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ROTARY JOINT UTILIZING A FLUID SLIP RING

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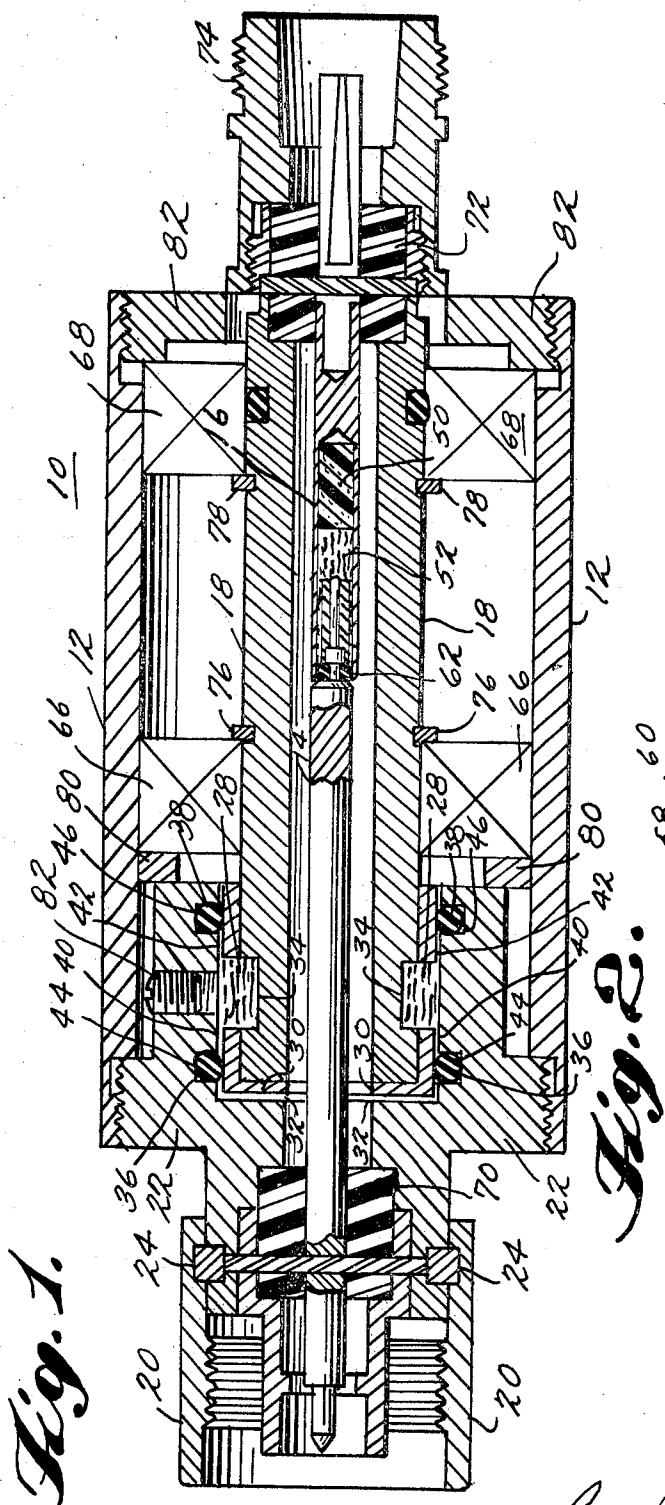


Fig. 1.

