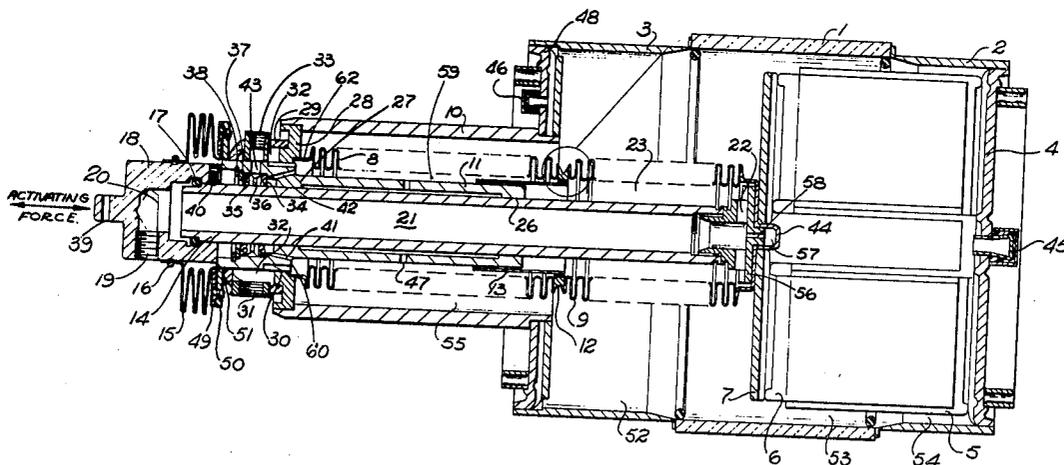


[72] Inventor **Joseph E. Oeschger**
 Palo Alto, Calif.
 [21] Appl. No. **889,531**
 [22] Filed **Dec. 31, 1969**
 [45] Patented **Mar. 23, 1971**
 [73] Assignee **International Telephone and Telegraph Corporation**
 New York, N.Y.

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Primary Examiner—Elliot Goldberg
Attorneys—C. Cornell Remsen, Jr., Walter J. Baum, Paul W. Hemminger, Charles L. Johnson, Jr. and Thomas E. Kristofferson

[54] **SINGLE BELLOWS WATER-COOLED VEHICLE CAPACITORS**
 10 Claims, 3 Drawing Figs.
 [52] U.S. Cl..... **317/243,**
 317/245, 174/15
 [51] Int. Cl..... **H01g 1/08**
 [50] Field of Search..... 317/243,
 244, 245; 174/15

ABSTRACT: A fluid cooled vacuum capacitor in which only a single metal bellows is required. Coolant is directed down the hollow center of the main shaft to the device and returns in a counterflow direction in the space between the shaft-bearing sleeve subassembly and the internal surface of the bellows. A unique fluid sealing arrangement includes primary and secondary shaft seals of the chevron type with circumferential expander springs and a leakage relief path between seals. Shaft bearings are metal-to-metal type and are fluid lubricated.



