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SHAFT SEAL FOR HIGH VACUUM CHAMBERS

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Fig. 1.

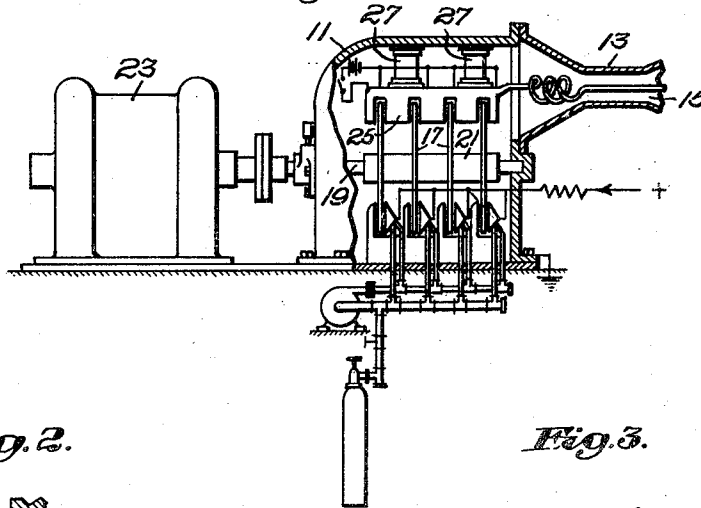


Fig. 2.

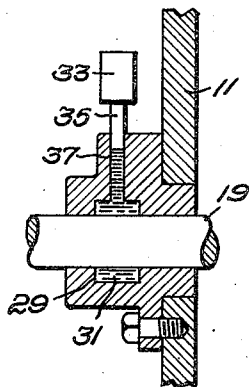


Fig. 3.

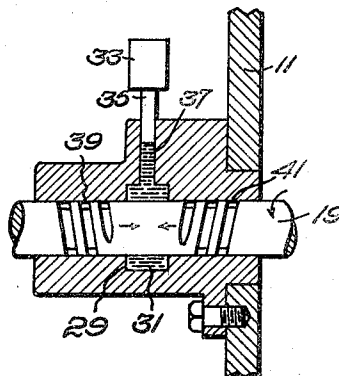
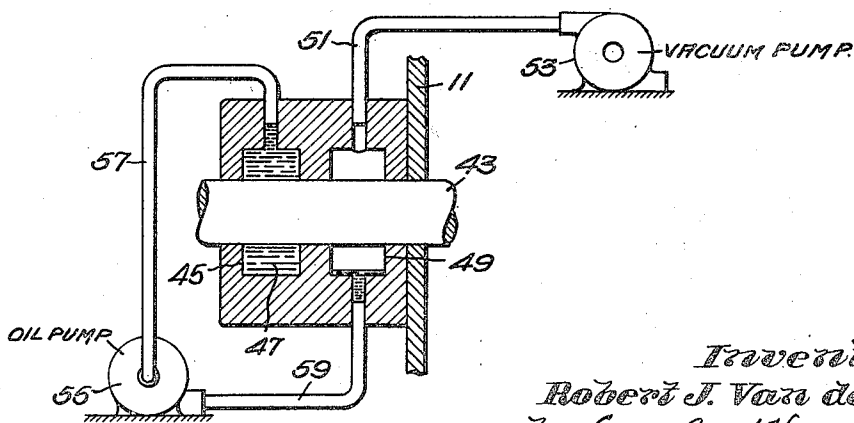


Fig. 4.



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SHAFT SEAL FOR HIGH VACUUM CHAMBERS

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6 Claims. (Cl. 286—19)

This invention relates to method of and apparatus for sealing high vacuum enclosures where motion is required to be transmitted into the enclosure, as by a shaft driven from an outside source of power, such as a motor operating under atmospheric conditions.

In many cases where a high vacuum is required to be maintained, and particularly where the evacuated space encloses high voltage electrodes having exposed conductive surfaces, it becomes necessary to transmit such motion to and within the enclosure without impairment of the vacuum and without deleterious effect on the insulating condition of the electrode surfaces by reason of the action of the sealing material, which action is peculiar to the use of a high vacuum. It is further necessary often to transmit efficiently through the walls of such an enclosure substantial amounts of power under high speed rotation.

