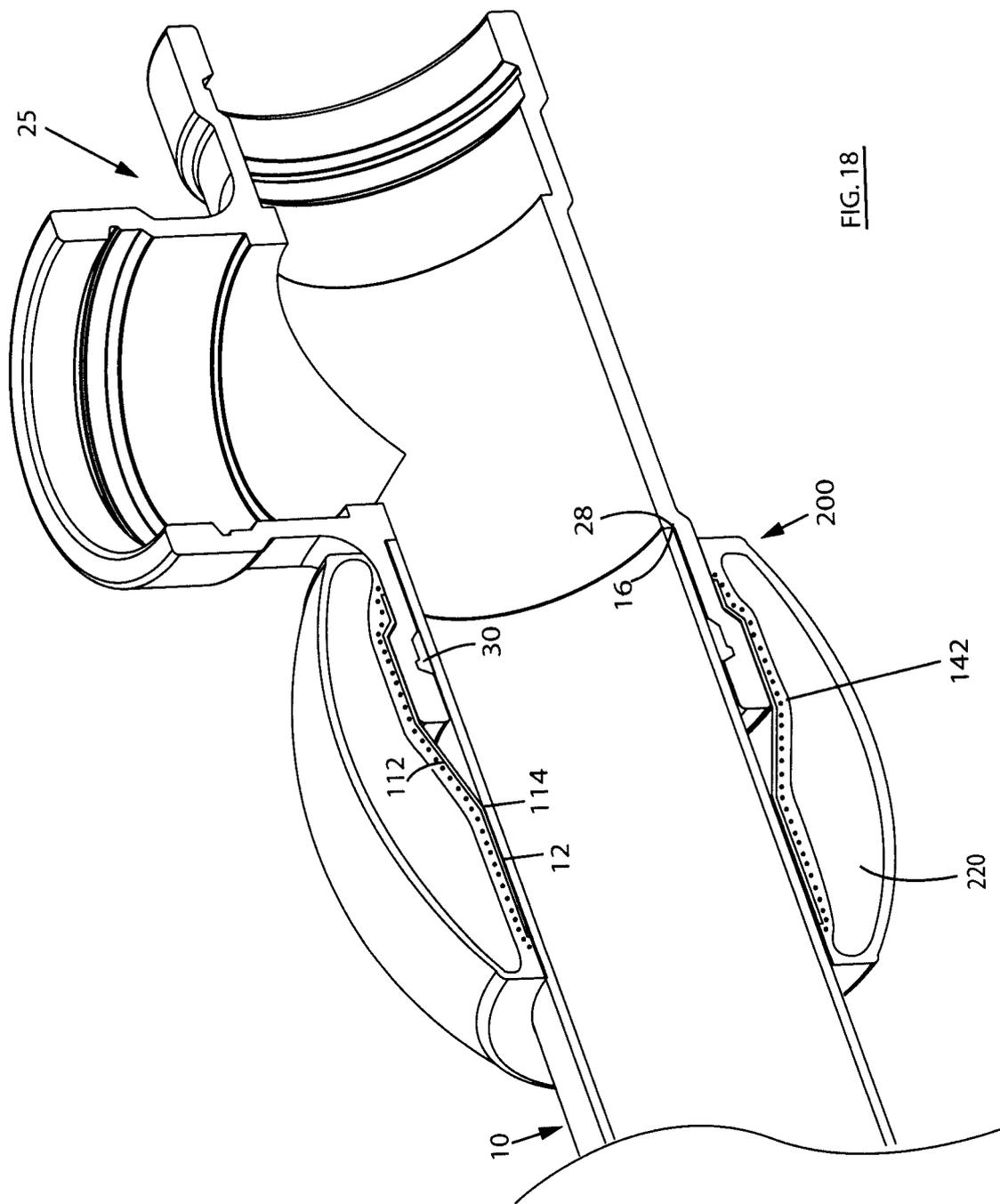


FIG. 18

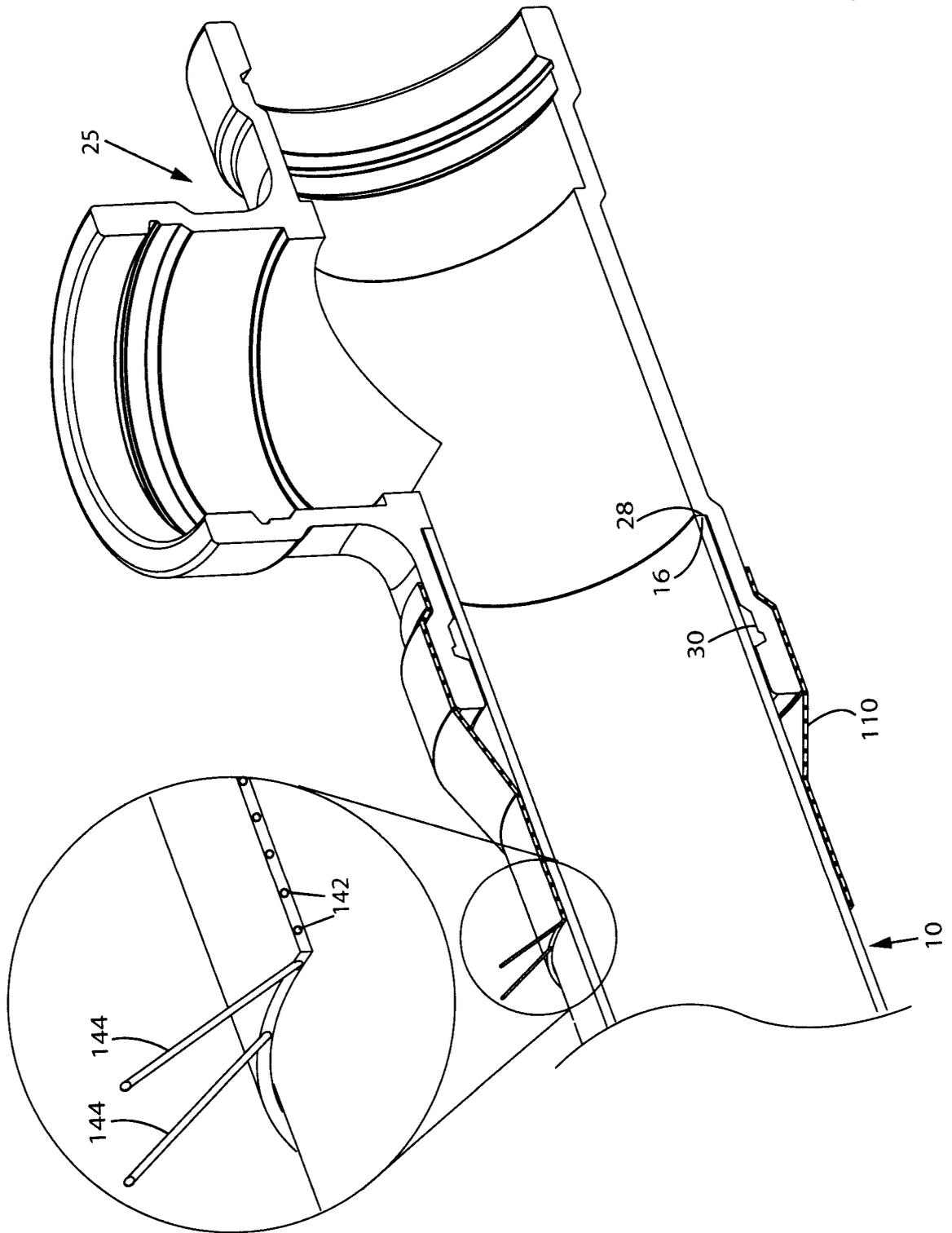
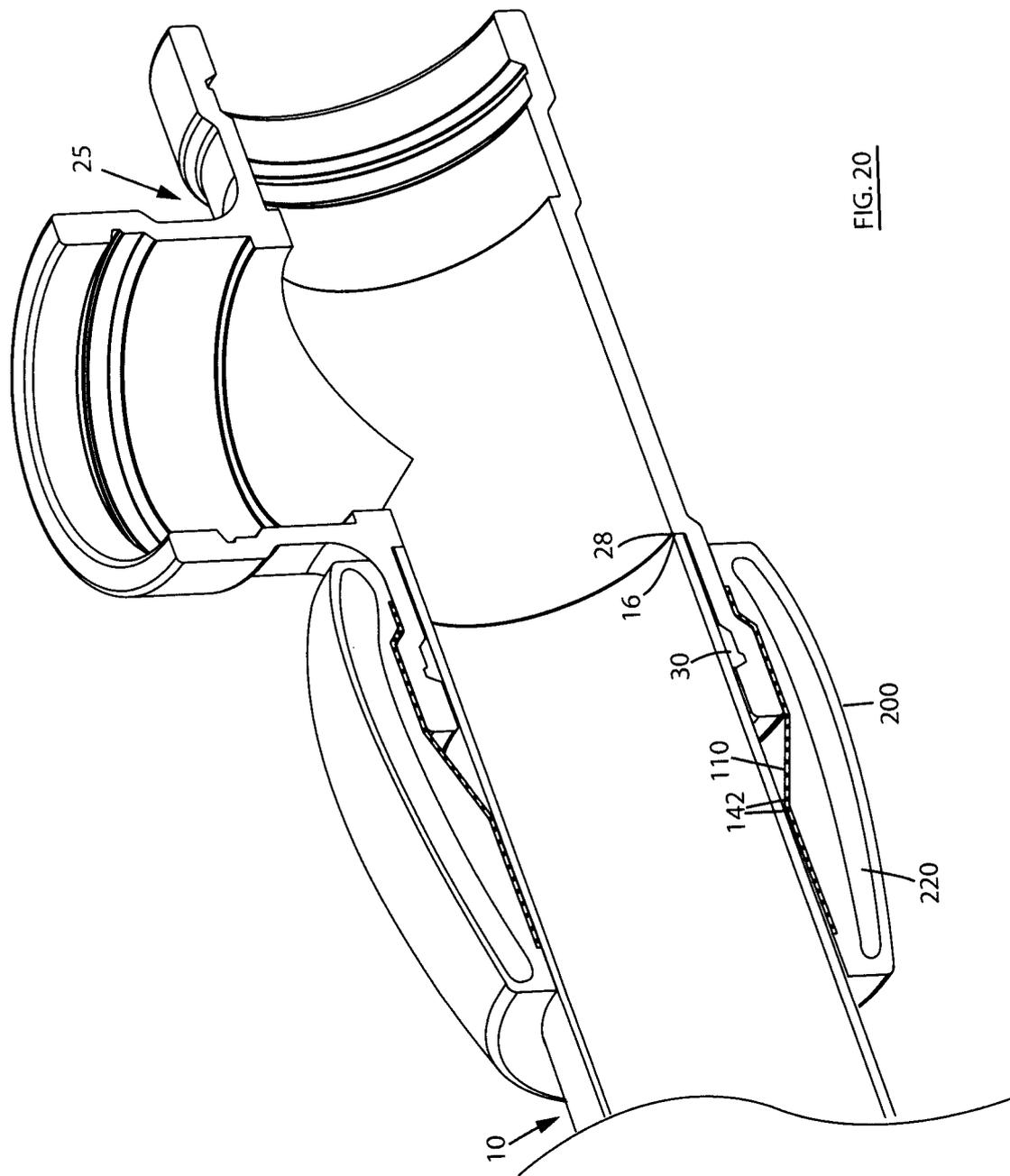