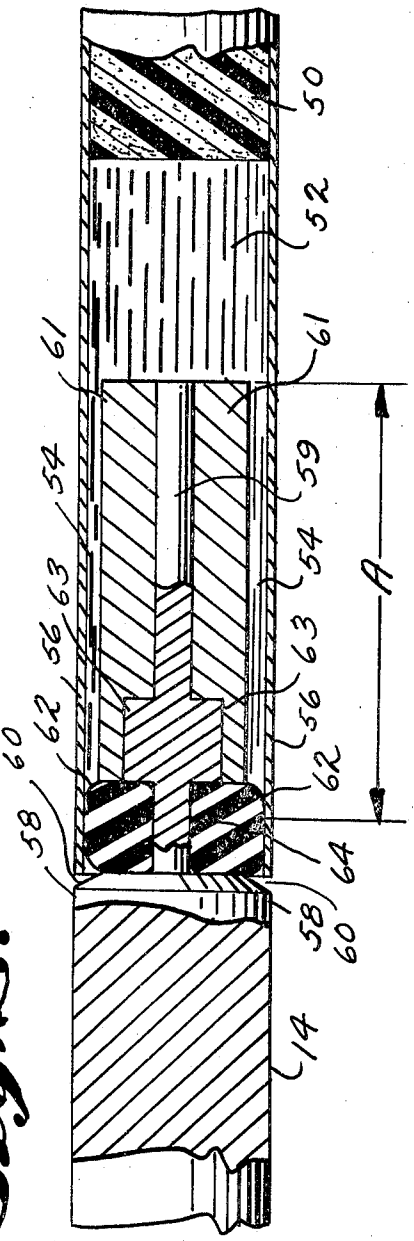


Fig. 2.

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ROTARY JOINT UTILIZING A FLUID SLIP RING

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U.S. Cl. 174—21 3 Claims

ABSTRACT OF THE DISCLOSURE

An improved coaxial rotary joint for passing a wide range of frequencies including separate paths for high and low frequencies, the low frequency path including a mercury slip ring between the inner conductors connected at the joint. The slip ring comprises a recess in one of the inner conductors and projection on the other extending into the recess, with an O-ring seal around the neck of the projection. Mercury is in the portion of the recess not occupied by the projection. To keep mercury in the portion of the recess in a narrow space between the projection and the wall of the recess, an expandable element is placed in the recess, which expands to occupy any space not filled with mercury.

This invention relates to electrical rotary joints and, in particular, to improved means for sealing a fluid (such as mercury) slip ring which may be used in electrical rotary joints. This invention also relates to improved means for passing RF or high frequency 1000 mc. to 12 gc. for example) energy through the inner conductors of a rotary joint.

This invention is an improvement of the copending application by the same inventor Ser. No. 592,402, filed Nov. 7, 1966, now Patent No. 3,426,309, entitled Rotary Joint and assigned to the same assignee as the present invention.

As has been discussed in the above-mentioned copending application, a serious problem arises in rotary joints which employ an electrically conducting fluid, such as mercury, as a slip ring because unacceptably high friction torque tends to develop between the seal for the fluid and the rotating members. In certain applications, such as where a rotary joint is employed to connect a rotating coaxial line to a stationary one, the high friction torque must be resisted by the outer conductor of the stationary coaxial line. However, these outer conductors are not designed to withstand high rotational stress and, hence the torque developed at the seal cannot become too high.

It is a primary purpose of this invention to provide an improved seal for fluid (such as mercury) slip rings employed in coaxial or non-coaxial rotary joints.

It is further the object of this invention to provide an improved coaxial rotary joint having a fluid (such as mercury) slip ring where the seal for the mercury develops a minimum amount of frictional torque between the stationary and rotating members.

It is a further object of this invention to provide an improved RF or high frequency path through the inner conductor of a coaxial rotary joint.

Other objects and advantages of this invention will become apparent upon reading the appended claims in conjunction with the following detailed description and the attached drawings, which:

FIGURE 1 is a cross section view of a rotary joint in accordance with the principles of the invention; and

FIGURE 2 is a detail portion of FIGURE 1.