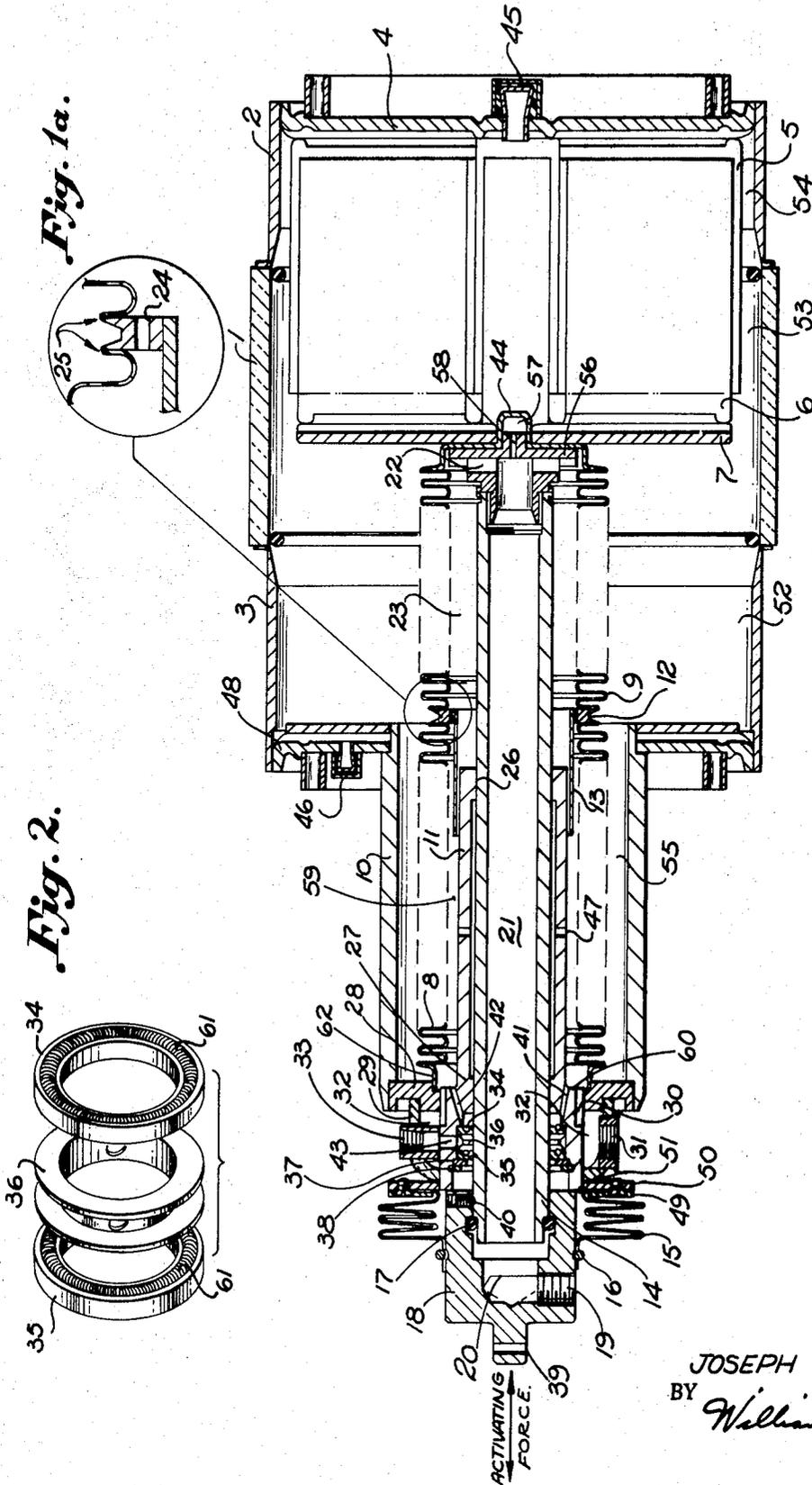


Fig. 1.

Fig. 2.

INVENTOR
 JOSEPH E. OESCHGER.
 BY *William T. O'Neil*
 AGENT.

SINGLE BELLOWS WATER-COOLED VEHICLE CAPACITORS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to mechanically actuated variable electrical parameter devices in vacuo, and more particularly to fluid cooled variable vacuum capacitors.

2. Description of the Prior Art

In the prior art, vacuum capacitors have been widely used in radio frequency circuits. The advantage of relatively high voltage and power handling capability for a given plate spacing and the large degree of freedom from the adverse effects of environmental conditions have caused such capacitors to be constructed in a variety of sizes.

As in all fundamentally reactive devices, there are inevitable interval losses from such causes as circulating radio frequency currents and series resistance (for example). In high power applications, the use of fluid cooling is frequently indicated in order that internally generated heat may be removed more efficiently than is possible by ordinary ambient air cooling. The result is that a fluid cooled capacitor of a given power dissipation rating is substantially smaller than it otherwise would be. In using the term fluid, it is to be understood that gases as well as liquids are included in the broadest sense. However, liquids have much higher specific heats than gases, so that they are by far the more efficient coolants at comparable flow rates. Accordingly, in the prior art as well as in the present invention, liquid cooling would normally be used unless very special reasons dictated the use of circulating gas as a coolant. The invention is adapted for the use of gas for the cooling fluid however.

