July 18, 1961 H. E. MEANS 2,992,618

LIQUID-METAL PUMP SEAL

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FIG. 1

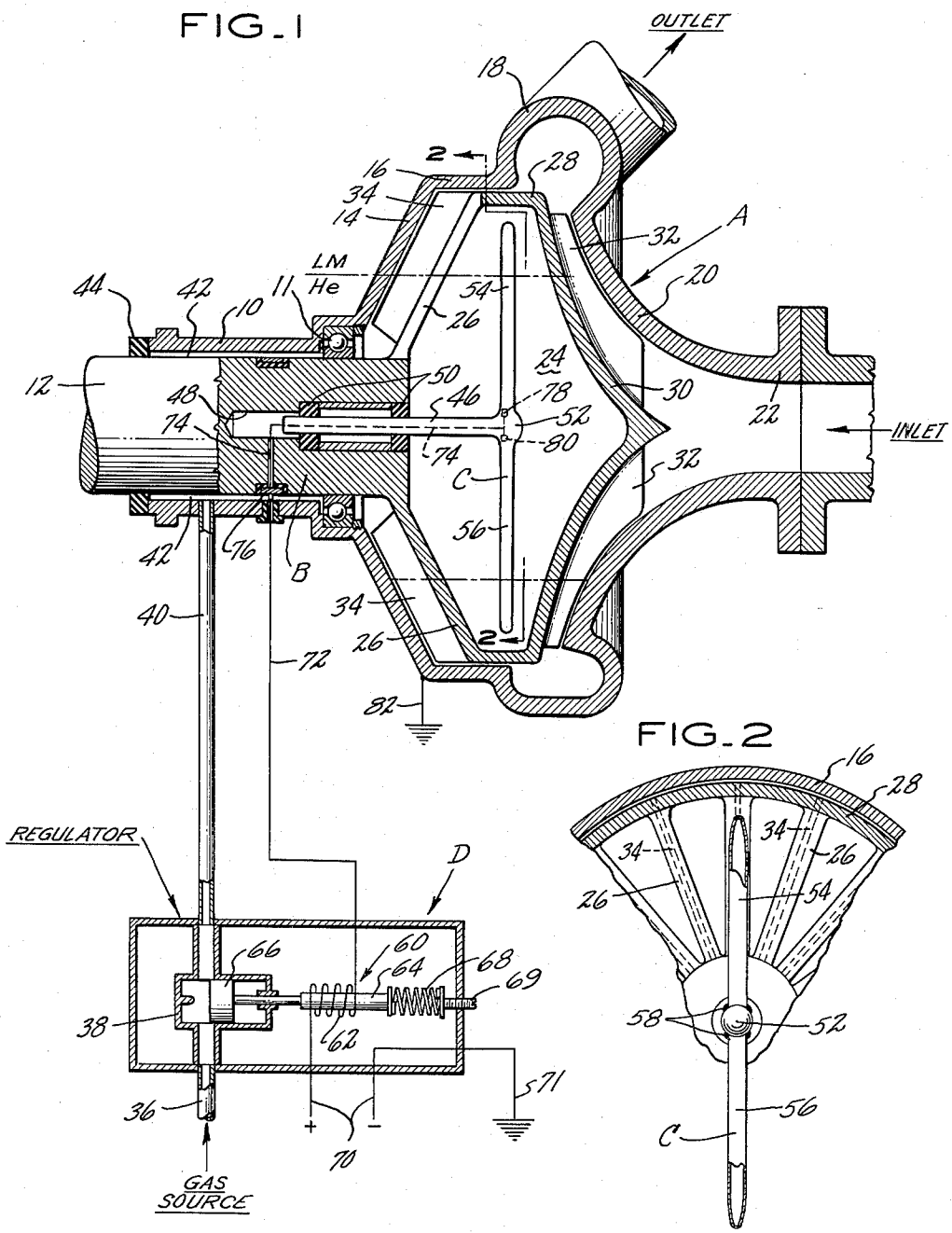


FIG. 2

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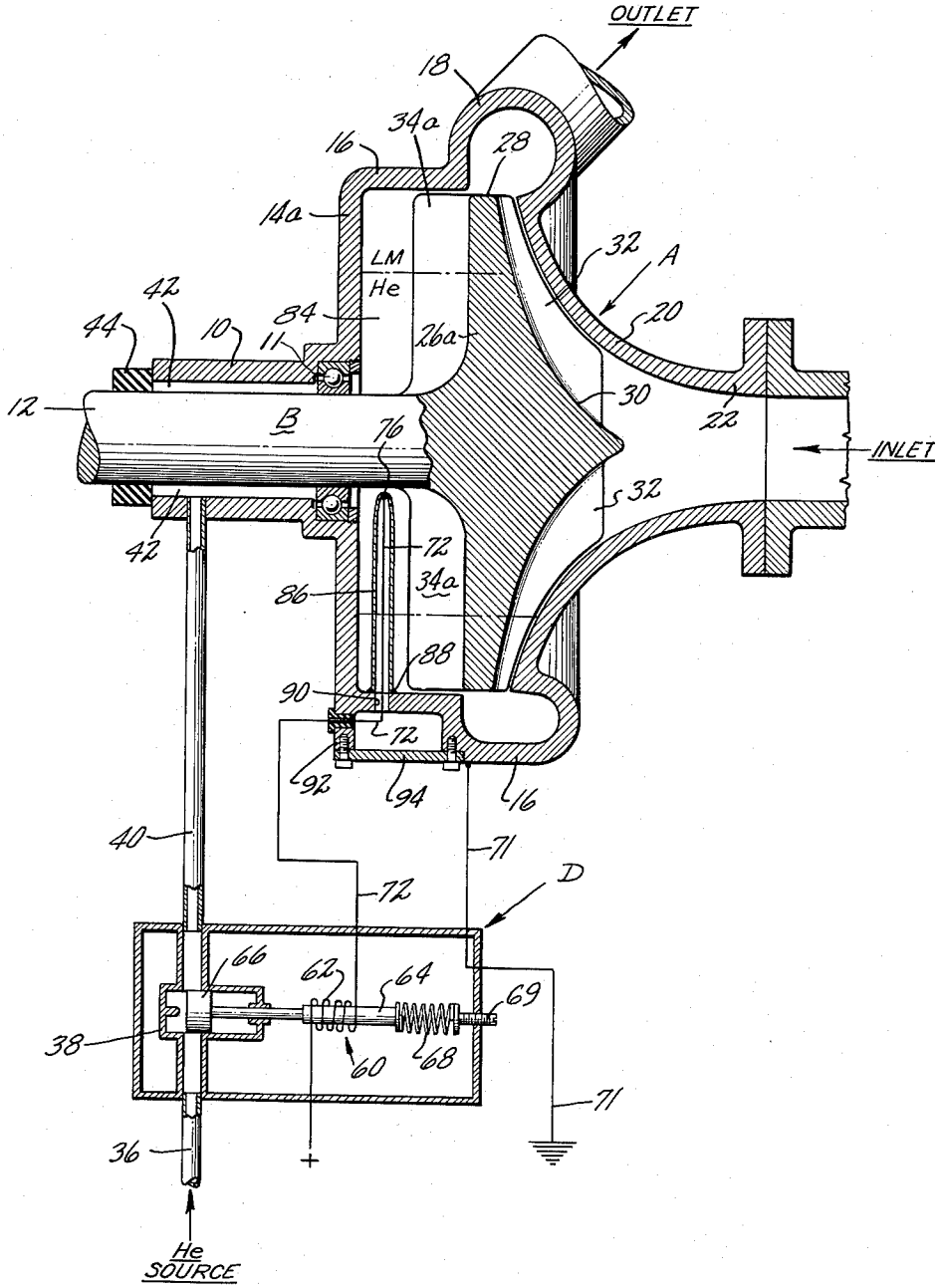
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FIG_3



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2,992,618

LIQUID-METAL PUMP SEAL

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12 Claims. (Cl. 103—103)

This invention relates to centrifugal pumps and particularly to dynamic gas seals for high-temperature liquid-metal pumps of this type.