FIG. 19



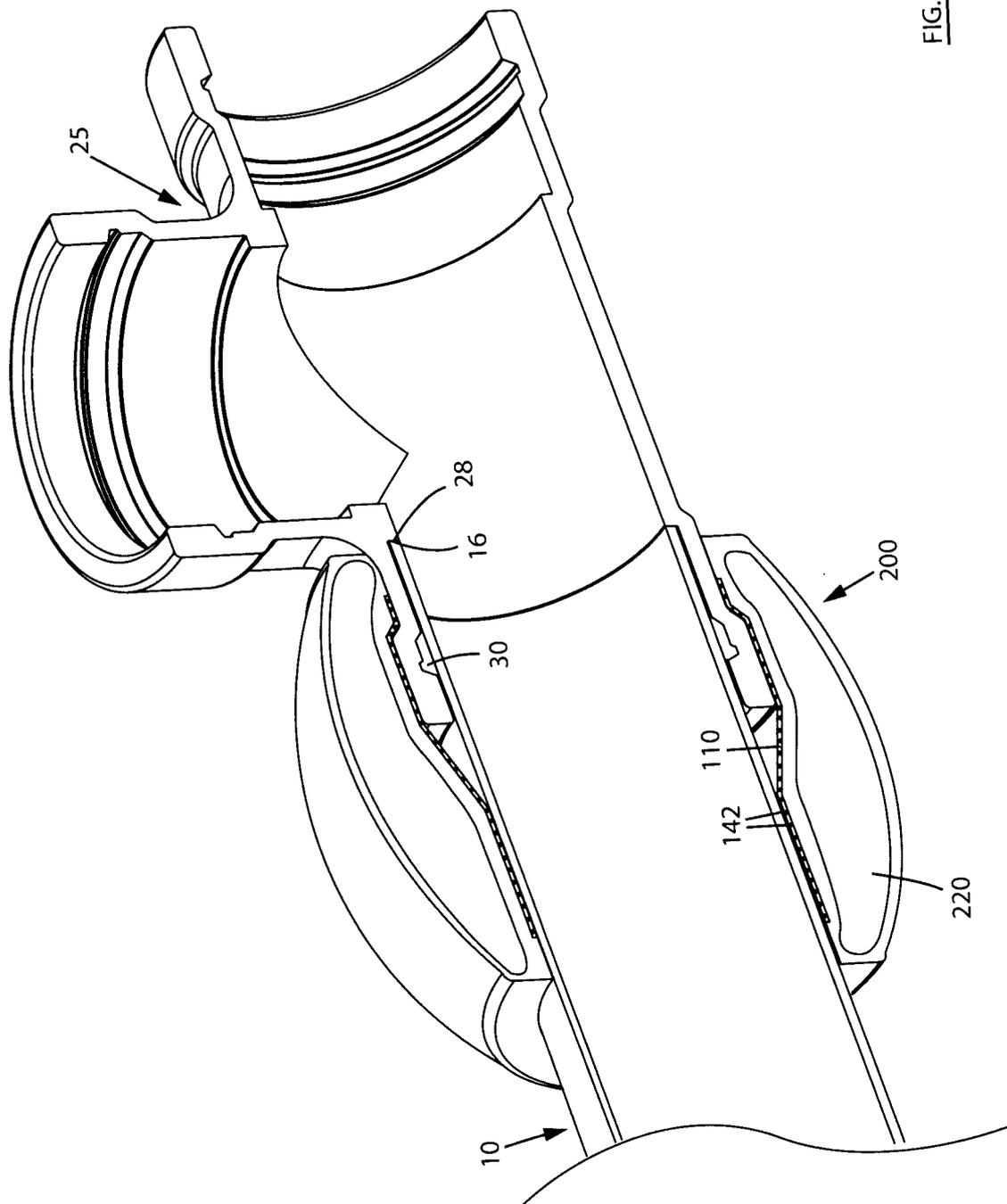


FIG. 21

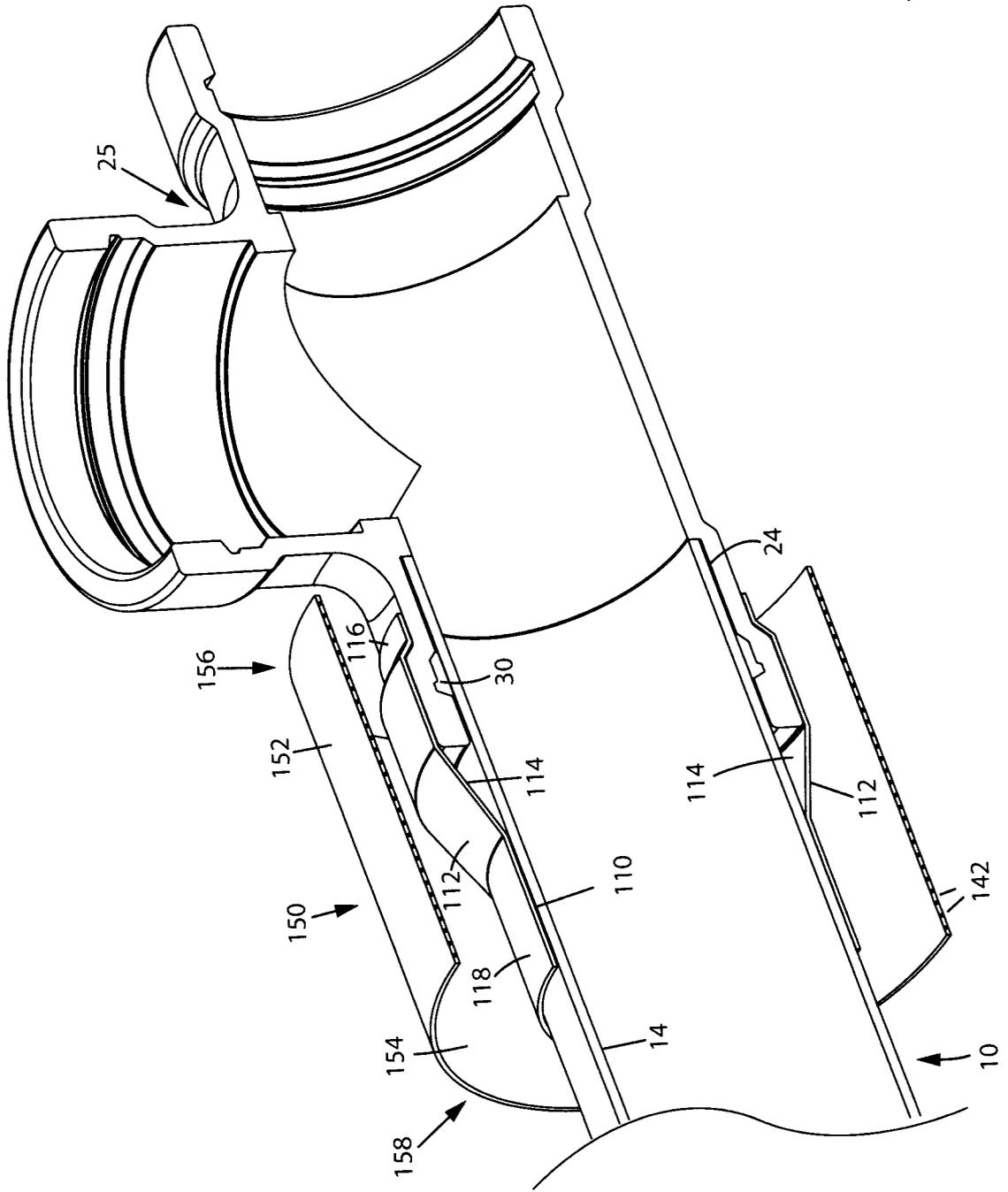


FIG. 22

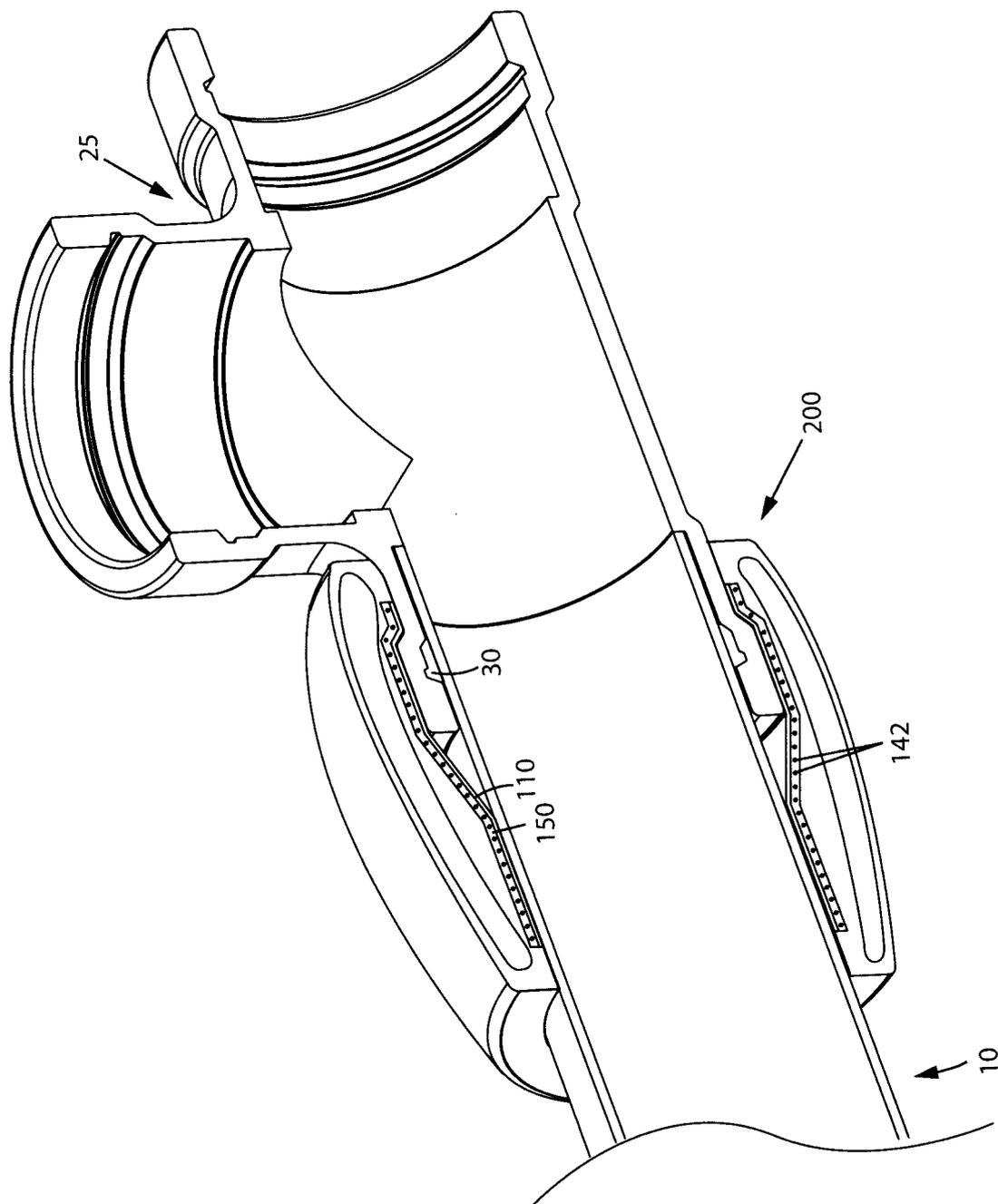


FIG. 23

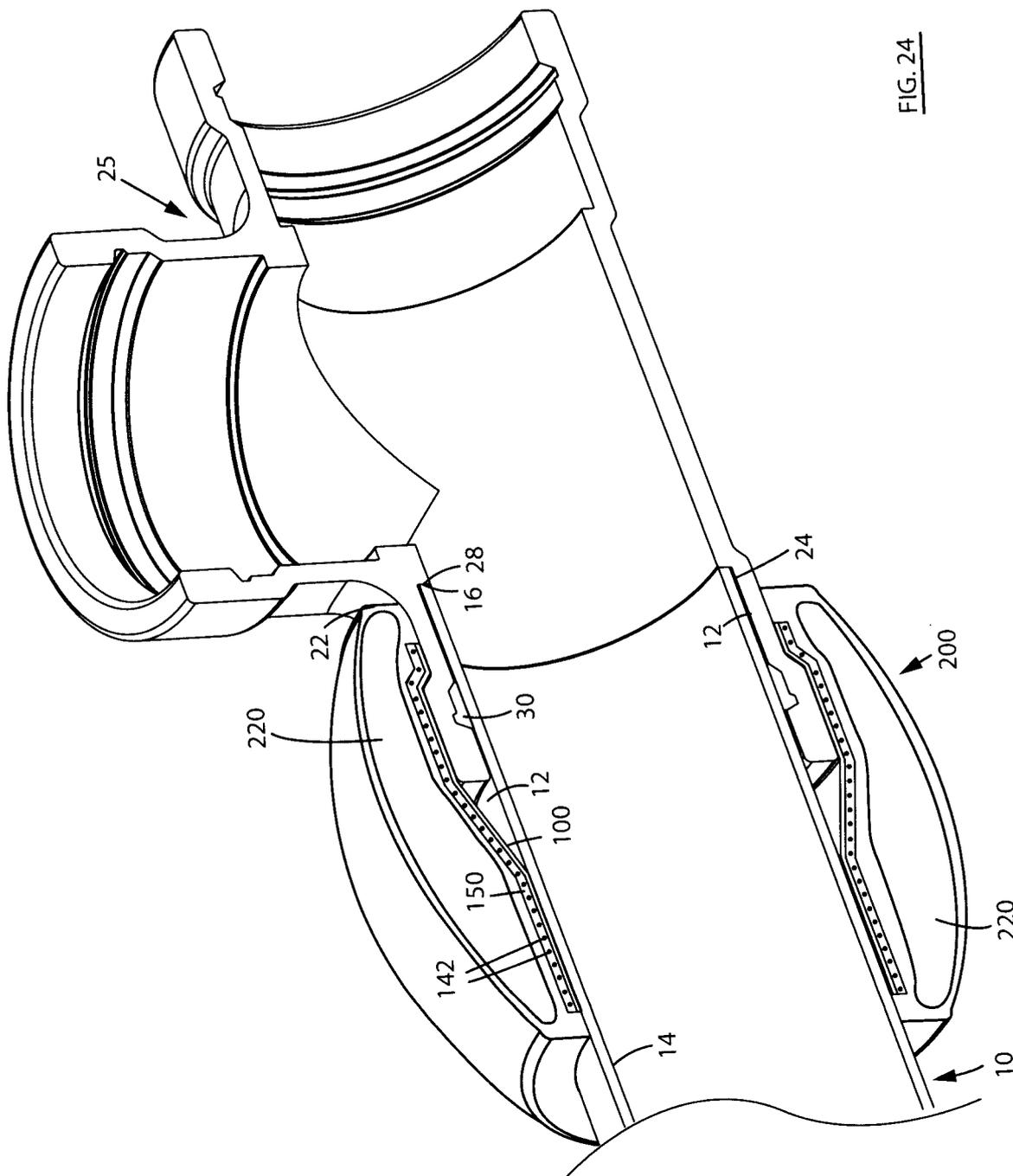


FIG. 24

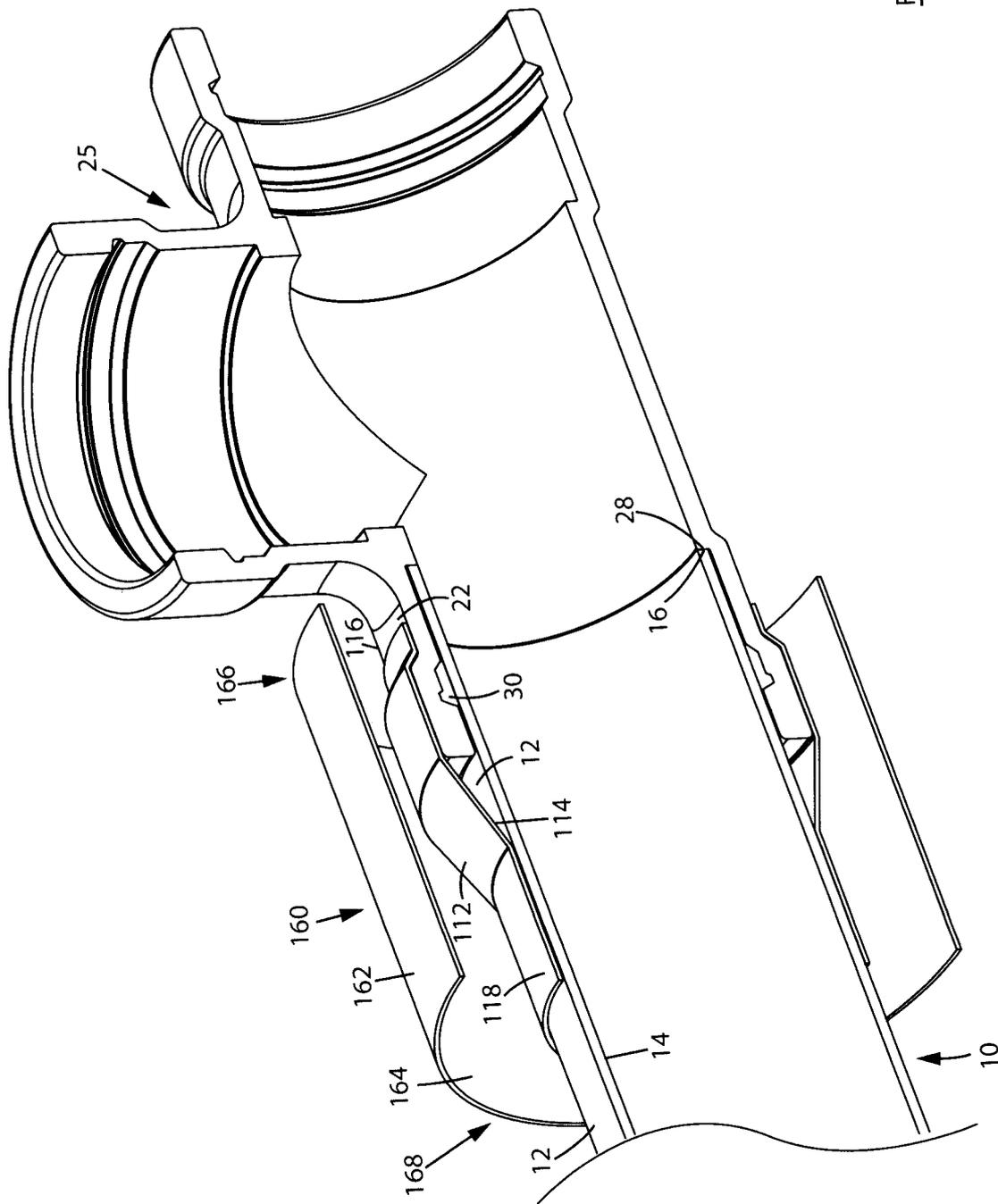
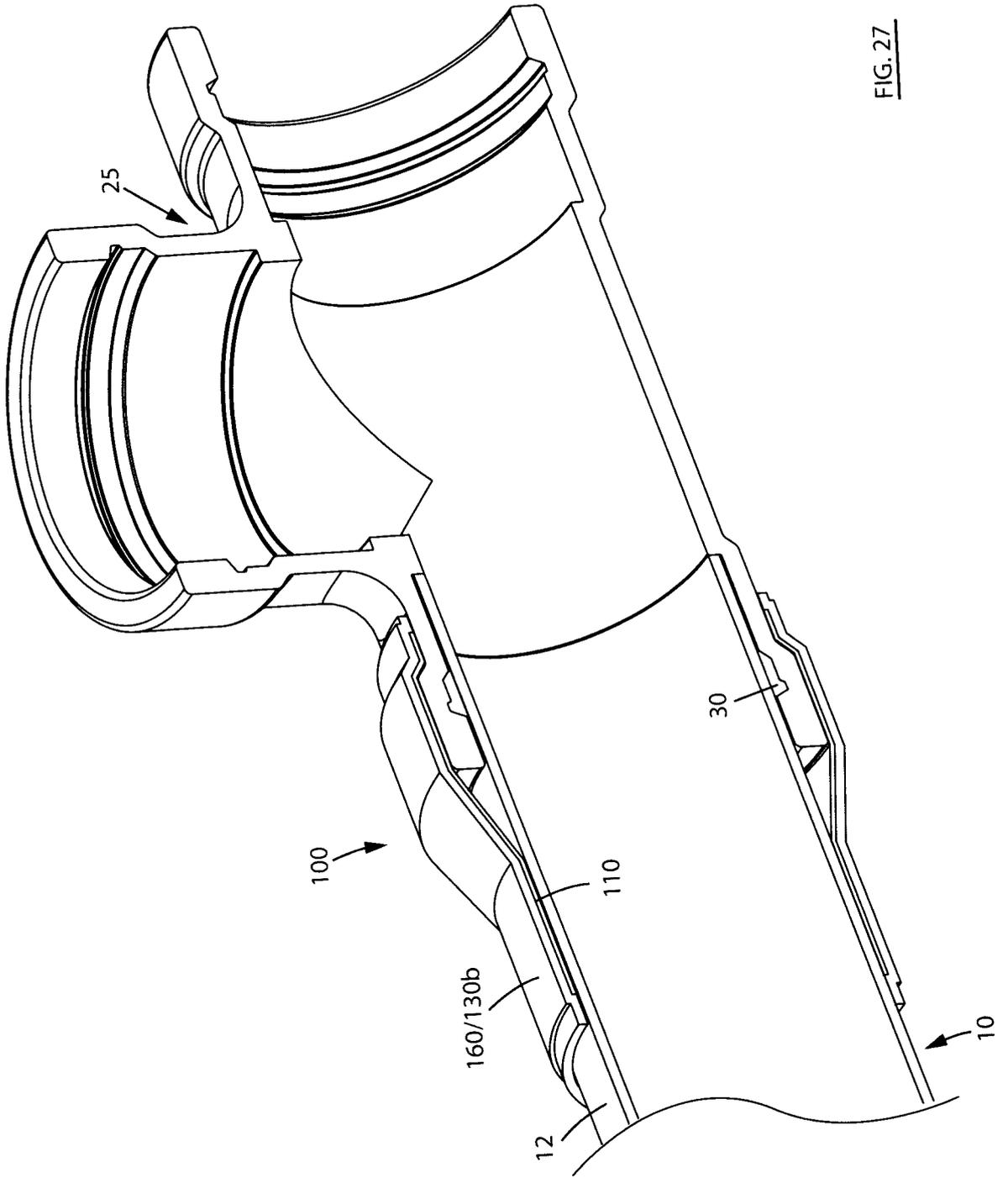