The use of high vacuum of the order here contemplated, which is represented by a pressure of 10^{-5} millimeters of mercury or less, presents a problem in respect to these questions which is entirely different from that presented by the sealing of a shaft used to transmit power to or from a chamber in which there is maintained sub-atmospheric pressures of the order commonly dealt with in the arts. This problem of transmitting motion into chambers evacuated to the degree herein contemplated, so far as known, has not heretofore been successfully solved.

The method which is commonly employed in cases where ordinary pressure ratios are encountered is to surround the shaft with a sealing chamber formed in the wall of the casing, the sealing chamber being filled with some packing material forming a barrier to the free passage of gas or fluid from one side of the seal to the other. It is, however, entirely inadequate in the case of a high vacuum of the type described, in which pressure ratios of the order of several hundred millions are quite general, to utilize means such as have been heretofore adopted without special and novel precautions as to the sealing material, its application and its surroundings.

This will be more readily understood from the fact that any bubble of air or other gas entering from the atmosphere through the sealed opening into a casing, where it is sought to maintain a vacuum of 10^{-5} millimeters of pressure, would necessitate the removal of about 760,000,000 times its volume to maintain that low pressure.

If a cubic millimeter of air at atmospheric pressure were to escape into a volume of one cubic meter at a pressure of 10^{-5} millimeters of mercury, its effect would be to approximately double the pressure in that volume. On the other hand, if the same amount of air at atmospheric pressure were to escape into a volume of one cubic meter at a pressure of one inch of mercury, which is the order of pressure ordinarily encountered at the vacuum end of a steam turbine, for example, the increase of pressure would be only about 0.00001 of 1%.

Investigation has shown that sealing materials presenting pores, crevices or interstices, or likely to develop such when placed under pressure, or materials carrying entrained air, are unsuited for this purpose, as are also sealing materials having a relatively high vapor pressure. A sealing material should preferably be incapable of transmitting shear, so as to collapse together when placed under pressure, and of a fluid-like character, that is to say, sufficiently fluid so that when collapsed it acquires and maintains a close and intimate contact with all surfaces to which it is applied. Most materials suitable for application to this purpose are organic, such, for example, as oil or grease, and have a greater or less vapor pressure which, without careful selection or treatment, renders them unsuitable for this use.

If a sealing material of relatively high vapor pressure is employed, it continues to emit or exude vapor, tending to enter the evacuated chamber and impair the vacuum. The vapor pressure of the sealing material should be preferably less than that of the pressure in the evacuated space, and in many cases the free passage of this vapor into the evacuated chamber must further be impeded to a point where its partial pressure within the chamber exercises only a negligible contaminating influence on the electrode surfaces. For example, in the case of a vacuum represented by a pressure of 10^{-5} millimeters, the vapor pressure of the sealing material should be substantially less than 10^{-5} millimeters and the pressure of this material within the chamber itself should be still less.

One of the objects of the present invention is to so select, apply and control the sealing material that no impairment of the maintained vacuum through leakage from without can take place.

Another object of the invention is to prevent the impairment of the surface conditions and therefore of the insulating qualities of high

voltage electrodes maintained in the vacuum.

Not only is it necessary to prevent in a substantially complete sense any leakage into the evacuated casing, but it further becomes necessary to substantially eliminate the contaminating influence on high voltage electrode surfaces of the vapor pressure of the sealing material itself.

Where sealing materials, such as oil and grease, are utilized, unless special precautions are taken, small minute quantities of the sealing material tend to creep along the surface of the shaft toward the interior of the casing and ultimately reach a position where they can diffuse into the vacuum. However minute they may be, they continually emit organic molecules through the physical process associated with the term "vapor pressure", which molecules distribute through the vacuum and become in substantial part deposited on the walls of the chamber and on the conductive surfaces of the electrodes. This depositing action continues, building up one molecular layer of organic matter after another on the electrode surfaces, until the depth of these contaminating layers is sufficient to support a vapor pressure. Eventually a state of equilibrium may be reached, where as much organic material is thrown off the electrode surface as is received. This process, however, has materially altered the insulating characteristics of the electrode surface in that, after such contamination has taken place, the total voltage and the gradient which could be previously supported between such electrodes are now substantially reduced.

This application is a continuation in part of my prior application, Serial No. 620,964, filed July 5, 1932, for Electrical transmission system.

