United States Patent

[11] **3,574,473**

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[21] Appl. No. **793,839**
[22] Filed **Jan. 24, 1969**
[45] Patented **Apr. 13, 1971**

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[32] Priority **Jan. 24, 1968, July 5, 1968**
[33] Switzerland
[31] **1142-68 and 10105-68**

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[54] **METHOD AND APPARATUS FOR COOLING PARTS OF PUMPS IN NUCLEAR REACTORS OR THE LIKE**
10 Claims, 8 Drawing Figs.

[52] **U.S. Cl.** **415/1,** 415/175, 415/112
[51] **Int. Cl.** **F04d 29/00,** F01d 1/00
[50] **Field of Search** 103/111; 230/132; 415/112, 175, 180

[56] **References Cited**
UNITED STATES PATENTS

1,910,811	5/1933	Peterson	415/175
2,687,096	8/1954	Armacost	415/175
2,888,878	6/1959	Cobb	103/111
2,910,328	10/1959	Frolich	103/111
2,921,533	1/1960	Williams	415/112
2,960,938	11/1960	Williams	103/111
3,275,330	9/1966	Rein et al	103/111
3,213,798	10/1965	Carswell	103/111
3,257,957	6/1966	Tracy	103/111

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ABSTRACT: A nuclear reactor pump wherein the shaft seals and radial bearings are cooled by cold water which is circulated by thermosiphon action when the shaft is idle and the pump chamber contains hot fluid. Streams of cold water for cooling of the bearing and of the seals are caused to flow through a common main cooler and thereupon enter the pump housing by way of a common inlet to flow toward separate outlets. The channel for the stream which cools the seals contains several flow restrictors.

