Nov. 5, 1968 A. LATHAM, JR 3,409,213

ROTARY SEAL AND CENTRIFUGE INCORPORATION

Filed Jan. 23, 1967 2 Sheets-Sheet 1

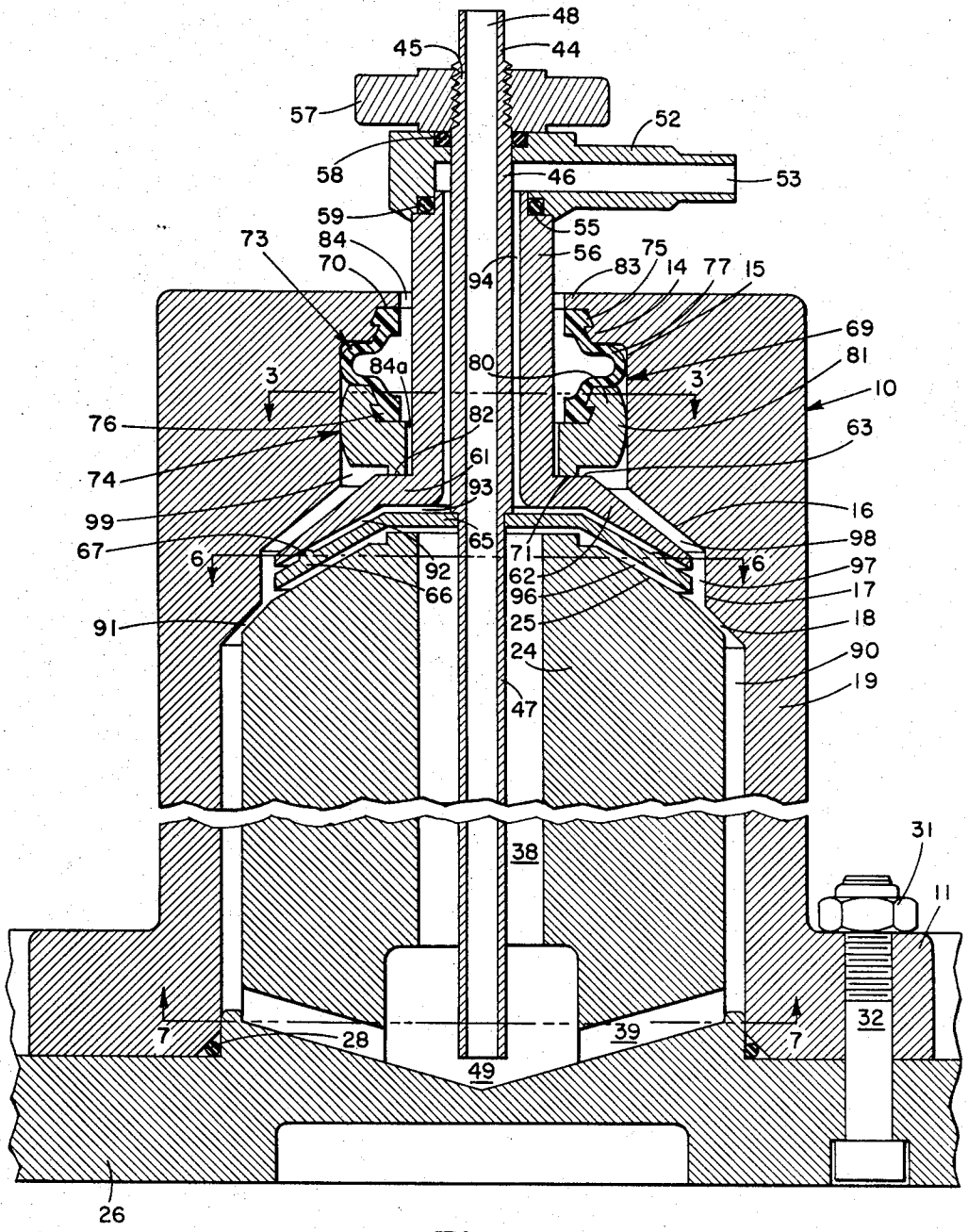

Fig. 1

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Filed Jan. 23, 1967 2 Sheets-Sheet 2

