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(54) ELECTRIC SUBMERSIBLE PUMP (ESP) THRUST MODULE WITH ENHANCED LUBRICATION AND TEMPERATURE DISSIPATION

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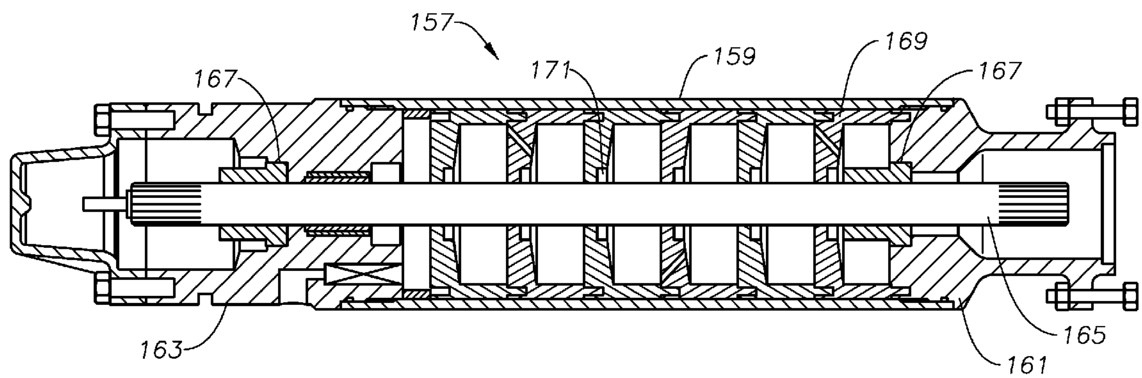
(57) **ABSTRACT**

A thrust module and a seal module for use in an electric submersible pump assembly is provided. The thrust module provides increased lubrication and heat dissipation while increasing sealing redundancies within the module. The thrust module includes a thrust bearing that absorbs thrust from the primary pump. A circulation pump assembly is coupled to the thrust bearing to circulate fluid through the thrust bearing and dissipate heat generated in the thrust bearing through a plurality of fins formed on an exterior surface of the circulation pump assembly. The seal module has labyrinth discs positioned within the seal module that inhibit fluid flow through the seal module. The seal module also includes check valves that release fluid from and allow fluid into the seal module at predetermined pressures. The sealing assembly is interposed between the thrust bearing and a primary pump of the electric submersible pump.