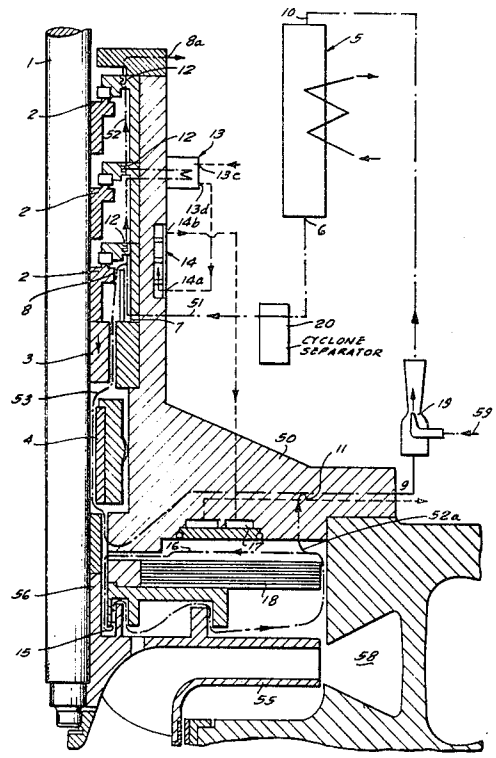
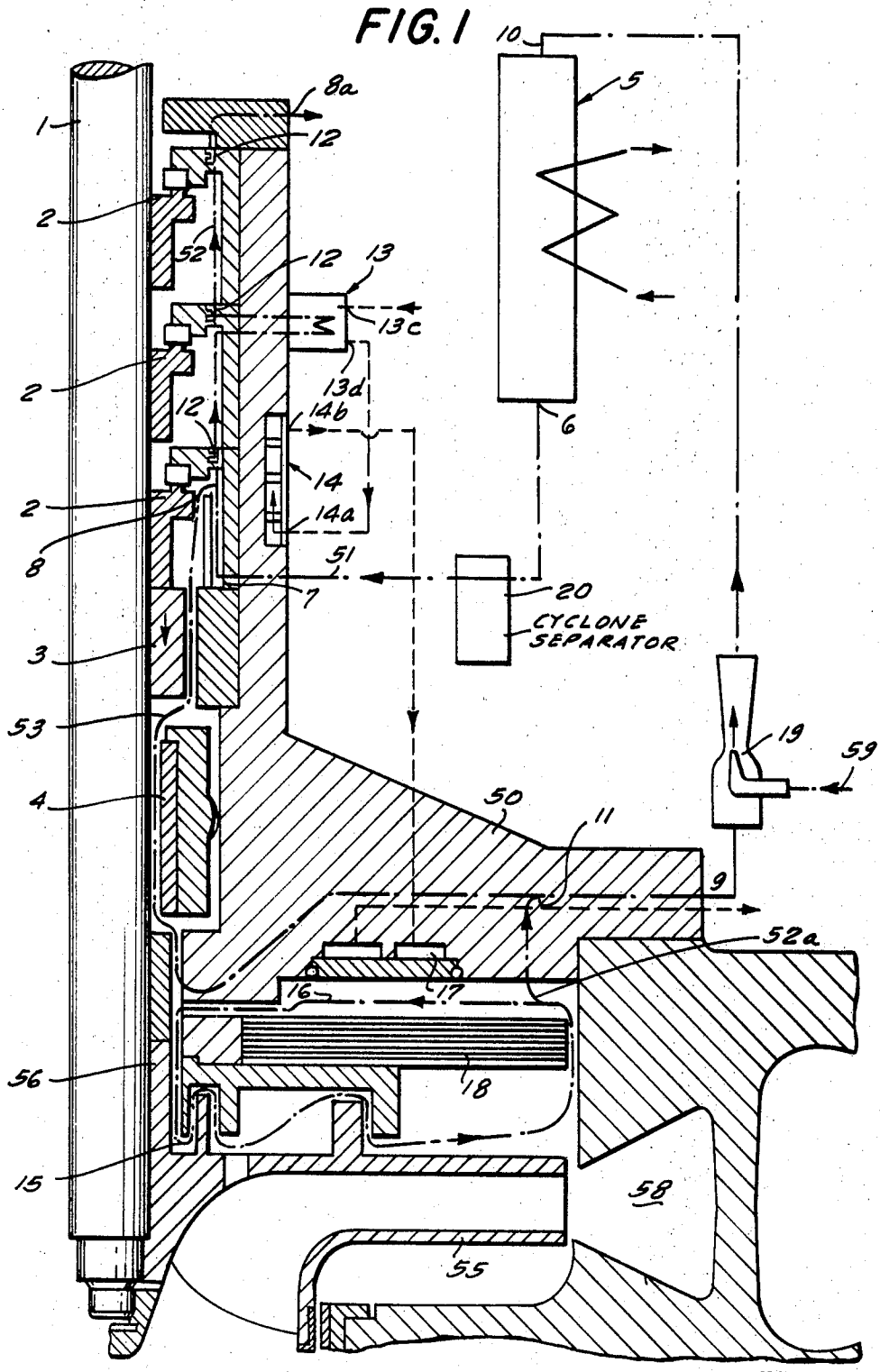
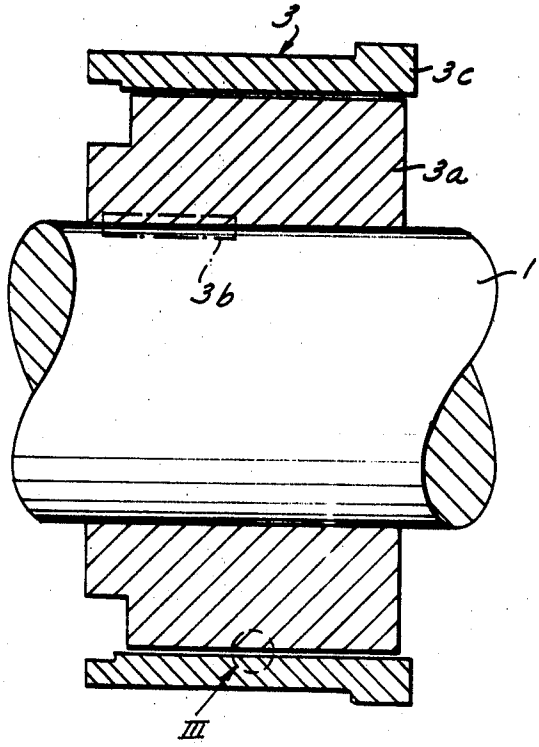