FIG. 25





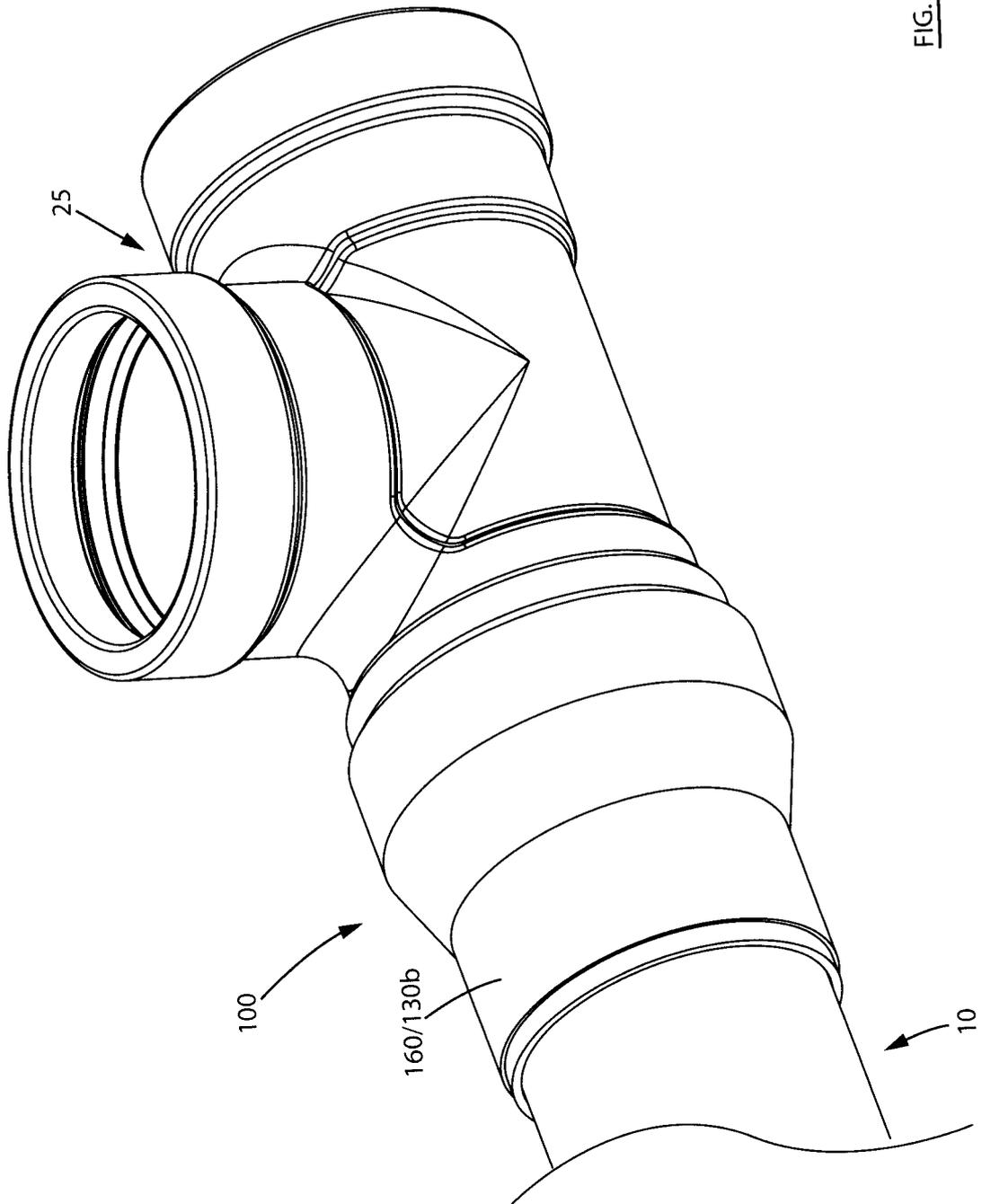


FIG. 28

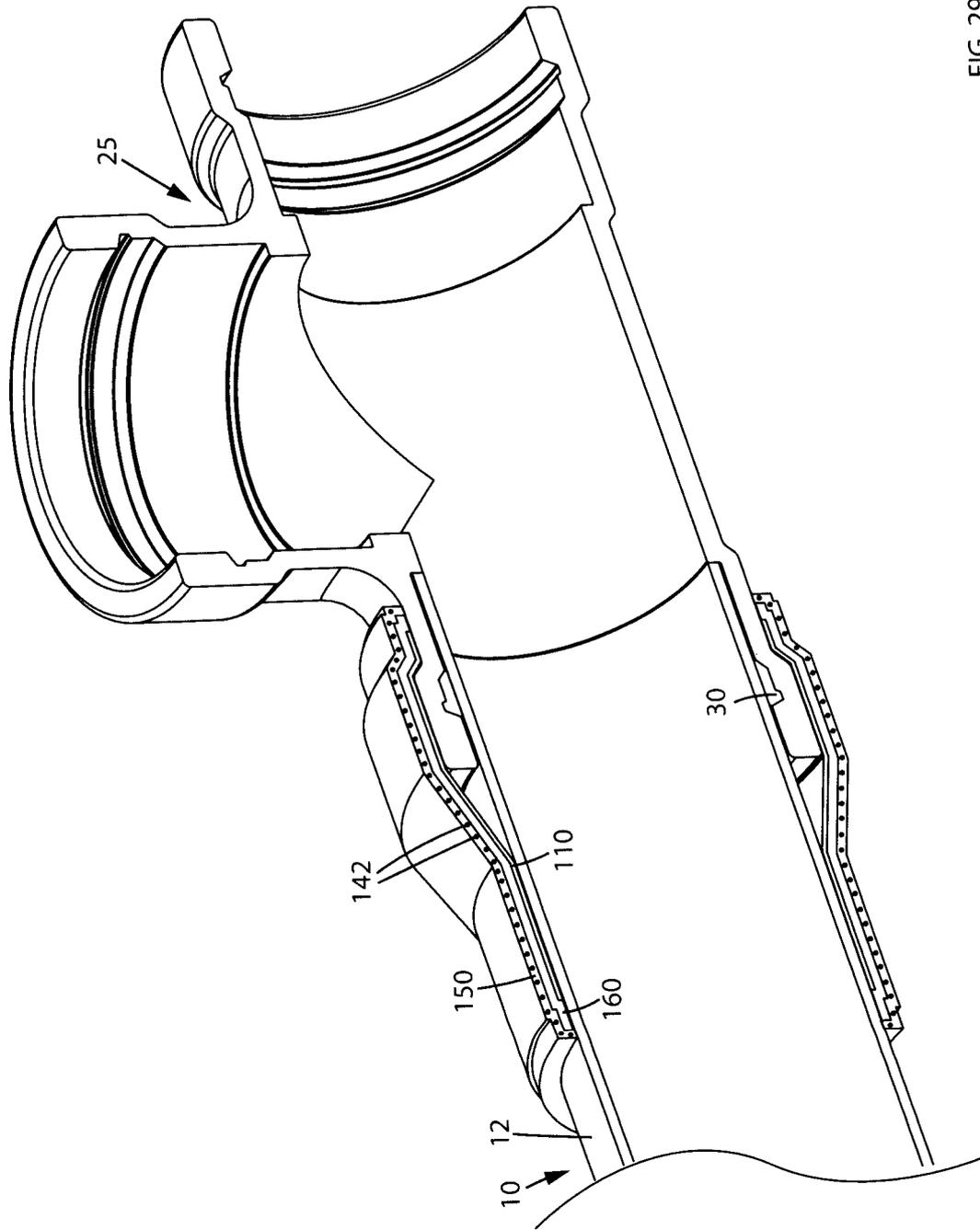


FIG. 29

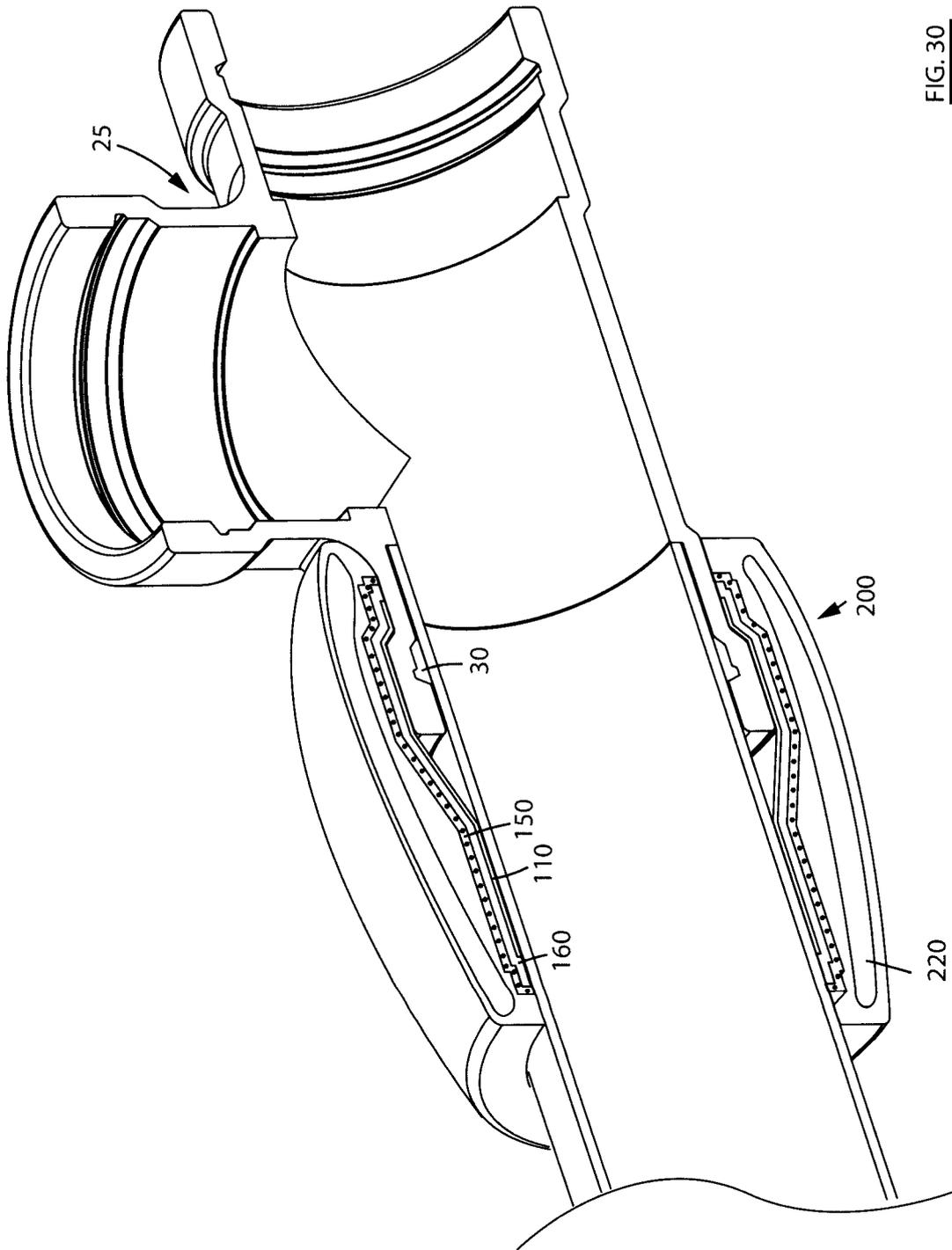


FIG. 30

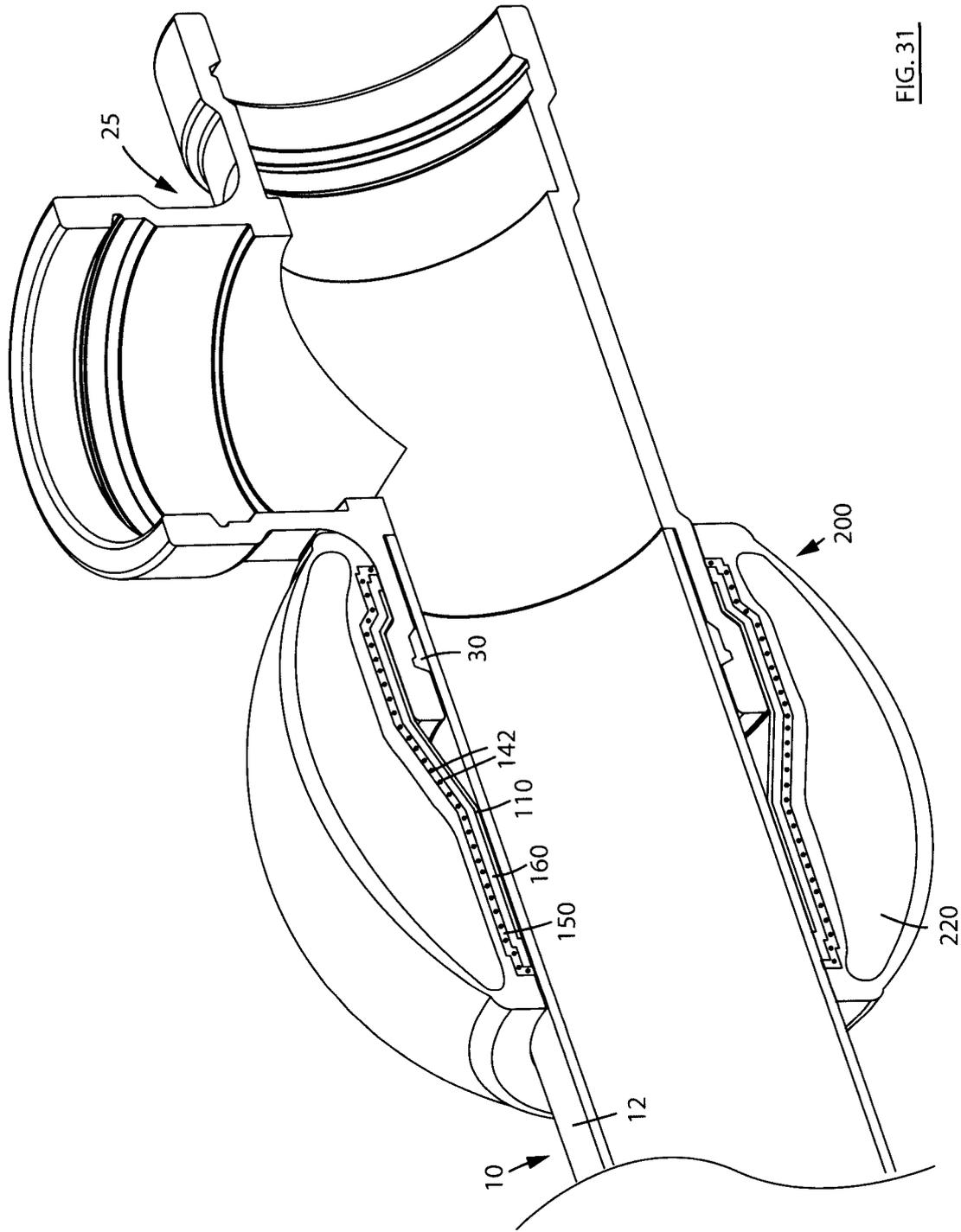


FIG. 31

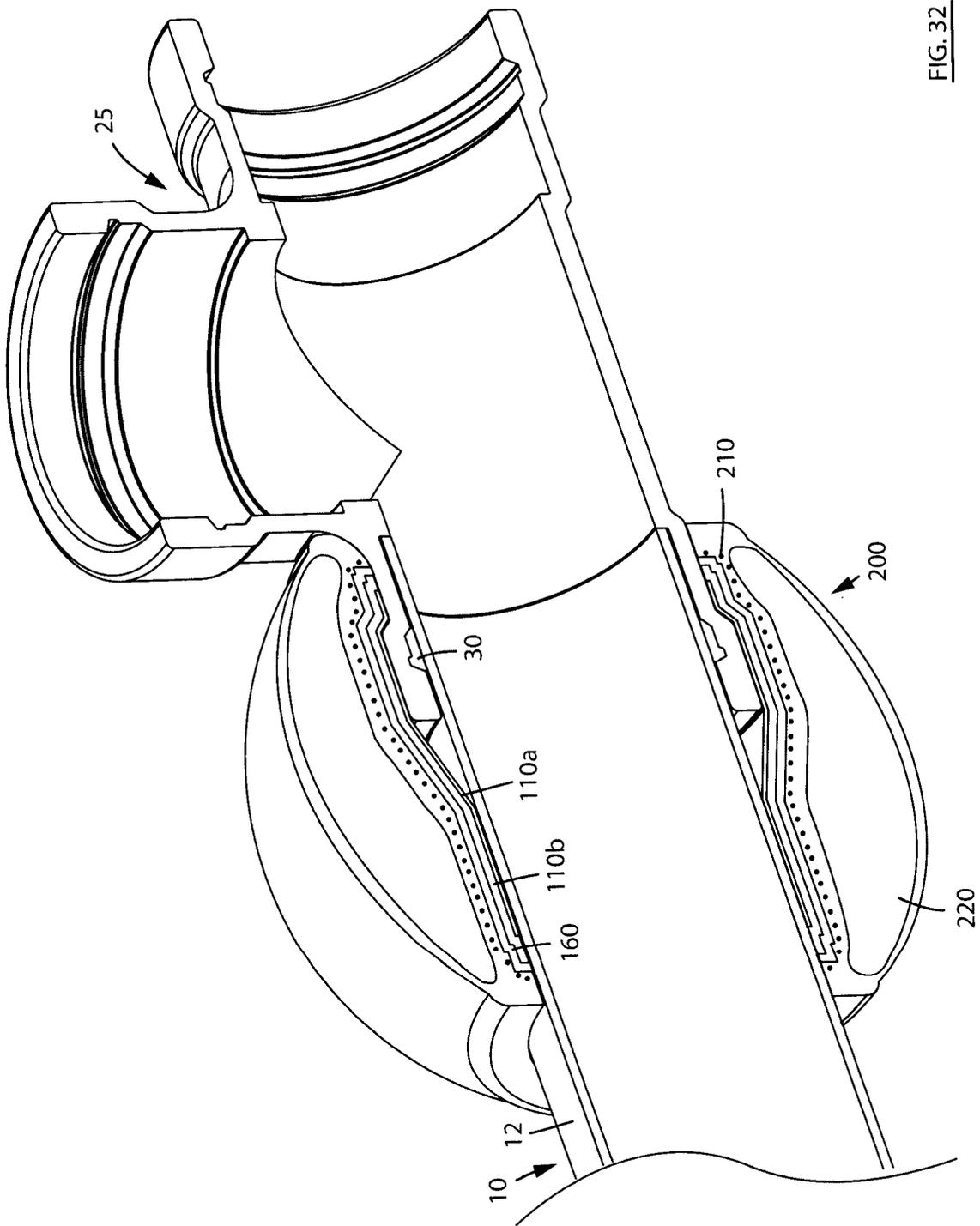


FIG. 32

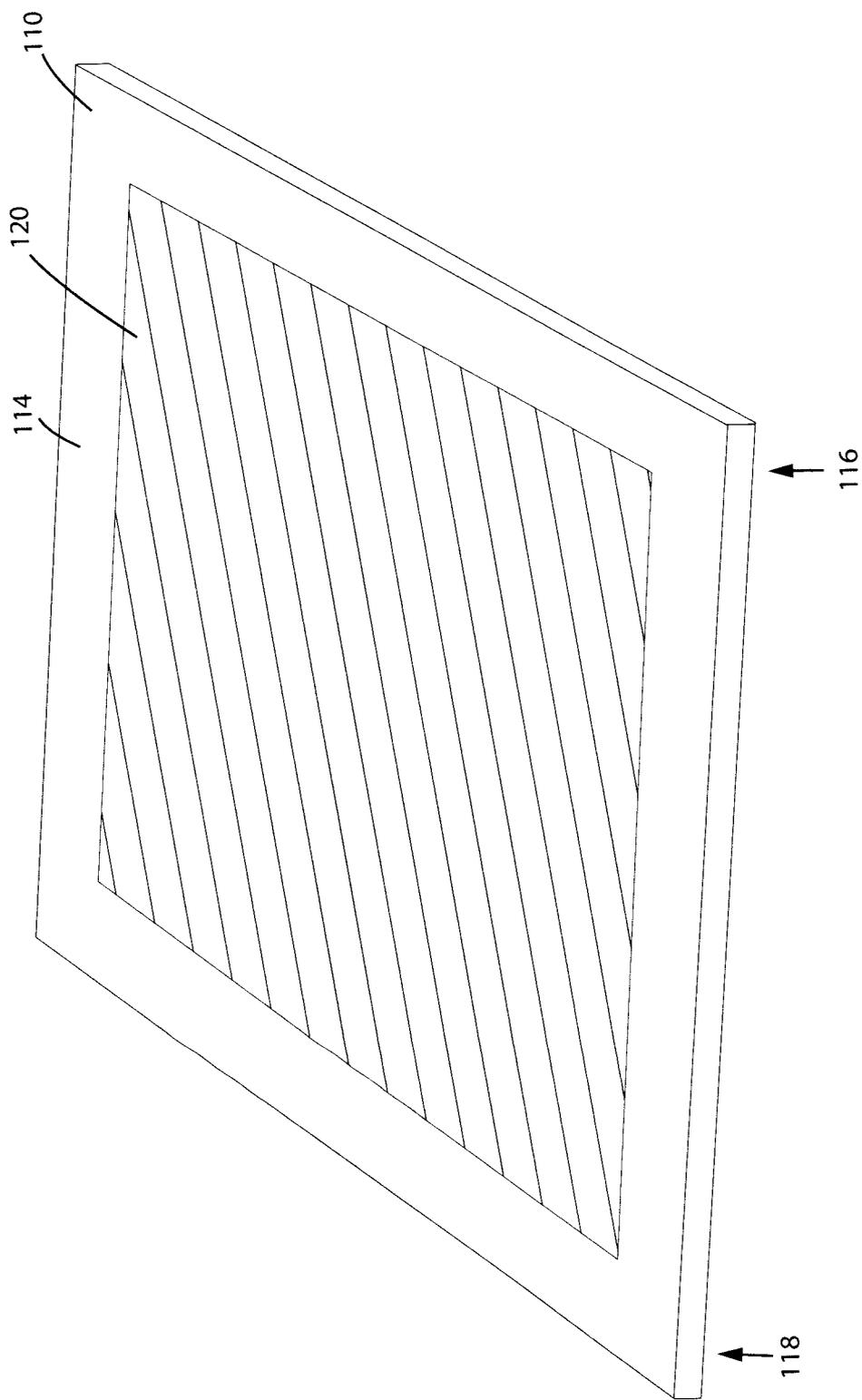


FIG. 33

