

[54] **COOLING MEANS FOR RADIAL BEARINGS IN NUCLEAR REACTOR PUMPS OR THE LIKE**

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[51] **Int. Cl.**..... **B01f 7/20**

[58] **Field of Search**..... 259/105, 6, 21, 41, 107, 259/122, 106, 64, 95, 97, 102, 103, 105

[56] **References Cited**

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[57] **ABSTRACT**

A pump for circulation of fluid in the interior of a nuclear reactor vessel has a tubular member which extends upwardly into the vessel and with clearance through an opening in the bottom wall of the vessel. A sleeve-like bearing element has a lower portion received with minimal clearance in the tubular member and an upper portion which defines with the tubular

member a first annular clearance having an enlarged ring-shaped upper portion for an auxiliary impeller which is driven by a pump shaft extending with clearance through the tubular member and having a second impeller in the interior of the vessel. The upper portion of the bearing element fixedly receives a bearing sleeve which defines with a cylindrical shield a second annular clearance communicating with a chamber for liquid coolant. The chamber is defined by a first mounting member which is received with clearance in the tubular member and supports the bearing element and a second mounting member which supports the shield and defines with the shaft a third annular clearance adapted to receive coolant through one or more channels in the lower portion of the second mounting member. When the chamber fails to receive a fresh coolant, the auxiliary impeller draws coolant from the lower part of the chamber, through the channel or channels of the second mounting member, through the third clearance, through one or more ports in the shield, through the second clearance, and into the upper portion of the first clearance. At the same time, the auxiliary impeller causes heated fluid to flow downwardly through the first clearance, through one or more passages in the tubular element, and into the upper portion of the chamber. Some coolant also flows from the port or ports into a further clearance between the shaft and the shield and enters the upper portion of the first clearance. The upper portion of the bearing element is surrounded by a first sleeve-like insulator, and the second portion of the bearing element surrounds and supports a second sleeve-like insulator which bounds the uppermost part of the chamber. The shield has a flange which defines with the adjacent portion of the bearing element a narrow annular sealing gap serving to throttle the flow of fluid from the upper end of the chamber into the lower end of the second clearance.