It is an object of this invention to provide improved means for maintaining a predetermined location for the interface between the liquid metal and the gas in such a pump.

More specifically, it is an object of this invention to provide a dynamic seal chamber back of the impeller in which a resistance probe is located which controls the admission of gas into the seal chamber.

Another object of this invention is to provide a self-cleaning rotary probe in such a pump.

A further object of the invention is generally to improve the construction and operation of centrifugal pumps.

These and other objects and advantages of the invention will be evident or will be pointed out in connection with a detailed description of two embodiments of the invention shown in the accompanying drawings. In these drawings:

FIG. 1 is a longitudinal sectional elevation of the improved pump;

FIG. 2 is a section taken along line 2—2 of FIG. 1 showing a front view of the probe; and

FIG. 3 is a longitudinal sectional elevation of a modified construction utilizing a stationary probe.

As herein shown, the pump includes a stationary housing A, a rotating shaft and impeller unit B, a resistance probe C, and control mechanism including a regulator D.

The housing includes a tubular sleeve **10** in which the shaft **12** is journalled in bearings, one of which is shown at **11**. The housing further includes an oblique wall portion **14** which carries an integral annular housing portion **16**. The portion **16** merges into an annular volute **18** which constitutes the pump-discharge chamber. Formed integral with the volute **18** is a curved somewhat conical portion **20** which terminates in a flanged inlet **22**.

Shaft **12** extends into the pump chamber and carries at its extended end a hollow impeller which forms a probe chamber **24**. The impeller consists of a plurality of oblique radial ribs **26** carried by shaft **12**, a cylindrical, peripheral portion **28** and a generally conical disc portion **30** adjacent to the inlet **22**. This portion **30** carries the pump vanes **32** and the ribs **26** carry back vanes **34**.

The peripheral portion **28** of the impeller has a very close clearance with the cylindrical portion **16** of the housing. Thus, the impeller disc **30** and its peripheral ring **28**, together with housing portion **14**, form a dynamic seal chamber in which the back vanes are located. A certain amount of liquid metal in the high-pressure discharge volute **18** leaks past the impeller periphery into the seal chamber. Means are provided, including a source of inert gas under pressure, to form a dynamic seal in the seal chamber back of the impeller disc. To this end the inert gas, herein helium, from a pressure source (not shown) is supplied through a conduit **36** to a valve **38** in regulator D, from which it passes through a conduit **40** into the space **42** between the housing sleeve **10** and the shaft **12**. This space has been somewhat exaggerated in the drawing for purposes of illustration. The helium flows along the annular passage between housing sleeve **10** and shaft **12** through the bearing **11** into the seal chamber back of impeller disc **30** where it opposes the body of liquid metal which is actuated by centrifugal force to form the annular

helium-liquid-metal interface, as shown in FIG. 1. An annular seal **44** is provided on shaft **12** against which the end of sleeve **10** abuts to prevent the escape of helium rearwardly along shaft **12**.

In the embodiment of FIG. 1 a two-armed resistance probe C is located in the probe chamber **24**. This consists of an axial tubular supporting shaft **46** which is mounted in an axial recess **48** in shaft **12** on two insulating supporting rings **50** which support the shaft **46** concentrically with shaft **12** and effect rotation of the probe with the shaft. Shaft **46** has a hub **52** in the probe chamber to which two resistance probes **54** and **56** are secured as by welding at **58** (FIG. 2). These probes are tubular members closed at their extremities and are formed of some suitable material having high electrical resistance.