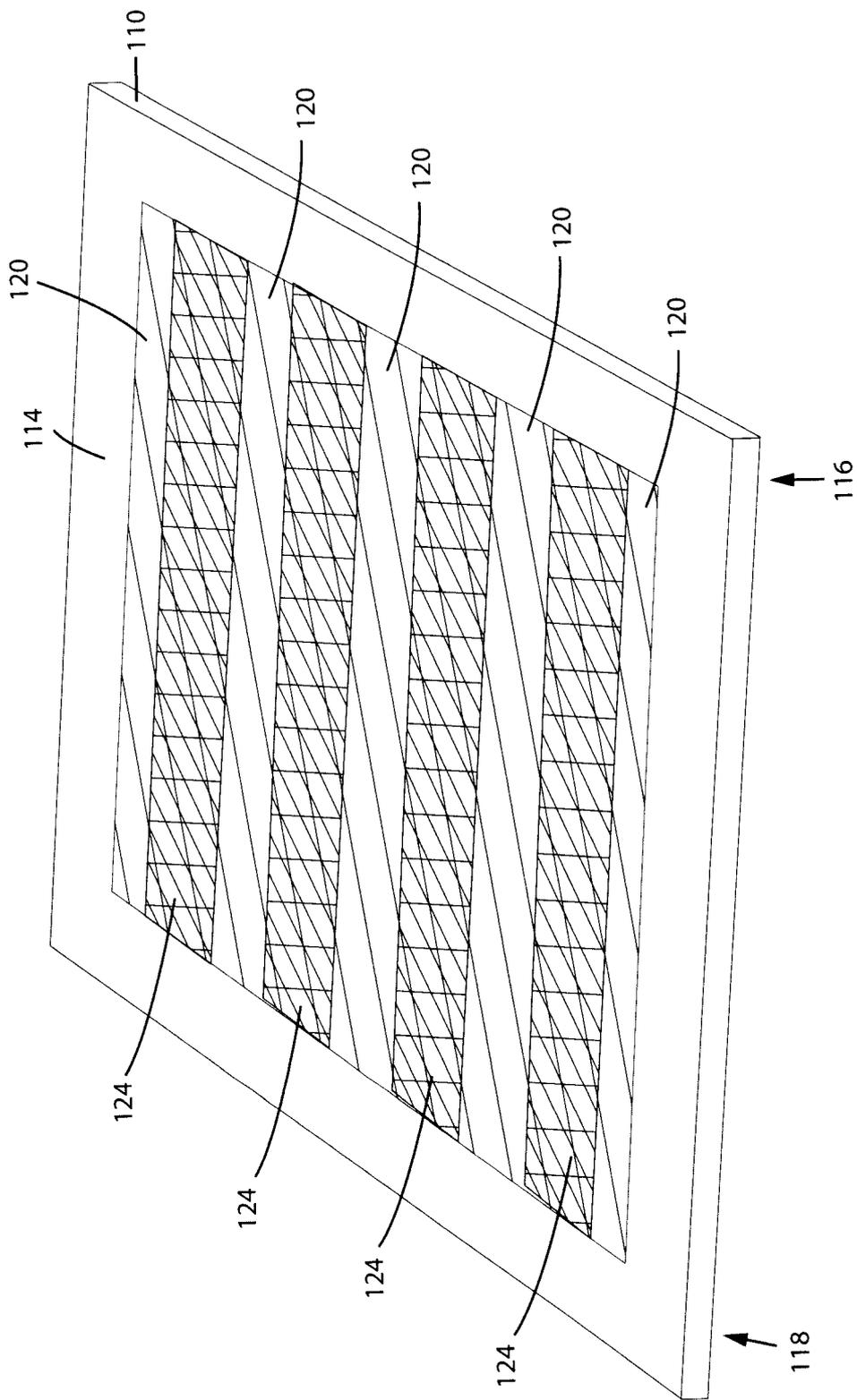


FIG. 34

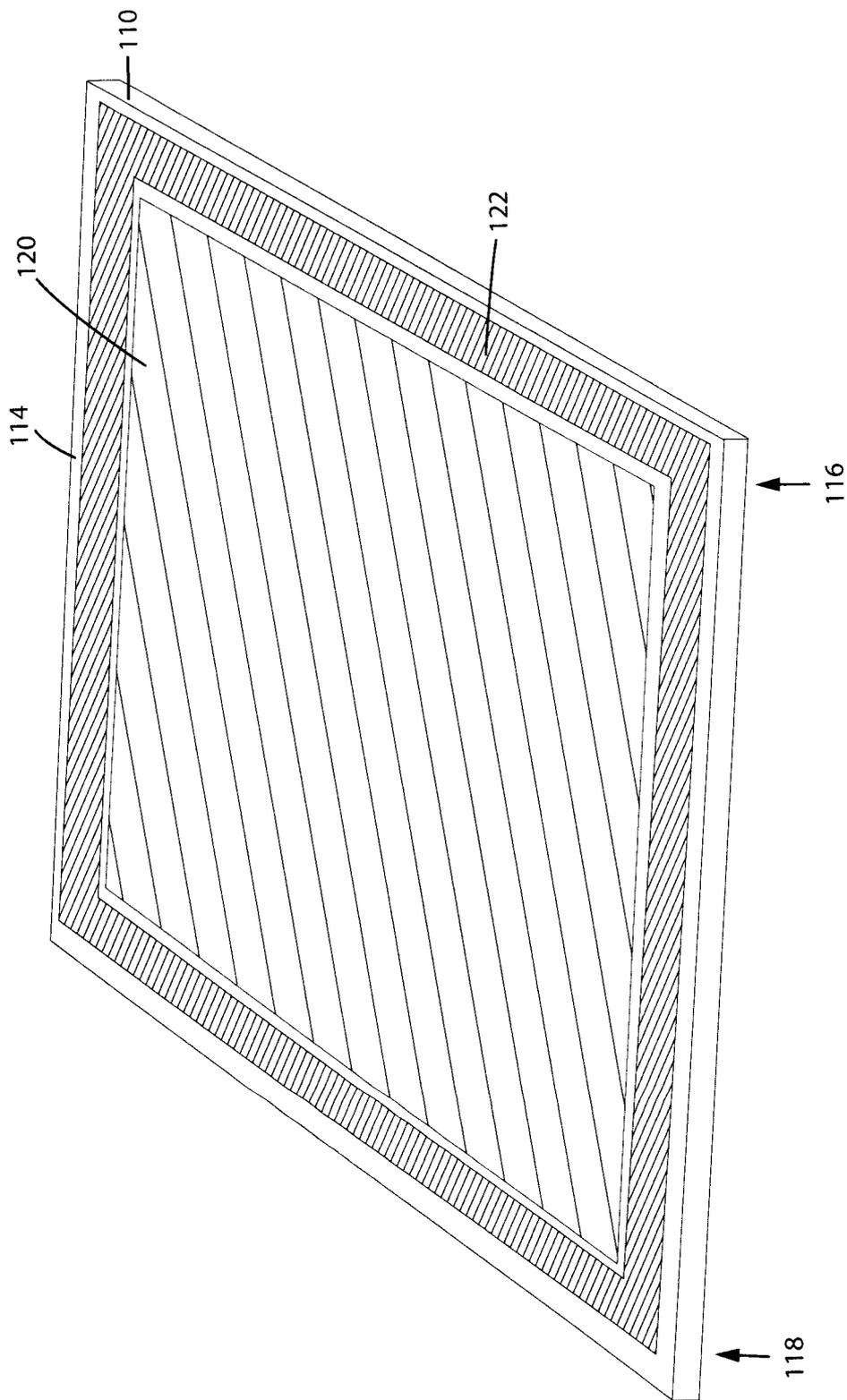


FIG. 35

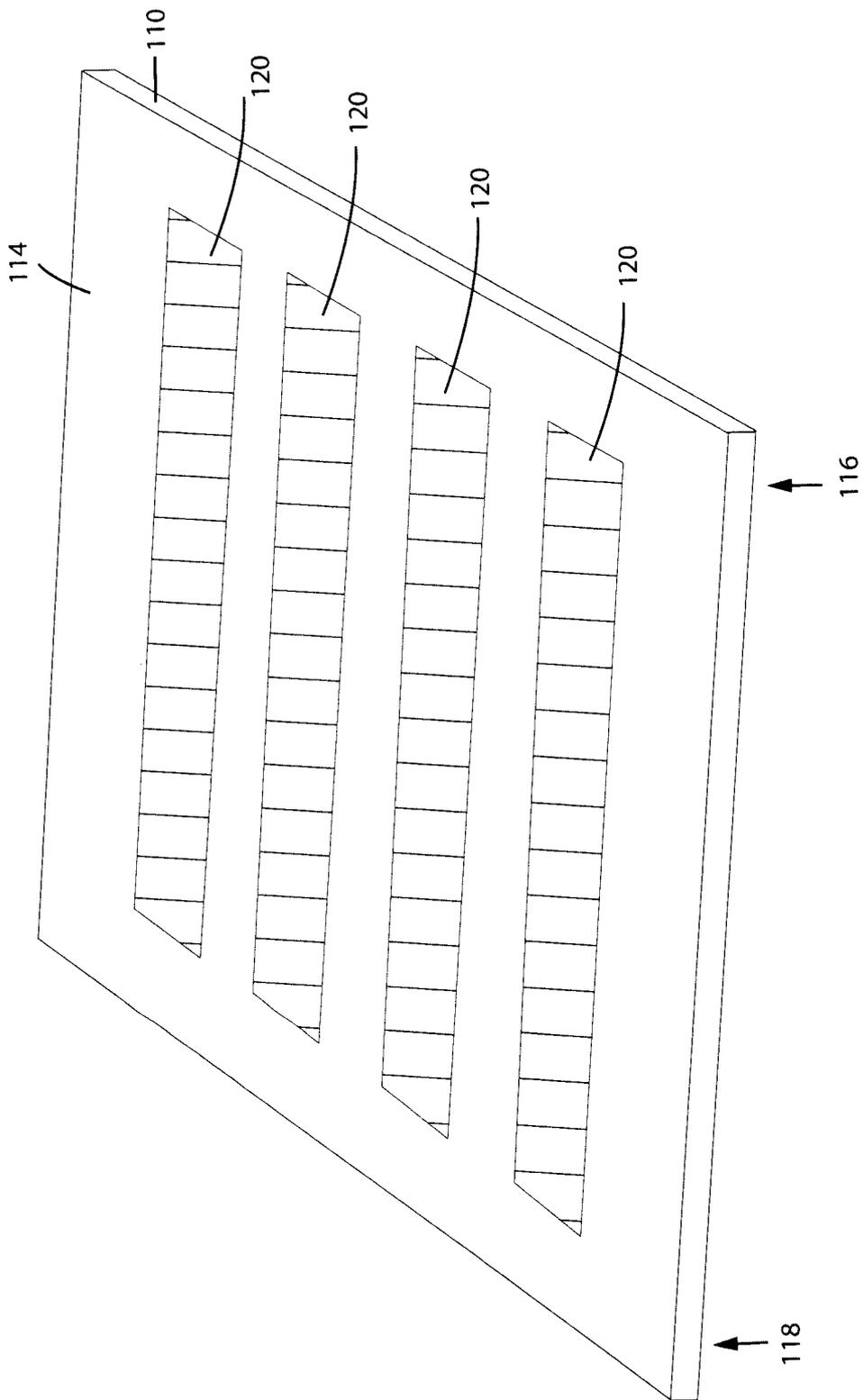


FIG. 36

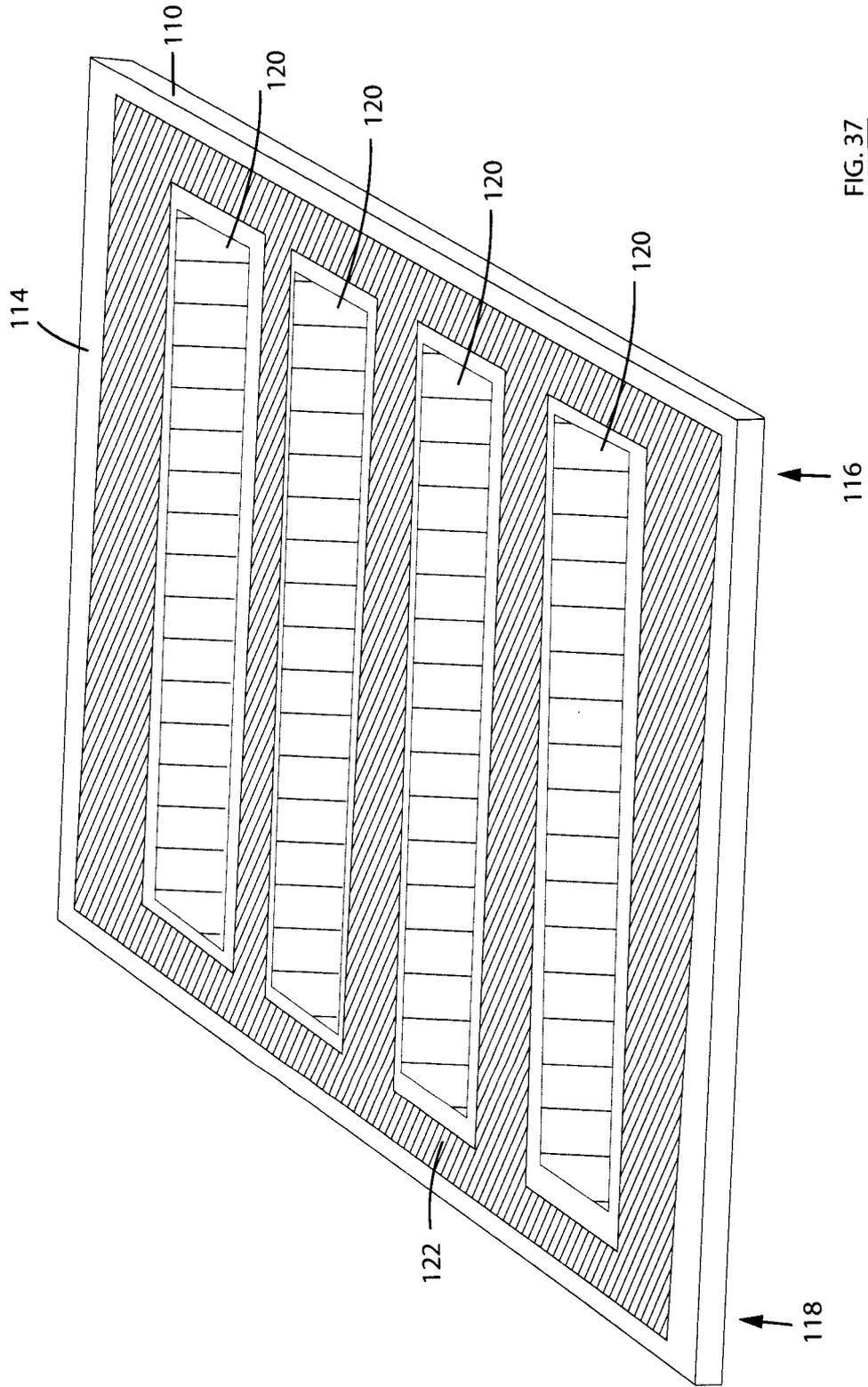


FIG. 37

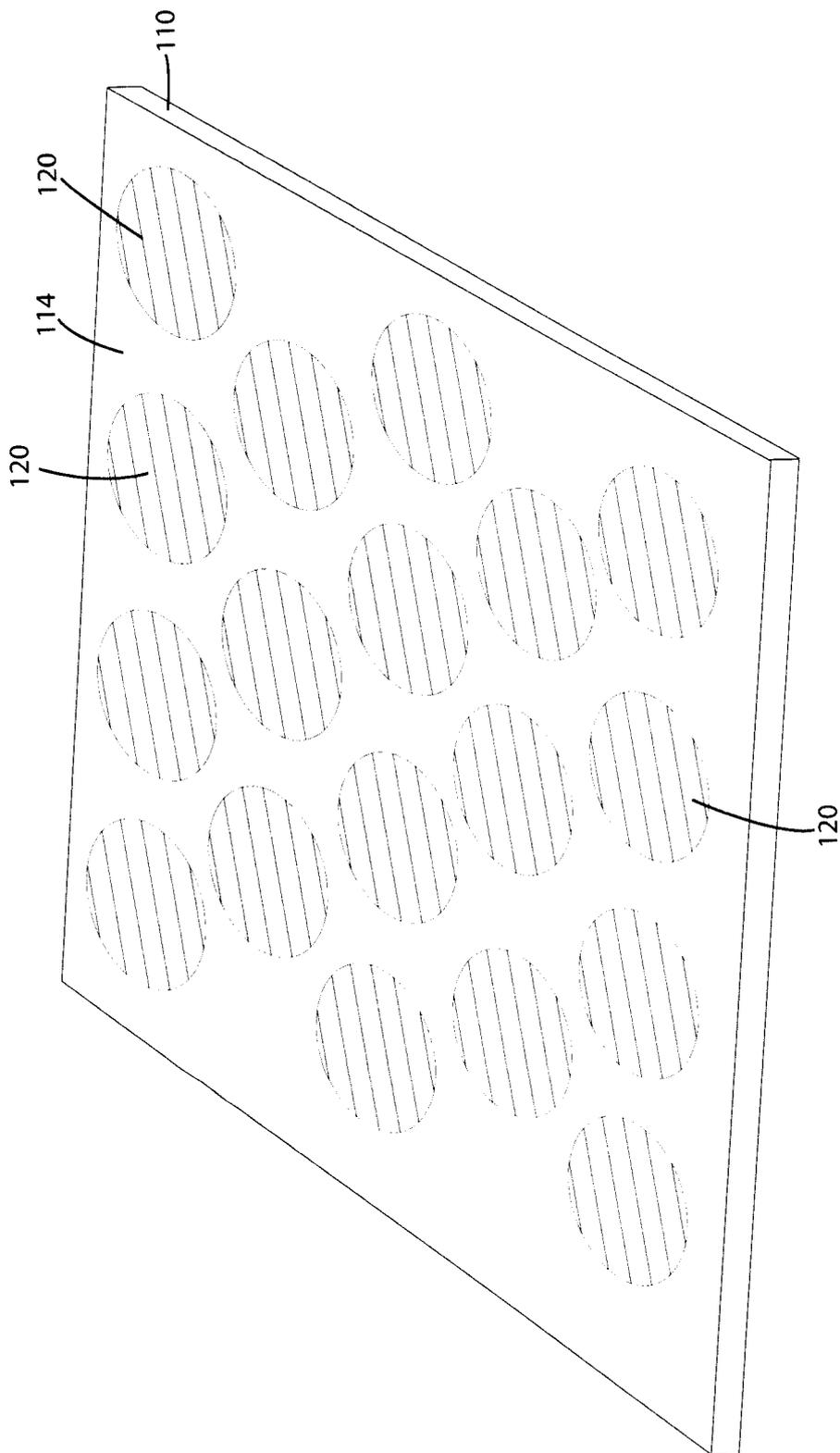


FIG. 38

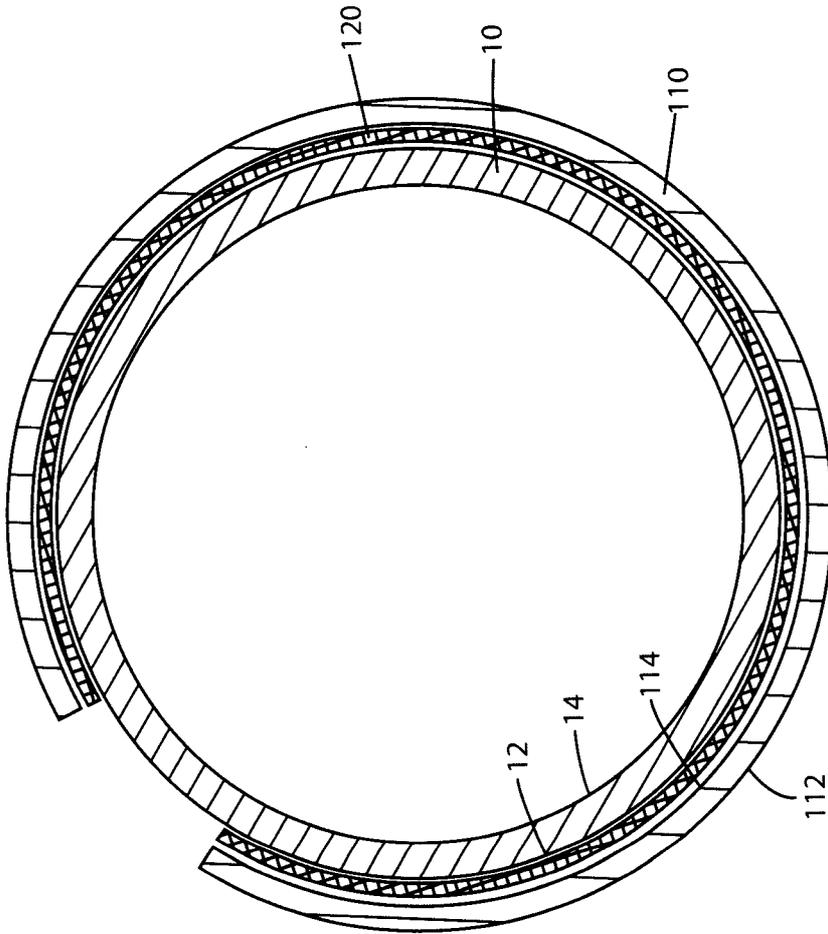


FIG. 39

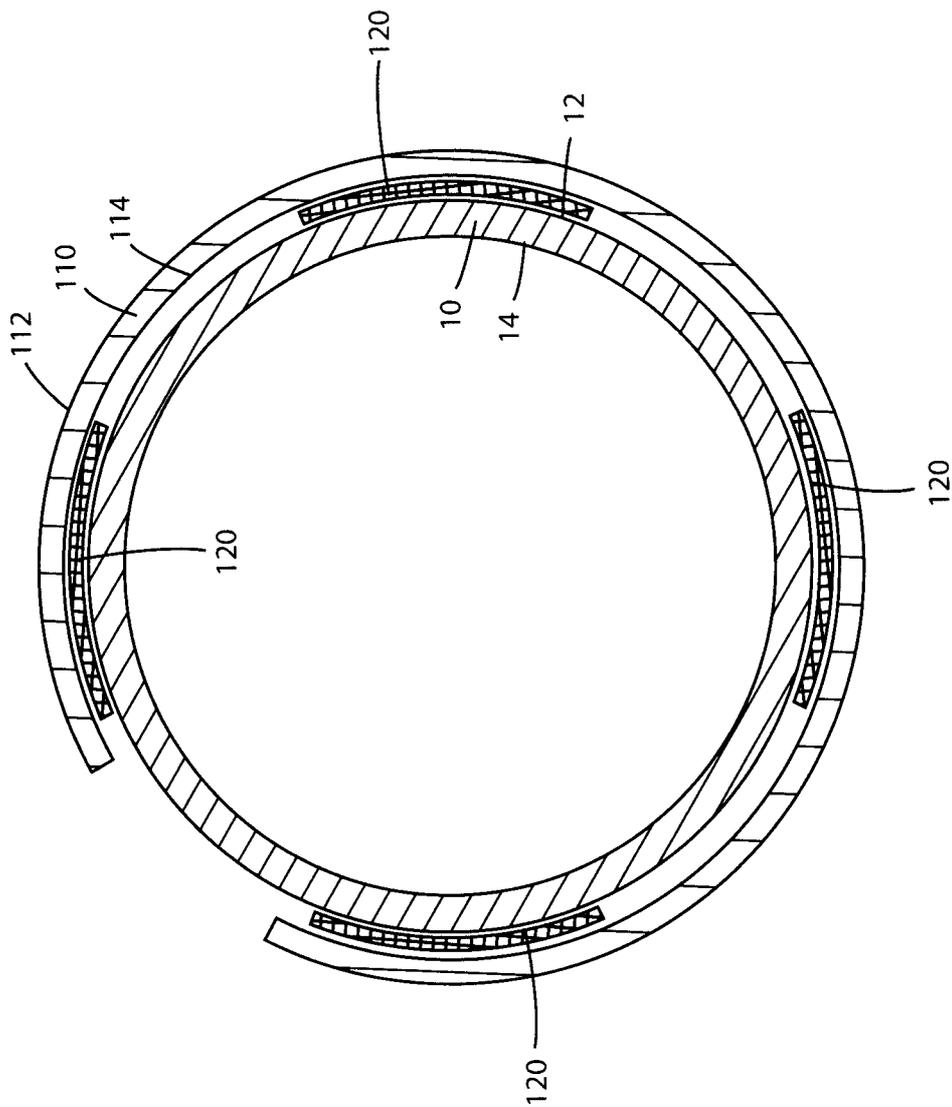