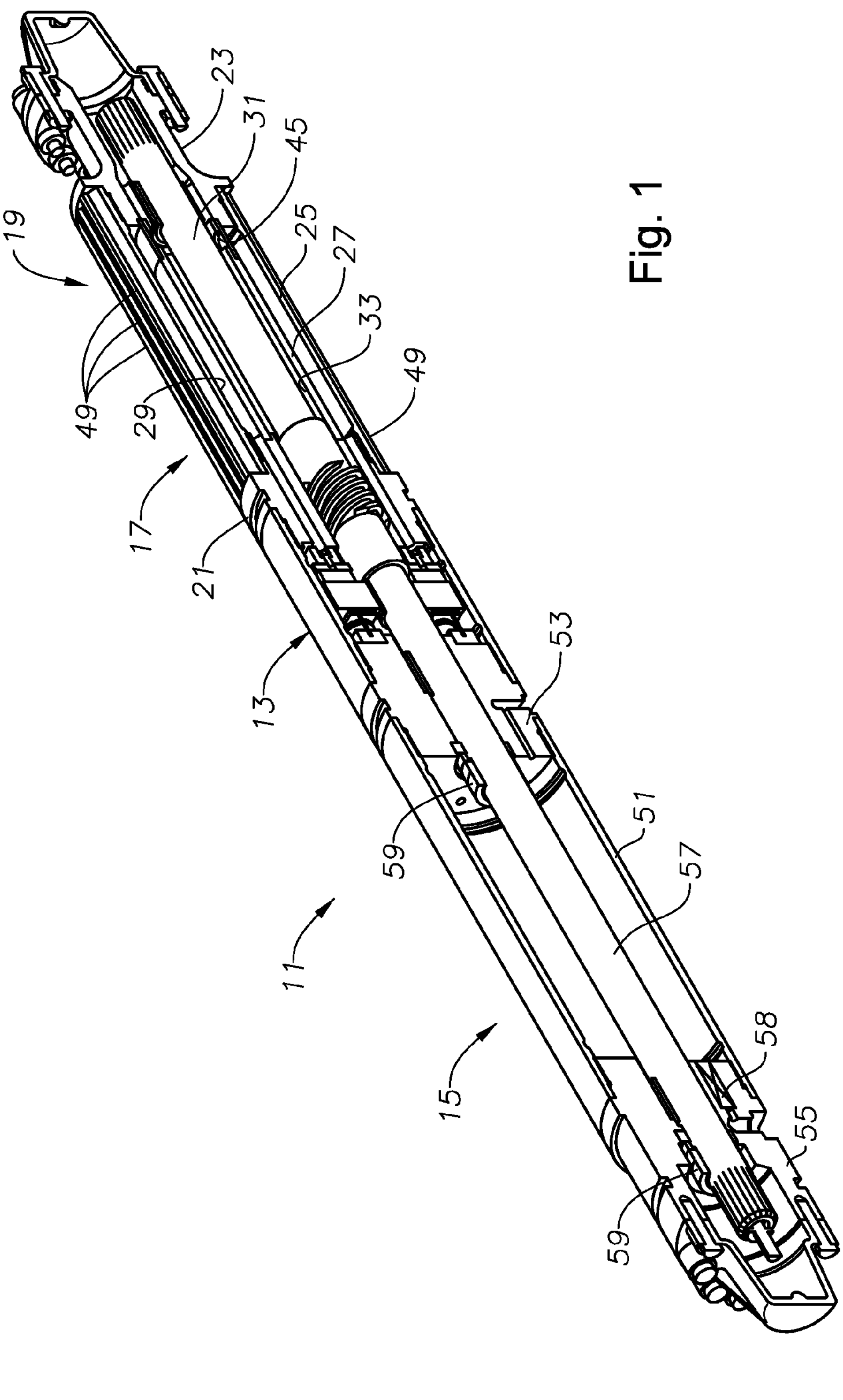


Fig. 1

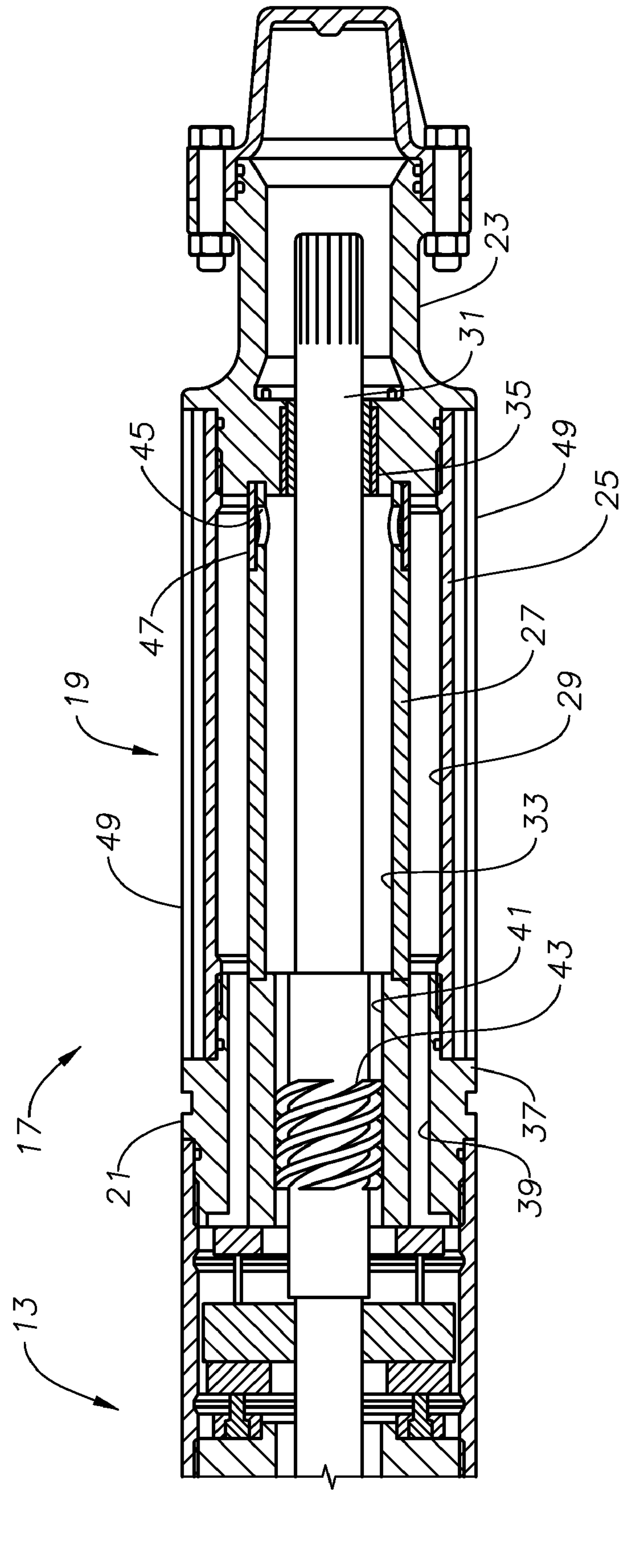


Fig. 2

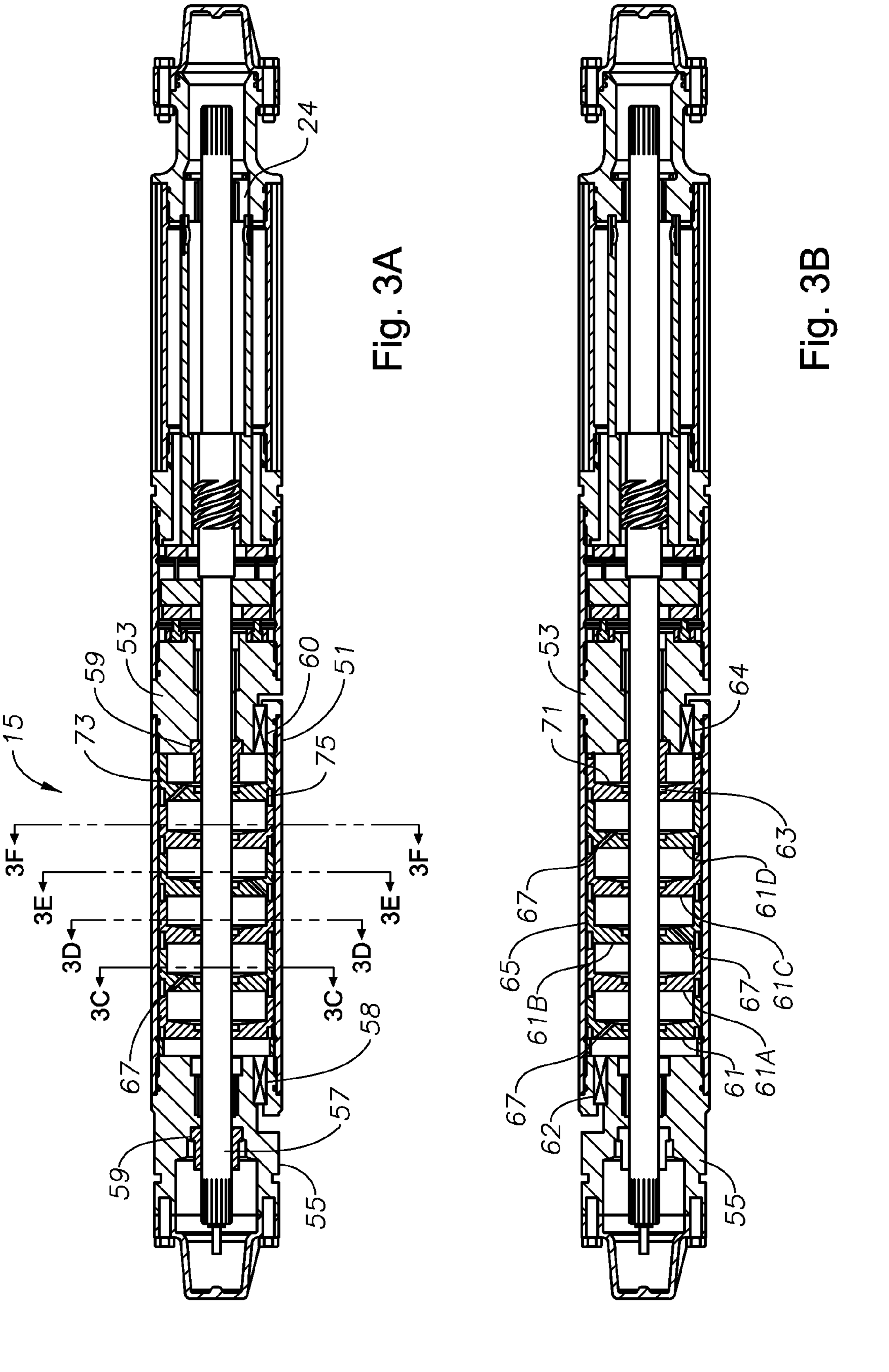

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Fig. 3A

Fig. 3B

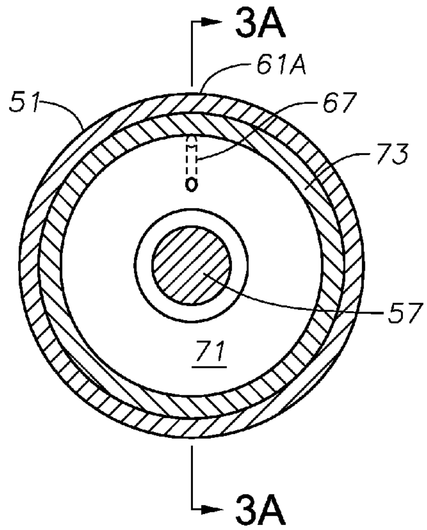

Fig. 3C

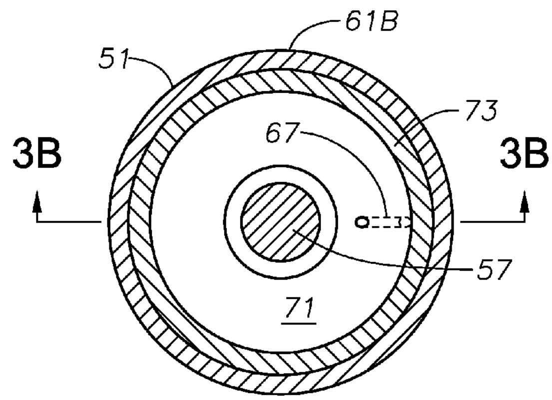

Fig. 3D

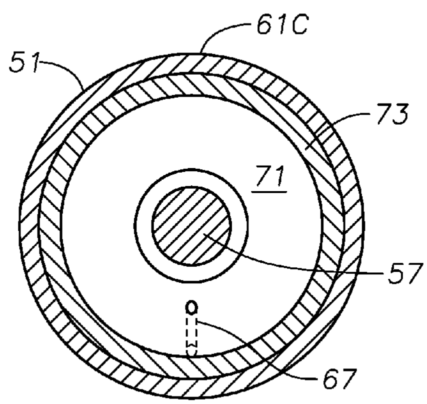

Fig. 3E

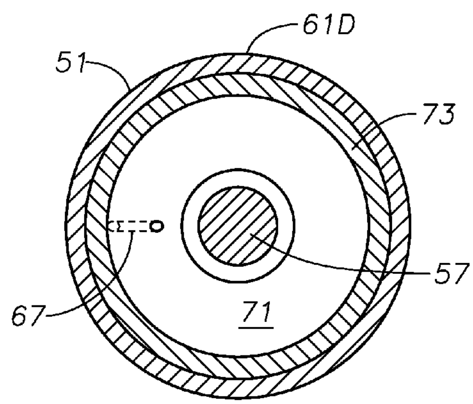

Fig. 3F

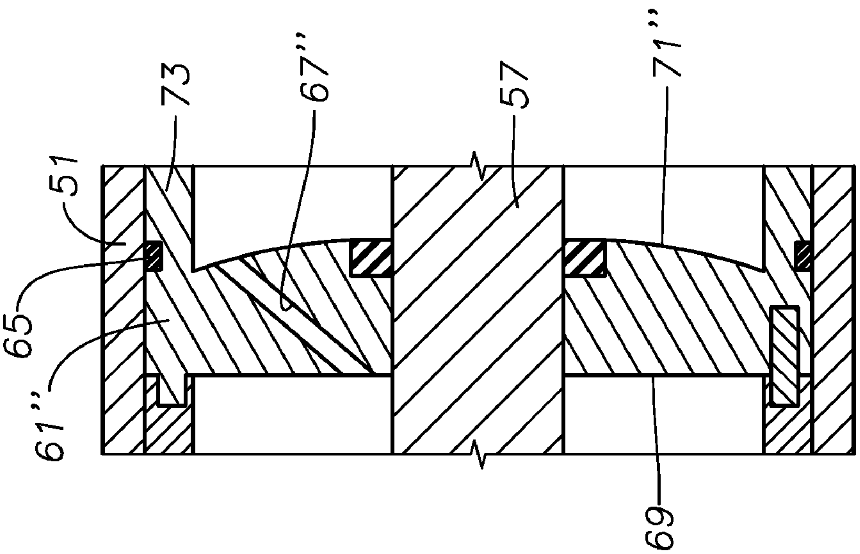

Fig. 3I

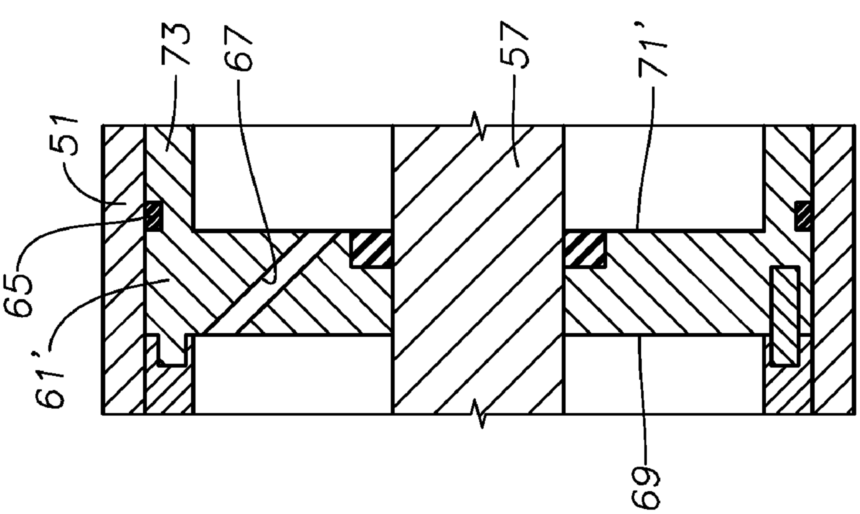

Fig. 3H

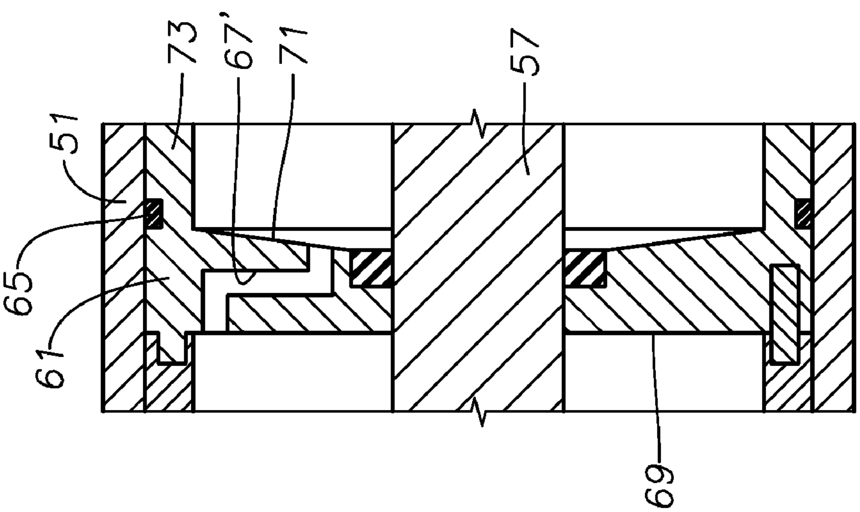

Fig. 3G

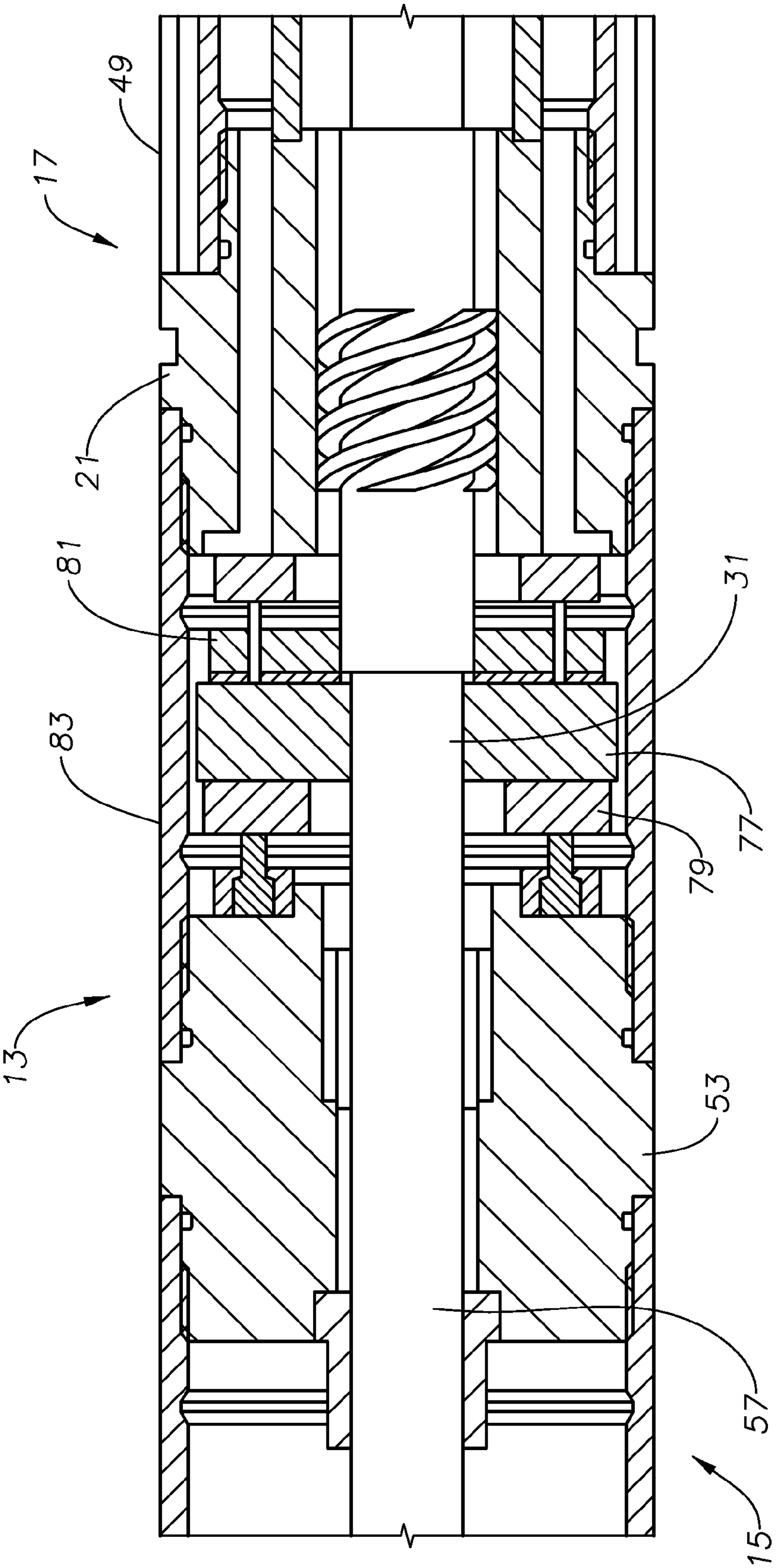

Fig. 4

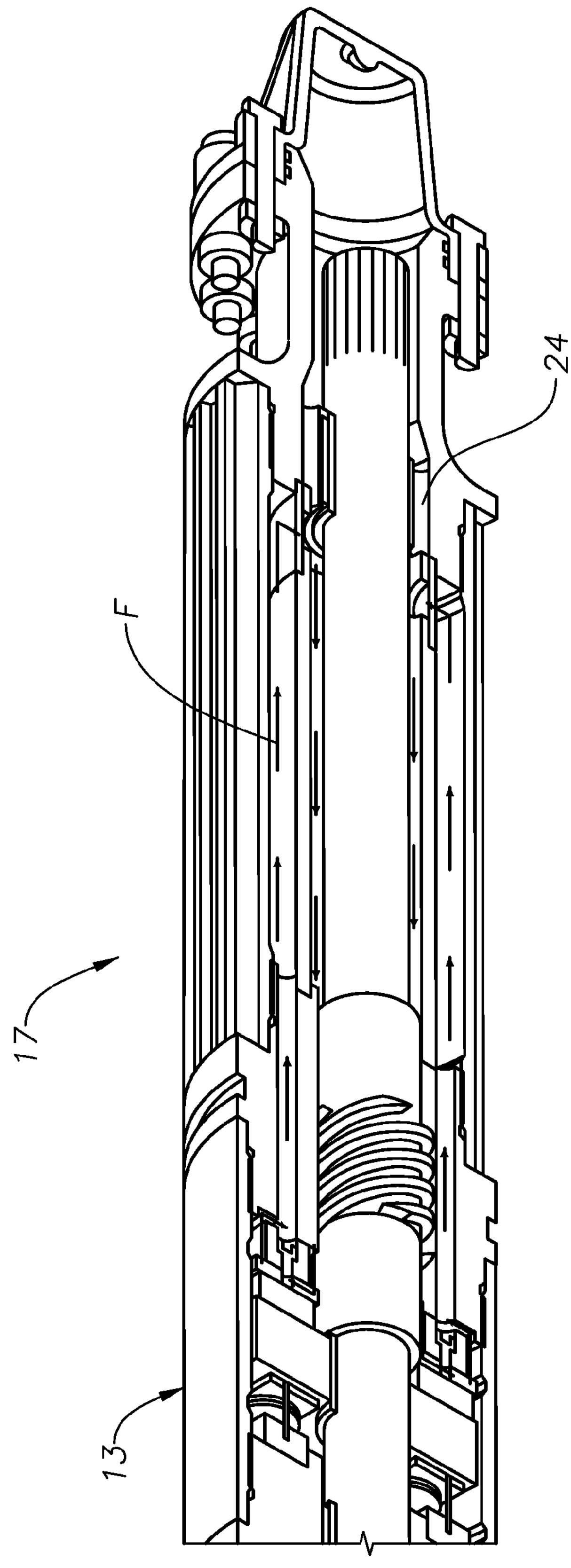

Fig. 5

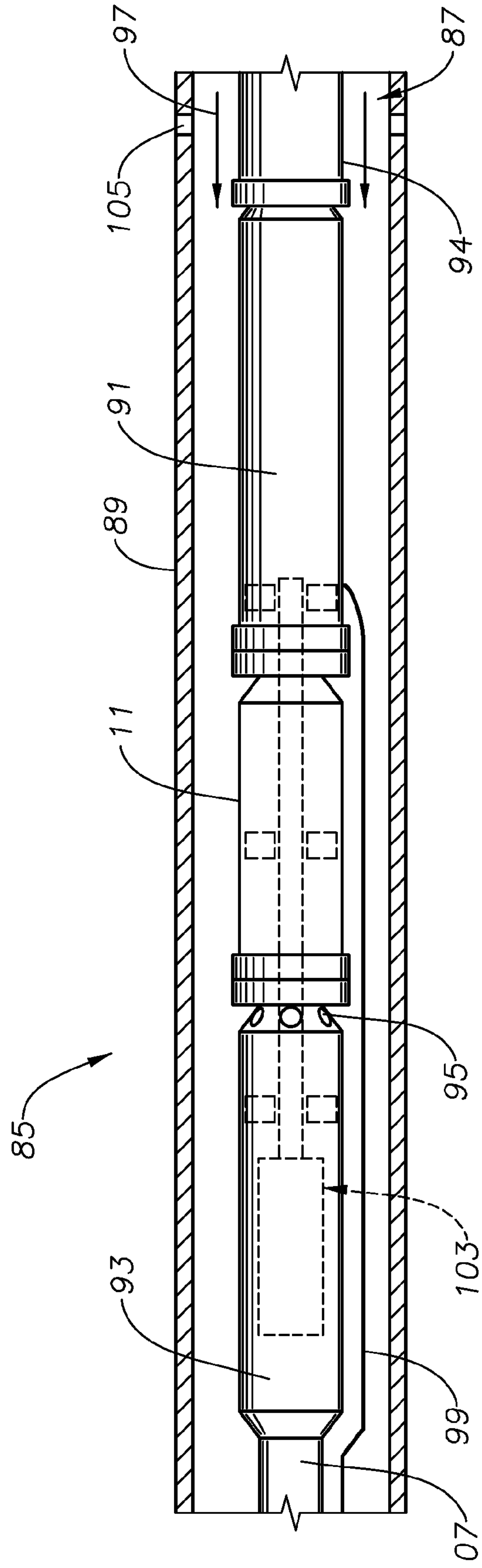

Fig. 6

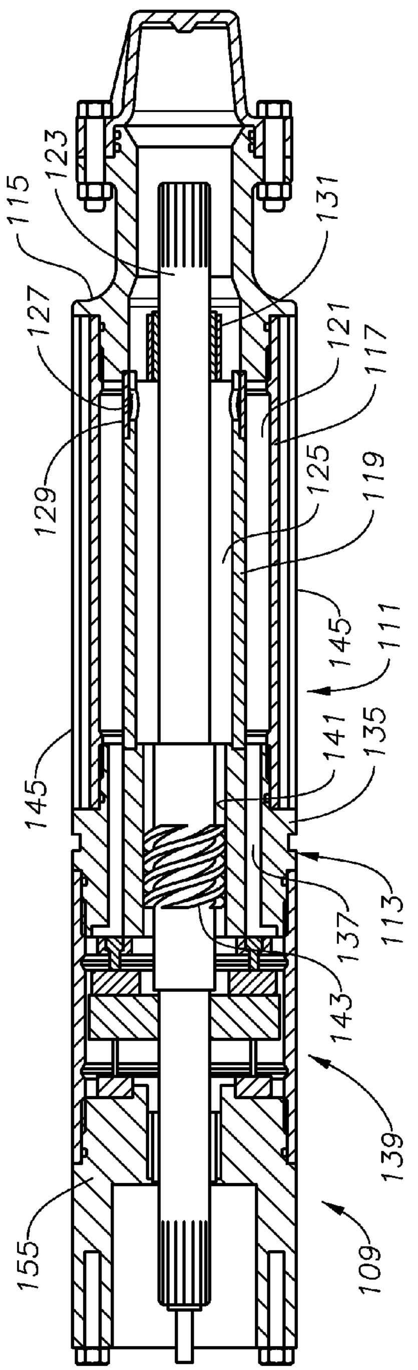
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Fig. 7

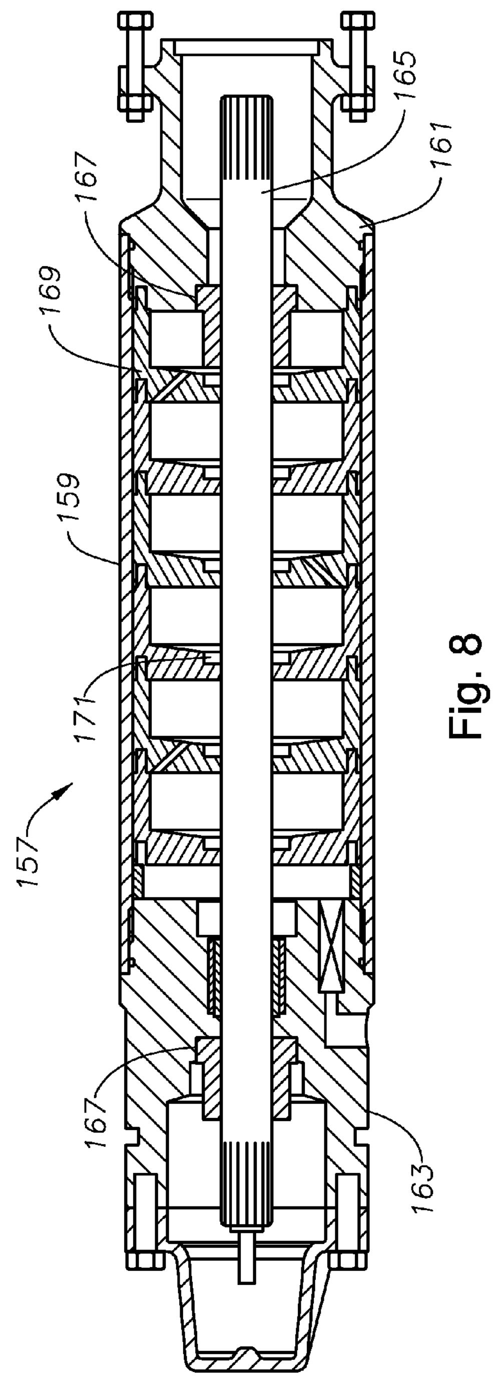
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Fig. 8

ELECTRIC SUBMERSIBLE PUMP (ESP) THRUST MODULE WITH ENHANCED LUBRICATION AND TEMPERATURE DISSIPATION

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] This invention relates in general to electric submersible pumps (ESPs) and, in particular, to an ESP thrust module with enhanced lubrication and temperature dissipation.

[0003] 2. Brief Description of Related Art

[0004] Electric submersible pump (ESP) assemblies are disposed within wellbores and operate immersed in wellbore fluids. These wellbore fluids may be corrosive or toxic and were they to penetrate the electric motor portion of the ESP, would cause failure of the electric motor and thus the ESP. Thus, ESPs include sealing assemblies interposed between the electric motor and the pump portion of the ESP. These sealing assemblies prevent the flow or seepage of wellbore fluids into the electric motor. However, present sealing assemblies provide only limited sealing between the pump and the electric motor. If the primary seals fail, then the sealing assemblies and subsequently the electric motor will be inundated with wellbore fluids. Therefore, there is a need for an improved sealing assembly that provides additional redundancy.