The invention will be best understood by reference to the following description when taken in connection with the accompanying illustrations of one or more specific embodiments thereof, while its scope will be more particularly pointed out in the appended claims.

In the drawing:

Fig. 1 is an elevation, partly in section, showing, as an example, one instance of an evacuated casing in which the generation of direct current is effected by means of an external motor driving a shaft passing into the casing;

Fig. 2 is a detail in section, showing the method of sealing the opening in the casing through which the driving shaft in Fig. 1 passes; and

Figs. 3 and 4 show details in section illustrating different modifications of the invention.

Referring to the drawing and particularly to Fig. 1, in order to present one illustrative instance of the conditions under which a shaft seal may be called upon to function in such a case as has been referred to, there are shown the structural features of an apparatus for the generation in vacuum of a high voltage direct current. This particular apparatus is described in detail in my aforesaid prior application, Serial No. 620,964. For the purpose of describing the present invention, the following explanation will suffice:

Referring to Fig. 1, the apparatus there illustrated comprises an air-tight, highly evacuated, generator casing 11 which opens into a conduit 13 within which there is also maintained a high vacuum, the inner walls of the casing and conduit being preferably of non-porous metal and having been subjected to an outgassing treatment to remove residual gases.

Within the conduit is a conductor 15 comprising an axial, central rod which is connected to a

positive source of direct-current electromotive force within the casing 11. The conductor extends through the evacuated conduit to a point where the current transmitted is to be utilized, the enveloping conduit forming the negative return conductor.

Within the casing 11 there is provided a generating apparatus, herein of the direct-current, electrostatic type, capable of generating high direct-current voltages, as, for example, of the order of 1,000,000 volts. Herein this comprises a plurality of non-conducting disks 17 mounted on a shaft 19 and spaced by sleeves 21, the shaft being driven by a source of external power, such as a turbine motor 23, and passing through a vacuum sealed opening in the casing 11.

Positive charges are placed on the lower portions of the disks 17 within the casing 11 by means of gas ionization, the provision for which is illustrated at the lower part of and below the casing 11, and the details of which are described in my aforesaid prior application.

Positive charges applied to the lower portions of the disks 17 are removed or neutralized by the collector electrode 25 having exposed conductive surfaces, the electrode being slotted to permit the passage of the disks and suspended from the upper wall of the casing by insulators 27. The electrode 25 is connected directly to the central conductor 15 and positive charges accumulated on the electrode are delivered to that conductor.

In order to provide a suitable vacuum insulation for generation of abnormally high voltages through generating devices of the type or class here referred to, a high vacuum is necessary, and this should be such as is represented by the pressure of 10^{-5} millimeters of mercury or preferably less.

To maintain any such vacuum, the entrance of any gases into the casing must be prevented and special precaution must be taken in sealing the shaft 19.

Referring to Fig. 2, the shaft 19 passes through a prolonged bore in the wall of the casing or, as herein, through a block-like bushing secured to the casing wall, the bore being accurately formed to fit about the shaft as closely as practicable. At a substantial distance from the evacuated space this bore is enlarged to provide an annular sealing chamber 29 encircling the shaft and filled with sealing material 31. Such sealing material is placed by any suitable means under a continuously maintained pressure substantially greater than the pressure on the pressure side of the enclosing wall and herein greater than the atmospheric pressure. Herein there is provided for that purpose a weight 33 carried by an upright rod 35 having a sliding fit in the vertical passage 37 which opens into the sealing chamber and which itself is partly filled with sealing material.

To secure close and intimate contact between the surfaces exposed and the sealing chamber, the sealing material should be devoid of air carrying spaces and should comprise a substantially homogeneous fluid or fluid-like material, that is to say, so capable of collapse under pressure and incapable of transmitting shear as to have the complete sealing effect required. A fluid-like plastic material having otherwise the characteristics herein referred to will suffice. Grease has been found to be satisfactory, as has a grease and graphite mixture in which graphite is in fine flakes. A grease-graphite mixture is

preferred as a sealing medium, the grease being of the low vapor pressure kind and functioning as the sealing medium proper, while the graphite, which can be obtained with negligible vapor pressure and is known for its lubricating qualities, is mixed intimately with the grease to prevent the too ready flow of the latter.