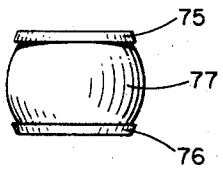

Fig. 2

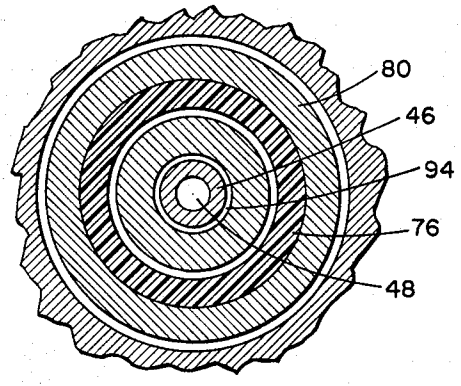

Fig. 3

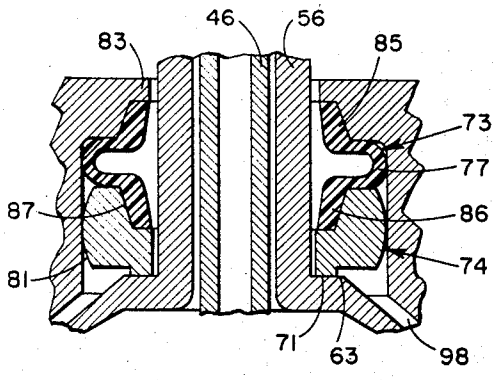

Fig. 4

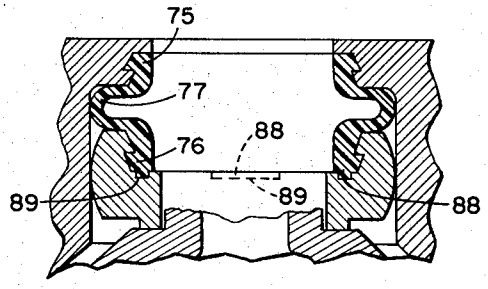

Fig. 5

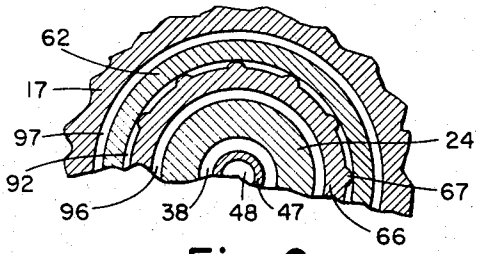

Fig. 6

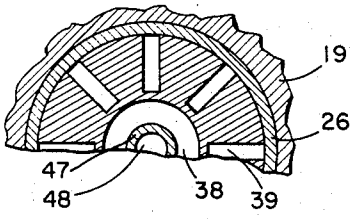

Fig. 7

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ROTARY SEAL AND CENTRIFUGE INCORPORATION

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14 Claims. (Cl. 233—21)

ABSTRACT OF THE DISCLOSURE

A rotary seal formed of a first rigid, low-friction member which contacts a moving rigid member with minimal friction to make the dynamic seal, and a second elastomeric member which provides a resilient static seal and a spring action force between the surfaces of the dynamic seal. The seal is particularly suitable for centrifuges for continuous sterile operations such as the treating of blood.

In the process of storing or handling human blood it is necessary to carry out certain steps, among which is centrifuging. Apparatus has been developed to meet the particularly stringent demands which accompany handling of blood to prevent it from suffering traumatic effects. Among such apparatus are the specially designed centrifuges described in my United States Patent 3,145,713 and in a co-pending application of Richard F Cole Ser. No. 442,765, now Patent No. 3,317,127, assigned to the same assignee as the present invention. Although the rotary seal of this invention is particularly well adapted for use in the centrifuges described in the aforementioned patent and patent application, it has broad applications to pumps, centrifuges, and to stirring and mixing devices used in processing temperature-sensitive materials.

In a centrifuge for sterile processing it is necessary to provide an effective seal between the rotating and stationary members of the apparatus. In centrifuges suitable for continuously handling blood or other fluids subject to contamination it is desirable that the centrifuge bowl and its associated parts perform the rotation while the conduits which make up the fluid inlet and outlet of the centrifuge remain stationary. This then requires an effective rotating seal in which frictional heating is so low and the dissipation of heat to heat sinks is so high that the blood, or other heat-sensitive fluid, will not be exposed to any hot spots. Further, it requires a seal which does not produce any particulate contaminants which might be introduced into the blood or other liquid during its passage through the centrifuge. It is also desirable that such apparatus have seals which are simple to install and maintain in a clean, sterile condition. An additional requirement for the seal is that it achieves very high reliability in service. This in turn requires that the seal is capable of tolerating moderate misalignment and vibration between the rotating and nonrotating parts.