[0005] The sealing assemblies also may include thrust bearings adapted to transfer the thrust generated by the pump in the opposite direction of the flow of wellbore fluids. Lubricating fluid is often interposed within the thrust bearings to allow a thrust runner coupled to an axial shaft within the thrust bearing to rotate relative to bearings supporting the axle. Operation of the thrust bearing generally cause this fluid to break down and wear over time. This is due in part to heat generated between the thrust runner and thrust bearing that causes a loss in viscosity of the lubricating fluid. The problem becomes exacerbated when the ESP is operated in subsurface/subsea wellbores. In these locations, the ESP can be subject to extremely high downhole temperatures. The high temperatures speed up the process of lubricating fluid breakdown. When the lubricating fluid breaks down, it may inhibit and even prevent operation of the thrust bearing, significantly decreasing the efficiency and life of the ESP. Therefore, there is a need for improved lubrication of thrust bearings within an ESP.

SUMMARY OF THE INVENTION

[0006] These and other problems are generally solved or circumvented, and technical advantages are generally achieved, by preferred embodiments of the present invention that provide an ESP thrust module with enhanced lubrication and temperature dissipation.

[0007] In accordance with an embodiment of the present invention, a submersible pump assembly is disclosed. The submersible pump assembly includes a rotary primary pump, a motor operationally coupled to the primary pump for driving the pump, a thrust bearing in a thrust bearing chamber, and a sealing