10 Claims, 2 Drawing Figures

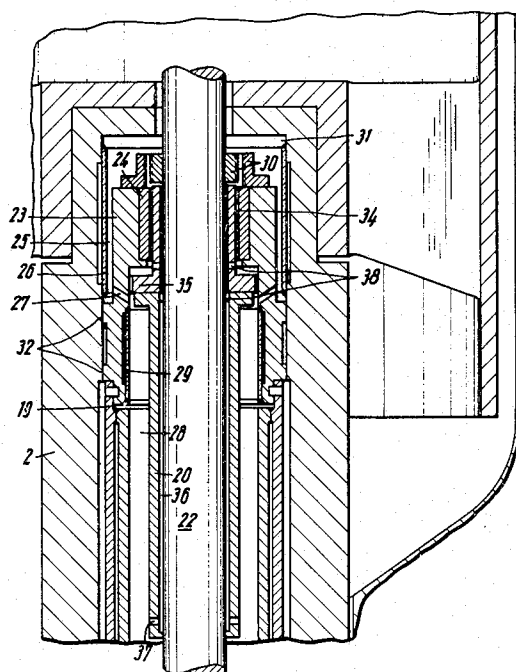


Fig. 1

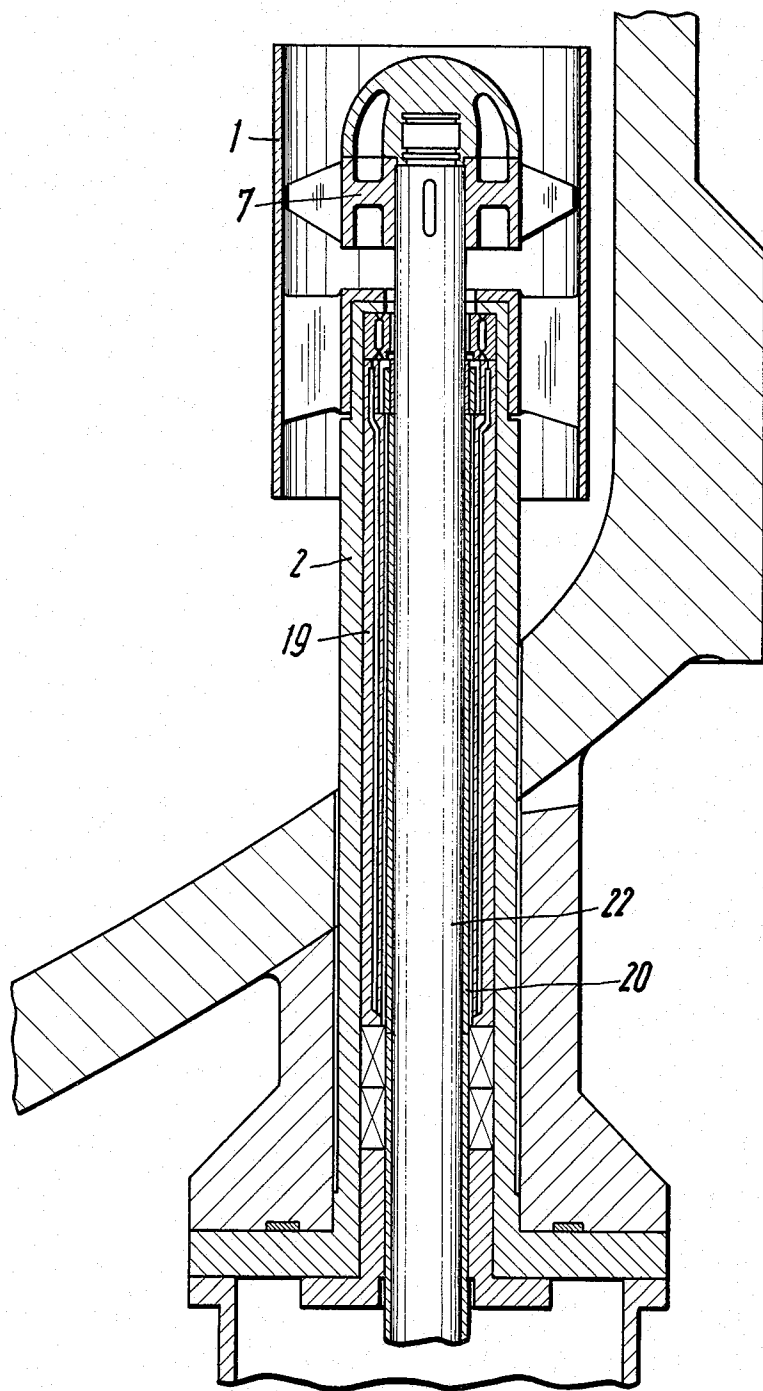
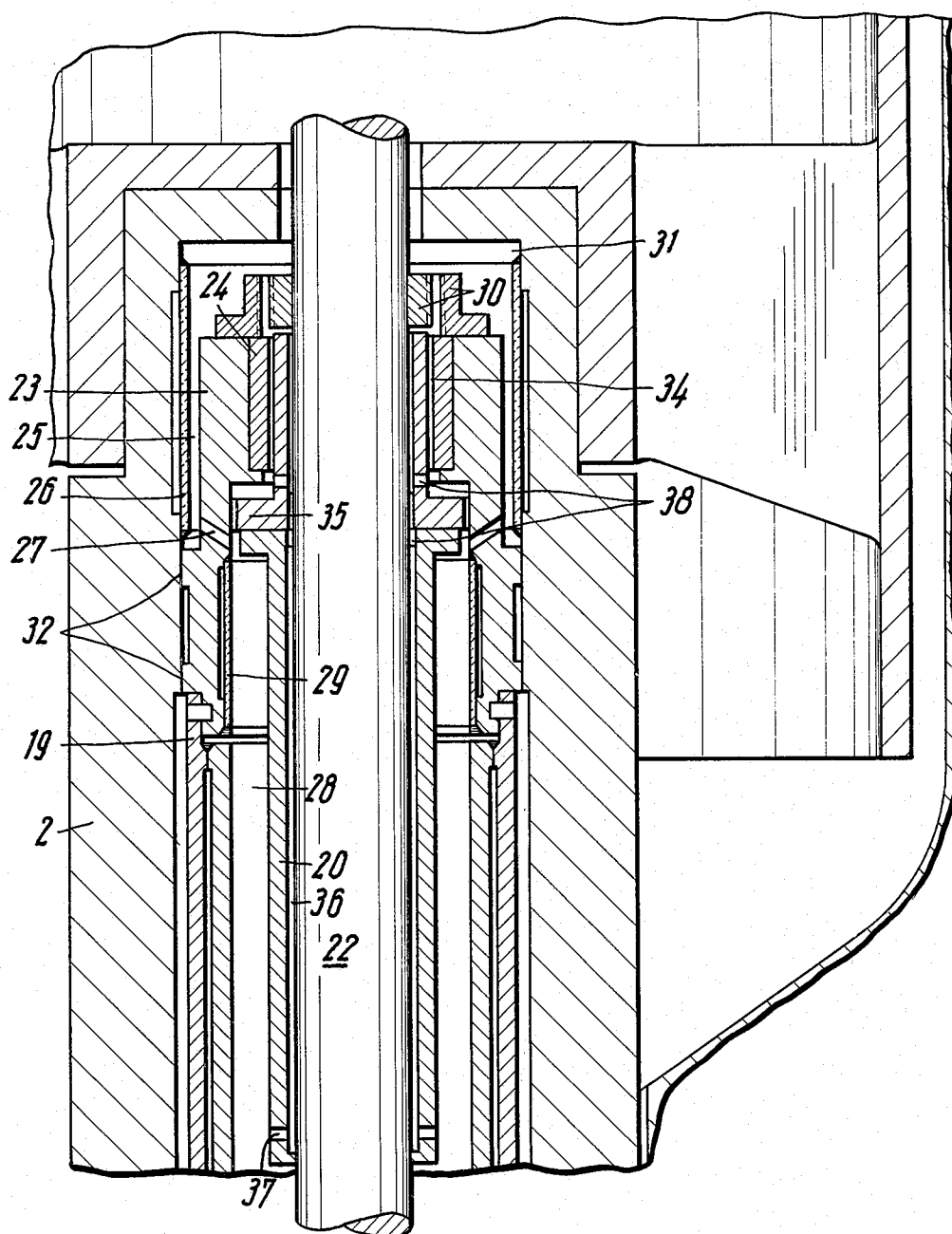