FIG. 1



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FIG. 2



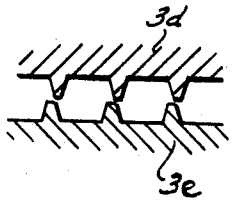


FIG. 3

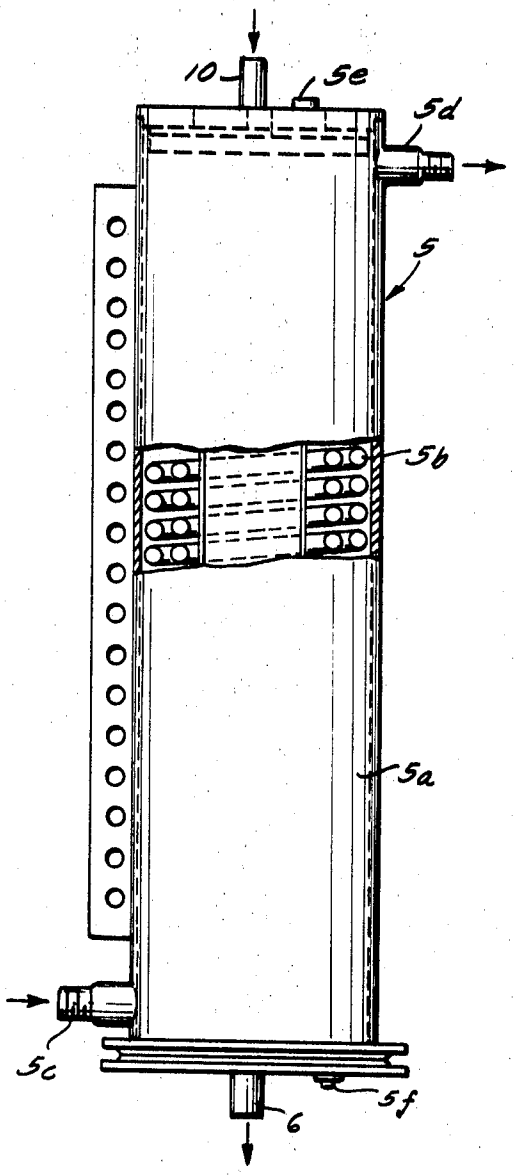
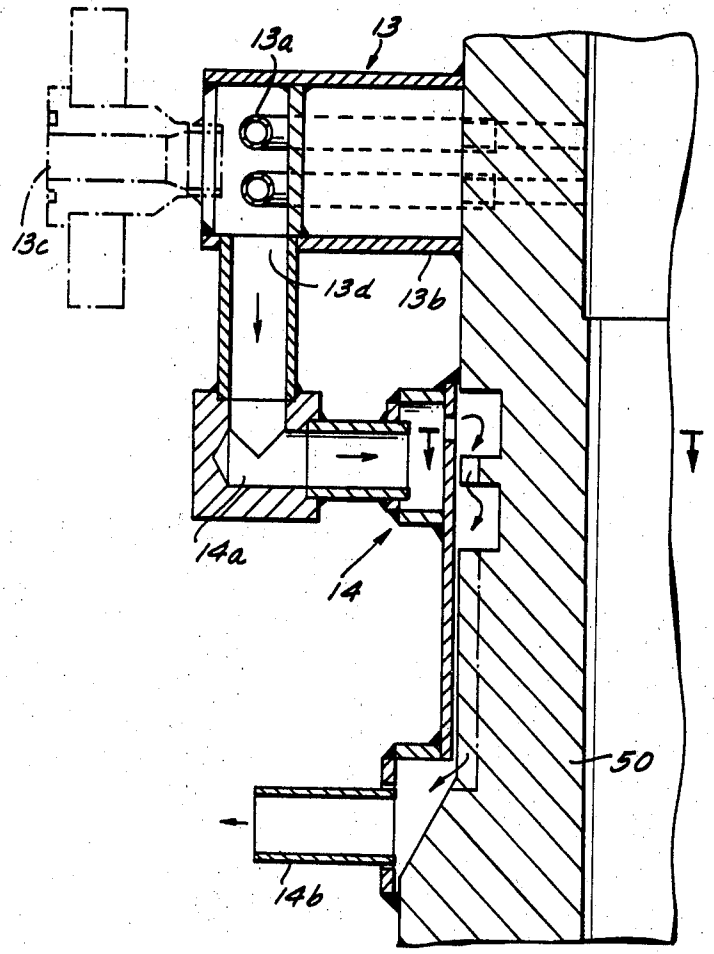