A prior art vacuum capacitor with fluid cooling is described in U.S. Pat. No. 3,270,259. In that reference, two internal concentric axial metal bellows are used to contain the fluid in the space between, whereas the evacuated space is between the outside bellows and the envelope of the device. Such devices are inherently rather expensive and difficult to construct. Many vacuum tight joints are necessary, and bellows life tends to be low. Moreover, alignment problems during final assembly are more difficult and the double bellows design forces the use of a relatively small central shaft and bearings of small diameter. This in turn lowers the mechanical resonance frequency of the entire movable capacitor plate end of the internal structure. The yield strengths of shaft and bearing assemblies is also correspondingly low. Accordingly, the environmental performance, particularly in respect to shock and vibration, are relatively poor compared to many types of non-fluid cooled single bellows vacuum capacitors. Steps taken to strengthen the double bellows unit by the use of stainless steel or other high strength materials for bearing bodies and shafts increased costs and did comparatively little to raise the resonant frequency of the cantilevered variable plate assembly.

SUMMARY OF THE INVENTION

The present invention deals directly with the aforementioned prior art disadvantages to produce a vacuum capacitor which is mechanically rugged, has a high frequency mechanical resonance, provides more effective fluid cooling than prior art vacuum capacitors and is relatively economically fabricated. This is because the coolant flow is through the hollow interior of the shaft itself and back around between the outside of the relatively massive bearing body and the inside bellows surface. Primary and secondary chevron seals provided between the shaft and bearing body adjacent to the fixed end of the bellows afford a fluidtight seal with backup in the event of any degree of failure (leakage) of the primary seal. A floating sleeve and internal flange arrangement sliding along the bearing body preserves the bellows concentricity and lateral rigidity. The bellows itself is actually in two sections axially. The adjacent interior end of each bellows section is joined (vacuum tight) to a corresponding face of the flange, by heliarc welding for example. The flange (which is actually a

washer or disc-shaped piece of itself) then travels axially with bellows compression and elongation, and the integral sleeve correspondingly slides over the bearing body outside diameter; thus providing radial and thrust support for the bellows, and controlling the tendency for the bellows to "snake."

Heat from the movable capacitor plate assembly is conducted into the bellows and into the shaft since these are firmly fixed to the said plates through relatively massive metal-to-metal contacts. The movable plates are mounted in a relatively heavy base plate and associated structure, as a result, the adjacent point at which coolant passes through the shaft wall openings into the volume between the shaft and bellows is a particularly effective heat transfer point.

The specific manner in which the apparatus of the present invention is constructed will be apparent from the detailed description hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an axial (longitudinal) sectional view of a vacuum capacitor incorporating the present invention. FIG. 1a amplifies the FIG. 1 showing of a bellows lateral stabilizer.

FIG. 2 amplifies the FIG. 1 showing of the liquidtight sliding shaft seal of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Although, as indicated, the present invention is applicable to a variety of devices operating a vacua, this detailed description will be undertaken in respect to the invention used in a vacuum capacitor.

Referring now to FIG. 1, the invention will be seen to be illustrated along with various structures which are of themselves prior art. The capacitor assembly is shown in section obtained by passing a plane through the axial centerline of the device. It will be noted that as used in devices of this type the structure is essentially symmetrical about the said axial centerline. A cylindrical ceramic body shell 1 provides insulation between the end bell members 2 and 3 which are metal members and provide connection terminals for the capacitor. The ceramic body shell is attached to the members 2 and 3 by means already known in this art. That process and other vacuum capacitor fabrication techniques applicable to the overall structure are described in the literature, including U.S. Pat. application No. 820,451, filed Apr. 30, 1969, and assigned to the assignee of the present application.

