(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 768 736 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
16.04.1997 Bulletin 1997/16

(51) Int. Cl.[6]: **H01R 17/12**, H01R 13/52

(21) Application number: **96114695.8**

(22) Date of filing: **13.09.1996**

(84) Designated Contracting States:
BE CH DE DK GB IT LI

(30) Priority: **16.10.1995 US 543808**

(71) Applicant: **kabelmetal electro GmbH**
30179 Hannover (DE)

(72) Inventor: **Gigas, George R.**
Madison, CT 06443 (US)

(74) Representative: **Döring, Roger, Dipl.-Ing.**
Alcatel Kabel Beteiligungs-AG,
Kabelkamp 20
30179 Hannover (DE)

(54) Moisture migration proof unpressurized radio frequency transmission system and method

(57) A water migration proof radio frequency transmission system and method is disclosed. The system comprises an unpressurized foam dielectric coaxial cable having a center conductor surrounded by a foam dielectric which is surrounded by an outer conductor. The system also comprises a connector for connecting the center and outer conductors of the cable to the center and outer conductors of an antenna. The connector includes sealing means for preventing moisture migration into the cable from the center conductor of the antenna. In one embodiment the connector has an insulative center conductor contact bead with an O-ring positioned on its outer periphery and with a bore in the bead press fit to an inner conductor contact which in turn connects to the coaxial cable center conductor. In another embodiment the bead includes a second O-ring within the bore for moisture sealing engagement with the inner conductor. The method uses such a connector within a dielectric foam coaxial cable to form a moisture proof radio frequency transmission system.

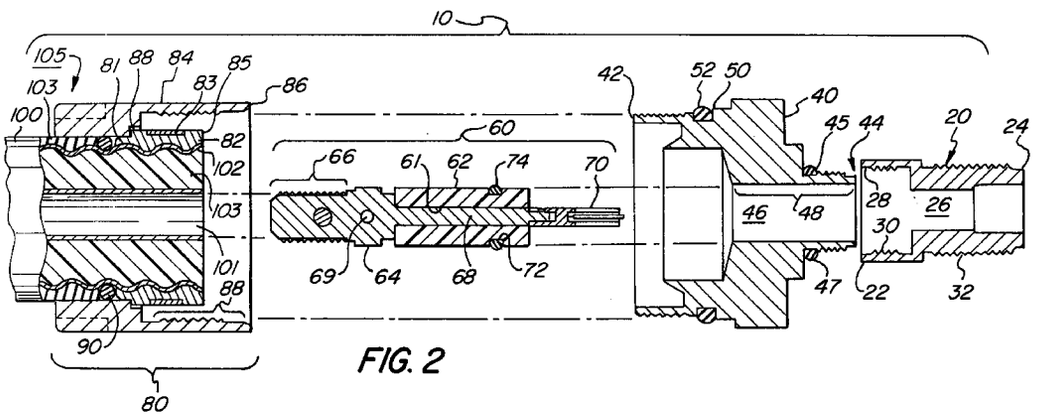

FIG. 2

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Description

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention generally relates to coaxial cable connectors for connecting coaxial radio frequency (RF) cables to other cables, antennas and transceivers. More particularly, the present invention relates to a moisture migration proof unpressurized radio frequency transmission system which includes the use of a coaxial RF cable connector structure that has internal and external seals.

Description of the Prior Art

Foam dielectric coaxial cable is typically used for cell-site antenna feed line cables and antenna interconnects for RF transmission. Such cable is often installed in vertical runs of up to 250 feet. Field reports from cell-site operators, as well as other two-way repeater operators, have indicated that transmission performance of cell-site antennas can be adversely affected by moisture migration within antenna feed line cables. Moisture migration is particularly troubling for cellular base station radio sites because such sites are often located in remote areas, subjected to harsh environments, exposed to radical temperature swings and barometric pressure changes day-in and day-out, as well as, in some areas, exposed to frequent precipitation.