The sealing material completely envelopes the shaft, filling all voids in the sealing chamber, and, when subjected to the pressure indicated, presents a sealing wall under greater pressure than that of the atmosphere. This prevents the entrance of air through the shaft bore past the sealing chamber, since the outward pressure on the grease or other sealing material is greater than the urge or pressure under which the atmosphere tends to force air through to the vacuum.

Investigation, however, has shown that the grease or other sealing material should have a relatively low vapor pressure, otherwise the vapor emitted from the sealing material will tend to flow in the clearance between the shaft and housing and to enter the vacuum with impairment thereof as previously mentioned.

The sealing material therefore should be so selected or so treated as to reduce its vapor pressure and preferably to a point where it is less than that in the vacuum sought to be maintained. If the vacuum is represented by a pressure of 10^{-5} millimeters of mercury, the vapor pressure of the sealing material should preferably be substantially less than 10^{-5} millimeters of mercury.

Preferably also means are provided to interpose between the sealing chamber and the vacuum chamber a high resistance path to vapor flow from seal to vacuum. In the construction illustrated in Fig. 2, this is provided by relatively prolonging the closely fitting shaft bore between the sealing chamber and the vacuum chamber, and in other modifications hereinafter referred to by further special provisions for that purpose.

As a further means for increasing the effectiveness of the vacuum seal, there may be utilized means such as illustrated in Fig. 3, where the shaft is provided at each side of the seal with helical grooves, one set 39 of which has a right-handed or clockwise disposition and the other set 41 has a left-handed or counterclockwise disposition, and so arranged with relation to the shaft rotation that the latter provides an impelling action tending to urge the sealing material back toward the seal,—inwardly from the driving end and outwardly from the vacuum end.

To provide further resistance to the bodily flow of the sealing material and to off-set and neutralize the effect of the vapor pressure on the vacuum, further provision may be made by the addition of a supplemental chamber interposed about the shaft between the sealing chamber and the vacuum chamber and serving the function of a trap. Such provision is illustrated in Fig. 4. The shaft 43 is there surrounded by the sealing chamber 45 filled with a suitable low-vapor-pressure, sealing medium 47 maintained under a super-atmospheric pressure and is also surrounded by a second chamber 49 formed in the walls of the enclosure between the chamber 45 and the point where the shaft 43 merges into the evacuated chamber. The chamber 49 serves to trap and retain the sealing material creeping along the shaft. This device prevents the sealing medium from reaching the vacuum chamber

and leaves a path of high resistance interposed. The ready flow of the vapor of the sealing medium from the chamber 49 to the evacuated space is thus enormously impeded and its effect on the vacuum is thereby minimized.

In the case of relatively large shafts or shafts having a high speed of rotation, or in other cases, it may be desirable to interpose about the shaft between the seal and the vacuum, or between the seal and the atmosphere, or between the seal and both the atmosphere and vacuum, a somewhat evacuated space so as to break the pressure difference on one or both sides of the seal. Accordingly, with the supplemental chamber 49 there may be employed, if desired, means for maintaining a low pressure or vacuum condition in such chamber. In Fig. 4 a low pressure condition is maintained in the supplemental chamber or trap 49 by connection of the upper part of the chamber through the pipe 51 to the suction side of a vacuum pump 53. Furthermore, instead of using a grease or grease-graphite mixture for the sealing medium, in the case of the modification shown in Fig. 4, a more fluid-like sealing medium may be employed, such as a heavy low vapor pressure oil. In this case the required pressure may be maintained on the sealing medium by means of a power driven oil pump 55, the pressure side of which is connected through the pipe 57 to the top of the sealing chamber 45. The bottom of the chamber 49 carries a small body of oil and has connection to the suction side of the oil pump 55 through the pipe connection 59. The pumps 53 and 55 may be mounted on the shaft 43, or, as herein shown, may be separate therefrom and driven through any suitable source of power.

Any small amount of oil escaping from the sealing chamber 45 into the chamber 49 becomes trapped therein, the pressure of the oil vapor and other gases in such chamber is maintained low by the action of the vacuum pump 53 and its further travel toward the evacuated space is impeded by the high resistance path so that its effect on the vacuum is minimized.

While I have herein shown and described, for the purposes of illustration the underlying principles of this invention and its application to the intended use, certain specific details, it is to be understood that these are subject to wide variations and modifications, all within the spirit of the invention.