Fig. 2



COOLING MEANS FOR RADIAL BEARINGS IN NUCLEAR REACTOR PUMPS OR THE LIKE

CROSS-REFERENCE TO RELATED APPLICATION

The present invention constitutes an improvement over and a further development of the invention which is disclosed in the commonly owned copending application Ser. No. 360,879 filed May 18, 1973, by Karl GAFFAL et al for "Pump Construction."

BACKGROUND OF THE INVENTION

The present invention relates to pumps in general, and more particularly to improvements in pumps which can be used for circulation of liquids in nuclear reactor vessels. Still more particularly, the invention relates to improvements in means for cooling the bearing or bearings for the shaft of a pump which serves to circulate a fluid in the interior of a plenum chamber, such as a boiling-water nuclear reactor vessel.

The copending application Ser. No. 360,879 of Gaffal et al discloses a pump construction wherein an inner tubular member extends through and beyond an outer tubular member which is affixed to a wall forming part of a nuclear reactor vessel. The shaft of the coolant circulating pump extends through the inner tubular member and rotates in a radial bearing installed in the inner end portion of the inner tubular member as well as in one or more shaft seals located in the inner tubular member but without the reactor vessel. The inner tubular member is surrounded in the vessel by a body of hot water and the radial bearing for the shaft is forcibly cooled by means of a circulating cooling medium. It has been found that the just-described pump construction operates satisfactorily only when the radial bearing receives a fresh stream of liquid coolant. If the admission of fresh liquid coolant is interrupted, for example, due to a malfunction of the system which supplies coolant into the inner tubular member, the resulting thermal shock can cause substantial changes in the width of clearances or gaps between parts which rotate with respect to each other and/or the formation of gaps in regions where the neighboring parts should engage with each other without any clearance.

SUMMARY OF THE INVENTION

An object of the invention is to provide a pump, particularly a pump for circulation of fluid in a nuclear reactor vessel, with novel and improved means for circulating a coolant through and around a hydrodynamic radial bearing for the pump shaft.