One of the primary driving forces for moving moisture into a cable's interior is pressure changes within the cable caused by changes in temperature. During the daytime in certain environments, a cable can be heated as much as 50 degrees Celsius or more from its night time low temperature. When heated, the pressure inside the cable increases causing air within the cable to escape through connector interfaces. Then, usually during the night, when the cable cools, the air pressure inside the cable is reduced causing a partial vacuum at the cable connector joints. If moisture is present near a cable connector joint, the partial vacuum at the joint can draw moisture into the cable connector.

Once moisture enters a cable, it can migrate anywhere within the cable. For example, the moisture may migrate between the center conductor and the foam dielectric The moisture may also migrate through the center conductor. The moisture may even migrate between the outer conductor and the foam dielectric.

Depending upon where such moisture ultimately collects, the moisture can cause minimal to serious signal degradation. Moisture collecting between the outer conductor and the foam dielectric surface can cause significant signal attenuation. Moisture collecting on the cross-section of the dielectric foam adjacent to the connector can cause a mismatch which results in VSWR degradation.

While it has been well recognized that moisture can migrate into the cable through exterior cable joints, and that measures have been taken to prevent this migration as shown by the use of O-rings at external connector joints as shown in U.S. Patent No. 5,137,470, it has not been recognized, until now, that moisture may also migrate into unpressurized cables through internal joints, such as along a center conductor contact assembly connected to an antenna, even though the exterior of the connector is moisture proof. Such internal migration also causes the same signal degradation problems when the moisture collects on the foam dielectric surface or the cross-section of the dielectric adjacent to the connector.

Connectors designed with air-tight seals between the cable and the outer conductor assembly, and between the outer conductor assembly and the center conductor assemblies, have been fabricated and used to enable a hollow center conductor of a coaxial cable to be pressurized or to enable pressurization of the region between the cable's center and outer conductors. The pressurized cable is further used to pressurize hollow antenna elements to provide them with structural rigidity. It has been discovered by the applicant that these connectors for pressurized cables are useful in unpressurized applications to prevent internal moisture migration into foam dielectric cable, such as along a center conductor contact assembly connected to an antenna.

SUMMARY OF THE INVENTION

It is a primary object of the present invention to provide a moisture migration proof radio frequency transmission system and a connector for use in such a system.

Other objects and advantages of the invention will be apparent from the following detailed description and the accompanying drawings.

In accordance with the present invention, the foregoing primary objective is realized by using a cable connector with a center conductor contact having press fit thereon an electrically insulative, cylindrically shaped center conductor contact bead having an O-ring seal receiving recess on its outer surface and an O-ring seal positioned in the recess. The bead includes a central bore which is dimensioned so as to require press fitting over the center conductor contact's bead receiving shaft. It has been discovered that the snug, press fit bead provides an adequate moisture barrier or seal between the center conductor contact's bead receiving shaft and the insulative bead even when the coaxial cable is subjected to widely variable ambient conditions. The O-ring seal on the bead provides a moisture barrier between the bead and an opening in an outer coupling body in an assembled connector. The use of a connector with the aforementioned moisture barriers in an unpressurized foam dielectric cable provides superior internal moisture migration resistance.

An O-ring may also be positioned within the central bore of the bead in lieu of press fitting the bead over the

center conductor contacts' bead receiving shaft.

BRIEF DESCRIPTION OF THE DRAWINGS

The drawings, not drawn to scale, include:

FIG. 1 which is a perspective view of an exterior of a coaxial cable connector;
FIG. 2 which is a longitudinal cross-sectional, semi-exploded view of a coaxial cable connector employing the insulative internal moisture barrier center conductor coupler bead;
FIG. 3 which is a longitudinal cross-sectional view of the same coaxial cable connector of FIG. 2 also including an external heat shrinkable boot as an additional external moisture migration barrier; and
FIG. 4 is a longitudinal cross-sectional view of an alternative embodiment of the center conductor contact bead having an O-ring positioned within the central bore of the bead in lieu of press fitting the bead over the center conductor contacts' bead receiving shaft.