assembly. The thrust bearing chamber is interposed between the motor and the primary pump and absorbs thrust from the primary pump. The seal assembly is coupled to the thrust bearing and further coupled to the primary pump. A circulation pump resides in the thrust bearing chamber and is in fluid communication with the thrust bearing to circulate fluid through the thrust bearing. A cooling chamber having a plurality of fins formed on an exterior portion of the cooling chamber is coupled to the thrust bearing chamber. The cooling chamber dissipates heat generated in the thrust bearing. The circulation pump is in fluid communication with the cooling chamber to circulate fluid from the thrust bearing through the cooling chamber.

[0008] In accordance with another embodiment of the present invention, a submersible pump assembly is disclosed. The submersible pump assembly includes a rotary primary pump, a motor operationally coupled to the primary pump for driving the pump, and a thrust bearing. The thrust bearing resides in a thrust bearing chamber between the motor and the primary pump. The thrust bearing absorbs thrust from the primary pump. A circulation pump in the thrust bearing chamber is in fluid communication with the thrust bearing to circulate fluid through the thrust bearing. A heat exchange housing defining a cooling chamber forms a portion of the thrust bearing chamber. The heat exchange housing has a plurality of fins formed on an exterior portion of the to dissipate heat generated in the thrust bearing, and the circulation pump is in fluid communication with the cooling chamber to circulate fluid from the thrust bearing through the cooling chamber. The submersible pump assembly includes a rotating shaft passing through a center of the heat exchange housing that is rotated in response to operation of the motor; the rotating shaft couples to and rotates the circulating pump.