Inasmuch as most of the mechanical details of the general type of rotary joint disclosed in FIGURE 1 are well known and since they have been thoroughly described in the above-mentioned copending application of applicant, the description of the mechanical features will only be briefly described in this application. The rotary joint is generally indicated at **10**. It incorporates a housing **12**, a stationary inner conductor or a first cylindrical inner conductor **14**, a rotating inner conductor or second cylindrical inner conductor **16**, and a rotating outer conductor or second cylindrical outer conductor **18**. Housing **12** and connector assembly member **22** comprise a stationary outer conductor or first cylindrical outer conductor. The first cylindrical outer conductor may, for ease of manufacture, be produced as an assembly. Although this invention is described in terms of certain members rotating and other members being stationary, it will be understood by those having ordinary skill in this art that the principles of this invention are applicable whenever relative rotation occurs between the outer and inner conductors **12** and **14** respectively, and the outer and inner conductors **18** and **16** respectively. Connector sleeve **20** receives a male member (not shown), sleeve **20** being secured to connector assembly member **22** via retaining ring 24. The outer conductor of the stationary coaxial line (not shown) connects to connecting member 26 and thus an electrical path is provided via member **26** and connector assembly member **22** to (1) mercury bath **28**, thereby providing a DC and low frequency path in the outer conductor, and (2) conducting member **30** via gap **32** thereby providing a capacitive, RF path from the stationary to the rotating conductor. The RF path in the outer conductor is completed to rotating outer conductor **18** since member **30** is in electrical contact therewith, member **30** being fixedly attached to conductor **18**. The gap **32** is preferably 0.001".

The DC path in the outer conductor through mercury slip ring **28** has been mentioned above. Recess **34** formed within member **18** provides a receptable for the mercury, further, the receptacle may be provided in member **22** or in members **22** and **18**. The mercury is sealed between stationary outer conductor **22** and rotating outer conductor portion **18** by sealing members or O-ring seals **36** and **38**. These rings are commercially available and a ring that has been successfully employed in this invention is O-ring No. 2–16 manufactured by Parker Seal Co. Other types of squeeze type molded seals can also be used. However, O-rings are preferred.

In order to prevent leakage through the seal of a mercury slip ring of a rotary joint, it is required that the seals be statically and dynamically fluid tight. A fluid tight seal is one which has no passage through which the fluid might escape. Squeeze type molded seals such as O-rings properly designed and installed have this fluid tight characteristic. In rotating seals, however, and especially in high speed rotating seal applications, certain problems arise which have caused rotating seals utilizing squeeze type molded seals (O-rings) to be considered impractical. These problems include the Joule effect which causes O-rings to contract when heated while under tensile stress such as that due to the installation. In an effort to counteract the difficulties arising from this problem, it is known to those skilled in this art that certain dimensions must be specified for rotary O-ring seals which will produce peripheral compressive O-ring stress due to the installation. Seals manufactured to these dimensions, however, are still unsatisfactory as high speed seals for mercury slip rings, this being evidenced by unacceptably high friction torque (at all speeds), heat and wear which eventually result in failure of the seal. This problem is particularly severe when the rotational friction must be resisted by torsional stress in a coaxial cable.

In the seals **36** and **38**, which have been successfully employed to seal a mercury slip ring, low friction torque is present at all speeds, no overheating occurs at high speeds, and a fluid type seal with long life results. The im-

provements result from first inserting the O-rings **36** and **38** respectively into O-ring gland grooves **44** and **46** which provide peripheral compression as has been mentioned above to minimize the Joule effects. After insertion into grooves **44** and **46**, the inner diameter of the O-rings (assuming that Parker No. 2–16 O-rings are used) is decreased to a preferred predetermined value (for example, an inner diameter of 0.603″ to 0.604″). The rotating shaft inner diameter (the diameter across member **30**) is established at a second accurately predetermined value (for example, 0.606″ to 0.607″) so that a radical squeeze of a third predetermined value (for example, 0.001″ to 0.003″) results when the rotating shaft is inserted through the installed O-ring. Broadly speaking, the amount of radial squeeze required is directly related to the cross section diameter of the O-ring.