DETAILED DESCRIPTION OF THE PRESENT INVENTION

Referring generally to the drawings, there is shown a coaxial cable connector **10**. Referring more specifically to FIG. 2, the connector **10** generally comprises several component parts which are shown in a semi-exploded view. The component parts include a nose assembly **20**, an outer conductor contact body **40**, an center conductor contact assembly **60**, and an outer conductor contact securing assembly **80**. As will be more fully explained below, to prevent moisture migration into the cable, the method of the present invention uses, a cable connector which is provided with seals or moisture barriers at all critical interfaces between its component parts. Most importantly, the method of the present invention uses a center conductor contact assembly that is fitted with a press fit insulative bead which provides internal moisture barriers to dramatically improve resistance to internal moisture migration. A detailed description of a connector embodiment employing the insulative bead is presented below. Connectors having the below described structure including a press fit bead have been used in pressurized cable applications wherein the cable is pressurized so as to pressurize antenna elements for structural rigidity purposes.

Referring to FIG. 2, the nose assembly **20** of the connector **10** is generally cylindrically shaped and includes a body coupling end **22** and an antenna coupling end **24**. The nose includes a varying diameter bore **26** extending from the body coupling end **22** to the antenna coupling end **24**. An O-ring seal receiving recess **28** is provided at the body coupling end **22**. A portion **30** of the interior diameter of the nose assembly **20**, adjacent to the O-ring seal receiving recess **28**, is threaded. The nose assembly **20** also includes an exterior threaded portion **32**, between the body coupling end **22** and the antenna coupling end **24**.

Connector body **40** is generally cylindrically shaped with a varying outside diameter along its length. The connector body **40** includes a threaded outer conductor coupling end **42**, a threaded nose assembly coupling end **44** with an O-ring seal receiving surface **45**, and a varying diameter cylindrical bore **46** extending from the outer conductor coupling end **42** to the nose assembly coupling end **44**. An insulative bead receiving portion **48** of the bore **46** is dimensioned to snugly receive an center conductor insulator bead **62**. The connector body **40** also includes an O-ring seal receiving recess **50** in which an O-ring seal **52** resides.

The center conductor contact assembly **60**, also generally cylindrically shaped, includes a metal center conductor contact body **64** having a threaded shank **66** dimensioned to fit within the center conductor of an RF cable, a bead receiving shaft **68** and a diametric bore **69**. The threaded shank **66** of the metal center conductor contact body **64** provides electrical connection to the center conductor of the RF cable. A pin **70**, for connection to another coaxial connector or an antenna, such as a type NF contact, is attached to the bead receiving shaft **68** and may be held in place by solder or any other suitable securing means such as threading, for example. The contact assembly **60** also includes the previously mentioned cylindrically shaped bead **62** having a lengthwise bore **61** therein and an O-ring receiving recess **72** on its outer surface in which an O-ring seal **74** may reside. In the preferred embodiment, the bead **62** is fabricated from virgin white poly-tetra-fluoro-ethylene, commonly known under the trademark TEFLON. Other insulative materials may be used for the bead **62** provided such materials have adequate electrical insulating properties. The diameter of the lengthwise bore of the TEFLON bead **62** is dimensioned to lit as snugly as possible to the bead receiving shaft **68**. Also, in the preferred embodiment, the bead **62** is dimensioned such that it must be press fit onto the bead receiving shaft **68**. A moisture barrier between the bead **62** and the bead receiving shaft **68** is created by the tight press fit between the bead and shaft.