FIG. 4

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FIG. 5



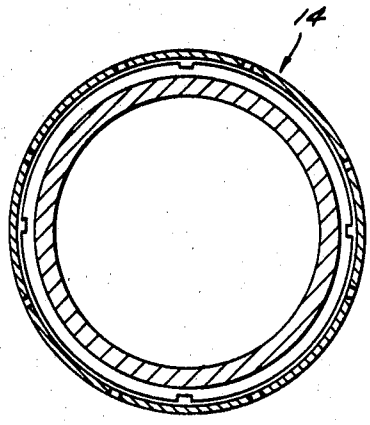


FIG. 6

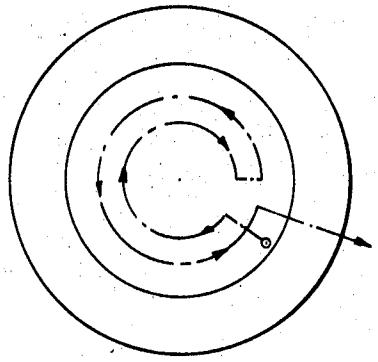
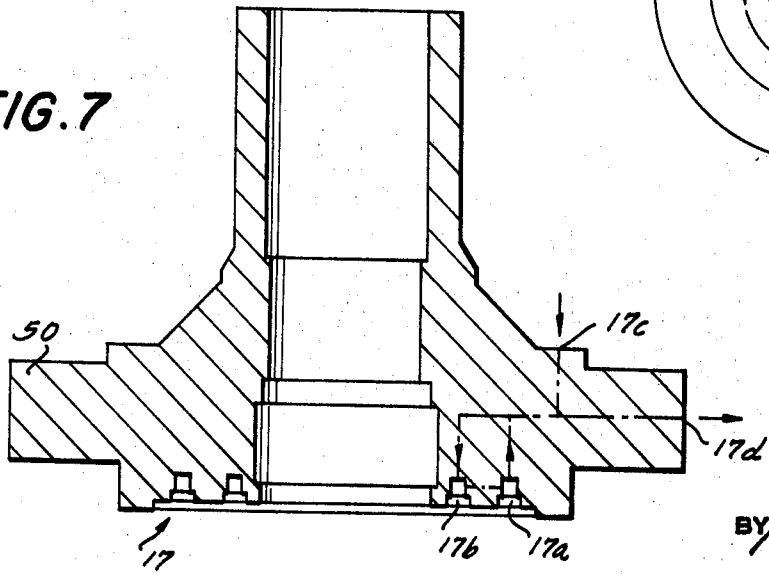


FIG. 8

FIG. 7



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METHOD AND APPARATUS FOR COOLING PARTS OF PUMPS IN NUCLEAR REACTORS OR THE LIKE

BACKGROUND OF THE INVENTION

The present invention relates to a method and apparatus for cooling shaft seals and antifriction bearings in pumps which circulate fluids at an elevated pressure, particularly in pumps which are utilized in the primary circuits of nuclear reactors.

It is already known to provide the shaft of a nuclear reactor pump with a sealing system which includes hydrodynamic slipring seals or hydrostatic shaft seals. Due to high pressure of fluids which are circulated by such pumps, the pressure differential between the spaces which are separated from each other by the shaft-sealing systems is very high. It is therefore advisable to employ a multistage sealing system, for example, a system which employs a series of two or three sets or groups of hydrodynamic slipring seals. A pressure distributing arrangement insures that the pressure differential between the areas sealed from each other by each set of seals is the same or nearly the same. A drawback of such sealing systems is that they necessitate the provision of two separate circuits for the shaft seals and for the radial antifriction bearings on the pump shaft. Such bearings are normally lubricated by water. One of the circuits is a cooling circuit for the shaft seals and bearings and the other circuit is a pressure dividing circuit which controls the pressure drop at the various stages. The cooling circuit normally includes an reactor pump which is mounted on the shaft of the reactor pump. When the reactor pump is idle and the fluid in the reactor circuit is hot, such hot fluid can penetrate into the bearings and shaft seals and is likely to cause extensive damage. In a sealing system with two circuits (namely, a cooling and a pressure dividing circuit), the supervision of pressure and temperature is not entirely satisfactory (internal circuits) or the cooling system is too expensive and too bulky due to the need for aerating and evacuating devices (external circuits).

When the sealing system employs hydrostatic shaft seals which are grouped in several stages, the regulation of pressure drop at the stages takes place in a fully automatic way. The cooling circuit for the bearings and seals necessitates the provision of an expensive cold water supply arrangement which employs separate high-pressure pumps serving to deliver cold water upstream of the shaft seals. If the water supply arrangement is defective, an auxiliary pump on the shaft of the reactor pump insures that the temperature of bearings and shaft seals does not exceed a predetermined value. Of course, the auxiliary pump is idle when the reactor pump is idle so that, if the cold water pumps are defective, the shaft seals and the bearings are overheated when the reactor circuit contains hot water.

SUMMARY OF THE INVENTION

An object of the invention is to provide a method of properly cooling the seals and bearings of the shaft in a nuclear reactor pump when the shaft is idle.

Another object of the invention is to provide a method of preventing penetration of hot water from the pump chamber into the bearings and seals when the pump shaft is idle or rotates at a low speed.

A further object of the invention is to provide a method of preventing penetration of solid particles from the pump chamber or from the sealing liquid into the streams which cool the seals and the bearings.