From inspection, it will be apparent that members 1, 2, 3, 4, 4a, 10, 2a, 62, 44, 24 and the bellows sections 8 and 9 comprise the sealed structure surrounding the evacuated volume. The said evacuated volume includes the contiguous spaces 52, 53, 54 and 55. Fixed capacitor plates 5 and movable capacitor plates 6 are respectively mounted on the end plane 4 and the movable base plate 7. The capacitor plates 5 and 6 typically are interleaving spirals or concentric "cans" variously described in the prior art including those references referred to in the foregoing prior art discussion. Tubulations 45 and 46 provide for process steps including flushing of the plate assembly, introduction of cleaning solutions and evacuation. It will be realized that any fluid introduced during processing into 45 tends to fill the entire volume to be evacuated and in doing so passes through the labyrinthine passages presented by the interleaved capacitor plates, on its way to the other tubulation 46. Both 45 and 46 are sealed after all processing steps including evacuation have been completed, as one of the very last steps in the manufacture of such vacuum capacitors. The bellows section 9 has a formed closed end illustrated at 44 which is in good thermal contact with the removable base plate 7. A space 57 is in communication with the coolant through a passage 58 in the member 56.

Furnace brazing operations can be employed to perfect joints among the bellows 8, annular end plate 2a, tubular body member 10, closure member 4a, end bell 3, ceramic body 1, end bell 2 and closure plate 4. These techniques are described in the technical literature, including the aforementioned U.S. Pat. application 820,451, filed Apr. 30, 1969.

Lateral alignment of the base plane 7 and its rigidity against lateral vibration are important matters design and constructionwise, in the subject device. Structural members associated with the annular end plate 28 provide a rigid mounting for a tubular bearing body member 11. In general, in this description, the left end of the device as illustrated in FIG. 1 will be referred to as the control end since it is here that mechanical thrust is applied which results in the interleaving or withdrawing of the plate assemblies 5 and 6. Fitted within the bearing body 11 is the hollow shaft 14 which has an axial bore or hollow interior 21. The clearance between the bearing body 11 and the shaft 14 is substantially more than necessary to provide a sliding fit except where the bearing body inside diameter is reduced at 26 and 27 to form bearing surfaces to support the shaft 14 at all times and to permit it to translate axially in response to thrust applied to the end cap 18. The end cap 18 is adapted to be activated axially by means of a linkage engaging the shear pin opening 39, for example. The activating force thus moves the entire end cap 18 and the shaft 14 which are joined by thread mating (for example) to 18. Setscrew 40 secures these parts against possible unscrewing.

Since the novel structure described includes a unique and much improved fluid cooling arrangement, the structure relating to this cooling function and the resultant fluid paths will next be described. At the outset, however, it is noted that although the term fluid is used to generally described the range of coolants useable in this device to include liquids and gases, by far the most common coolant used in devices of this type is water or a liquid solution which is mostly water with a few corrosion inhibiting additives, etc. The two main liquid connections are shown at 19 and 31 and although either could be considered the inlet or outlet, it was desirable in a particular embodiment of this invention to introduce the liquid coolant at 19 and permit it to exit at 31. This is because liquid flow in this direction reaches the vicinity of the bellows end 44 cooler than if it had reached the same point in the reverse flow direction. Accordingly the temperature gradient between the coolant and the heat conducting parts in the vicinity of 44 was larger and the heat transfer correspondingly greater.

Since the entire end cap 18 is movable in response to the activating force, it will be evident that a flexible connection at 19 is required. Liquid entering at 19 first reaches the space 20 within 18 and proceeds down the hollow internal volume 21 of the shaft 14. As illustrated in FIG. 1, there are at least two lateral passageways, typically 22, which pass coolant readily through the shaft assembly wall at these points. The number of passages 22 existing radially about the circular cross section of the shaft assembly in this location is a matter of design, considering that the bellows header is cooled mostly at this point. The plate 56 is a substantial recipient of conducted heat from 7 (and other parts adjacent to the capacitor plates). Coolant passing through the passages 22 will be seen to return toward the control end of the device in the volume 23 between shaft 14 and bellows section 9. The bellows header 44, being dimpled in the center, acts as an alignment spindle for movable plate assembly, and the cavity created at 57 is opened to the fluid by passage 58.