The regulator D also includes a solenoid **60** having a winding **62** and a core **64**. The core **64** is connected to a piston **66** of valve **38** to control the flow of helium through the valve, a compression spring **68** being provided to bias the movable valve **66** constantly into a closed position against a stop. A direct current electrical circuit **70** has one side thereof grounded at **71**. The solenoid **60** is included in series in the other side of this circuit which includes a conductor **72** which is connected to a conductor **74** in the rotating shaft **12** through a slip ring **76**. The conductor **74** extends through the hollow shaft **46** and is connected at **78** and **80** to the base of probes **54** and **56**. The pump housing A is grounded at **82**.

In operation, the liquid metal that has leaked through the annular passage between the periphery **28** of the impeller disc and the casing portion **16**, forms an annular body which is held in position in the periphery of the seal chamber, as shown in FIG. 1, by centrifugal force. The position of the liquid-metal-helium interface, however, is determined by the pressure of the helium gas in the probe chamber. In other words, the amount of liquid metal which can leak through into the seal chamber is directly dependent upon the helium pressure maintained in the seal chamber.

The helium supply to the seal chamber is normally shut off by the action of compression spring **68** on the movable valve member **66**. Assuming that the pump is rotating and liquid metal begins to leak slowly into the seal chamber, it will be evident that as the ends of the probes **54** and **56** become immersed in the liquid metal, the resistance in the circuit **70** will be decreased since the liquid metal has a lower electrical resistance than the material of the probe. As a result more current will flow in the circuit **70** and solenoid coil **62** will open the movable valve member **66** to admit helium to the seal chamber until sufficient helium pressure has been built up to balance the pressure of the liquid metal leaking into the seal chamber.

It will thus be evident that the liquid-metal-helium interface can be held at any selected level in the seal chamber and that this level can be changed by adjusting the force of spring **68** as provided for by screw **69**. It will further be evident that an accurate positioning of the liquid-metal-helium interface is possible as a result of the rotating probes which due to their rotation are self-cleaning and hence have a constant resistance per unit length.

It will be understood that a single probe could be used as far as the electrical considerations are concerned. The use of two diametrically opposite probes, however, produces a dynamically balanced construction.

In FIG. 3 a somewhat modified arrangement is shown utilizing a single stationary probe. Here a generally similar housing A is provided for the rotating shaft and impeller B, except that the oblique housing portion **14** of FIG. 1 is made into a radial casing wall **14*a*** and the back vanes **34*a*** are likewise radial. In this way an annular space **84** is provided in the seal chamber between the back vanes **34*a*** and the casing portion **14*a***.

A single resistance probe 86 is provided in this space having its base welded at 88 to the cylindrical housing portion 16 in a fluid-tight manner. A passage 90 through the housing in alignment with the probe is enclosed by a nipple 92 having a cover 94. The probe 86 is tubular and of high electrical resistance similar to one of the probes 54 and 56 in FIG. 1. In this instance, however, the conductor 72 is extended through the probe to its closed extremity where it is connected to the probe at 76.

In the operation of this modified form, as fluid in the high-pressure discharge chamber 18 leaks past the impeller disc into the seal chamber, it gradually immerses the base of the probe 86, reducing the resistance of the circuit including solenoid coil 62. As a result, more current will flow in the circuit and the solenoid will move the movable valve member 66 in a valve-opening direction to admit helium through pipe 40 into the space 42 between the housing sleeve 10 and the shaft 12. This will cause the helium pressure to build up in the seal chamber and oppose further leakage of liquid metal into the chamber.

While a direct current control circuit has been shown and described herein for purposes of simplicity, it will be understood that an alternating circuit can be used if desired. The particular circuit used forms no part of the present invention since resistance probes and their circuits are well-known in the instrumentation art. For a complete showing of a high-resistance probe and its alternating current circuit, see pages 348 and 349 of the Liquid-Metals Handbook—Sodium-NaK Supplement, July 1, 1955, Atomic Energy Commission, Department of the Navy, Washington, D.C.