[0009] In accordance with yet another embodiment of the present invention, a submersible pump assembly is disclosed. The submersible pump assembly includes a rotary primary pump, a motor operationally coupled to the primary pump for driving the pump, and a sealing chamber housing coupled between the motor and the primary pump. A sealing chamber rotating shaft is supported within the sealing chamber housing and driven by the motor. The assembly also includes a plurality of labyrinth discs mounted in sealing engagement with but non-rotating engagement with the sealing chamber rotating shaft. Each labyrinth disc has a periphery that seals to the sealing chamber housing and further seals to the sealing chamber rotating shaft, thereby dividing the sealing chamber housing into chambers between each labyrinth disc. The submersible pump assembly includes at least one well fluid inlet in the sealing chamber housing. At least two check valves allow fluid flow into the sealing chamber housing, and at least two check valves permit fluid flow out of the sealing chamber housing. The check valves are positioned within the sealing chamber housing so that fluid may flow into and out of the sealing chamber housing at a predetermined pressure. The labyrinth discs also contain ports extending from an area proximate to the sealing chamber housing on a first surface to an area proximate to the sealing chamber rotating shaft on a second surface. The ports provide a tortuous fluid flow path for well fluid through the labyrinth discs to inhibit fluid flow through the sealing chamber assembly.

[0010] An advantage of a preferred embodiment is that it provides a thrust bearing with improved performance and service life. This is accomplished through the disclosed embodiments that increase lubrication fluid flow through the thrust bearing during operation of the thrust bearing. In addition, improved thrust bearing performance and service life may be accomplished through the disclosed embodiments that increase the rate of heat transfer from the thrust bearing to the surrounding environment, thereby maintaining optimal operating conditions for the lubrication fluid of the thrust bearing. Furthermore, improved thrust bearing performance and service life may be accomplished through the disclosed embodiments that provide an improved sealing apparatus to maintain the isolation of the thrust bearing and the lubricating fluid from the wellbore fluids pumped to the surface by an ESP.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] So that the manner in which the features, advantages and objects of the invention, as well as others which will become apparent, are attained, and can be understood in more detail, more particular description of the invention briefly summarized above may be had by reference to the embodiments thereof which are illustrated in the appended drawings that form a part of this specification. It is to be noted, however, that the drawings illustrate only a preferred embodiment of the invention and are therefore not to be considered limiting of its scope as the invention may admit to other equally effective embodiments.

[0012] FIG. **1** is a sectional perspective view of a thrust bearing module in accordance with an embodiment of the present invention.

[0013] FIG. **2** is a sectional view of a cooling chamber of the thrust bearing module of FIG. **1**.

[0014] FIG. **3**A is a sectional view of an alternative embodiment of a sealing chamber assembly in accordance with an embodiment of the present invention.

[0015] FIG. **3**B is a sectional view of the alternative embodiment of the sealing chamber assembly of FIG. **3**A taken through a plane perpendicular to the section of **3**A as shown by line **3**B-**3**B of FIG. **3**D.

[0016] FIG. **3**C-**3**F are sectional views of the sealing chamber of FIG. **3**A illustrating clocking of vent passages of FIG. **3**A.

[0017] FIG. **3**G-**3**I are sectional views of alternative components of the sealing chamber of FIG. **3**A.

[0018] FIG. **4** is a sectional view of the thrust bearing of FIG. **1**.

[0019] FIG. **5** is a sectional perspective view of the cooling chamber assembly and thrust bearing of FIG. **1** illustrating a fluid flow path through the cooling chamber assembly and the thrust bearing.

[0020] FIG. **6** is a sectional view of an electric submersible pump assembly incorporating the thrust bearing module of FIG. **1**.

[0021] FIG. **7** is a thrust bearing lubrication module in accordance with an embodiment of the present invention.

[0022] FIG. **8** is a sealing assembly in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0023] The present invention will now be described more fully hereinafter with reference to the accompanying drawings which illustrate embodiments of the invention. This invention may, however, be embodied in many different forms and should not be construed as limited to the illustrated embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout, and the prime notation, if used, indicates similar elements in alternative embodiments.

[0024] In the following discussion, numerous specific details are set forth to provide a thorough understanding of the present invention. However, it will be obvious to those skilled in the art that the present invention may be practiced without such specific details. Additionally, for the most part, details concerning ESP operation, construction, and the like have been omitted inasmuch as such details are not considered necessary to obtain a complete understanding of the present invention, and are considered to be within the skills of persons skilled in the relevant art.

[0025] Referring to FIG. **1**, thrust module assembly **11** includes a thrust bearing assembly **13**, a sealing chamber assembly **15**, and a cooling chamber assembly **17**. Cooling chamber assembly **17** includes a heat exchanger assembly **19**, and a guide assembly **21**.

[0026] Referring to FIG. **2**, heat exchanger assembly **19** forms one end of cooling chamber assembly **17** and includes a cooling chamber base **23**, a heat exchange housing **25**, and an interior housing **27**. Heat exchange housing **25** and interior housing **27** are tubular members with interior housing **27** having a smaller diameter than heat exchange housing **25** such that when interior housing **27** is inserted into heat exchange housing **25** and mounted to cooling chamber base **23**, an annular fluid reservoir chamber **29** will be formed. A cooling chamber shaft **31** passes through cooling chamber base **23** and inner diameter housing **27** to form an annular flow passage **33** between cooling chamber shaft **31** and interior housing **27**. Interior housing **27** includes openings **45** proximate to cooling chamber base **23**. Openings **45** pass through a wall of interior housing **27**, thereby allowing flow of fluid from fluid reservoir **29** into fluid flow passage **33**. In the illustrated embodiment, filters **47** are mounted over openings **45** to prevent the passage of particles larger than a predetermined size from fluid reservoir **29** into fluid flow passage **33**. Filters **47** are positioned so that fluid flow will cause filters **47** to maintain their position over openings **45**. A person skilled in the art will understand that any suitable means to secure filters **47** over openings **45** are contemplated and included in the disclosed embodiments. In the illustrated embodiment, filters **47** may be plated metal filter elements. A person skilled in the art will understand that the filters **47** may comprise wrapped screen or other unspecified filter media designed to prevent flow of particulates from fluid reservoir **29** into flow passage **33**. Cooling chamber shaft **31** is supported by a bearing **35** within cooling chamber base **23** and has a splined end for coupling to additional equipment.

[0027] Guide assembly **21** mounts to heat exchanger assembly **19** opposite cooling chamber base **23**. Guide assembly **21** includes a pump housing **37** that mounts to heat exchange housing **25** and interior housing **27**. Pump housing **37** defines a plurality of tubular flow passages **39** positioned to allow flow of fluid from an area proximate to thrust bearing assembly **13** into fluid reservoir chamber **27**. Pump housing **37** further defines a pump chamber **41**. Pump chamber **41** is coaxial with annular flow passage **33**. In the illustrated embodiment, guide assembly **21** includes a guide vane type pump **43** mounted to cooling chamber shaft **31** within pump chamber **41**. The pitch of pump **43** is selected based on the fluid viscosity and the resonance time necessary to maximize the heat transfer from the circulating fluid to heat exchange housing **25** within fluid reservoir **29**.

[0028] Referring to FIG. **1**, heat exchange housing **25** includes a plurality of fins **49** formed on an exterior diameter portion of heat exchange housing **25**. Fins **49** run the length of heat exchange housing **25** and conduct heat from fluid reservoir **29** through a wall of heat exchange housing **25** into the environment surrounding cooling chamber assembly **17**. In the illustrated embodiment, fins **49** are of a number, size, and shape such that fins **49** double the exterior diameter surface area of heat exchange housing **25** over a heat exchange housing **25** without fins **45**. In the illustrated embodiment, the exterior diameter surface of each fin **49** coincides with the exterior diameter of thrust bearing module **11**. Thus, a significant increase of the surface area of cooling chamber housing **25** is accomplished without an increase in the outer diameter of the thrust assembly when compared to current thrust bearing modules and assemblies. A person skilled in the art will understand that the number size and shape of fins **49** may be varied to accommodate the particular application of cooling chamber assembly **17**.

[0029] In operation of cooling chamber assembly **17**, cooling chamber shaft **31** rotates in response to rotation of an ESP pump motor (not shown). Rotation of cooling chamber shaft **31** causes pump **43** to rotate. As pump **43** rotates it will draw fluid from fluid passageway **33** through pump chamber **41** and then through thrust bearing assembly **13** as illustrated by flow path F in FIG. **5**. In turn, fluid within thrust bearing assembly **13** will be forced through flow passages **39** into fluid reservoir **29**, and fluid within fluid reservoir **29** will circulate across filters **47** through openings **45** into flow passage **33**. As fluid flows through thrust bearing assembly **13**, heat generated through operation of thrust bearing assembly **13**, described in more detail below, will transfer into the fluid, thereby heating the fluid. This fluid will then flow into fluid reservoir **29** where the heat will transfer from the fluid into heat exchange housing **25**. The heat is then conducted by heat exchange housing **25** through fins **49** and into the ambient environment. A person skilled in the art will understand that lubricating fluid within cooling chamber assembly **17** may communicate with lubricating fluid within an electric motor **91** coupled to cooling chamber base **23**. As shown in FIG. 3A and FIG. **5**, cooling chamber base **23** may include flow passages **24** permitting such fluid communication. In this manner, cooling chamber assembly **17** may aid in both cooling of and debris removal from electric motor **91**.

[0030] Referring to FIG. **1**, sealing chamber assembly **15** includes a chamber housing **51**. Chamber housing **51** includes a first end **53** secured to thrust bearing **13**, and a second end **55** adapted to couple sealing chamber assembly **15** to an external device such as a pump, pump intake, or another sealing chamber assembly **15**. A sealing chamber shaft **57** is supported within sealing chamber assembly **15** at first end **53** and second end **55**. Sealing chamber shaft **57** may rotate and may have an end coupled to cooling chamber shaft **31** of cooling chamber assembly **17** such that rotation of shaft **57** will cause rotation of shaft **31**, and rotation of shaft **31** will cause rotation of shaft **57**. Rotational shaft seals **59** allow shaft **57** to rotate within sealing chamber assembly **15**, while preventing wellbore fluids from passing along shaft **57** to the subsequent pump element, such as the electric motor. Incorporating a second rotational shaft seal **59** proximate to thrust bearing assembly **13**, as shown herein, provides additional redundancy within sealing chamber assembly **15**. This provides a decrease in the instances of contamination between wellbore fluid outside thrust bearing module **11** and thrust bearing assembly **13** and the electric motor (not shown) providing mechanical energy to the system, while also inhibiting migration of lubricating fluid in thrust bearing assembly **13** out of thrust bearing assembly **13**.