It is therefore a primary object of this invention to provide an improved rotary seal particularly well suited for use in centrifuges. It is another object of this invention to provide a rotary seal of the character described which does not develop localized heating and which does not produce particulate contaminants. It is another object of this invention to provide such a rotary seal which is simple to construct, install, and maintain. It is still a further object to provide a seal which will operate with complete reliability despite moderate misalignment and vibration of the rotating and nonrotating parts. Other objects of the invention will in part be obvious and in part be apparent hereinafter.

The invention accordingly comprises the features of construction, combination of elements, and arrangement

of parts which will be exemplified in the construction hereinafter set forth and the scope of the invention will be indicated in the claims.

A number of different types of rotary seals have been used in the prior art. These generally include one or more O-ring secondary seals in addition to a carbon ring and a metallic mating ring. In many cases they require as many as six different component parts and their rubbing surfaces, where the dynamic seal is effected, tend to overheat.

Summary of the invention

The rotary seal of this invention is formed of only two members. The upper member is an elastomeric member which forms, through an upper contoured section, a static seal with a rotating member of the centrifuge which has a complementary configuration. The lower member of the rotary seal may be a carbon or graphite member which is contoured to fit the upper member and which has a lower surface which forms a low friction dynamic seal with a stationary member of the centrifuge. The surface of the stationary member which contacts the lower member of the rotary seal may be hard surfaced aluminum. Such a rubbing contact does not generate particulate contaminants. The aluminum, being a good heat conductor, rapidly dissipates and conducts away any localized heating generated by the dynamic seal. If the seal is to be reused, it is preferred that the two members are keyed to make it easy to snap them together and to separate them for sterilizing.

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawings in which:

FIG. 1 is a cross section of a centrifuge incorporating one embodiment of the rotary seal of this invention;

FIG. 2 is a side elevational view of the upper member of the rotary seal of FIG. 1 removed from the sealing assembly of the centrifuge;

FIG. 3 is a cross section through the rotary seal of FIG. 1 taken along line 3—3 of that figure;

FIGS. 4 and 5 are cross sections of two additional embodiments of the rotary seal;

FIG. 6 is a partial cross section through the upper part of the centrifuge of FIG. 1 taken along line 6—6 of that figure and drawn to a smaller scale; and

FIG. 7 is a cross section through the lower part of the centrifuge of FIG. 1 taken along line 7—7 of that figure and drawn to a smaller scale.

The rotary sealing assembly of this invention is shown in detail in FIG. 1 as it may be installed in a centrifuge suitable for processing blood. Reference should also be had to various cross-sectional drawings where indicated. The main centrifuge body **10** terminates in its lower end in a flange **11**. Internally it defines a cavity, and it can be considered to be formed of a number of different sectional configurations. Reading from top to bottom in FIG. 1 these are a keyed section **14**, a first small cylindrical section **15**, an inclined section **16**, a second cylindrical section **17**, a second inclined section **18**, and finally a main cylindrical section **19** which, as will become apparent later, contains the major portion of the centrifuge core. The core can be seen to be made up of a central cylindrical section **24**, having a conical or inclined upper section **25** and a core flange **26**. This flange is adapted for engagement with a driving chuck in the well-known manner of centrifuge design and construction. This is done by affixing the body and core through their respective flanges **11** and **26**, sealed with an O-ring **28**, by means of flange screws **30** and nuts **31** and using the larger flange to grip a chuck (not shown).

A core passage **38** runs axially through the center of

the core **24** an da plurality of inclined radial passages **39** are drilled from the outside of the lower end of the cylindrical section of the core into the core passage.

The seal assembly rotates with the bowl and core, while other components of the centrifuge remain stationary as will be now described. Feed tube **44** is connected by any suitable means not shown to the source of liquid to be centrifuged. In its upper section this has a threaded section **45** which then gives way to a thicker walled section **46** and subsequently to a thinner walled section **47** which is within core passage **38** and axially aligned therein. The feed tube thereby defines a fluid passage **48** which offers direct communication between the fluid source and the volume within the centrifuge defined at the confluence **49** of the axial core passage **38** and the inclined radial passages **39** of the core.