In the case of the Parker No. 2–16 the cross section diameter of the O-ring is 0.070″; thus, in the above example the radial squeeze of the shaft, compressing the installed O-ring in a radially outward direction, equals 1.4% to 4.3% of the O-ring cross section diameter. The conventional shaft diameter for the rotary O-ring seal recommended by those skilled in the art would have resulted in a radial squeeze of 7.9% to 9.3%. Tests using the recommended dimensions were unsuccessful in this application resulting in excess friction torque, overheating, and wear and ultimate failure as a fluid type seal. The O-ring seal squeezed in accordance with the teachings of this invention will function satisfactorily with liquid such as mercury in spite of mercury's non-lubricating properties. This seal would also work for fluids which do lubricate if used at moderate fluid pressures and would provide the advantage of reduced seal torque.

The preferred seal material for the O-ring is nitrile rubber impregnated with MoS_2 such as Parker Seal Company's compound No. N163–7, which has a hardness of 70 durometer. This compound and hardness has proven satisfactory but obvious variations will occur to those having ordinary skill in this art. For example, graphite is a useful (although, in the light of tests, less efficient) solid lubricant with which the O-ring compound can be impregnated. Other solid lubricants may be used if the material is compatible with the other materials (mercury, nickel plated steel, plastics and brass) with which the lubricant impregnated O-ring would be in contact. It is also possible that suitable O-ring compounds could be impregnated with useful non-solid lubricants.

Referring to FIGURES 1 and 2, the inner conductor will now be discussed. The entire area **52** is filled with mercury. In particular, the area **54** along length A is filled with mercury. This is done in order to minimize the effect of the inner conductor joint to RF signals, as will be more apparent hereinafter. The low frequency and DC signals flow from the stationary to the rotating members of the inner conductor joint through the entire mercury pool, while the RF signals are capacitively coupled from hollow cylindrical portion **56** of stationary inner conductor **16** to portion **58** of rotating inner conductor **14** across gap **60**. Gap **60** is equivalent to a "groove" around the inner conductor as long as there are no air pockets along lenth A. This groove must be kept to a minimum. If not, a "discontinuity capacitance" of sufficient value will occur and impede the efficient transfer of RF signal energy. That is, if air pockets exist along length A, then the inner conductor joint may still operate as desired because the air pockets act as small series capacitors to the RF signal; however, if the orientation of the rotary joint is changed the air pockets will move and their new location and size may be such that the RF impedance has increased to a point where there is poor transfer of RF signal energy through the rotary joint.

In order to insure that the void along length A is completely filled with mercury and that no air bubbles are present, it is necessary that the mercury filled cavity be maintained under a constant fluid pressure. In the preferred configuration shown, a unique use of closed cell polyurethane foam **50** is employed. During installation all air is removed from the cavity and as the stationary inner conductor and rotating inner conductor are moved together in an axial direction to achieve the proper positioning of the parts, a cylindrical shaped piece of the closed cell plastic foam is placed under compression compressing the gas within the cells of the foam. This permits the compressed foam to act as a pneumatic spring maintaining fluid pressure within the mercury filled cavity and forcing the mercury into the cylindrical void described above along length A.

Thus, the joint of the inner conductor constitutes an improvement over the joint shown in FIGURE 3 of the beforementioned copending application. As can be seen from this FIGURE 3 of the copending application and FIGURE 2 of this application, the construction of the joints is substantially different, the most important difference being that the mercury in the instant invention is forced into the annular space surrounding projection **54** up to a point approximately adjacent gap **60**.

The detailed construction of the joint of the inner conductor of FIGURE 2 includes a projection **59** which is integrally connected to stationary inner conductor **14**. Member **61** is mounted on projection **59**, the members **59** and **61** both being electrically conductive. A raised portion **63** on projection **58** and member **61** act as a retaining member for O-ring **62** which seals the mercury bath.

O-ring **62** should also be compressed in a manner similar to that already described with respect to seals **36** and **38**. Thus, the seal **62** should be squeezed in a direction radial outward from the center axis of projection **58** by an amount equal to 1.4% to 4.3% of the cross section diameter of the seal **62**, this seal being shown in its squeezed condition in FIGURE 2.

Referring now to FIGURE 1, the remaining mechanical features of the rotary joint will now be described.