[0031] As shown in FIG. **3**A and FIG. **3**B, sealing chamber assembly **15** includes first, second, third, and fourth check valves **58**, **60**, **62**, and **64**, respectively. First and third check valves **58**, **62** reside within head **55** of sealing chamber assembly **15**. Second and fourth check valves **60**, **64** reside within first end of sealing chamber assembly **53**. Third and fourth check valves **62**, **64** are offset **90** degrees from the positions of first and second check valves **58**, **60**. First and fourth check valves **58**, **64** are configured to allow fluid flow into sealing chamber assembly **15** from the wellbore, and second and third check valves **60**, **62** are configured to allow fluid flow into the wellbore from sealing chamber assembly **15**. In the illustrated embodiment, second and third check valves **60**, **62** will open when pressure within sealing chamber assembly **15** reaches a predetermined maximum pressure, such as 50 p.s.i., thereby allowing lubricating fluid within sealing chamber assembly **15** to flow out of sealing chamber assembly **15**. Similarly, first and fourth check valves **58**, **64** will open when pressure within sealing chamber assembly **15** reaches a predetermined minimum pressure, thereby allowing wellbore fluid to flow into sealing chamber assembly **15**. In this manner, check valves **58**, **60**, **62**, **64** will prevent catastrophic failure of thrust module assembly **11** by both preventing over pressurization and under pressurization of thrust module assembly **11**, both of which could lead to catastrophic failure of the components of thrust module assembly **11**.

[0032] As illustrated in FIG. **3**A, sealing chamber assembly **15** can include a plurality of labyrinth discs **61**. Each labyrinth disc **61** mounts within sealing chamber housing **51** and seals to sealing chamber housing **51** and sealing chamber shaft **57**. Labyrinth discs **61** seal to sealing chamber shaft **57** with lip seals **63**. An exterior diameter portion of each labyrinth disc **61** seals to sealing chamber housing **51** with a labyrinth o-ring **65**. Labyrinth discs **61** do not rotate in response to rotation of sealing chamber shaft **57**. Each labyrinth disc **61** also includes a vent passage **67** extending between a first surface **69** of each labyrinth disc **61** to a second surface **71** of each labyrinth disc **61**. In the illustrated embodiment, vent passages **67** extend from an area of labyrinth disc **61** proximate to sealing chamber shaft **57** to an area proximate to sealing chamber housing **51**. Vent passages **67** may be straight as shown, or include a plurality of turns as shown in FIG. 3G. In the illustrated embodiment, second surface **71** is concaved to facilitate removal of air within sealing chamber assembly **15** during manufacture of sealing chamber assembly **15**.

[0033] Vent passage **67** comprises a fluid flow path through each labyrinth disc **61**. Vent passage **67** allows for some movement of fluid across each labyrinth disc **61** while making the flow passage across the labyrinth disc as arduous as possible. This allows some movement of fluid to equalize pressures in the varying chambers created by multiple labyrinth discs **61** within sealing chamber housing **51** while inhibiting movement of lubrication fluid within thrust bearing assembly **13** out of the assembly into the wellbore. This also inhibits movement of wellbore fluids into thrust bearing assembly **13** and the electric motor (not shown) by forcing the wellbore fluids migrating into seal chamber assembly **15** through check valves **58**, **60**, **62**, and **64** through a tortuous flow path. A blocking fluid having a density heavier than the expected density of the wellbore fluids may be used within sealing chamber assembly **15** to further inhibit movement of wellbore fluids.

[0034] Each labyrinth disc **61** also includes an annular protrusion or cylindrical wall **73** on an exterior diameter portion of labyrinth disc **61**. Annular protrusion **73** locates each labyrinth disc **61** coaxial with sealing chamber shaft **57** and provides a spacing element between the adjacent labyrinth disc **61**. At an end of each annular protrusion **73** distal from second surface **71**, annular protrusion **73** is bored at four locations spaced equidistant around annular protrusion **73**. Each bore is adapted to receive a pin **75**. Each pin **75** mounts within one bore in annular protrusion **73** and further mounts within a corresponding bore defined within surface **69** of each labyrinth disc **61**. Pin **75** prevents rotation of each labyrinth disc **61** relative to the adjacent labyrinth disc **61**, helping to maintain each labyrinth disc **61** stationary within sealing chamber housing **51**. In addition, each pin **75** maintains the corresponding labyrinth disc **61** in the proper orientation relative to the adjacent labyrinth discs **61** as described in more detail below.

[0035] Each labyrinth disc **61** includes one vent passage **67**. During manufacture of sealing chamber assembly **15** each labyrinth disc **61** is rotated or "clocked" relative to the adjacent labyrinth disc **61** to misalign vent passages **67**. This causes each vent passage **67** to be oriented **90** degrees from the vent passages **67** in the adjacent labyrinth discs **61**. As shown in FIGS. **3**C through **3**F, adjacent labyrinth discs **61**A, **61**B, **61**C, and **61**D each have a vent passage **67** and an annular protrusion **73**. Referring to FIG. **3**C, vent passage **67** of labyrinth disc **61**A is at the twelve o'clock position as shown in FIG. **3**C. The next adjacent labyrinth disc **61**B has a vent passage **67** at the three o'clock position as shown in FIG. **3**D. The labyrinth disc **61** adjacent to labyrinth disc **61**B is labyrinth disc **61**C. Vent passage **67** of labyrinth disc **61**C occupies the six o+clock position as shown in FIG. **3**E. Labyrinth disc **61**D, adjacent to labyrinth disc **61**C has a vent passage **67** located at the nine o'clock position as shown in FIG. **3**F. Subsequent labyrinth discs **61** will continue to have vent passages **67** clocked ninety degrees from the previous vent passage **67**.

[0036] By clocking each vent passage **67** relative to the adjacent vent passages **67**, the tortuousness of the fluid flow path across each labyrinth disc **61** is increased. This will further inhibit movement of wellbore fluid from an area external to thrust bearing module **11** and the associated electric motor (not shown) to an area internal to thrust bearing module **11**. Similarly, this will inhibit movement of lubricating fluid from an area internal to thrust bearing module **11** to an area external to thrust bearing module **11**. A person skilled in the art will understand that alternative embodiments may clock each labyrinth disc **61** at an angle greater than or less than ninety degrees.

[0037] Referring to FIG. **3**A, sealing chamber assembly **15** may be assembled horizontally or vertically, then pressure tested and filled with fluid. A blocking fluid may then be pumped into sealing chamber assembly **15**. In the embodiment illustrated in FIG. **3**A, when vertically assembled, air trapped between each labyrinth disc **61** will migrate to the apex of concave profile **71**. There the air may escape from vent passages **67**. When placed horizontally in operation, wellbore fluid may migrate into sealing chamber housing **51** as described above. By clocking each vent passage, as described with respect to FIGS. **3**B through **3**E, the wellbore fluid that migrated into sealing chamber housing **51** will be blocked by labyrinth discs **61** and unable to find a direct path through sealing chamber assembly **15**. Instead, the wellbore fluid must traverse a tortuous flow path through the misaligned vent passages **67**; thus, decreasing instances of contamination of the lubricating fluid in thrust bearing **13**. This will help to decrease the rate of lubricating fluid deterioration. Similarly, lubricating fluid in thrust bearing **13** that migrates out of thrust bearing **13** into sealing chamber assembly **15** will be inhibited from free flowing from thrust bearing **13**. Vent passages **67** will aid in keeping the pressure within sealing chamber assembly **15** and thrust bearing module **11** uniform throughout the module.

[0038] Referring to FIG. **3**G, in an alternative embodiment of labyrinth disc **61**, vent passage **67'** extends between first surface **69** and second surface **71** of labyrinth disc **61** as described above with respect to FIG. **3**A. Vent passage **67'** defines a fluid flow path through labyrinth disc **61** that requires the fluid to make at least two turns as it flows from the second surface **71** to the first surface **69**.

[0039] Referring to FIG. **3**H, in another embodiment of labyrinth disc **61**, labyrinth disc **61'** includes the elements of labyrinth disc **61** of FIG. **3**A. In the alternative embodiment, second surface **71'** is perpendicular to cooling chamber shaft **57**. Referring to FIG. **3**I, in yet another embodiment of labyrinth disc **61**, labyrinth disc **61"** includes the elements of labyrinth disc **61** of FIG. **3**A. In the alternative embodiment, second surface **71"** is convex, again facilitating removal of air during manufacture. Vent passage **67"** may be oriented to extend from second surface **71"** proximate to annular protrusion **73** to first surface **69** proximate to sealing chamber shaft **57**. In each alternative embodiment, labyrinth discs **61** may be clocked as described above with respect to FIGS. **3**C-**3**F.