As an added feature of the novel structure it will be noted that the two bellows sections 8 and 9 are joined to an annular disc or washer shaped member 12 which in turn joined to a sleeve 13. Since the joining of the two bellows sections to 12 requires a vacuumtight seal, prefabrication of these parts before final assembly requires vacuumtight joining of bellows sections 8 and 9 to 12. For this purpose, two circumferential heliarc weld beads 25 are deposited. The clearance between the sleeve 13 and the bearing body 11 is just sufficient to permit 13 to slide easily over 11 in this liquid lubricant environment. A plurality of axial passages 24 through the member 12 provide for the flow of coolant liquid from the space 23 through to the space 59 and along parallel to the bearing body 11. The bearing body shoulder 60 is provided with slots 30 in its circumferential contact surface with 28. The coolant liquid flowing through space 59 is able to proceed into a liquid plenum space 32 through these slots 30. A plenum end bell 29

joined with 28, and with bearing body 11 adjacent to the end flange 50 as illustrated, provides the enclosure of the said liquid plenum 32. Members 29 and 50 are preferably brazed together at 51. The exit liquid connection 31 communicates directly with the plenum space 32. Bellows 15, anchored to the end cap 18 by a spring clamp 16, acts merely as a dust cover and is not required to resist the liquid pressure. The said liquid pressure is contained by a novel double sliding seal arrangement comprising seals 34 and 35 to be described in more detail hereinafter.

The O-ring seal 17 acts merely as a fixed gasket since there is no relative motion between 14 and 18. A clamp plate 49, screwed to the end flange 50 serves to anchor the bellows 15 to the nonmoving structure of the device. As indicated previously, the bearing surfaces 26 and 27 and the sliding surfaces between 13 and 11 are liquid lubricated and openings typically shown at 47 through the bearing body wall are provided to encourage some fluid circulation in the space between 14 and 11. Since the bearing surface 27 is liquid lubricated in sliding, a seal between the shaft and bearing body is a practical functional necessity. The said unique seal consists to two teflon (or like fluorocarbon chevron seals, each with expander spring 61 in a circumferential groove in the pressure receiving face thereof. A perforated spacer ring, as for example as shown at 36, provides a leakage receiving volume between the two seals. FIG. 2 shows these seals 34 and 35 and the spacer ring 36 in exploded view of their functional relationship for a better understanding of their exact configuration. The actual leadage space provided around spacer 36 communicates with a radial passage 43 in the large diameter body of 11 and from there to an external connection 33. The seal 34 may be thought of as being the primary seal at this point of relative motion between 11 and 14. Seal 35 may be thought of as a back up, or secondary seal and is retained in a counterbore in the large end of the bearing body 11 by an expansion ring 38 seated in a corresponding groove in the said counterbore. A washer 37 holds the seal 35 in place. The actual shape of the counterbore can be utilized to hold the seal 34 in place axially at the opposite end of the seal assembly.

Relief passages 41 and 42 (typical) provide relief from possible entrapment of wear products in the space against the spring face of seal 34. FIG. 2 also shows the nature of the circumferential expander springs 61 which operate to preserve the chevron shape of these seals for bearing against the shaft outside and bearing body inside surfaces.

Appropriate materials for the various parts of the complete structure not specifically indicated in this description are well known in this art. The novel structure is obviously adapted for inclusion in glass body versions of the apparatus described.

Various modifications and variations within the intended scope of the present invention will suggest themselves to those skilled in the art, once the inventive concepts are understood. Accordingly, it is not intended that this description or the drawings hereof are to be considered as limiting the scope of this invention.