Ball bearing assemblies **66** and **68** are disposed between stationary housing **12** for rotating inner conductor **18** to facilitate axial and radial alignment therebetween. Annular members **70** and **72** respectively support stationary inner conductor **14** and rotating inner conductor **16**. Members **70** and **72** are preferably made from Teflon. Female connector **74** is adapted to receive a rotating coaxial line as shown in FIGURE 1.

Clip rings **76** and **78** respectively prevent ball bearing assemblies **66** and **68** from axially sliding along rotating outer conductor **18**. Spacer washer **80** mechanically separates member **22** from ball bearing assembly **66**. Static O-ring **81** prevents leakage of fluid into the joint.

Nut **82** is employed to hold the entire assembly together, preventing axial movement of the rotating and stationary components with respect to each other. The torque to which nut **82** is tightened affects the spacing of gaps **32** and **60**. As the nut **82** is screwed into housing **12**, a force is applied to assembly **68** forcing it against clip ring **78**. As the nut is further screwed into housing **12**, the load is transmitted through clip ring **76** and ball bearing assembly **66**, thereby securing assembly **66** against spacer washer **80**. As the load is applied to clip ring **76**, a slight movement to the left of rotating outer conductor **18** and rotating inner conductor **16** will take place due to deflections in the affected components. The width of gap **32** and of gap **60** can be adjusted appropriately by selectively varying the thickness of spacer washer **80**.

Set screw **82** is removed whenever recess **34** must be filled with mercury, the position of set screw **82** with respect to recess **34** not being critical.

The term "DC and low frequency" typically includes frequencies from DC to 1000 mc. while the term "high frequency or radio frequency" typically includes frequencies from about 1000 mc. to 12 gc. of course, one having ordinary skill in this art can vary the ranges in accordance with the requirements of a given application.

Numerous modifications of the invention will become apparent to one of ordinary skill in the art upon reading the foregoing disclosure. During such a reading, it will be evident that this invention has provided unique rotary joint for accomplishing the objects and advantages herein stated. Still other objects and advantages, and even further modifications will be apparent from this disclosure. It is to be understood, however, that the foregoing disclosure is to be considered exemplary and not limitative, the scope of the invention being defined by the following claims.

What is claimed is:

1. A coaxial rotary joint comprising:

a first cylindrical outer conductor;

a second cylindrical outer conductor concentric with said first outer conductor, said first and second conductors being relatively rotatable with respect to one another;

means for coupling DC and low frequency signals from one of said outer conductors to the other;

means for coupling signals of higher frequencies than said DC and low frequency signals from said one outer conductor to said other outer conductor;

a first cylindrical inner conductor having a projection extending therefrom;

a second cylindrical inner conductor having a recess;

an electrically conductive fluid bath in said recess for coupling DC and low frequency signals between said inner conductors;

means mounting said inner conductors for rotation with respect to each other with said projection in but not filling said recess, and with an annular gap between said first inner conductor and the rim of said second inner conductor adjacent said recess, for coupling said signals of higher frequencies between said inner conductors;

means sealing between said first and second inner conductors to retain fluid in said recess, there being an annular space between said second inner conductor and the portion of said projection in said recess beyond said sealing means and a reservoir space in said recess beyond the distal end of said projection, said reservoir space communicating with said annular space and

compressed means in said reservoir space occupying space in said recess not occupied by said fluid bath and capable of occupying any space in said reservoir vacated by leakage of said third bath thereby assuring that said annular space will be filled with said fluid bath.

2. A coaxial rotary joint as set forth in claim 1 in which said means for maintaining said electrically conductive fluid in said annular space comprises a resilient member in said recess which is compressed when said projection is inserted into said recess.

3. A coaxial rotary joint as set forth in claim 2 in which said means for maintaining said electrically conductive fluid in said means for maintaining said electrically conductve fluid in said annular space comprises closed cell foam plastic.

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U.S. Cl. X.R.

174—86; 339—5