FIG. 40

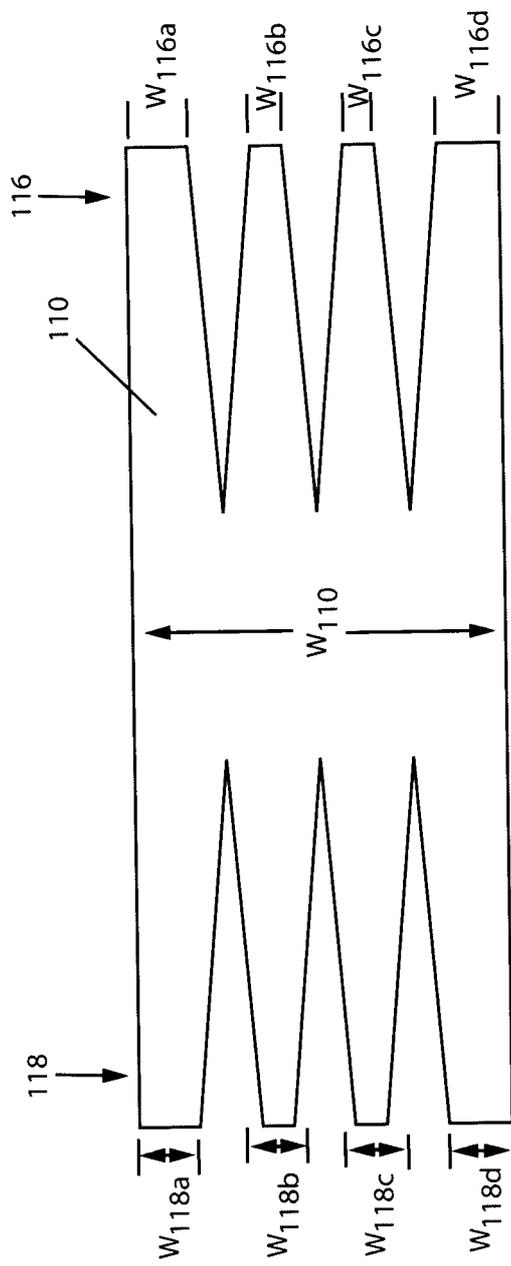


FIG. 41a

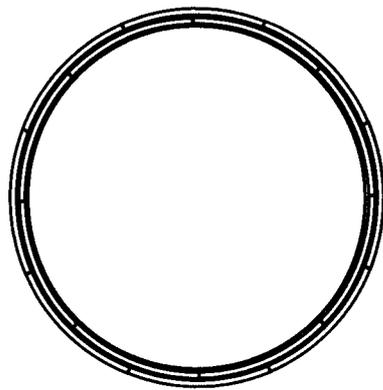


FIG. 41b

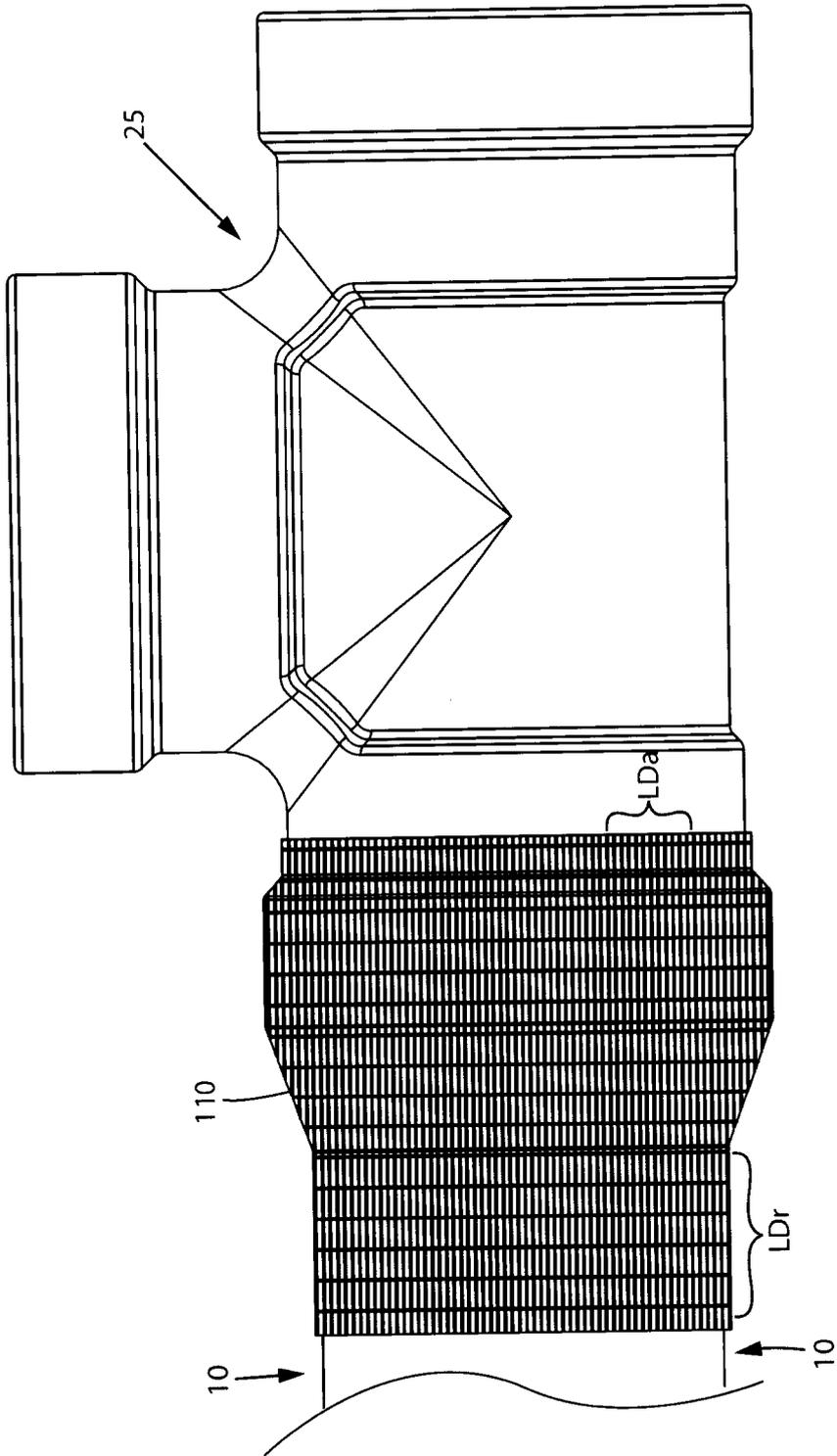


FIG. 42

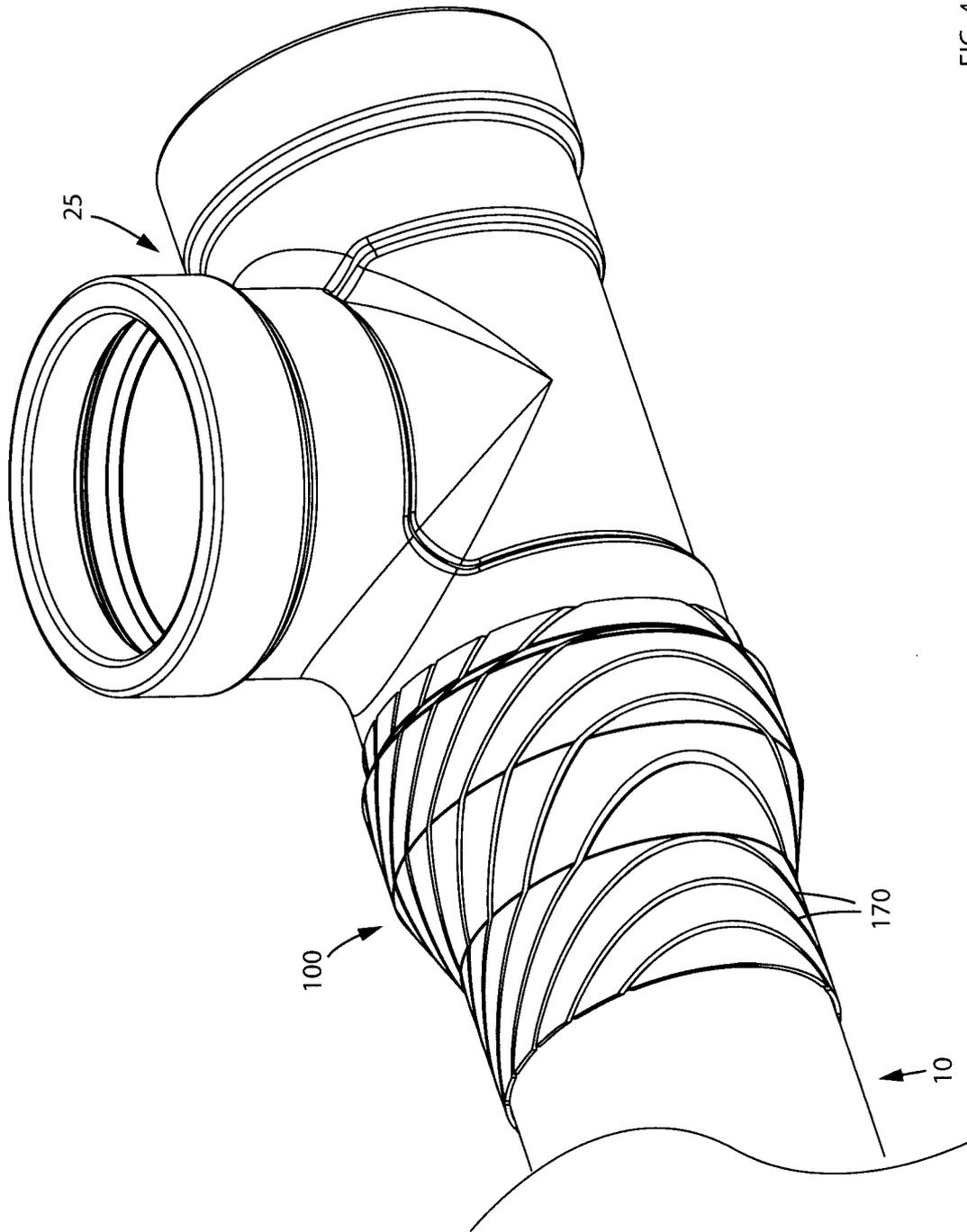


FIG. 43

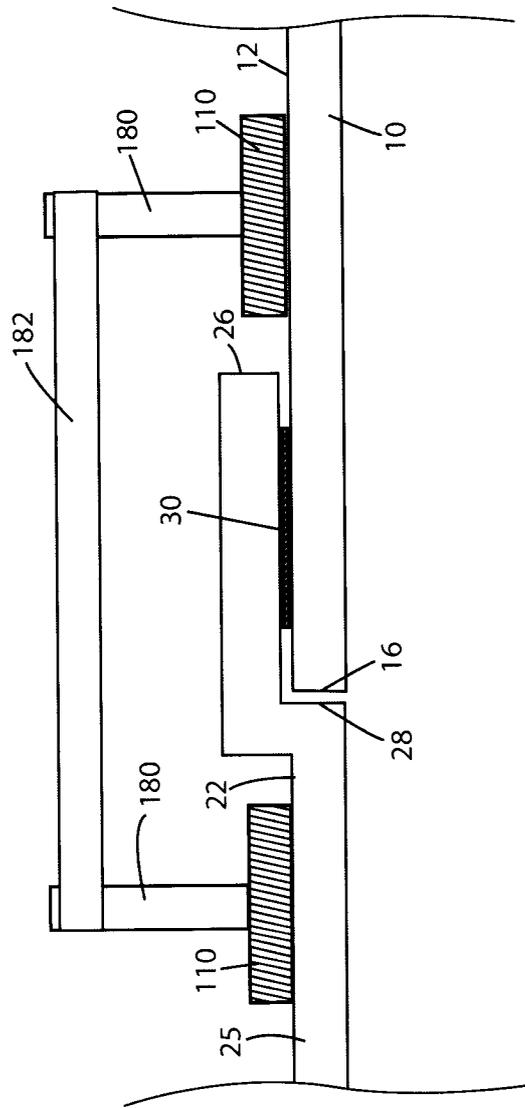


FIG. 44

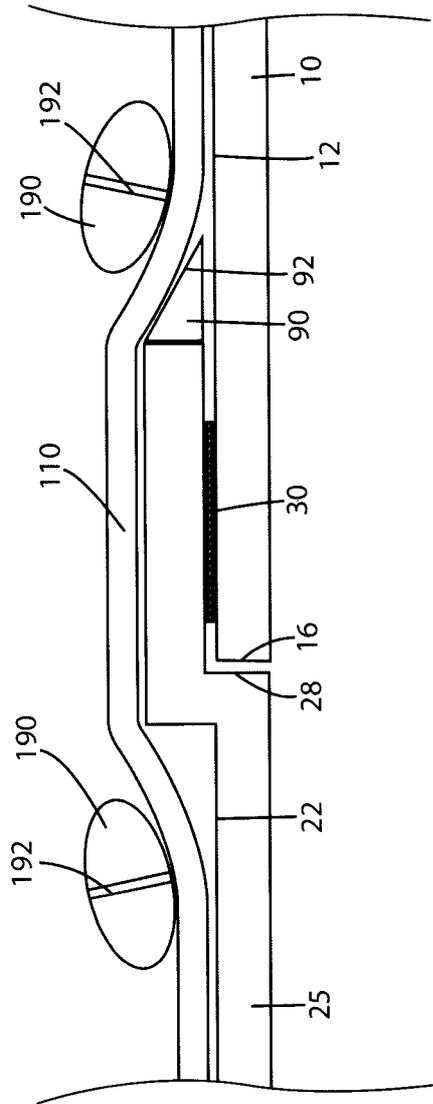


FIG. 45