FIG. 4 illustrates an alternative embodiment of the cylindrically shaped bead **62'** where a second O-ring receiving recess **71** is positioned within the lengthwise bore **61** for receipt of an O-ring **73**. In this embodiment the diameter of the central bore is dimensioned to slide over receiving shaft **68**, with O-ring **73** providing the moisture barrier therebetween.

The outer conductor contact securing assembly **80** comprises a collet **82** which is generally angularly shaped and includes a cable jacket end **83**. The collet **82** is used to grasp the outer conductor and make electrical contact therewith. The inside diameter of the collet **82** is shaped to match the ribbed outer conductor **102** of a cable **100** having a foam dielectric **103**. Typically, the collet **82** comprises two collet halves which are posi-

tioned bound the outer conductor **102** of the cable **100** and held together by a retaining spring or clip **83** substantially surrounding the collet halves. An example of two collet halves held together by a retaining spring is shown in U. S. Patent 5,454,735, assigned to the assignee of the present invention, and the description therein is incorporated by reference.

In addition to the collet **82**, the assembly **80** includes a back nut **84** which has a body coupling end **86**, a collet abutting end **88**, and a threaded portion **90** between the body coupling end **86** and the collet contacting end **88**. The assembly **80** also includes an O-ring seal receiving surface **87** adjacent to the body coupling end **86** to which O-ring **52** may be positioned against. The assembly **80** also includes an O-ring seal **90** positioned between the outer conductor **102** of the cable and the back nut **88**.

FIG. 2 illustrates the connector **10** in the fully assembled, externally and internally moisture migration proof site suitable for use in severely varying ambient conditions. According to the method, the connector **10** is assembled and attached to the cable **100** in a conventional manner so as to form an unpressurized radio frequency transmission system **105**. Ordinarily, a sufficient length of the outer protective jacket **103** of the cable **100** is stripped off, exposing a length of outer conductor **102**. The cable **100** is inserted through the back nut **84**, and through the O-ring seal **90** which has an inside diameter approximately the same size as the outside diameter of the outer conductor **102**. The collet **82** is attached to the exposed outer conductor **102** so that one end is adjacent to the O-ring seal **90** and the other end is adjacent to the end of the cable **100**.

The center conductor threaded shank **66** is threaded to the center conductor **101**. A rod (not shown) may be inserted into the diametric bore **69** to facilitate threading of the threaded shank **66** of the center conductor into the center conductor **101** of the cable **100** since the metal conductor **64** is generally cylindrically shaped. The O-ring groove **72** in the bead **62** is fitted with the O-ring seal **74**.

Once the shank **66** of the center conductor assembly **60** is secured to the center conductor **101**, O-ring seal **52** is placed in O-ring seal receiving groove **50** and the body **40** is securely threaded to the back nut's threaded portion **88**. When the back nut **84** and the body **40** are secured, the O-ring seal **52** is snugly positioned between back net **84** and the O-ring seal receiving groove **50** and forms a tight, moisture proof seal. Also, when the back nut **84** and the body **40** are securely coupled, the insulative bead **62** resides in the bead receiving portion **48** of bore **46**. A moisture barrier between the bead **62** and the bead receiving portion **48** of bore **46** is formed by O-ring **74** positioned between recess **72** and bead receiving portion **48**. A moisture barrier between the bead **62** and the center conductor's bead receive shaft **68** is provided by the press fitting of the bead **62** on the shaft **68**, or for the alternative bead embodiment **62'** shown in FIG. 4, by O-ring **73**. It has been found that the two aforementioned moisture barriers provide greatly improved internal moisture migration resistance in an unpressurized coaxial cable.

Finally, after an O-ring seal **47** is positioned on O-ring receiving surface **45** of the body, the nose assembly **20** is securely coupled to the body **40**. After the nose assembly **20** and body **40** are securely coupled via their respective opposing threaded portions, O-ring seal **47**, positioned between the nose assembly **20** and the body **40**, provides a moisture seal for the joint therebetween.