It will be evident that by this invention means has been provided for automatically maintaining the liquid-metal-helium interface in the seal chamber of a centrifugal pump at the desired level while the pump is stationary during filling as well as during rotation. In this connection it should be noted that these pumps are usually vertically mounted and are located at the top of the liquid-metal circulating system. When, in filling the system, the liquid metal rises to the level of the probe, the sudden decrease in resistance in the probe circuit automatically admits the gas to balance the liquid metal and stops filling. It will further be evident that this has been accomplished in a simple inexpensive mechanism which is free from trouble in operation.

While only two embodiments of the invention have been shown herein, it will be understood that various changes may be made in the construction and arrangement of the parts within the scope of the invention.

I claim:

1. In a centrifugal pump for liquid metal, a housing, an impeller in said housing, a dynamic seal for the liquid metal including a source of helium under pressure, means to establish a helium-liquid-metal interface in said pump housing, and means for maintaining said interface at a predetermined level including an electric circuit including a resistance probe in said housing having one end immersed in the liquid metal forming said interface, said circuit also including means responsive to variations in resistance of said probe as the level of said interface varies for controlling the admission of helium to said housing.

2. In a centrifugal pump for liquid metal, a housing, an impeller having a disc dividing said housing into a pumping chamber and a seal chamber, said impeller having pumping vanes in said pumping chamber and back vanes in said seal chamber, means for admitting an inert gas under pressure into said seal chamber to oppose the body of liquid metal therein which has leaked into said seal chamber from said pumping chamber, a valve controlling the admission of said gas, a resistance probe having one end thereof normally immersed in said body of leakage fluid, and an electric circuit including said probe and having means therein responsive to changes in resistance of said probe for controlling said valve.

3. In a centrifugal pump, a housing, a shaft journalled in said housing having one end extended into said housing, an impeller disc on the extended end of said shaft dividing said housing into a pumping chamber and a dynamic seal chamber, pumping vanes on one side of said impeller disc in said pumping chamber, back vanes on the other side of said disc in said seal chamber, means including a supply of helium under pressure for introducing helium into said seal chamber to oppose the liquid metal which has leaked past said impeller disc into said seal chamber, resistance probe means in said seal chamber having one end immersed in the liquid metal in said chamber, and means responsive to a decrease in resistance of said probe due to an increase in liquid-metal leakage for admitting helium into said chamber.

4. In combination, a pump housing, a shaft having one end extended into said housing, an impeller on the extended end of said shaft having an impeller disc dividing the interior of said housing on opposite sides of said disc into a pumping chamber and a seal chamber, discharging pumping vanes in said pumping chamber and back vanes in said seal chamber, means including a supply of inert gas under pressure for admitting gas to said seal chamber to oppose pumped fluid which has leaked into said seal chamber, said means including a regulating valve in the gas line leading to said chamber, and a resistance probe having one end thereof immersed in said leakage fluid, an electric circuit including said probe, and means responsive to changes in resistance of said probe for actuating said valve to maintain a predetermined constant level of leakage fluid in said seal chamber.

5. A system for maintaining the surface of leakage fluid in a chamber of a pump housing at a predetermined level including a resistance probe having one end immersed in the leakage fluid in said chamber, a source of inert gas under pressure, a valve controlling the admission of said gas to said chamber, and an electric circuit including said probe, said circuit also including means responsive to changes in resistance of said probe due to variation in the level of said fluid for controlling the operation of said valve.

6. The combination in a liquid-metal pump of a pump housing, a shaft extended into said housing, an impeller disc mounted on the extended end of said shaft for rotation therewith, said housing having an axial inlet and an annular high-pressure outlet located on one side of said impeller disc, said disc dividing said housing into a pumping chamber and an annular seal chamber on the other side of said disc, back vanes on said disc in said seal chamber, pumping vanes on the inlet side of said disc in said pumping chamber, dynamic seal means in said seal chamber including a helium inlet to said seal chamber for forming a liquid-metal-helium interface with the liquid metal which leaks past said disc, and means for maintaining said interface at a predetermined level in said seal chamber including a resistance probe in said seal chamber in position to intersect said interface, a source of helium under pressure, a valve in said helium inlet, and electric circuit means including said probe responsive to changes in the level of said interface for operating said valve.