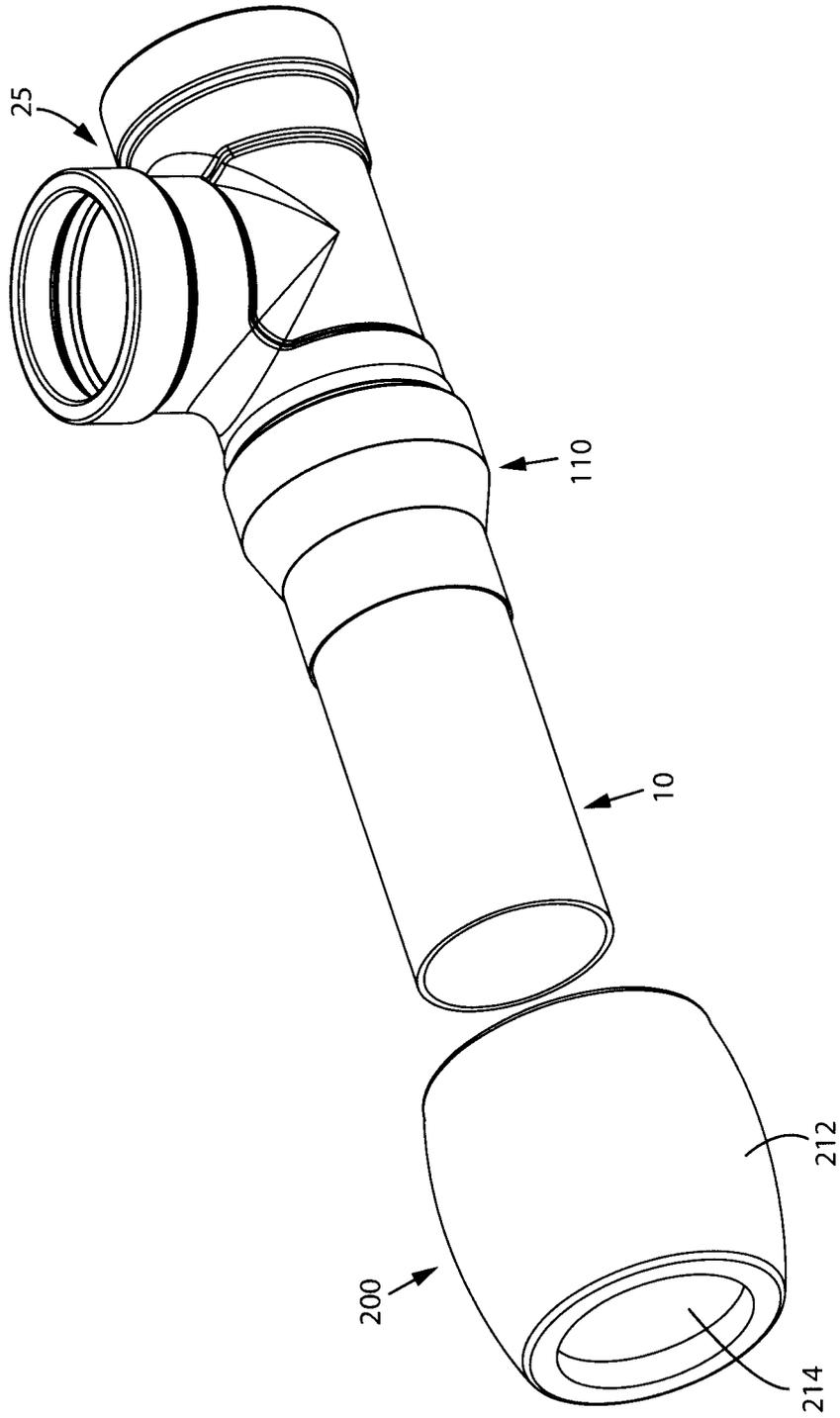


FIG. 46

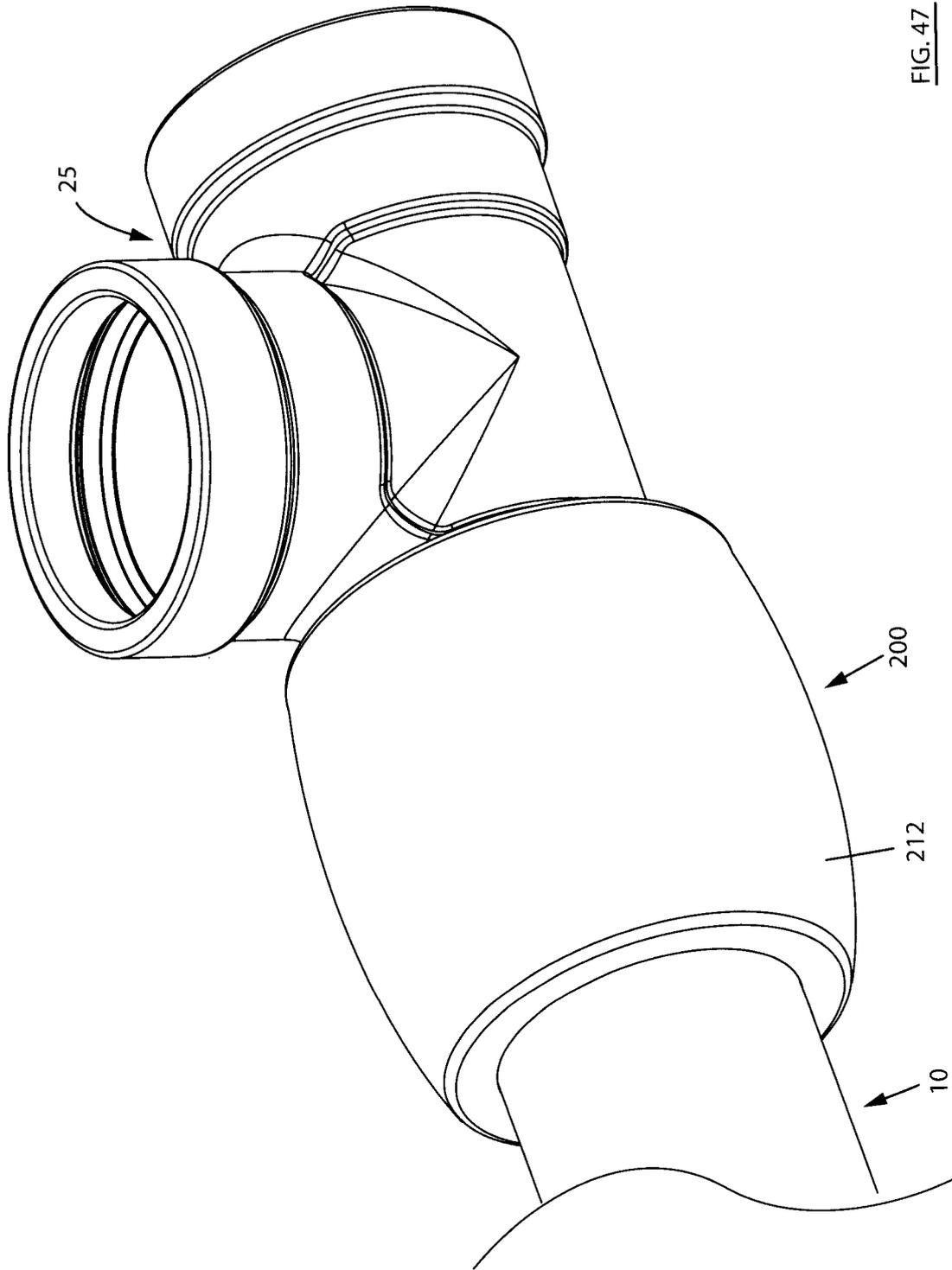


FIG. 47

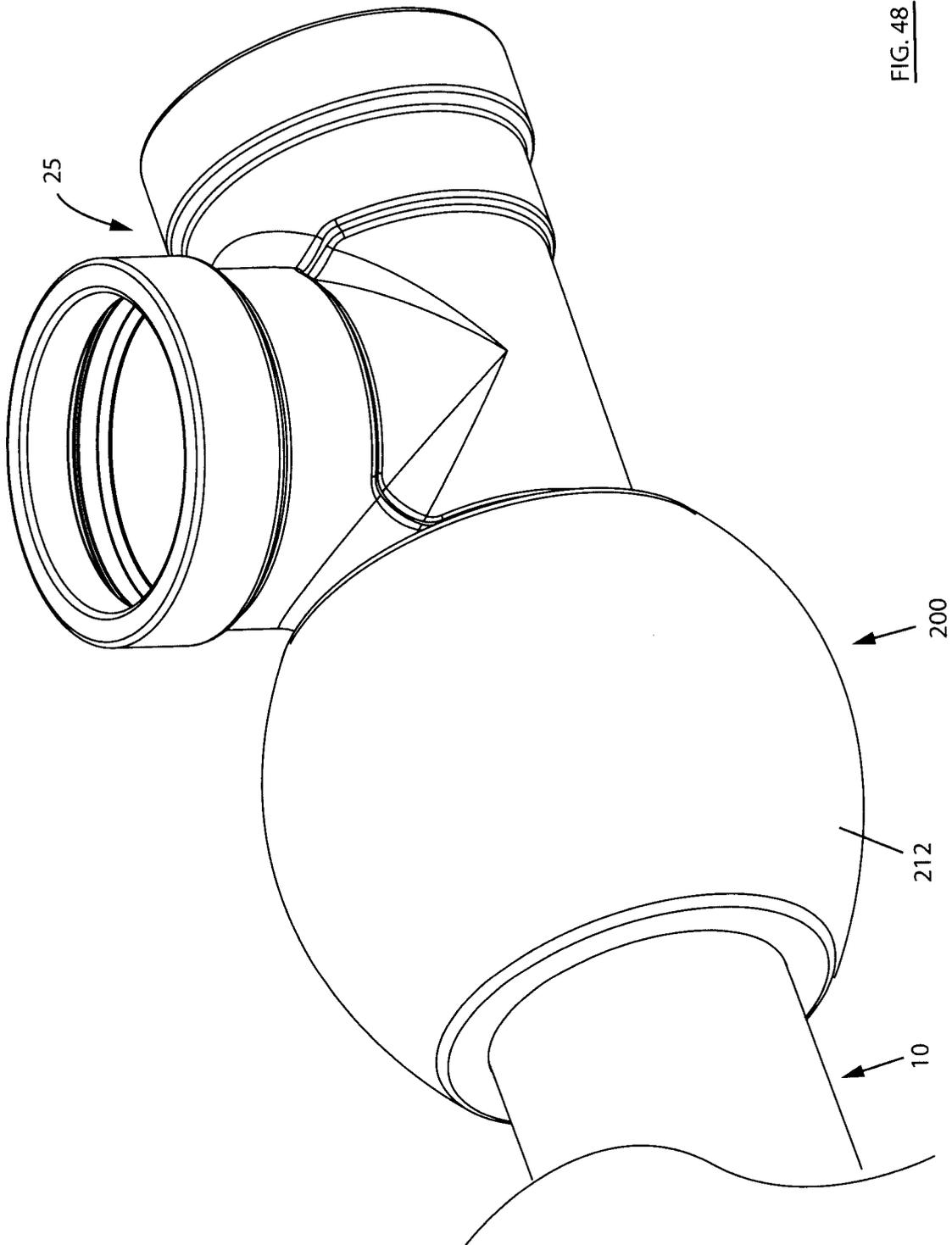


FIG. 48

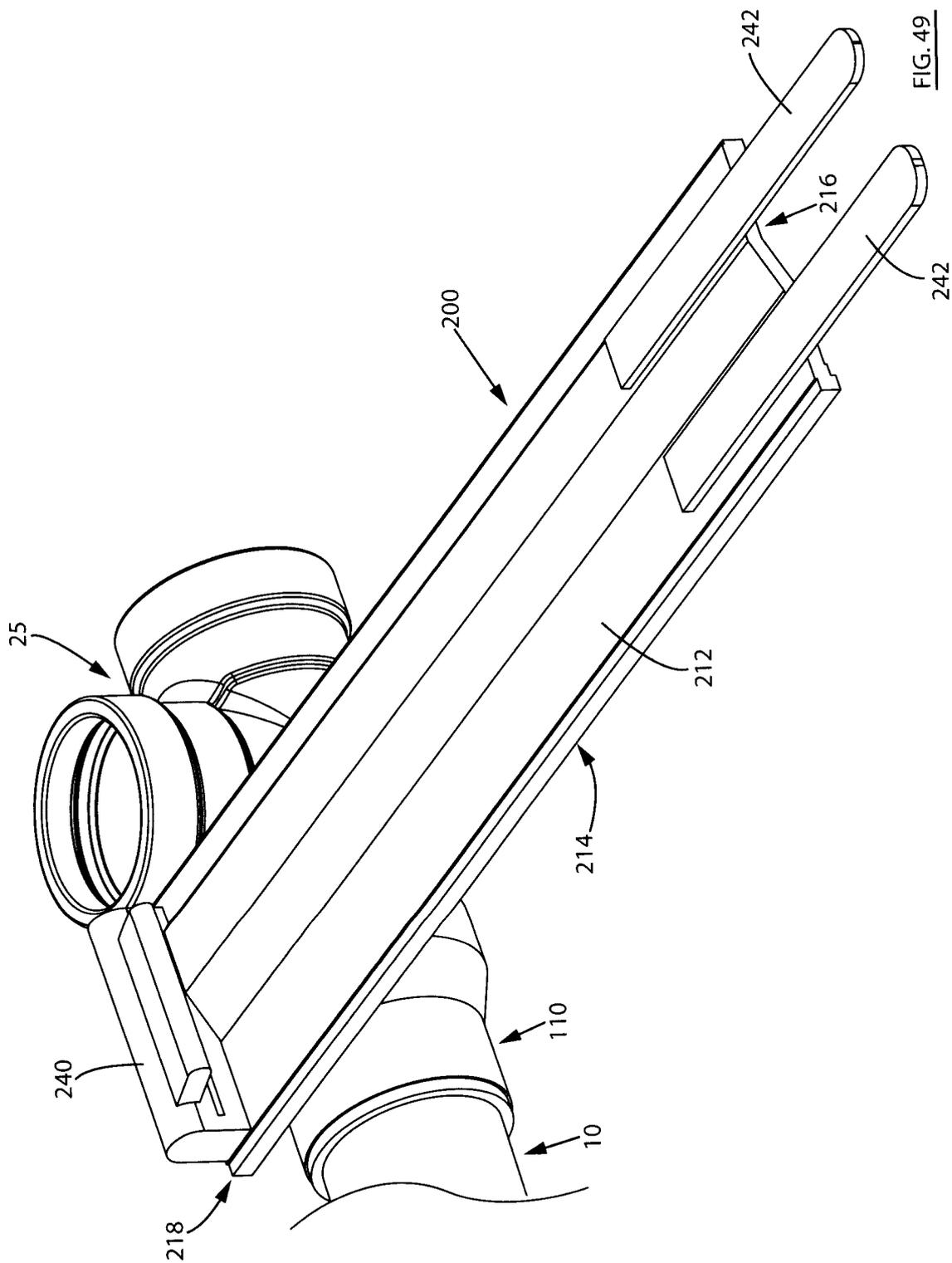


FIG. 49

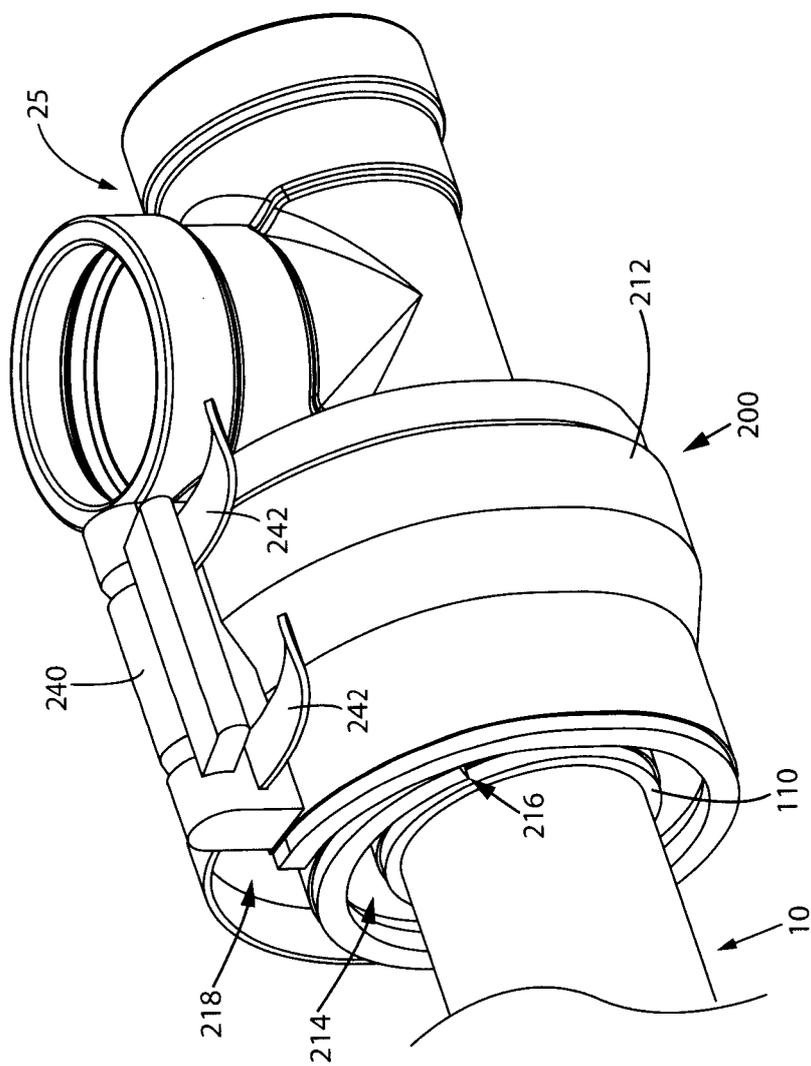
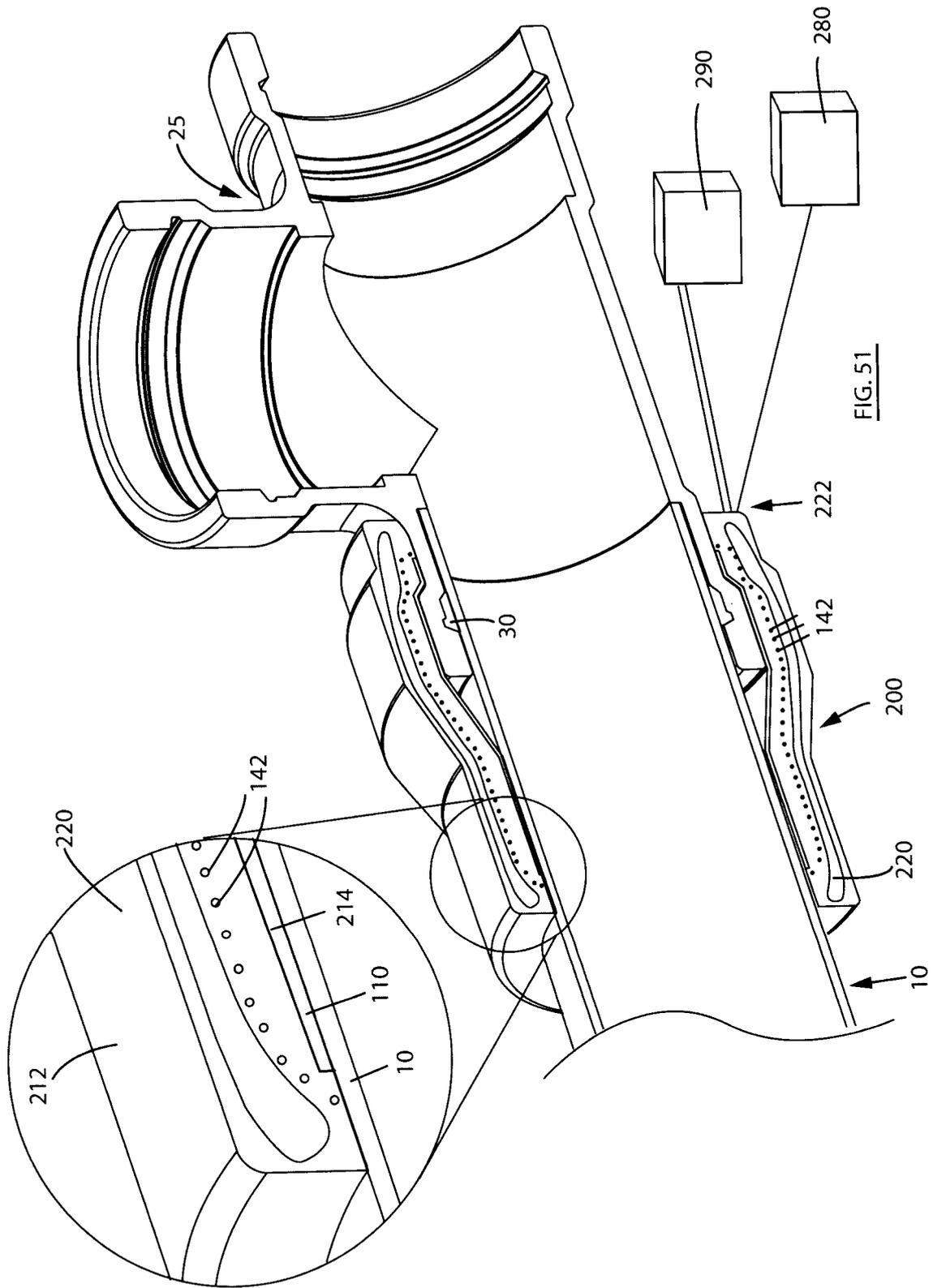
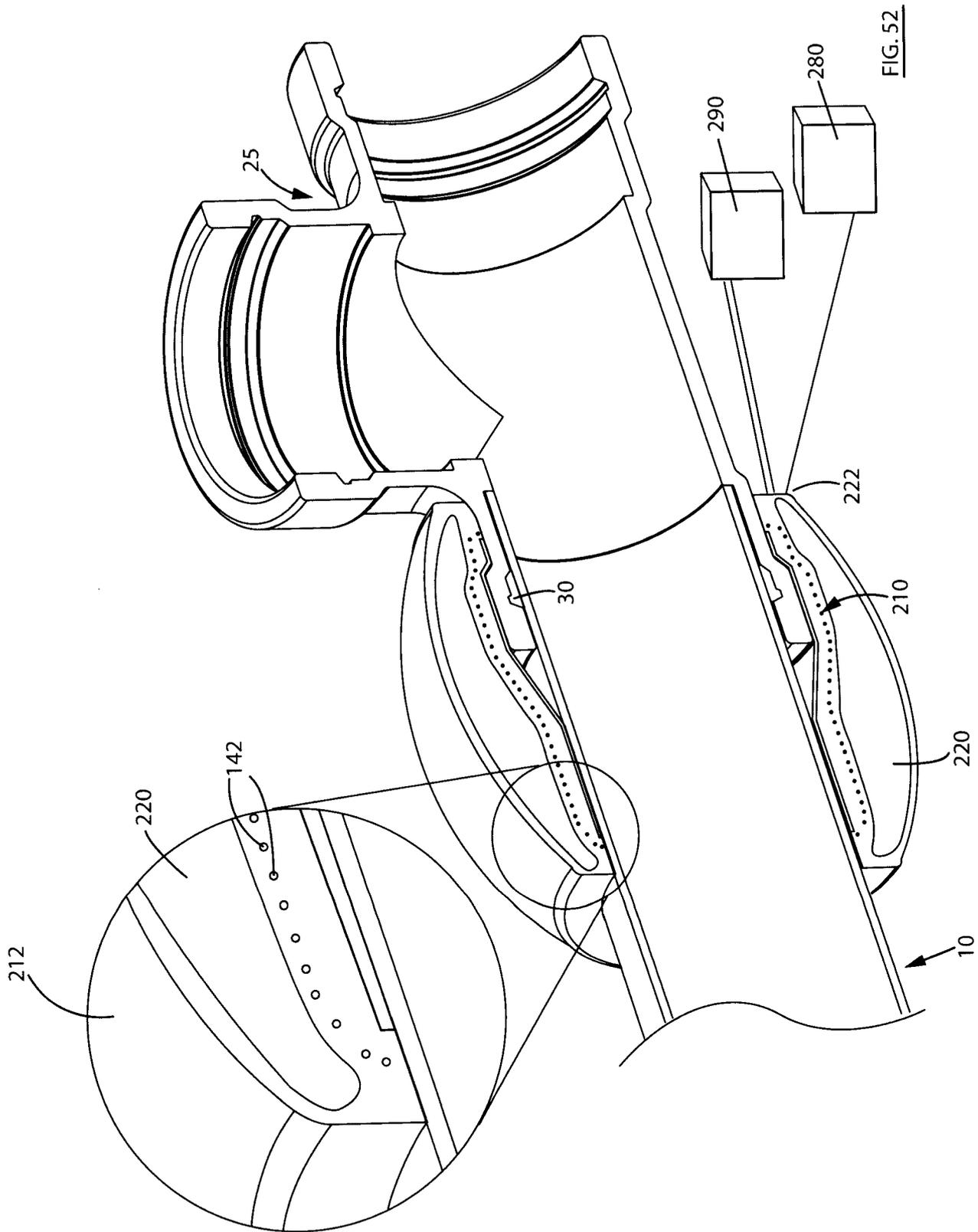