FIG. 1 illustrates the appearance of the assembled connector **10** which may be used in the method of the present invention. It should be appreciated by those skilled in the art that the joints between the body **40** and back nut **84**, as well as between the back nut **84** and the cable jacket **103**, are still exposed to the environment and the joints, if small enough, could provide some capillary action to draw moisture therein. A heat shrinkable sleeve **120** of sufficient length, may be fitted over the connector so as to cover the above mentioned joints between the body **40** and the back nut **84**, and between the back nut **84** and the cable jacket **103**. Once sleeve **120** is fitted over the connector **10**, heat may be applied to the sleeve **120** to shrink the diameter of the sleeve **120** so as to provide a continuous, tight fitting exterior moisture barrier over the above mentioned joints.

As can be seen from the foregoing detailed description and drawings, the present invention provides a moisture migration proof radio frequency transmission system formed by foam dielectric coaxial cable in combination with the above-described connector. The present invention also describes a method for forming a moisture proof radio frequency transmission system and although such a system and method has been described with respect to one or more particular embodiments, it will be understood that other embodiments of the present invention, such as the type of coaxial cable used and the like, may be employed without departing from the spirit and scope of the present invention. Hence, the present invention is deemed limited only by the appended claims and the reasonable interpretation thereof.

Claims

1. A water migration proof, unpressurized radio frequency transmission system, comprising:

   an unpressurized foam dielectric coaxial cable further comprising:

   a center conductor,
   a foam dielectric surrounding the center conductor, and
   an outer conductor surrounding the foam dielectric; and

   a connector for connecting the unpressurized foam dielectric cable to an antenna, the con-

nector further comprising:

means for connecting the outer conductor of the dielectric foam cable to an outer conductor of the antenna, and
means for connecting the center conductor of the dielectric foam cable to a center conductor of the antenna, the means further including sealing means for preventing water migration from the antenna's center conductor to the cable.

2. The system of claim 1, wherein the means for connecting the outer conductor further includes sealing means for preventing water migration from interfaces between the outer conductor and said outer conductor connecting means and for preventing water migration from interfaces between said outer conductor connecting means and the outer conductor of the antenna.

3. A system as defined in claim 1, wherein the means for connecting the center conductor of the dielectric foam coaxial cable to the center conductor of the antenna comprises:

a connector body having an opening formed therethrough,
an insulative center conductor contact bead positioned within the opening of connector body, the bead including a bore, and an O-ring receiving groove on the surface of the bead adjacent the connector body,
an O-ring positioned between the O-ring receiving groove of the bead and the connector body forming a moisture migration barrier between the bead and the body,
an inner conductor contact having means for electrical connection to the center conductor of the unpressurized foam dielectric coaxial cable, and having a shaft press fit in the bore of the bead so as to form a moisture migration barrier therewith, and
means for electrically connecting the inner conductor contact to the center conductor of the antenna.

4. The system of claim 1, wherein the means for connecting the center conductor of the dielectric foam coaxial cable to the center conductor of the antenna comprises:

a connector body having an opening formed therethrough,
an insulative center conductor contact bead positioned within the opening of connector body, the bead including a bore, an O-ring receiving groove on the surface of the bead adjacent the connector body, and an O-ring receiving groove in the bore of the bead,
an O-ring positioned between the O-ring receiving groove of the bead and the connector body forming a moisture migration barrier between the bead and the body,
an O-ring positioned within the O-ring receiving groove in the bore to form a moisture migration barrier between the bead and the center conductor of the coaxial cable,
an inner conductor contact having means for electrical connection to the center conductor of the unpressurized foam dielectric coaxial cable, and having a shaft for sliding engagement with the bore of the bead and for engagement with the O-ring positioned within the O-ring receiving groove in the bore so as to form a moisture migration barrier therewith, and
means for electrically connecting the inner conductor contact to the center conductor of the antenna.