I claim:

1. In a vacuum sealing device for a rotary shaft, the combination with a casing the walls of which enclose a highly evacuated space, of a rotary shaft having entrance through the walls thereof, means for maintaining a vacuum condition in said space represented by a pressure of the order of 10^{-5} millimeters of mercury, means providing a sealing chamber encircling a portion of said shaft passing through said walls, a sealing medium filling said chamber devoid of air carrying spaces and having a vapor pressure no greater than the pressure of said evacuated space, means for maintaining said medium under a pressure greater than the pressure difference on opposite sides of said enclosing walls, and means interposing between said medium and said evacuated space and about said shaft a path of high resistance to the passage of vapor emitted from said medium.

2. In a vacuum sealing device for a rotary shaft, the combination with a casing the walls of which enclose a highly evacuated space, of a rotary shaft having entrance through the walls thereof, means for maintaining a vacuum condition in said space

represented by a pressure not greater than 10^{-5} millimeters of mercury, means providing a sealing chamber encircling a portion of said shaft passing through said walls, a sealing medium filling said chamber devoid of air carrying spaces and having a low vapor pressure, means for maintaining said medium under a pressure greater than the pressure difference on opposite sides of said enclosing walls, and means interposing between said medium and said evacuated space and about said shaft a path of high resistance to the passage of vapor emitted from said medium.

3. In a vacuum sealing device for a rotary shaft, the combination with a casing the walls of which enclose a highly evacuated space, of a rotary shaft having entrance through the walls thereof, means for maintaining a vacuous condition in said space represented by a pressure not greater than 10^{-5} millimeters of mercury, means providing a sealing chamber encircling a portion of the shaft in the enclosing walls of said space, a fluid-like sealing medium filling said chamber having a low vapor pressure, means for maintaining said medium under a pressure greater than the pressure difference on the opposite sides of the walls, means for preventing the entrance of vapor from said sealing medium into said evacuated space including a trapping chamber cooperatively related to said shaft between the sealing medium and said space for storing the creepage of sealing medium from said sealing chamber, and a path of high resistance between said trapping chamber and said evacuated space and about said shaft to the passage of vapor emitted from said chamber to said space.

4. In a vacuum sealing device for a rotary shaft, the combination with a casing the walls of which are enclosed by a highly evacuated space, of a shaft having entrance through the walls thereof, means providing a sealing chamber encircling a portion of the shaft passing through said walls, a sealing medium having a low vapor pressure filling said chamber, means for maintaining said chamber under a pressure greater than the pressure difference on opposite sides of said enclosing walls, means providing a second chamber cooperatively related to said shaft between said sealing medium and said evacuated space for storing the creepage of sealing medium from said

sealing chamber, means connected to said second chamber for maintaining a low sub-atmospheric pressure therein, and means interposing between said second chamber and said evacuated space and along said shaft a path of high resistance to the passage of vapor emitted from said medium.

5. In a vacuum sealing device for a rotary shaft, the combination with a casing the walls of which enclose a highly evacuated space, of a rotary shaft having entrance through the walls thereof, means providing a sealing chamber encircling a portion of the shaft passing through said walls, a fluid-like sealing medium filling said chamber, pumping means for maintaining said medium under a pressure greater than the pressure difference between opposite sides of said enclosing walls, means providing a second chamber cooperatively related to said shaft between the region of seal and said evacuated space for storing the creepage of sealing medium from said sealing chamber, a path of high resistance between said second chamber and said evacuated space and about said shaft to the passage of vapor emitted from said second chamber to said space, and means connected to said second chamber for maintaining a low pressure condition therein, the lower part of said second chamber having connection to the suction side of said pumping means.

6. In a vacuum sealing device for a rotary shaft, the combination with a casing the walls of which enclose a highly evacuated space, of a rotary shaft having entrance through the walls thereof, means for maintaining a high order of vacuous condition in said space, means providing a sealing medium encircling a portion of said shaft passing through said walls, said sealing medium having a low vapor pressure of the order of that in said evacuated space, means for maintaining said medium under a pressure greater than that outside of the walls of said enclosed evacuated space, and means interposing between said medium and said evacuated space and about said shaft a path of high resistance to oppose the creepage of sealing medium and passage of its vapor from said sealing chamber to said evacuated space.

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