[0040] Referring to FIG. **4**, there is shown thrust bearing assembly **13** assembled to sealing chamber assembly **15** and cooling chamber assembly **17**. Thrust bearing assembly **13** includes a thrust runner **77**, up thrust bearings **79**, and primary thrust bearings **81**. Thrust runner **77** mounts to cooling chamber shaft **31** such that as cooling chamber shaft **31** rotates, thrust runner **77** will rotate within a thrust housing **83** coupling pump housing **21** to first end **53** of sealing chamber assembly **15**. Thrust runner **77** has an exterior diameter slightly smaller than the inner diameter of thrust housing **83**, such that fluid may flow between the exterior diameter surfaces of thrust runner **77** and the interior diameter surface of thrust housing **83**. During operation, thrust generated by an electric submersible pump (not shown) will force thrust runner **77** against primary bearings **81** as cooling chamber shaft **31** rotates. Fluid circulated by pump **43** will wedge between the interfacing surfaces of thrust runner **77** and primary bearings **81**, lubricating the bearing surfaces and absorbing the heat generated by the frictional forces between thrust runner **77** and primary bearings **81**.

[0041] During operation of thrust bearing module **11**, rotating shaft seal **59** proximate to sealing chamber end **53** will seal sealing chamber shaft **57**; thus, preventing migration of lubricating fluid in thrust bearing assembly **13** into sealing chamber assembly **15**. Similarly, rotating shaft seal **59** proximate to sealing chamber end **55** will seal sealing chamber shaft **57**; thus, preventing migration of wellbore fluid outside of thrust bearing assembly **11** into sealing chamber assembly **15**. However, pressure differences between the operating components, such as the thrust bearing assembly **13** and the sealing chamber assembly **15** may cause lubricating fluid in thrust bearing assembly **13** to migrate past rotating shaft seal **59** into sealing chamber assembly **15**. Similarly, pressure differences between the operating environment and the sealing chamber assembly **15** may cause migration of wellbore fluid past rotating shaft seal **59** into sealing chamber assembly **15**.

[0042] Additionally, lubricating fluid and wellbore fluid may migrate past or leak past check valves **58**, **60**, **62**, **64** into sealing chamber assembly **15**. Still further, pressurization issues, such as extreme over pressurization or under pressurization may cause check valves **58**, **60**, **62**, **64** to open allowing flow into sealing chamber assembly **15** or out of sealing chamber assembly **15**. Any wellbore fluid or lubricating fluid that migrates into sealing chamber assembly **15** will comingle with a high temperature blocking fluid filling areas between each labyrinth disc **61**. Labyrinth discs **61** will allow fluid flow only through vent passages **67**. The "clocking" of the vent passages will necessitate that any fluids that migrate into sealing chamber assembly **15** will be unable to flow directly from end **55** to end **53** and vice versa. Instead the flow must move through vent passages **67** first at an upper end then, off to a side and so on. In addition, because vent passages **67** do not pass through labyrinth discs **61** parallel to rotating shaft **57**, fluid migrated into sealing chamber assembly **15** will have increased difficulty traversing across each labyrinth disc. Thus, labyrinth discs **61** will limit the amount of intermingling or contamination of lubricating fluid in thrust bearing **13** and cooling chamber assembly **17** caused by pressurization issues within thrust bearing module **11**.

[0043] With reference now to FIG. **6**, an example of an electrical submersible pumping (ESP) system **85** is shown in a side partial sectional view. ESP **85** is disposed in a wellbore **87** that is lined with casing **89**. In the embodiment shown, ESP **85** comprises a motor **91**, a thrust module **11** attached to an uphole end of the motor **91**, and a pump **93** above thrust module **11**. Fluid inlets **95** shown on the outer housing of pump **93** provide an inlet for wellbore fluid **97** in wellbore **87** to enter into pump section **93**. A gas separator (not shown) could be mounted between thrust module **11** and pump section **93**. A pressure equalizer **94**, such as a metal bellows, may be mounted below the motor to reduce a pressure differential between lubricant in the motor and wellbore fluid **97**. In the illustrated embodiment, ESP **85** is in a horizontal placement within wellbore **87**. A person skilled in the will understand that ESP **85** may also be in a vertical placement within wellbore **87**.

[0044] In an example of operation, pump motor **91** is energized via a power cable **99** and rotates an attached shaft assembly **101** (shown in dashed outline). Although shaft **101** is illustrated as a single member, it should be pointed out that shaft **101** may include cooling chamber shaft **31** and sealing chamber shaft **57** of FIG. **1**. As shown in FIG. **6**, shaft assembly **101** extends from motor **91** through thrust module **11** to pump section **93**. Impellers **103** (also shown in dashed outline) within pump section **93** are coupled to an upper end of shaft **101** and rotate in response to shaft **101** rotation. Impellers **103** comprise a vertical stack of individual members alternatingly interspaced between static diffusers (not shown). Wellbore fluid **97**, which may include liquid hydrocarbon, gas hydrocarbon, and/or water, enters wellbore **87** through perforations **105** formed through casing **89**. Wellbore fluid **97** is drawn into pump **93** from inlets **95** and is pressurized as rotating impellers **103** urge wellbore fluid **97** through a helical labyrinth upward through pump **93**. The pressurized fluid is directed to the surface via production tubing **107** attached to the upper end of pump **93**. As impellers **103** urge wellbore fluid **97** upward impellers **103** generate a thrust in the opposite direction that is reacted to by thrust runner **77** of FIG. **1** and FIG. **5**.

[0045] Embodiments of the present invention may comprise only cooling chamber assembly **17**. As shown in FIG. **7**, a cooling chamber assembly **109** includes a heat exchanger assembly **111**, and a guide assembly **113**. Heat exchanger assembly **111** forms one end of cooling chamber assembly **109** and includes a cooling chamber base **115**, a heat exchange housing **117**, and an interior housing **119**. Heat exchange housing **117** and interior housing **119** are tubular members with interior housing **119** having a smaller diameter than heat exchange housing **117** such that when interior housing **119** is inserted into heat exchange housing **117** and mounted to cooling chamber base **115**, an annular fluid reservoir chamber **121** will be formed between heat exchange housing **117** and interior housing **119**. A cooling chamber shaft **123** passes through cooling chamber base **115** and inner diameter housing **119** to form an annular flow passage **125**. Interior housing **119** includes openings **127** proximate to cooling chamber base **115**. Openings **127** pass through a wall of interior housing **119**, thereby allowing flow of fluid from fluid reservoir **121** into fluid flow passage **125**. In the illustrated embodiment, filters **129** are mounted over openings **127** to prevent the passage of particles larger than a predetermined size from fluid reservoir **121** into fluid flow passage **125**. In the illustrated embodiment, filters **129** may be plated metal filter elements. A person skilled in the art will understand that the filters **129** may comprise wrapped screen or other unspecified filter media designed to prevent flow of particulates from fluid reservoir **121** into flow passage **125**. Cooling chamber shaft **123** is supported by a bearing **131** within cooling chamber base **115** and has a splined end for coupling to additional equipment.

[0046] Guide assembly **113** mounts to heat exchanger assembly **111** opposite cooling chamber base **115**. Guide assembly **113** includes a pump housing **135** that mounts to heat exchange housing **117** and interior housing **119**. Pump housing **135** defines an annular flow passage **137** positioned to allow flow of fluid from an area proximate to a thrust bearing assembly **139** into fluid reservoir chamber **121**. Pump housing **135** further defines a pump chamber **141**. Pump chamber **141** is coaxial with annular flow passage **137**. In the illustrated embodiment, guide assembly **113** includes a guide vane type pump **43** mounted to cooling chamber shaft **123** within pump chamber **141**. The pitch of pump **143** is selected base on the fluid viscosity and the resonance time necessary to maximize the heat transfer from the circulating fluid to heat exchange housing **117** within fluid reservoir **121**.

[0047] Heat exchange housing **117** includes a plurality of fins **145** formed on an exterior diameter portion of heat exchange housing **117**. Fins **145** run the length of heat exchange housing **117** and conduct heat from fluid reservoir **121** through a wall of heat exchange housing **117** into the environment surrounding cooling chamber assembly **109**. In the illustrated embodiment, fins **145** are of a number, size, and shape such that fins **145** double the exterior surface area of heat exchange housing **117** over a heat exchange housing **117** without fins **145** without increasing the exterior diameter of the assembly. A person skilled in the art will understand that the number, size, and shape of fins **145** may be varied to accommodate the particular application of cooling chamber assembly **109**.

[0048] A thrust bearing **139** will couple to an end of cooling chamber assembly **109** proximate to pump assembly **113**. Thrust bearing **139** includes a thrust runner **147**, up thrust bearings **149**, and primary thrust bearings **151**. Thrust runner **147** mounts to cooling chamber shaft **123** such that as cooling chamber shaft **123** rotates, thrust runner **147** will rotate within a thrust housing **153** coupling pump housing **135** to a thrust bearing head **155**. Thrust bearing head **155** includes an end adapted to receive and allow coupling of a rotating shaft from a subsequent assembly, such as a another thrust bearing assembly or a sealing chamber assembly. Thrust runner **147** has an exterior diameter slightly smaller than the inner diameter of thrust housing **153**, such that fluid may flow past thrust runner **147** between the exterior diameter surfaces of thrust runner **147** and the interior diameter surface of thrust housing **153**. During operation, thrust generated by an electric submersible pump (not shown) will force thrust runner **147** against primary bearings **151** as cooling chamber shaft **123** rotates. Fluid circulated by pump **143** will wedge between the interfacing surfaces of thrust runner **147** and primary bearings **151**, lubricating the bearing surfaces and absorbing the heat generated by the frictional forces between thrust runner **147** and primary bearings **151**. The embodiment of FIG. **7** does not intend a seal section such as seal chamber assembly **15** of FIG. **3**A.