A header **52**, having a supernatant outlet conduit **53** is slipped down over section **46** of the feeder tube to rest on a shoulder **55** of an effluent tube **56**. This external assembly is held in place by means of a threaded knurled nut **57** and sealing is accomplished through the use of O-ring seals **58** and **59**. The effluent tube **56** terminates at its lower end in a horizontal section **61** which, in turn , is integral with a frusto conical section **62**. The horizontal section **61** provides a shoulder **63** for supporting the sealing assembly. Directly below the horizontal and inclined sections of the effluent tube is positioned a passage-defining member affixed to the enlarged section **46** of the feeder tube and consisting of a horizontal section **65** and an inclined section **66**, the latter having a row of protuberances **67** (see FIG. 6) which act as spacer means between the two passage-defining members. These are ground on top so that they are on the same conical surface and at an angle corresponding to the conical angle of the contacting surface of section **62**.

The rotary sealing assembly is generally indicated by the numeral **69** and it forms a fluid-tight seal between the rotating centrifuge body **10** and the stationary members made up of the feed tube and the effluent tube. Since the rotary seal rotates with bowl **10** it must form a static seal at **70** and a dynamic seal at **71**. It accomplishes this by forming a friction grip at its upper section with the centrifuge body and by making rubbing contact at the point of the dynamic seal **71**.

The seal assembly is formed of an upper elastomeric member **73** and a lower rigid, low-friction member **74**. The upper elastomeric member **73** can be considered to have three sections: namely, an upper keyed section **75**, a lower keyed section **76**, and thin deformable central section **77**. The elastomeric member is molded in the configuration shown in FIG. 2. It is preferably molded of a material having an intermediate degree of hardness, e.g., from about 25 to 55 on the durometer scale. It will be seen that when this member is installed in the seal assembly (FIG. 1) the central deformable section is compressed; and in this compressed state the upper and lower keyed sections are forced against their corresponding contacting surfaces. If the elastomeric member is formed of an excessively hard material it will be difficult to mold and insert; while if it is too soft it will not hold its shape.

If the centrifuge or other device in which the seal is installed is used to process liquid which must be maintained free from contamination, then the elastomeric sealing member must be formed of a material which can tolerate autoclaving or similar sterilizing. It must also be of a material with which such liquids may come in contact without experiencing any reaction therewith. In the case of centrifuges for processing blood the silicone rubbers have been found to be particularly well suited.

The lower rigid, low-friction seal member **74** has an upper keyed section **80** which is adapted to engage and snap into the lower keyed section **76** of elastomeric member **73**. The central section **81** of the rigid, low-friction seal member is seen to have a spherical radius and its lower section **82** is in the form of a cylindrical collar, the bottom surface of which makes rubbing contact with shoulder **63**. This rigid, low-friction seal member is typically formed from carbon or graphite. However, it may also be formed of a molded polytetrafluoroethylene which is desirably loaded (at least on its surface) with a material such as graphite or other rigid, wear-resistant substance. The effluent tube **56** is preferably formed of aluminum and its shoulder **63** which makes rubbing contact with sealing member **74** is given a treatment to harden it. Typically, this consists of forming a relatively thick oxide coating on it to give it, in effect, a sapphire surface which is harder than the surface of sealing member **74**. The rubbing contact surfaces should be accurately lapped. The resulting dynamic seal at **71** is one which is low in friction, very resistant to wear and does not generate any particulate contaminant matter. Heat generated at the dynamic seal is conducted by effluent tube **56** to tube gripping means (not shown) for dissipation into the atmosphere.

The spherical radius of the central section of sealing member **74** permits the sealing assembly to tolerate moderate misalignment and also prevents any possible damage which might be done to the member during its installation in the centrifuge. The rotary seal assembly is so designed as to be maintained in its proper position at all times while permitting gross clearances between the two members and the outside wall of the effluent tube **56**. The clearance **84** between the upper member and tube **56** may be $\frac{1}{16}$ inch or even more; while the clearance **84***a* between the lower member (which is less than clearance **84**) may be up to about $\frac{1}{16}$ inch. Such relatively large clearances are possible because of the design and configuration of the seal assembly and because of the configuration of the housing around it, particularly to the lip **83** which prevents the upper part of the elastomeric member **73** from extruding upward and around the outer surface of the effluent tube **56**. The gross clearances which are possible permit the apparatus to tolerate some misalignment of the rotating and non-rotating components without causing wear through bearing contact; and the protuberances **67** used as spacers between **62** and **66** prevent any distortion of the sealing assembly at the surface of the dynamic seal **71**.