I claim:

1. In a device utilizing an extendable metal bellows protruding from an exterior end into an evacuated envelope for providing mechanical motion within said evacuated envelope to a heat dissipating device, said mechanical motion being provided by a shaft through the interior of said bellows to apply motive force to the interior end of said bellows, the combination comprising:

means including an axial bore within said shaft and at least one radial fluid passage through the wall of said shaft adjacent to said bellows interior end, to permit return fluid flow in the volume between said shaft and said bellows;

fluid seal means for sealing the volume between said bellows and said shaft against fluid leakage while permitting at least thrust motion of said shaft with respect to said exterior bellows end;

and means for providing fluid connections to the exterior end of said shaft bore and to said volume between said

shaft and said bellows substantially at said exterior end, thereby to establish a circuit for flow of coolant fluid.

2. A vacuum capacitor assembly including fixed plates located adjacent one end within a vacuumtight housing of substantially circular cross section, movable plates arranged to be interleaved and withdrawn with respect to said fixed plates in response to axial movement of a substantially concentric shaft within said housing mechanically connected to said movable plates, and an extendable metal bellows vacuum sealed to said shaft at one end adjacent said movable plates and to said housing at the control end, whereby the evacuated volume surrounds said plates and extends between said bellows and said envelope, the combination comprising:

a tubular bearing body mechanically supported from said control end and extending cantilevered within said bellows, said bearing having at least a portion of its inside diameter sufficiently small over at least two axial increments to form interior bearing surfaces for said shaft.

means including an axial bore in said shaft for conducting cooling fluid axially through said shaft toward said plates; means comprising at least one radial opening through said shaft wall adjacent said movable plate vacuum seal, whereby said cooling fluid passes into the space between said bellows and the outside perimeter of said bearing body;

means comprising a fluid plenum surrounding the perimeter of said bearing at said control end;

passage means comprising at least one generally axial opening through a portion of said bearing body at said control end so as to allow fluid passage from the space between said bellows and said bearing body outside perimeter into said plenum;

means comprising a substantially fluidtight ring shape seal between said shaft and the inside surface of said bearing body, said seal being adapted to permit sliding of said shaft within said bearing body while maintaining said fluidtight characteristic of said ring seal.

3. The invention defined in claim 2, further defined in that said bearing body comprises an axial section of enlarged outside diameter thereby forming a shoulder which acts as an end plate at the control end of said bellows, said bearing body is counterbored from said control end at the location of said ring seal, thereby to provide an annular receptacle for said bearing,

and said passage means is through said shoulder.

4. The invention set forth in claim 3, further defined in that said ring seal includes at least one fluorocarbon ring of the type having an elongated helical wire spring inserted in a circumferential groove in the face of said ring facing the direction of fluid pressure.

5. The invention set forth in claim 3 in which said seal comprises primary and secondary seals separated by a nonsealing spacer, and additional means are provided for externally venting the volume between said seals, thereby to provide a backup for said primary seal and external relief for and evidence of leakage around said primary seal.

6. The invention set forth in claim 2, further defined in that said bearing body includes at least one radial opening in the wall of said bearing body thereby to provide a fluid path between said volume between said bellows and said outside perimeter of said bearing body and the radial clearance between said shaft and said bearing body and said shaft along the axial distance between said bearing surfaces, thereby to provide at least some fluid circulation adjacent to said shaft and to enhance the fluid lubrication of said bearing surfaces.

7. The invention set forth in claim 2, further defined in that said bellows is divided into a plurality of axial sections, said sections are butt joined in a vacuumtight manner to a washer having an outside diameter comparable to the outside diameter of said bellows and an inside diameter joined to a sleeve having an inside diameter which freely fits over the outside diameter of said bearing body, thereby to provide lateral stiffness for said bellows.

8. The invention set forth in claim 7 further defined in that said washer includes at least one axial fluid passage enhancing fluid flow between said bearing body and said bellows.

9. The invention set forth in claim 3, further defined in that said bearing body includes at least one fluid relief passage between said counter bore on the pressurized side of said primary seal and said volume between said bellows and said bearing body.

10. The invention set forth in claim 5 further defined in that said means for externally venting said volume between said chevron seals comprises a passage which is fluidtight with respect to said plenum and passes through said plenum and its external wall thereby to provide said external venting.

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