Another object of the invention is to provide a pump wherein the radial bearing for the pump shaft is properly cooled even if the flow of fresh coolant to the pump is interrupted.

A further object of the invention is to provide a pump wherein the radial bearing means for the pump shaft can be properly cooled for extended periods of time even if the flow of fresh coolant to the bearing means is interrupted for relatively long intervals.

An additional object of the invention is to provide a novel and improved hydrodynamic bearing for the shaft of a pump which is used for circulation of fluid in a plenum chamber, especially in the vessel of a nuclear reactor plant.

Still another object of the invention is to provide a bearing which can be installed in existing pumps with

minimal alterations in the construction and/or mode of operation of such pumps.

The invention is embodied in an arrangement for circulation of a hot liquid in a nuclear reactor or the like. The arrangement comprises a vessel which can contain a supply of hot fluid and includes a support (e.g., a bottom wall) having an opening, a tubular member which is preferably indirectly secured to the support and extends with clearance through the opening and into the interior of the vessel so as to be surrounded by hot fluid, a pump shaft which is rotatable in the tubular member and has a first impeller installed in the vessel and serving to circulate the fluid therein, a tubular bearing element provided in the tubular member in the interior of the vessel and having a first portion which is nearest to the opening of the support and is received in the tubular member with minimal or negligible clearance and a second portion which defines with the tubular member a first annular clearance, a bearing sleeve which is fixedly received in the second portion of the bearing element and spacedly surrounds the shaft, a first tubular mounting member which supports the bearing element, a second tubular mounting member which is disposed between the shaft and the first mounting member and supports a cylindrical shield disposed between the bearing sleeve and the shaft, a coolant receiving chamber between the two mounting members, and an auxiliary impeller mounted on the shaft in that portion of the first clearance which is remotest from the opening of the support. When the chamber fails to receive a fresh coolant, the auxiliary impeller causes relatively cool coolant to flow from the lower part of the chamber through one or more channels provided in the second mounting member, through a second annular clearance between the shaft and the second mounting member, through one or more radial ports in the cylindrical shield, through a third annular clearance between the shield and the bearing sleeve, and into the aforementioned portion of the first clearance. From there, the relatively hot coolant flows through the first clearance, through one or more passages provided in the first portion of the bearing element, and into the upper portion of the chamber to be mixed with relatively cool coolant.

The novel features which are considered as characteristic of the invention are set forth in particular in the appended claims. The improved pump itself, however, both as to its construction and its mode of operation, together with additional features and advantages thereof, will be best understood upon perusal of the following detailed description of certain specific embodiments with reference to the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is an axial sectional view of a pump which is disclosed in the copending application Ser. No. 360,879; and

FIG. 2 is an enlarged fragmentary axial sectional view of a pump which embodies the invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

FIG. 1 shows a pump construction which is identical with that illustrated in FIG. 1 of the copending application Ser. No. 360,879. There are shown an inner tubular member 2', an outer tubular member 3', a support or wall 4' which forms part of a nuclear reactor vessel, a radial bearing 6', a pump shaft 22', an impeller 7' which is rotated by the shaft 22', a guide wheel 1', two

mounting sleeves 19', 20', a shaft seal 15', and a socket 16' receiving additional bearings for the pump shaft 22'. The inner tubular member 2' extends with clearance through an opening 4a' of the support or wall 4' and into the interior of the vessel.

FIG. 2 shows the improved pump construction wherein all such parts which are identical with or clearly analogous to the corresponding parts of FIG. 1 are denoted by similar reference characters but without a prime. It will be noted that FIG. 2 shows on a larger scale only that portion of the inner tubular member 2 which extends through the opening 4a of the support or wall 4 and upwardly into the interior of the vessel including the wall 4. The upper or innermost portion of the tubular member 2 surrounds a cylindrical bearing element 23 and each of these parts is self-supporting and is mounted in cantilever fashion. The upper portion of the bearing element 23 supports a bearing sleeve 24 and such upper portion is shrunk around and is thus rigid with the sleeve 24. The lower portion of the bearing element 23 is received in the tubular member 2 with a minimum of clearance, as at 32, and is connected with a sleeve-like mounting member 19 which extends with clearance into the tubular member 2. An annular clearance or gap 25 is provided between the upper portion of the bearing element 23 (above 32) and the internal surface of the adjacent portion of the tubular member 2. The clearance 25 is surrounded by a sleeve-like heat insulator 26 which is fitted into the tubular member 2 at its upper and lower ends. The major portion of the insulator 26 is surrounded by a shallow annular recess 2a in the internal surface of the tubular member 2. The recess 2a may be filled with air or evacuated.