[0049] In operation of cooling chamber assembly **109**, cooling chamber shaft **123** rotates in response to rotation of an ESP pump motor (not shown). Rotation of cooling chamber shaft **123** causes pump **143** to rotate. As pump **143** rotates it will draw fluid from fluid passageway **125** through pump chamber **141** and then through thrust bearing assembly **139** along a pathway similar to that illustrated in FIG. **5**. Referring to FIG. **7**, fluid within thrust bearing assembly **139** will be forced through flow passage **137** into fluid reservoir **121**, and fluid within fluid reservoir **121** will circulate across filters **129** through openings **127** into flow passage **125**. As fluid flows through thrust bearing assembly **139**, heat generated through operation of thrust bearing assembly **139** will transfer into the fluid, thereby heating the fluid. This fluid will then flow into fluid reservoir **121** where the heat will transfer from the fluid into heat exchange housing **117**. The heat is then conducted by heat exchange housing **117** through fins **145** and into the ambient environment.

[0050] Other embodiments of the present invention may include only sealing chamber assembly **15** and not a cooling chamber **17**. As illustrated in FIG. **8**, a sealing chamber assembly **157** includes a chamber housing **159**. Chamber housing **159** includes first and second ends **161**, **163** adapted to couple sealing chamber assembly **157** to an external device such as an electric motor, another sealing chamber assembly **157**, a thrust bearing module **11**, a thrust bearing, or the like. In the illustrated embodiment, first end **161** is adapted to insert into an end module of a subsequent device, and second end **163** is adapted to receive an end module of a subsequent device. A sealing chamber shaft **165** is supported within sealing chamber assembly **157** at first end **161** and second end **163**. Sealing chamber shaft **165** may rotate and may have splined ends for coupling to additional rotating shafts such that rotation of shaft **165** will cause rotation of the additional shafts and vice versa. Rotational shaft seals **167** will support sealing chamber shaft **165** within ends **161**, **163**. Rotational shaft seals **167** allow shaft **165** to rotate within sealing chamber assembly **159**, while preventing wellbore fluids from passing along shaft **165** to the subsequent pump element, such as the electric motor.

[0051] Sealing chamber assembly **157** can include a plurality of labyrinth discs **169**. Each labyrinth disc **169** mounts within sealing chamber housing **159** and seals to sealing chamber housing **159** and sealing chamber shaft **165**. Labyrinth discs **169** seal to sealing chamber shaft **165** with lip seals **171**. Each labyrinth disc **169** includes the components of and operates as labyrinth discs **61** of FIGS. **3**A-**3**I.

[0052] Accordingly, the disclosed embodiments provide numerous advantages. For example, the disclosed embodiments provide a thrust module for an ESP with improved lubrication of the thrust bearing. In addition, the disclosed embodiments provide a thrust module that increases the rate of heat transfer from the thrust bearing to the surrounding environment while also filtering particles from the lubricating fluid. This is accomplished by a finned cooling chamber housing that is maintained within the primary outer diameter of the thrust module assembly. This decreases the wear on the thrust bearing and increases the longevity of the thrust bearing by decreasing the rate of break down of the lubricating fluid. In addition, the disclosed embodiments provide an improved sealing chamber assembly that provides additional redundancy to reduce the likelihood that wellbore fluid will migrate into the thrust module and ultimately the electric motor providing mechanical energy to the thrust module. Furthermore, the labyrinth sealing assembly decreases the rate of migration of assembly fluid into the surrounding wellbore. This will decrease the amount of any maintenance needed for the thrust bearing and the electric motor, while also increasing the useful life of the ESP.

[0053] It is understood that the present invention may take many forms and embodiments. Accordingly, several variations may be made in the foregoing without departing from the spirit or scope of the invention. Having thus described the present invention by reference to certain of its preferred embodiments, it is noted that the embodiments disclosed are illustrative rather than limiting in nature and that a wide range of variations, modifications, changes, and substitutions are contemplated in the foregoing disclosure and, in some instances, some features of the present invention may be employed without a corresponding use of the other features. Many such variations and modifications may be considered obvious and desirable by those skilled in the art based upon a review of the foregoing description of preferred embodiments. Accordingly, it is appropriate that the appended claims be construed broadly and in a manner consistent with the scope of the invention.

What is claimed is:

1. A submersible pump assembly comprising:
- a rotary primary pump;
- a motor operationally coupled to the primary pump for driving the pump;
- a thrust bearing in a thrust bearing chamber between the motor and the primary pump that absorbs thrust from the primary pump;
- a seal assembly coupled to the thrust bearing; and
- a circulation pump in the thrust bearing chamber in fluid communication with the thrust bearing to circulate fluid through the thrust bearing; and
- a cooling chamber having a plurality of fins formed on an exterior portion of the cooling chamber to dissipate heat generated in the thrust bearing, the circulation pump in fluid communication with the cooling chamber to circulate fluid from the thrust bearing through the cooling chamber.

2. The submersible pump assembly of claim **1**, further comprising a pressure equalizer mounted below the motor.

3. The submersible pump assembly of claim **1**, further comprising:
- a heat exchange housing having an exterior containing the plurality of fins;
- a rotating shaft passing through a center of the heat exchange housing and rotated in response to operation of the motor; and
- wherein the circulation pump is coupled to and rotated by the rotating shaft.

4. The submersible pump assembly of claim **3**, further comprising:
- a flow path extending from the circulation pump to the thrust bearing; and
- a filter element in the flow path to remove particles from the circulating fluid.

5. The submersible pump assembly of claim **1**, wherein the seal assembly comprises
- a sealing chamber housing;
- a sealing chamber rotating shaft supported within the sealing chamber housing and driven by the motor;
- a plurality of labyrinth discs mounted in sealing engagement with but non-rotating engagement with the sealing

chamber rotating shaft, each labyrinth disc having a periphery that seals to the sealing chamber housing and to the sealing chamber rotating shaft, thereby dividing the sealing chamber housing into chambers between each labyrinth disc;

at least one well fluid inlet in the sealing chamber housing;

a plurality of one-way check valves positioned within the sealing chamber housing so that fluid may flow into and out of the sealing chamber housing at a predetermined pressure; and

the labyrinth discs further contain ports that provide a tortuous fluid flow path for well fluid through the labyrinth discs.

6. The submersible pump assembly of claim **5**, wherein each labyrinth disc has a concave profile on a surface perpendicular to a sealing chamber shaft axis and proximate to the thrust bearing.

7. The submersible pump assembly of claim **5**, wherein each labyrinth disc has a convex profile on a surface perpendicular to a sealing chamber shaft axis and proximate to the thrust bearing.

8. The submersible pump assembly of claim **5**, wherein the port of each labyrinth disc extends from an area proximate to the sealing chamber housing on a first surface to an area proximate to the sealing chamber rotating shaft on a second surface.

9. The submersible pump assembly of claim **8**, wherein the port of each labyrinth disc includes at least two right angle turns.

10. The submersible pump assembly of claim **5**, wherein ports of adjacent discs are misaligned with each other.

11. The submersible pump assembly of claim **5**, wherein the plurality of one way valves comprise two check valves allowing fluid flow into the sealing chamber housing and two check valves permitting fluid flow out of the sealing chamber housing.

12. A submersible pump assembly comprising:

a rotary primary pump;

a motor operationally coupled to the primary pump for driving the pump;

a thrust bearing in a thrust bearing chamber between the motor and the primary pump that absorbs thrust from the primary pump; and

a circulation pump in the thrust bearing chamber in fluid communication with the thrust bearing to circulate fluid through the thrust bearing;

the thrust bearing chamber having a heat exchange housing defining a cooling chamber;

wherein the heat exchange housing has a plurality of fins formed on an exterior portion of the heat exchange housing to dissipate heat generated in the thrust bearing, the circulation pump in fluid communication with the cooling chamber to circulate fluid from the thrust bearing through the cooling chamber;

a rotating shaft passing through a center of the heat exchange housing and rotated in response to operation of the motor; and

wherein the circulation pump is coupled to and rotated by the rotating shaft.

13. The submersible pump assembly of claim **12**, further comprising a pressure equalizer mounted below the motor.

14. The submersible pump assembly of claim **12**, further comprising:

a flow path extending from the circulation pump to the thrust bearing; and

a filter element in the flow path to remove particles from the circulating fluid.

15. A submersible pump assembly comprising:

a rotary primary pump;

a motor operationally coupled to the primary pump for driving the pump;

a sealing chamber housing coupled between the motor and the primary pump;

a sealing chamber rotating shaft supported within the sealing chamber housing and driven by the motor;

a plurality of labyrinth discs mounted in sealing engagement with but non-rotating engagement with the sealing chamber rotating shaft, each labyrinth disc having a periphery that seals to the sealing chamber housing and to the sealing chamber rotating shaft, thereby dividing the sealing chamber housing into chambers between each labyrinth disc;

at least two check valves allowing fluid flow into the sealing chamber housing and at least two check valves permitting fluid flow out of the sealing chamber housing positioned within the sealing chamber housing so that fluid may flow into and out of the sealing chamber housing at predetermined pressures; and

the labyrinth discs further contain ports extending from an area proximate to the sealing chamber housing on a first surface to an area proximate to the sealing chamber rotating shaft on a second surface such that the ports provide a tortuous fluid flow path for well fluid through the labyrinth discs.

16. The submersible pump assembly of claim **15**, further comprising a pressure equalizer mounted below the motor.

17. The submersible pump assembly of claim **15**, wherein each labyrinth disc has a concave profile on a surface perpendicular to a sealing chamber shaft axis and proximate to the thrust bearing.

18. The submersible pump assembly of claim **15**, wherein each labyrinth disc has a convex profile on a surface perpendicular to a sealing chamber shaft axis and proximate to the thrust bearing.

19. The submersible pump assembly of claim **15**, wherein the port of each labyrinth disc includes at least two right angle turns.

20. The submersible pump assembly of claim **15**, wherein ports of adjacent discs are misaligned with each other.

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