Modifications may be made in the configurations of the two members making up the rotary seal. Two of these modifications are illustrated in FIGS. 4 and 5. In FIG. 4 the barbs of the keyed sections are eliminated and replaced with straight-lined sections **85** and **86** in the elastomeric member and a corresponding section **87** in the rigid, low-friction member. This design is satisfactory for sealing members which are to be used only once and then thrown away. In such one-use seal assemblies the elastomeric and rigid, low-friction members may also be bonded along the lower contacting surfaces of sections **86** and **87** with a suitable adhesive, such as a silicone calking compound.

In the modification of FIG. 5 the bottom surface of the keyed section **76** of the elastomeric member is formed with several spaced tongues **88** and the mating surface of the rigid, low-friction member has corresponding grooves **89**. This tongue-and-groove arrangement contributes to the locking of these two members. This type of locking is, of course, also applicable to the embodiment of FIG. 4.

The flow of the fluid into the centrifuge and the discharge of the supernatant liquid from the centrifuge may best be explained by tracing the various passages through which the liquid enters and the effluent is discharged. The fluid to be centrifuged travels downwardly through stationary passage **48** and onto rotating surface **49** from which it passes by centrifugal force through radial passages **39** into annular passage **90** which will be seen to be defined between the internal wall of the centrifuge body section **19** of the bowl and the external wall of the cylindrical core section **24**. The primary centrifugal processing occurs in space **90**. The supernatant liquid passes up

through narrow passage **91**, which is defined between the inclined sections of the body and core, through passage **97** and then into passage **92** which is defined by the passage defining member **62** and **66**. This, in turn, communicates with a horizontal passage **93** defined between sections **61** and **65** and finally enters the annular passage **94** which is defined between the enlarged section **46** of the feed tube and the effluent tube **56**. This passage **94** leads directly into discharge conduit **53**. Regions **38**, **96** and **98** remain filled with air, or other gases, which was present in the bowl at the start of the operation.

An examination of FIG. 1 will show that the seal affords complete protection for the fluid being treated. There is no way in which contaminants, including bacteria, dust, etc., can enter the centrifuge through the rotary seal; and there is no way in which any of the liquid can be removed except through the fluid passage provided. There is therefore provided a completely isolated processing volume and a sterile regime.

A centrifuge, constructed as shown in FIG. 2 has been used to centrifuge components of human blood to concentrate platelets from platelet-rich plasma and wash the platelets to remove plasma. The rotary seal performed satisfactorily and the platelets thus prepared exhibited excellent morphological characteristics and other desirable attributes.

It is, of course, within the scope of this invention to use the rotary seal in a device wherein the seal, along with that portion of the apparatus with which it makes a static seal, remains stationary while the remaining portion of the device rotates. The seal may also, of course, be used in any equipment, other than centrifuges, where similar operational requirements exist.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained and, since certain changes may be made in the above construction without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawing shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

I claim:

1. A sealing assembly capable of effecting a fluid-tight seal between two components, one of which is rotatable relative to the other, comprising in combination:

(a) an elastomeric ring member capable of forming a static seal with one of said components and having upper and lower sections with friction-generating outer surfaces and a pressure-deformable central section; and

(b) a rigid, low-friction ring member capable of forming a dynamic seal and having an upper section adapted to form a friction grip with said lower section of said elastomeric member, a central section the outer surface of which is contoured and defined by a spherical radius, and a lower surface adapted to make a low-friction rubbing contact with a surface of the other of said components.

2. A sealing assembly in accordance with claim **1** wherein said elastomeric ring member is formed of a silicone rubber having a hardness between about 25 and 55 on the durometer scale.

3. A sealing assembly in accordance with claim **1** wherein said rigid, low-friction ring member is formed of graphite.

4. A sealing assembly in accordance with claim **1** wherein said rigid, low-friction ring member is formed of polytetrafluoroethylene at least the rubbing surface of which is filled with a rigid, wear-resistant material.