FIG. 50





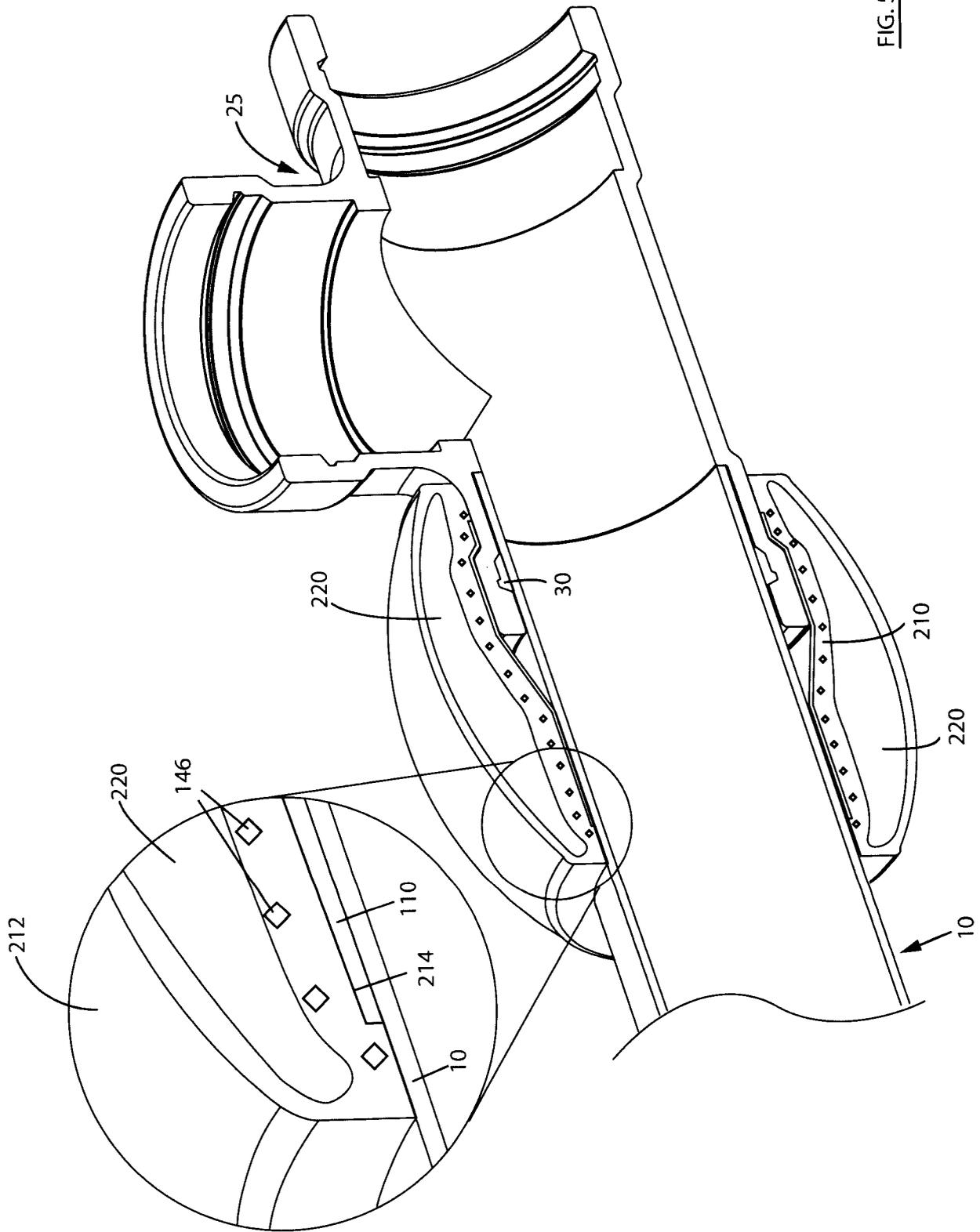


FIG. 53

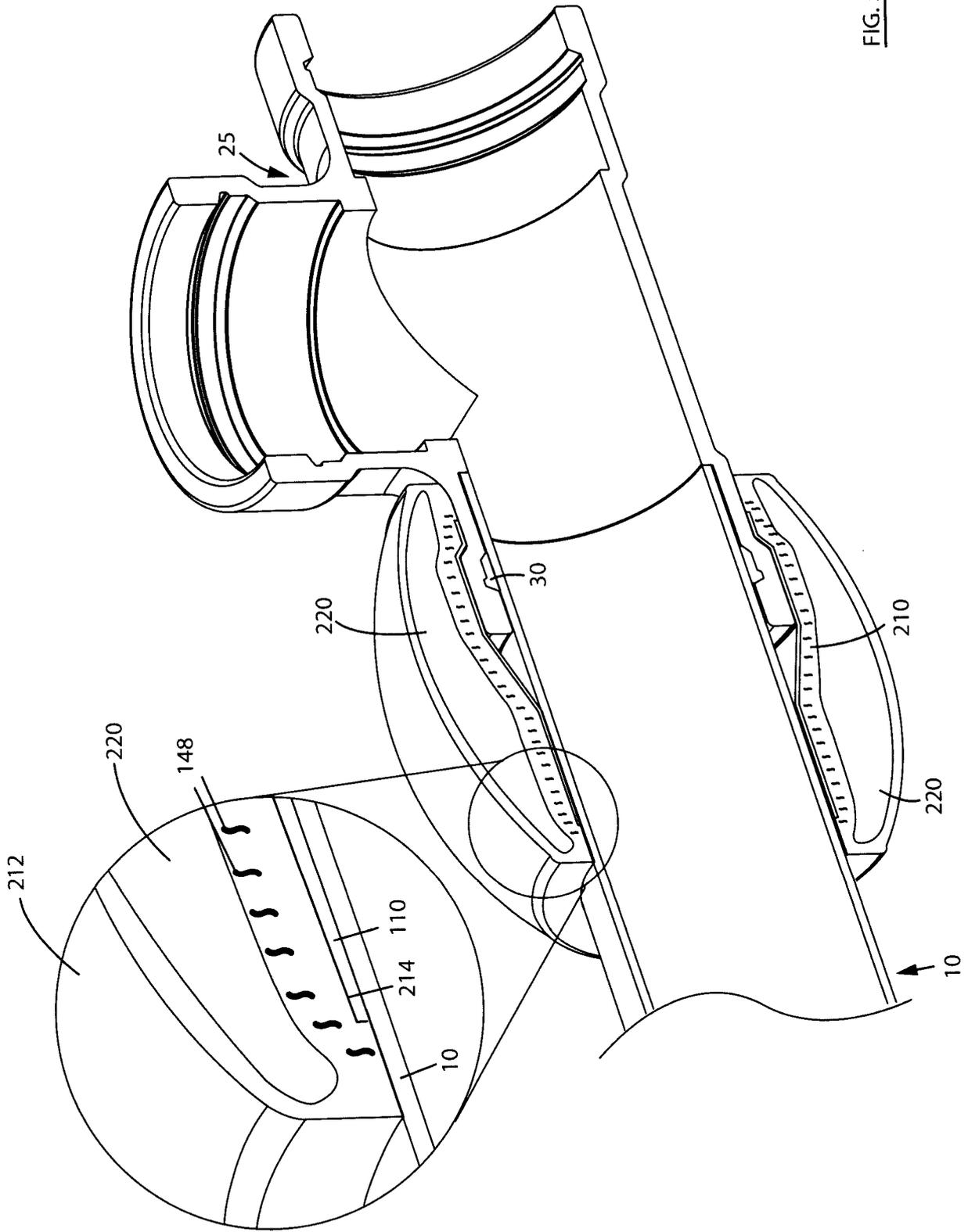


FIG. 54

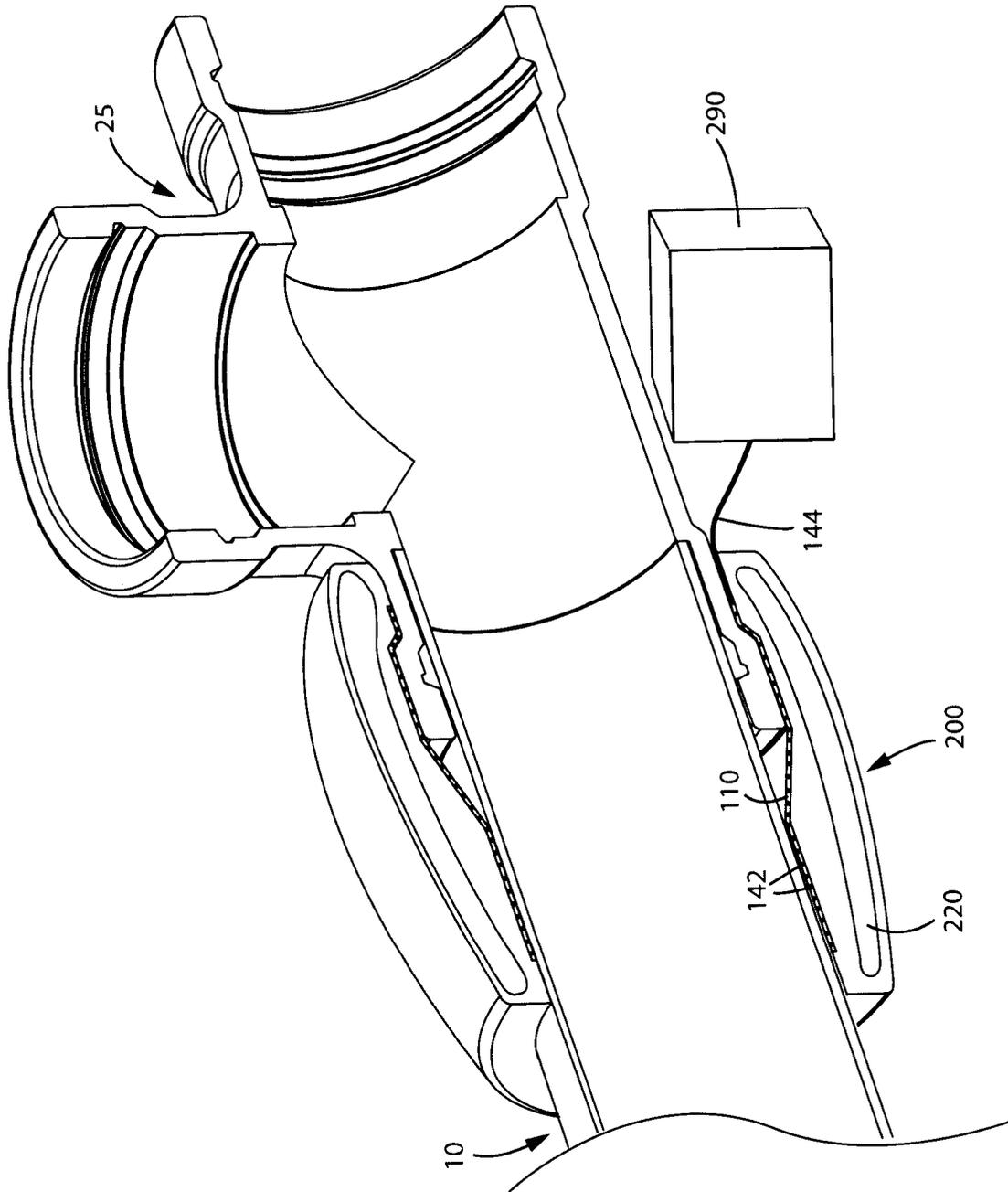


FIG. 55

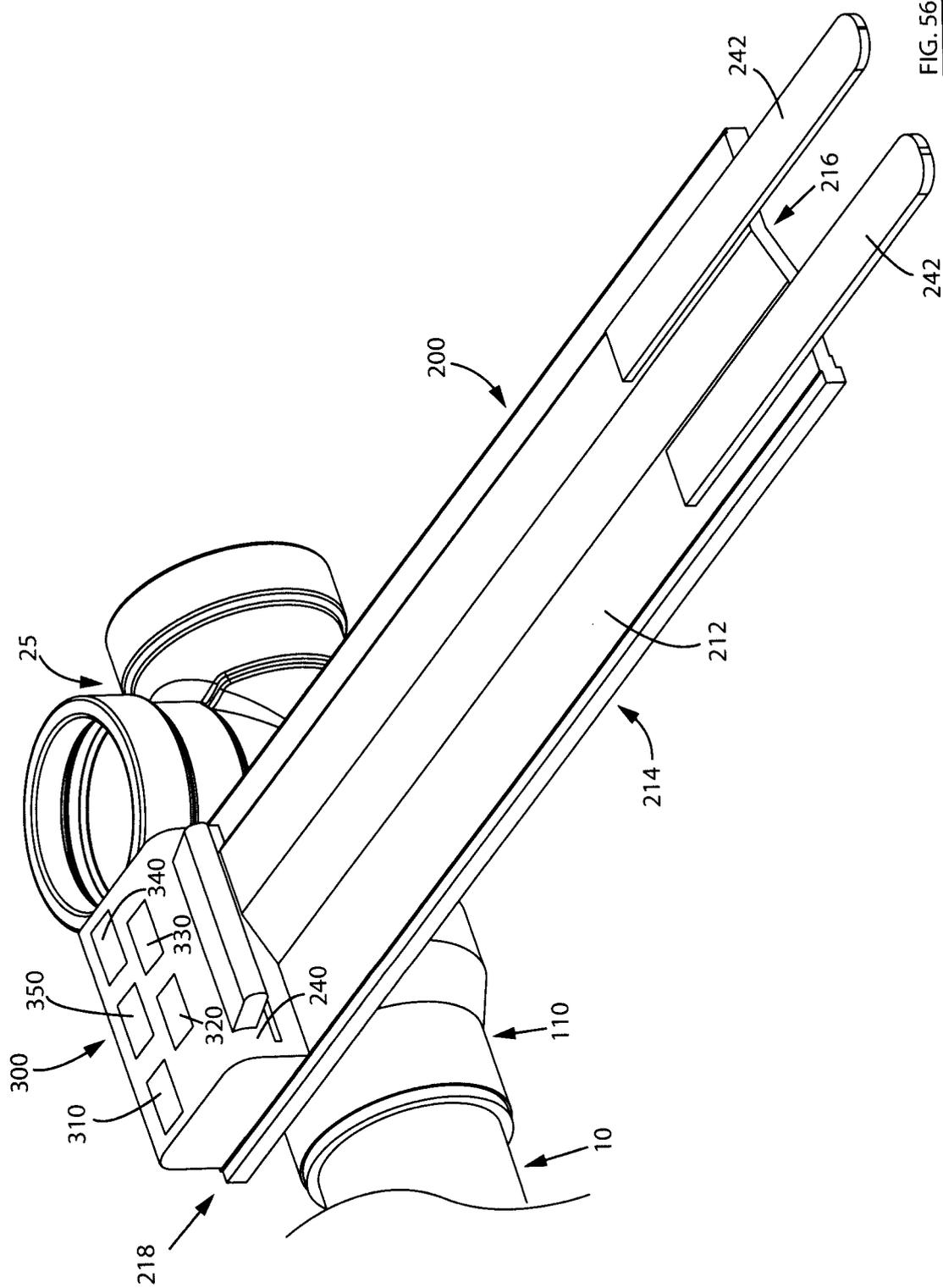


FIG. 56