7. In a centrifugal pump for liquid metal, a housing, a shaft having one end extended into said housing, an impeller in said housing on the extended end of said shaft including an impeller disc dividing said housing into a high-pressure pumping chamber and a dynamic seal chamber, pumping vanes on said disc in said pumping chamber, back vanes on said disc in said seal chamber, means including a source of inert gas under pressure for supplying gas to said seal chamber, a valve controlling admission of said gas, a radial electrical-resistance probe in said seal chamber carried by said shaft and rotatable

therewith, and an electric circuit including said probe, said circuit also including means responsive to changes in the resistance of said probe as the helium-liquid-meal interface in said seal chamber varies for actuating said valve.

8. In a centrifugal pump for liquid metal, a housing, a pump shaft having one of its ends extended into said housing, an impeller in said housing on the extended end of said shaft including an impeller disc dividing said housing into a pumping chamber and a seal chamber, means including a source of inert gas under pressure for supplying gas to said seal chamber, a valve controlling admission of said gas, two diametrically opposed radial electrical-resistance probes in said seal chamber carried by said shaft and rotatable therewith, and an electrical circuit including said probes, said circuit also including means responsive to changes in the resistance of said probes as the gas-liquid-metal interface in said seal chamber varies for actuating said valve.

9. In a centrifugal pump for liquid metal, a housing, a pump shaft having one of its ends extended into said housing, an impeller in said housing on the extended end of said shaft including an impeller disc dividing said housing into a pumping chamber and a seal chamber, means including a source of inert gas under pressure for supplying gas to said seal chamber, a valve controlling admission of said gas, said shaft having a recess in its extended end, a hollow probe shaft mounted in said recess and insulated from said pump shaft, a hub on the end of said probe shaft, two diametrically opposite resistance probes carried by said hub and rotatable with said pump shaft, said probes having high electrical resistance, and an electrical circuit including a conductor connected to the base of said probes, and a solenoid operatively connected with said valve, said circuit also including the winding for said solenoid.

10. In a centrifugal pump for liquid metal, a housing, a shaft having one end extended into said housing, an impeller disc on the extended end of said shaft dividing said housing into a pumping chamber and a seal chamber, means for admitting an inert gas under pressure into said seal chamber to oppose the body of liquid metal which has leaked into said seal chamber, a valve controlling the admission of said gas, a resistance probe normally having its base immersed in the leakage metal and having its base secured to said housing and projecting radially from said liquid metal into said seal chamber, and an electric

circuit including a conductor connected to the tip of said probe and having means therein responsive to changes in resistance of said probe for controlling the operation of said valve.

11. A system for maintaining the surface of a rotating body of leakage fluid in a pump housing at a predetermined level including a hollow resistance probe closed at one end, said probe being mounted at its open end on said housing and projecting through the body of leakage metal into said housing chamber, a source of inert gas under pressure, a valve controlling the admission of gas to said chamber to oppose said body of rotating fluid, and an electric circuit including a conductor extended through said housing at the base of said probe and through said hollow probe and connected to the tip of said probe, said circuit also including electrical means responsive to changes in resistance of said probe due to variation in the level of said fluid for controlling the operation of said valve.

12. A system for maintaining the surface of a rotating body of leakage fluid in a pump housing chamber at a predetermined level including an elongated hollow resistance probe closed at one end, said probe being secured to said housing about an opening therein and extending through the rotating leakage fluid into said chamber, a source of inert gas under pressure, a valve controlling the admission of said gas to said chamber, a solenoid having a winding for opening said valve, and an electric circuit including a conductor extended through the opening in said housing through said hollow probe and electrically connected to said probe at its closed end, said solenoid winding also being included in said circuit.

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