The bearing element 23 is formed with one or more substantially radially extending bores or passages 27 which establish communication between the clearance 25 and an annular coolant-containing chamber 28 between a second sleeve-like mounting member 20 and the aforementioned mounting member 19. A narrow sealing gap 35a is provided between the internal surface of the bearing element 23 and an annular flange 35 above the upper end of the mounting member 20. The flange 35 is adjacent to and is located above the passages 27.

The passages 27 are located above a sleeve-like insulator 29 which is installed in the lower portion of the bearing element 23 in a manner similar to the mounting of insulator 26 in the upper portion of the tubular member 2. The insulator 29 surrounds with clearance the upper end portion of the mounting member 20 below the flange 35. The annular clearance between the mounting member 20 and the pump shaft 22 is shown at 36. This clearance 36 communicates with the chamber 28 through one or more bores or channels 37 provided in a lower portion of the mounting member 20. Moreover, the clearance 36 communicates with an annular clearance 34 adjacent to the internal surface of the bearing sleeve 24 by way of the aforementioned narrower sealing gap 35a which surrounds the flange 35. The cylindrical part or shield 135 which includes the flange 35 and rests on the mounting member 20 is surrounded by the clearance 34 and has one or more radial bores or ports 38 wherein the fluid can flow between the clearance 34 and a clearance 235 between the cylindrical part 135 and the adjacent portion of the pump shaft 22.

The shaft 22 carries one portion of an auxiliary impeller 30 another portion of which is mounted on top of the bearing element 23. The impeller 30 is installed in a ring-shaped space 31 above the bearing element 23 and draws coolant through the clearance 34, 235 and into the space 31. The space 31 constitutes an enlarged upper or inner end portion of the clearance 25.

The operation is as follows:

In normal operation of the pump, a first stream of cooling medium flows through the hydrodynamic bearing including the bearing element 24 by flowing from the chamber 28 into the ring-shaped space 31 via gap 35a and clearance 34. A parallel second stream of cooling medium flows from the chamber 28, through the channels 37 in the mounting member 20, clearance 36 between the shaft 22 and mounting member 20, and ports 38 in the cylindrical part or shield 135 on top of the mounting member 20. The auxiliary impeller 30 induces the flow of a fluid stream into the annular clearance 25 between the tubular member 2 (and more particularly the insulator 26) and the upper portion of the bearing element 23 and thereupon through the passages 27 back into the chamber 28. The insulator 26 prevents an overheating of the stream which is induced by the impeller 30 while such stream flows downwardly in the annular clearance 25. Such stream cools the external surface of the upper portion of the bearing element 23. A higher temperature of the bearing element 23 is normally desirable in the regions 32 where the tolerance between the internal surface of the tubular member 2 and the external surface of the bearing element 23 is negligible. The insulator 29 is surrounded by this heated portion of the bearing element 23 and reduces the likelihood of excessive heating of fluid in the adjacent portion of the chamber 28. It will be noted that, whereas the insulator 26 prevents an overheating of the upper portion of the bearing element 23, the insulator 29 prevents an exchange of heat between the relatively hot lower portion of the bearing element 23 and the fluid in the upper part of the chamber 28. Owing to the provision of insulators 26, 29, and by proper selection of the materials of the tubular member 2 and bearing element 23, the tolerances between the tubular member 2 and element 23 in the regions 32 remain unchanged, irrespective of the temperature of fluid in the clearance 25 and/or chamber 28.