5. A water migration proof, unpressurized radio frequency transmission system, comprising:

an unpressurized foam dielectric coaxial cable further comprising:

a center conductor,
a foam dielectric surrounding the center conductor, and
an outer conductor surrounding the foam dielectric; and

a connector assembly for connecting the outer and inner conductors of the unpressurized foam dielectric coaxial cable to an antenna, the connector assembly having internal moisture migration resistance, the connector assembly comprising:
a connector body having an opening therein for receiving an insulative center conductor contact bead,
means for electrically connecting the body to the outer conductor of the coaxial cable,
means for electrically connecting the connector body to the outer conductor of an antenna,
an insulative inner conductor contact bead positioned within the opening of the connector body, the bead including a bore, and further including an O-ring receiving groove on its surface adjacent to the connector body,
an O-ring positioned between the O-ring receiving groove of the bead and the connector body forming a moisture migration barrier between the bead and the body,
an inner conductor contact having means for electrical connection to the center conductor of the unpressurized foam dielectric cable, and having a shaft press fit in the bore of the bead

so as to form a moisture migration barrier;
and
means for electrically connecting the inner conductor contact to the center conductor of the antenna.

6. A system as defined in claim 5, wherein the means for electrically connecting the connector body to the outer conductor of the coaxial cable includes means for preventing water migration from interfaces between the outer conductor and said outer conductor connecting means and for preventing water migration from interfaces between said outer conductor connecting means and the outer conductor of the antenna.

7. A connector assembly for use in forming a water migration resistant, unpressurized radio frequency transmission system including:

an unpressurized foam dielectric coaxial cable having:

a center conductor,
a foam dielectric surrounding the center conductor, and
an outer conductor surrounding the foam dielectric; and

an antenna for communication therewith;
wherein the connector assembly is used for connecting the outer and inner conductors of the unpressurized foam dielectric coaxial cable to the antenna, the connector assembly having internal moisture migration resistance, the connector assembly comprising:
a connector body having an opening therein for receiving an insulative center conductor contact bead;
means for electrically connecting the connector body to the outer conductor of the coaxial cable;
means for electrically connecting the connector body to the outer conductor of an antenna;
an insulative inner conductor contact bead positioned within the opening of the connector body, the bead including a bore and further including an O-ring receiving groove on its surface adjacent to the connector body;
an O-ring positioned between the O-ring receiving groove of the bead and the connector body forming a moisture migration barrier between the bead and the body;
an inner conductor contact having means for electrical connection to the center conductor of the unpressurized foam dielectric cable, and having a shaft press fit in the bore of the bead so as to form a moisture migration barrier; and
means for electrically connecting the inner conductor contact to the center conductor of the antenna.

8. A method for making a water migration proof, unpressurized radio frequency transmission system, the method comprising:

providing an unpressurized foam dielectric coaxial cable further comprising:

a center conductor,
a foam dielectric surrounding the center conductor, and
an outer conductor surrounding the foam dielectric;

providing a connector for connecting the unpressurized foam dielectric coaxial cable to an antenna, the connector further comprising:

means for connecting the outer conductor of the dielectric foam coaxial cable to an outer conductor of the antenna, and
means for connecting the center conductor of the dielectric foam coaxial cable to a center conductor of the antenna, the means further including sealing means for preventing water migration from the antenna's center conductor to the coaxial cable.