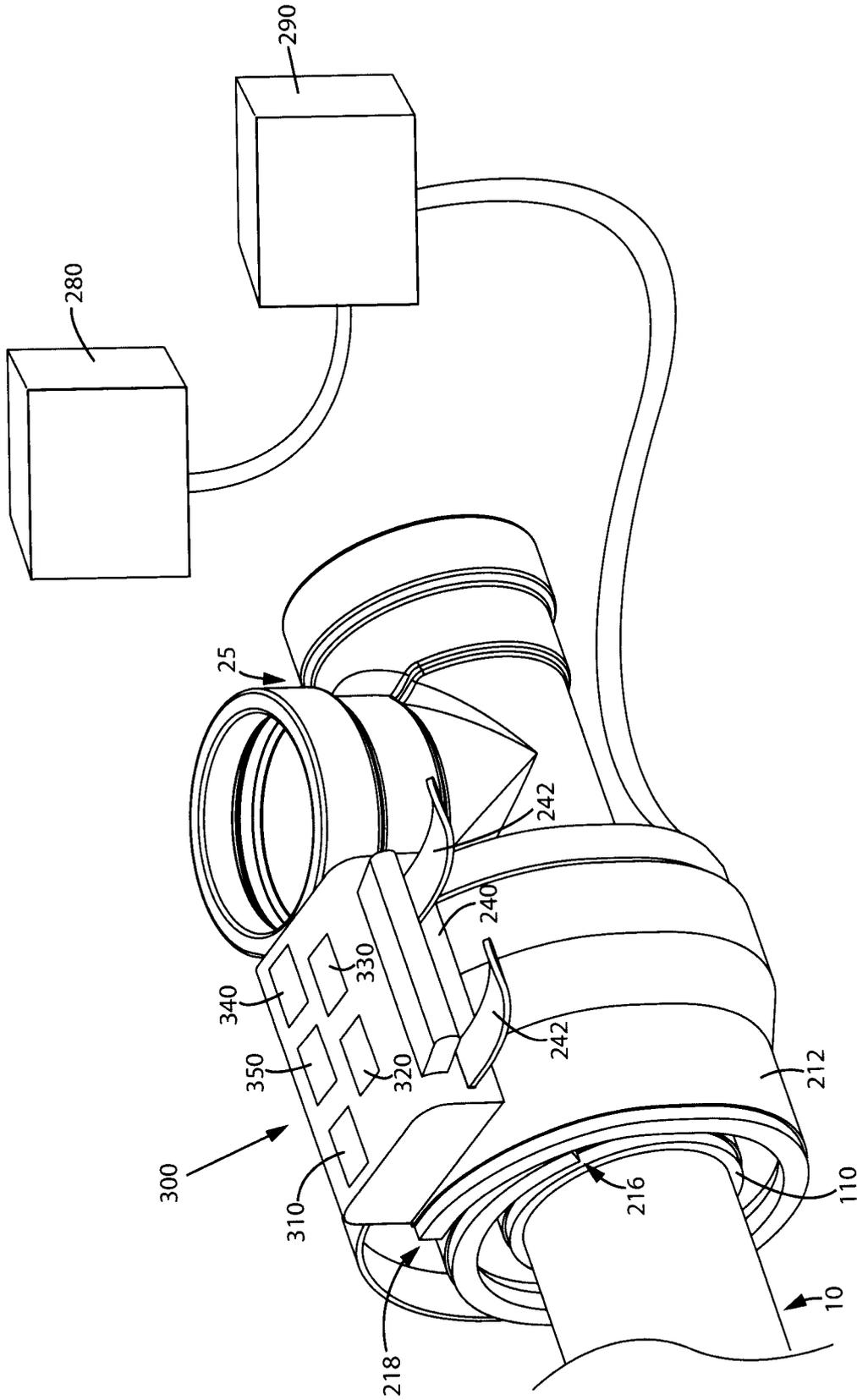


FIG. 57

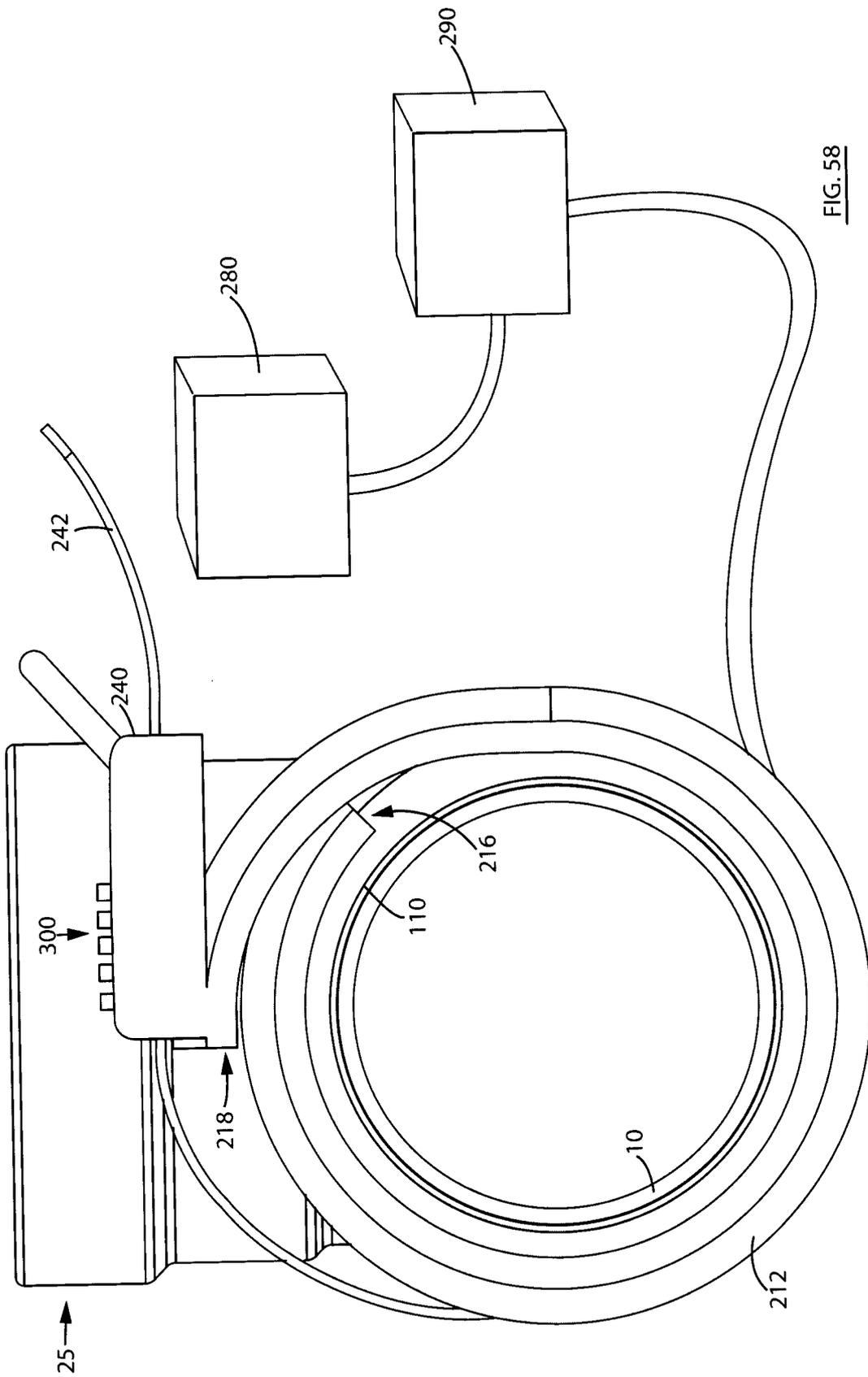


FIG. 58

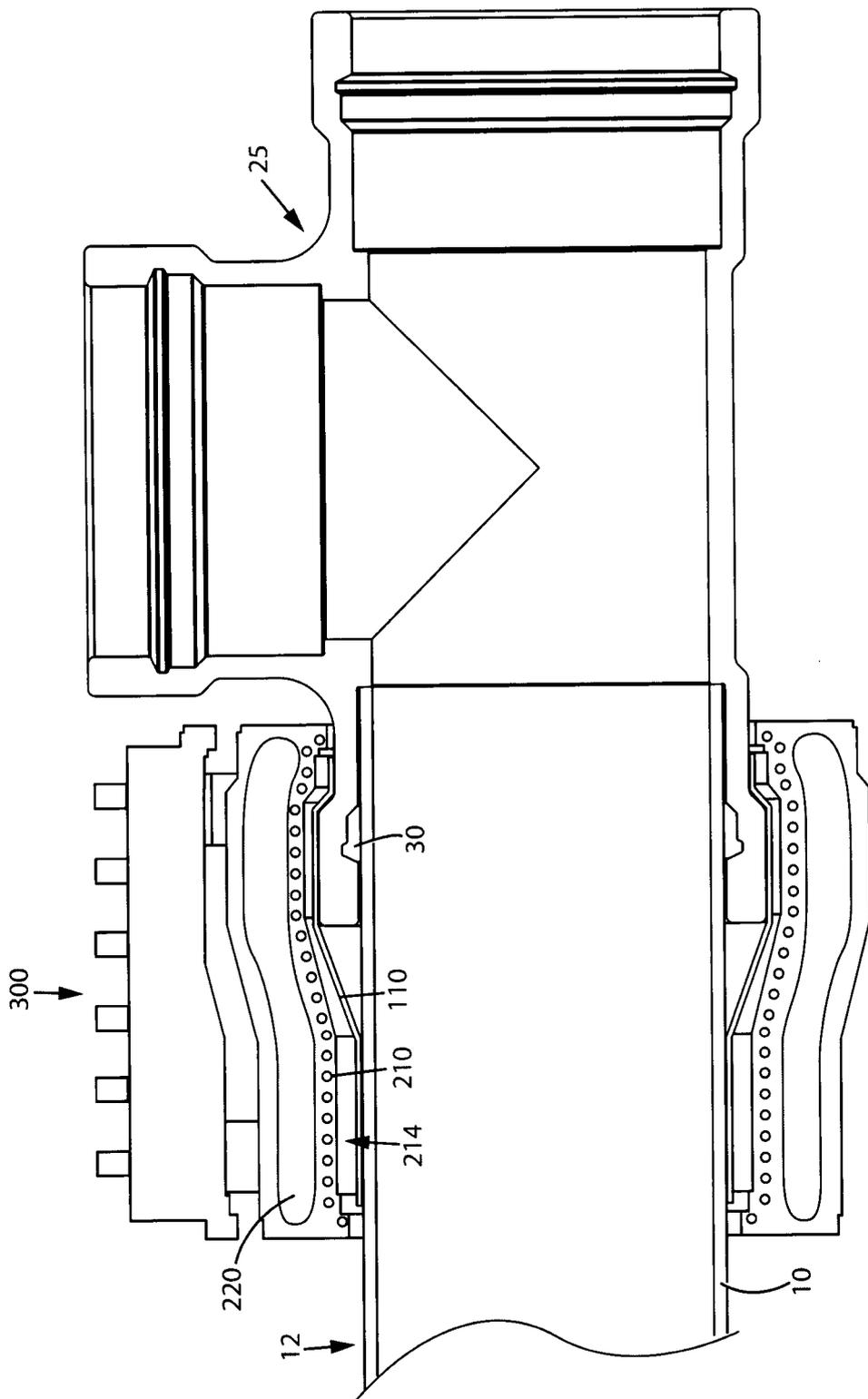


FIG. 59

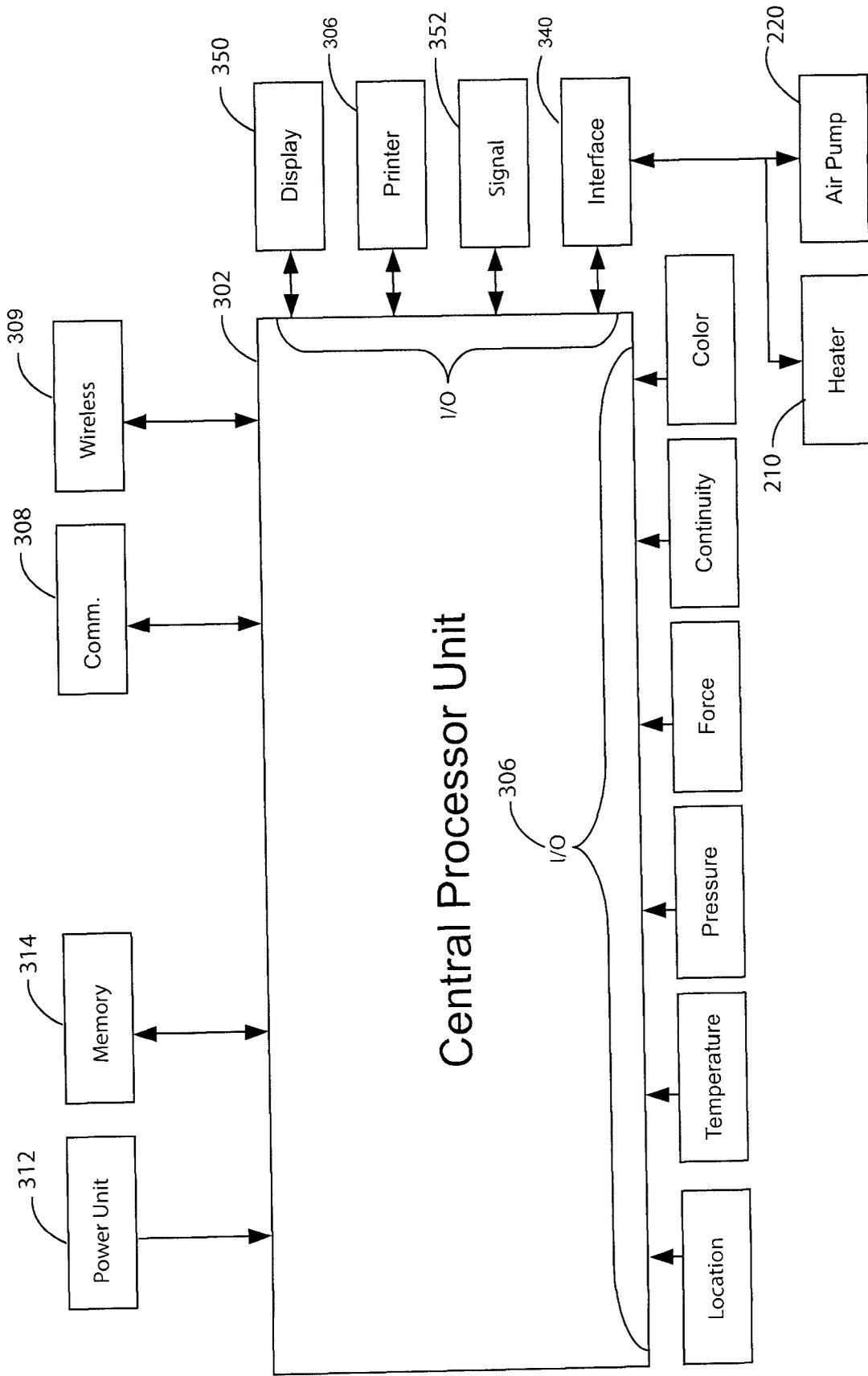


FIG. 60

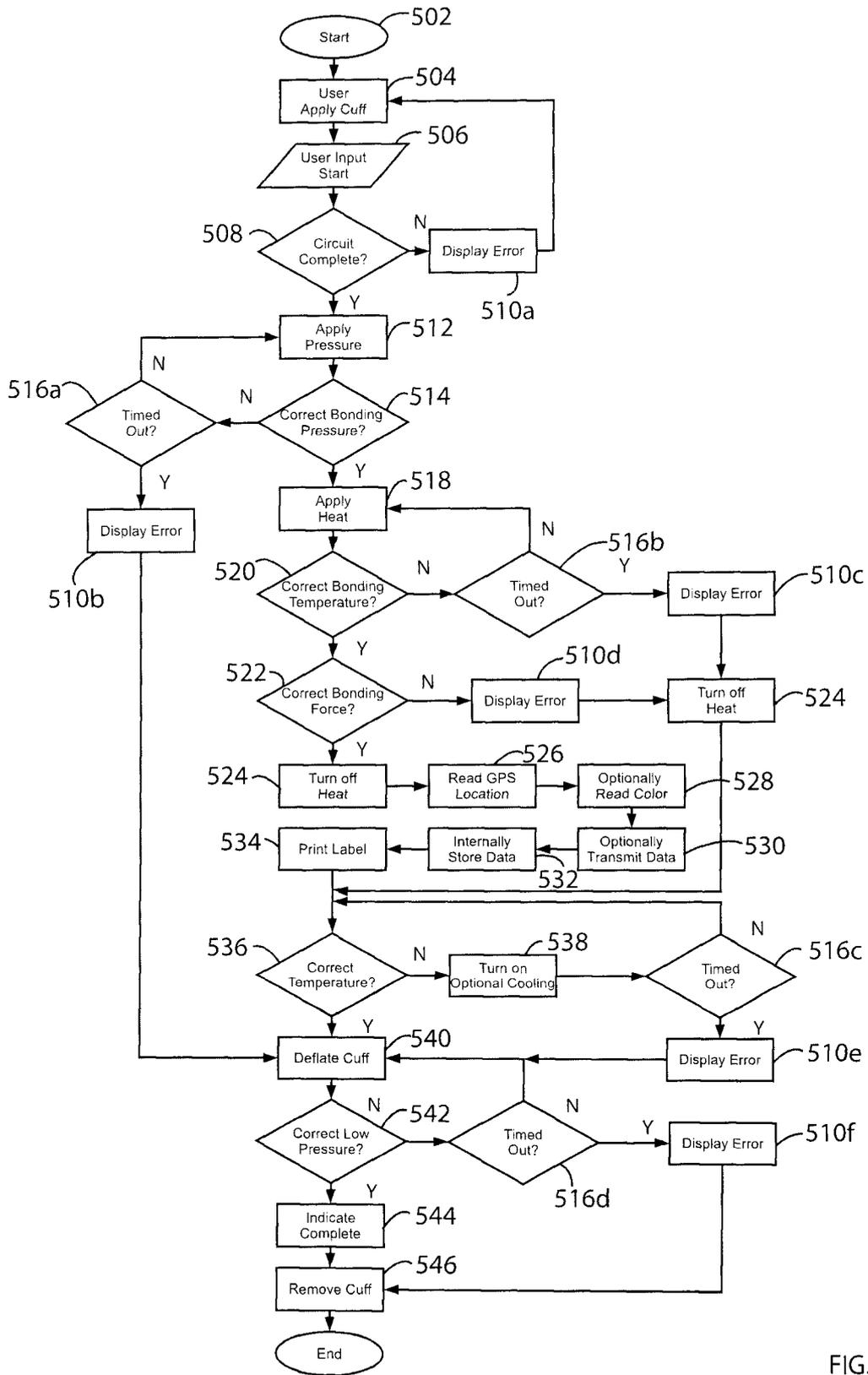


FIG. 61