If the flow of liquid coolant (e.g., water) into the lower part of the chamber 28 is interrupted for one or more reasons, the auxiliary impeller 30, in combination with the narrow sealing gap 35a, insures 35a, satisfactory cooling of the bearing sleeve 24 by causing a stream of fluid to flow from the lower part of the chamber 28, through the channels 37, through the clearance 36 and space 31, through the clearance 25, and into the upper part of the chamber 28 via passages 27. The narrow sealing gap 35a opposes the flow of fluid from the upper part of the chamber 28 into the clearance 34; however, the impeller 30 draws fluid from the clearance 36, through the ports 38 and clearance 34 into the space 31 so that the bearing sleeve 24 is properly cooled. Also, such flow of coolant reduces the likelihood of excessive narrowing of the clearance 34. The impeller 30 prevents the flow of fluid from the space 31 into the clearance 34, i.e., such coolant is compelled to flow downwardly in the clearance 25 and back into the upper portion of the chamber 28 wherein it flows downwardly toward the channels 37 to be drawn into the clearance 36. The temperature of fluid in the space

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31 rises when the chamber 28 ceases to receive fresh coolant from below, and the temperature in the space 31 then exceeds the temperature in the chamber 28. The relatively hot fluid flows from the space 31 and through the clearance 25 to heat the bearing element 23 from without. Such relatively hot fluid enters the upper portion of the chamber 28 via passages 27 so as to be mixed with cooler fluid in the chamber 28. The cooler fluid leaves the lower end of the chamber 28 via channels 37 and flows upwardly in the clearance 36, through the ports 38 and into the clearance 34 as well as through the clearance 235 to return into the space 31. The cylindrical part 135 constitutes a protective shield for that portion of the shaft 22 which is surrounded by the bearing element 24. The just-described mode of circulating the coolant when the chamber 28 ceases to receive fresh coolant reduces the likelihood of more rapid heating and resulting expansion of the thin-walled cylindrical part 135 than that of the thick-walled bearing element 23. This reduces the possibility of a widening or narrowing of the clearance 34 between the part 135 and bearing sleeve 24. A widening of the clearance would render the radial bearing useless.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that other can, by applying current knowledge, readily adapt it for various applications without omitting features which fairly constitute essential characteristics of the generic and specific aspects of our contribution to the art and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the claims.

What is claimed as new and desired to be protected by Letters Patent is set forth in the appended claims:

1. In an arrangement for circulation of liquid in a nuclear reactor, the combination of a vessel arranged to contain a supply of hot fluid and including a support having an opening; a tubular member secured to said vessel and extending with clearance through said opening and into said vessel so as to be surrounded by hot fluid; a pump shaft rotatable in said tubular member and having a first impeller installed in said vessel to circulate the fluid therein; a tubular bearing element provided in said tubular member in the interior of said vessel and having a first portion nearer to said opening and tightly fitted into said tubular member and a second portion defining with said tubular member a first annular clearance; a bearing sleeve fixedly received in said second portion of said element and spacedly surrounding said shaft; a first tubular mounting member connected with said element; a second mounting member

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located in and defining with said first mounting member an annular coolant receiving chamber, said first and second mounting members being disposed between and being respectively spaced apart from said tubular member and said shaft, said element having at least one passage connecting said chamber with said first clearance; a second impeller mounted on said shaft in that portion of said first clearance which is remotest from said opening and arranged to draw fluid from said chamber through at least one channel of said second mounting member, through a second clearance between said second mounting member and said shaft, through a third clearance within said bearing sleeve, and into said first clearance.

2. The combination of claim 1, further comprising sleeve-like insulator means provided in said tubular member and surrounding said first clearance.

3. The combination of claim 1, further comprising sleeve-like insulator means interposed between said second portion of said element and said chamber.

4. The combination of claim 1, wherein said portion of said first clearance constitutes a ring-shaped space surrounding a portion of said shaft and surrounded by said tubular member.

5. The combination of claim 1, further comprising a cylindrical shield installed on said second mounting member and interposed between said third clearance and said shaft, said shaft and said shield defining a fourth clearance communicating with said portion of said first clearance.

6. The combination of claim 5, wherein said shield has at least one port connecting said third and fourth clearances at a point remote from said portion of said first clearance.

7. The combination of claim 5, wherein said shield has a flange defining with said element a narrow sealing gap between said chamber and said third clearance.

8. The combination of claim 1, wherein said tubular member, said mounting members and said shaft extend upwardly through said opening and into said vessel.

9. The combination of claim 1, further comprising a cylindrical shield supported by said second mounting member and located between said third clearance and said shaft, the wall thickness of said shield being less than the wall thickness of said element.

10. The combination of claim 1, further comprising a second tubular member rigid with said support and fixedly secured to said first mentioned tubular member without said vessel.

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