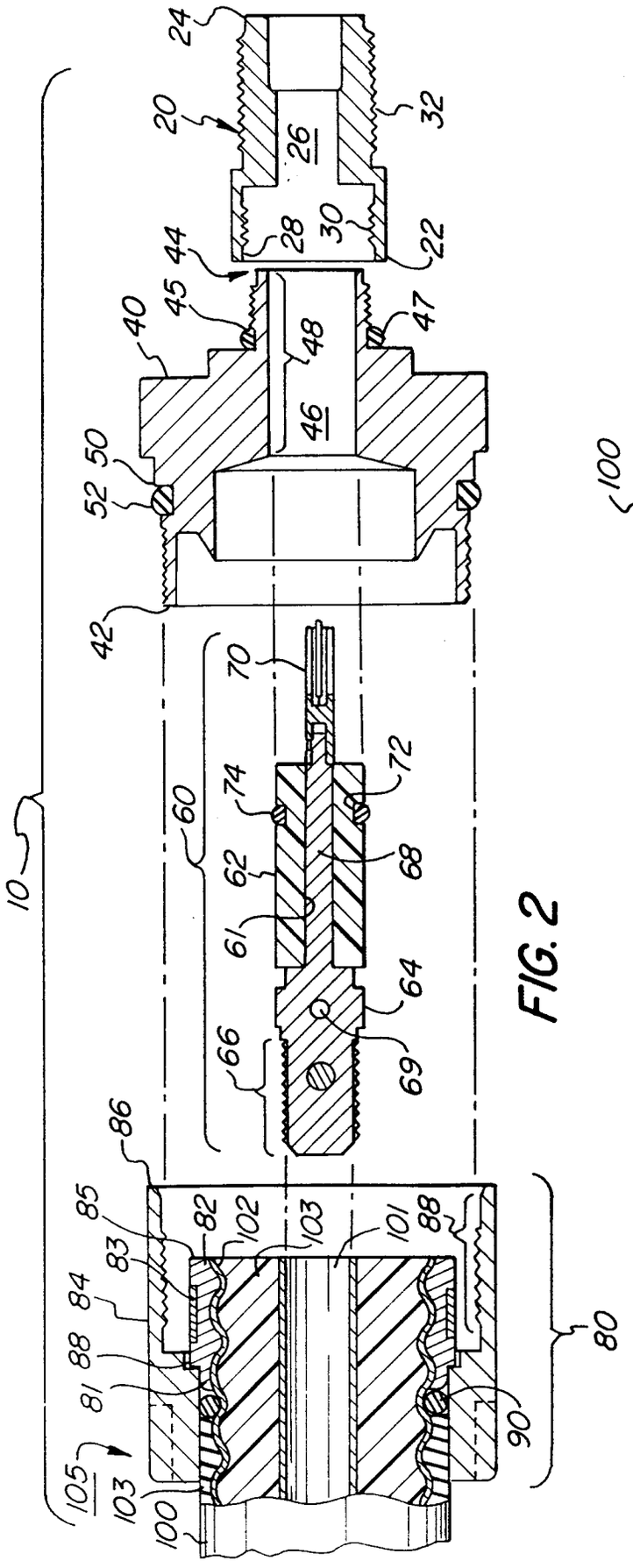
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FIG. 2

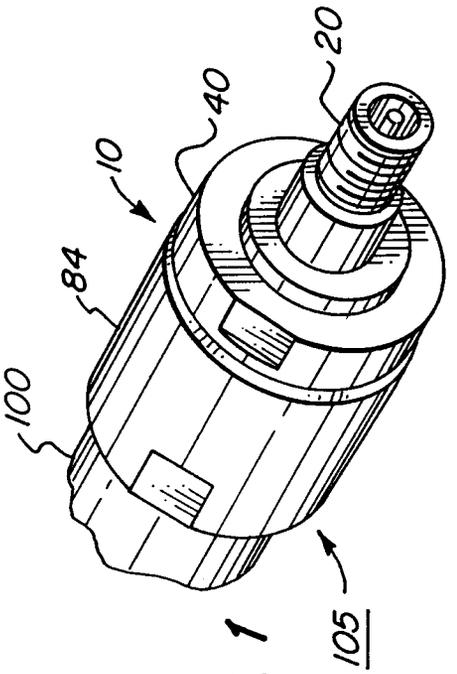
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FIG. 1