5. A sealing assembly in accordance with claim **1** wherein said upper and lower sections of said elastomeric ring member and said upper section of said rigid, low-friction ring member have barbed edges whereby they are keyed to effect a snap fit between said members and with said one of said components.

6. A sealing assembly in accordance with claim **1** wherein a portion of the surfaces of said ring members forming said friction grip have a plurality of tongues and grooves adapted to enhance said friction grip.

7. A centrifuge having a rotating assembly of components and a stationary assembly of components in axial alignment therewith, characterized in that it has incorporated therein a sealing assembly capable of effecting a fluid-tight seal between said rotating assembly and said stationary assembly, said sealing assembly comprising in combination

(a) an elastomeric ring member capable of forming a static seal with said rotating component and having upper and lower sections with friction-generating outer surfaces and a pressure-deformable central section; and

(b) a rigid, low-friction ring member capable of forming a dynamic seal and having an upper section adapted to form a friction grip with said lower section of said elastomeric member, a central section the outer surface of which is contoured and defined by a spherical radius, and a lower surface adapted to make a low-friction rubbing contact with a surface of said stationary component.

8. A centrifuge in accordance with claim **7** wherein said stationary component is adapted to conduct any frictionally generated heat away from said surface where said rubbing contact is made thereby to prevent the heating of the fluid being centrifuged.

9. A centrifuge in accordance with claim **8** wherein at least that part of said stationary component which is adapted to conduct heat is formed of aluminum and said surface of said stationary component where said rubbing contact is made is oxidized to form a sapphire-like surface.

10. A centrifuge adapted to process liquids which must be maintained free from contaminants and from localized heating and having a first and second assembly of components one of which is capable of rotating relative to the other, comprising in combination

(a) said first assembly of components comprising

(1) feed tube means extending into said centrifuge and having attached to the wall thereof at a point intermediate between its two ends a horizontal ring which terminates in a first downwardly inclined skirt,

(2) effluent tube means surrounding said feed tube means above said horizontal ring and defining therewith an annular channel adapted to provide supernatant liquid withdrawal means, said effluent tube means terminating at its lower end in a horizontally disposed shoulder member having a second downwardly inclined skirt, said shoulder member providing a dynamic sealing surface; said horizontal ring and first downwardly inclined skirt of said feed tube means being positioned below said collar member and said second downwardly inclined skirt of said effluent tube means and arranged in spaced relationship therewith to define a fluid passage communicating between the centrifuge and said annular channel;

(b) said second assembly of components comprising

(1) a centrifuge core having a centrally positioned passage into which said feed tube extends,

(2) a centrifuge housing surrounding said centrifuge core and defining around at least a portion of said effluent tube means a recess adapted to hold a rotary seal assembly; and

(c) a rotary seal assembly disposed around said efflu-

ent tube means and defining a spacing therewith, said seal assembly comprising

(1) an elastomeric ring member capable of forming a static seal with a portion of the surface of said recess of said centrifuge housing said elastomeric ring member having upper and lower sections with friction-generating outer surfaces and a pressure-deformable central section; and

(2) a rigid, low-friction ring member capable of forming a dynamic seal and having an upper section adapted to form a friction grip with said lower section of said elastomeric member, a central section the outer surface of which is contoured and defined by a spherical radius, and a lower surface adapted to make a low-friction rubbing contact with said dynamic sealing surface of said shoulder of said effluent tube means.

11. A centrifuge in accordance with claim **10** wherein said effluent tube means is formed of a material having a high heat conductivity and said dynamic sealing surface of said shoulder member is treated to increase its hardness.

12. A centrifuge in accordance with claim **11** wherein said high heat conductivity material is aluminum and said dynamic sealing surface is oxidized aluminum to provide a sapphire-like surface.

13. A centrifuge in accordance with claim **10** wherein said spacing between said elastomeric ring member of said seal assembly and said effluent tube is at least 1/16 inch and said spacing between said hard-surface ring member and said effluent tube is no greater than 1/16 inch, whereby minor misalignments of said centrifuge components may be tolerated without developing bearing surfaces.

14. A centrifuge in accordance with claim **10** wherein second downwardly inclined skirt has a circle of spaced protuberances of the same height adapted to contact the lower surface of said first downwardly inclined skirt thereby to define said fluid passage and to prevent distortion of said sealing assembly at said dynamic sealing surface.

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