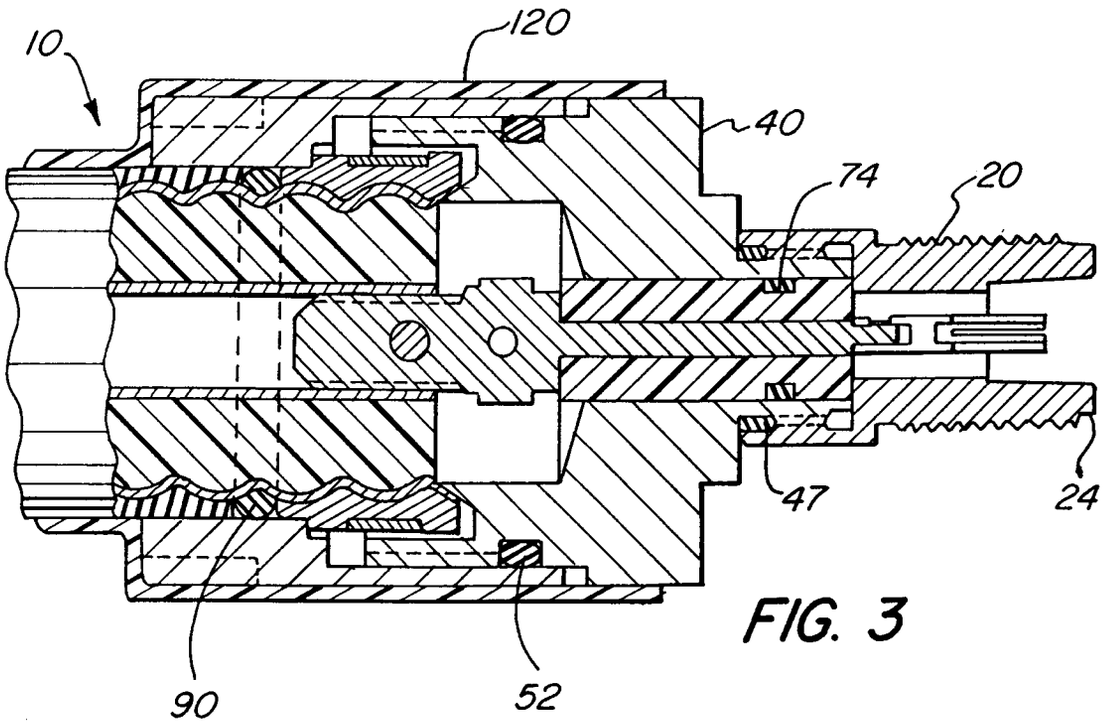

FIG. 3

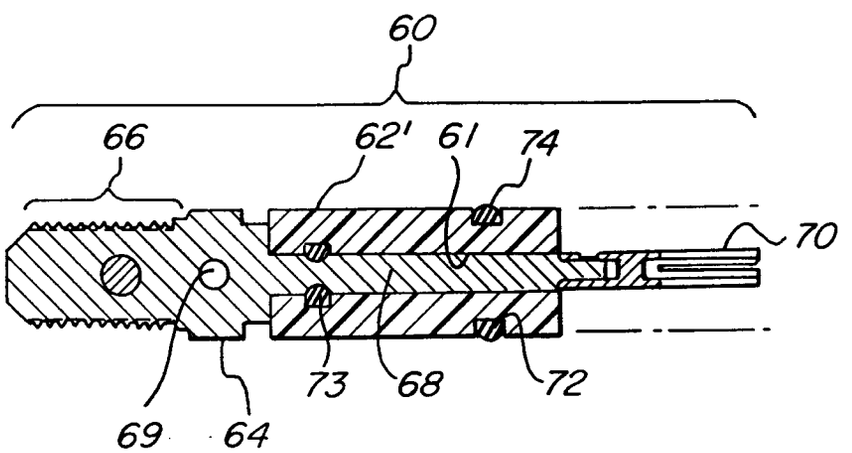

FIG. 4