An additional object of the invention is to provide a nuclear reactor pump which embodies novel means for cooling the bearings and shaft seals in accordance with the above outlined method.

One feature of my invention resides in the provision of a method of cooling the bearing and seals for the shaft of a pump or analogous apparatus which circulates fluid at an elevated pressure and wherein the shaft rotates in a housing and the bearing is located between the seals and the impeller. The method comprises the steps of conveying through the

housing a first stream of cold water along the seals while the shaft rotates, simultaneously conveying through the housing a second stream of cold water which flows through the bearing, cooling the streams externally of the housing in a common cooler, and conveying such streams through the housing by thermosiphon action when the shaft is idle and the pump chamber contains hot fluid so that the direction of flow is then the same as when the shaft rotates.

A further stream of cold water may be circulated along a portion of the shaft between the bearing and the impeller to prevent penetration of hot fluid from the pump chamber into the bearing.

In accordance with a further feature of my invention, the water can be accelerated by a nozzle upstream of the point where the streams are cooled in a common cooler, and solid particles which might be present in the thus accelerated streams are preferably separated therefrom in a cyclone separator prior to admission of cooled streams into the housing.

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

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a fragmentary schematic sectional view of a nuclear reactor pump wherein the bearing and the sealing units for the pump shaft are cooled in accordance with the present invention;

FIG. 2 is an enlarged sectional view of an auxiliary pump in the structure of FIG. 1;

FIG. 3 is an enlarged view of a detail within the circle III shown in FIG. 2;

FIG. 4 is an enlarged partly elevational and partly sectional view of a main cooler in the structure of FIG. 1;

FIG. 5 is an enlarged fragmentary sectional view of two auxiliary coolers in the structure of FIG. 1;

FIG. 6 is a horizontal sectional view as seen in the direction of arrows from the line VI–VI of FIG. 5;

FIG. 7 is an enlarged sectional view of a further cooler in the structure of FIG. 1; and

FIG. 8 is a schematic bottom plan view of the structure shown in FIG. 7.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, the shaft 1 of the reactor pump is surrounded by three ring-shaped sealing units 2 and drives an auxiliary pump 3. This shaft is mounted in oil-lubricated bearings (not shown) located at a level above the uppermost sealing unit 2 of FIG. 1 and in a water-lubricated radial bearing 4 located below the innermost sealing unit 2. The purpose of the sealing units 2 is to prevent escape of fluid from the pump housing 50 in a direction from the lower toward the upper end of the shaft 1 as viewed in FIG. 1.

The cooling circuit includes the auxiliary pump 3 and causes a main stream 51 of coolant to circulate in the directions indicated by arrows. The coolant is water which is cooled in a high-pressure main cooler 5 and leaves this cooler by way of an outlet 6 to enter a first system of channels in the pump housing 50 at 7, i.e., between the auxiliary pump 3 and one of the sealing units 2. Some of the thus admitted coolant (see the stream 53) flows downwardly through the pump 3 and radial bearing 4 and leaves the housing 50 at 9 to reenter the cooler 5 by way of an inlet 10. At the point 8, the remainder of the coolant (see the stream 52) which is admitted into the housing 50 at 7 branches off and flows upwardly to serve as a pressure-dividing means and as a means for cooling the sealing units 2. This stream 52 of coolant is lost

to the cooling circuit but an equal amount of coolant (stream 52*a*) is admitted to the branch stream 53 at 11, i.e., upstream of the outlet 9 of the housing 50. The stream 52*a* which merges into the stream 53 at 11 carries hot water. The stream 53 which is pumped by auxiliary pump 3 through the radial bearing 4 and housing 50 toward the outlet 9 and inlet 10 entrains the hot water stream 52*a* and thus prevents hot water of the stream 52*a* from flowing toward and into the bearing 4, i.e., the stream 52*a* is compelled to flow from 11 to 9, thereupon through 10 and into the main cooler 5 to leave this main cooler at 6 as part of the main stream 51 which flows toward the inlet 7. It will be seen that only cold water can circulate through the radial bearing 4 and sealing units 2.

The channel for the stream 52 which branches from the main stream 51 at 8 contains several throttling passages or restrictors 12 which effect a requisite drop in pressure so that the pressure of cooling water drops stepwise during flow from the point 8 to an outlet 8*a* downstream of the uppermost restrictor 12 of FIG. 1. The coolant which flows through the restrictors 12 exchanges heat with and thereby cools the corresponding sealing units 2. Due to the fact that the stream 52 flows upwardly and that the restrictors 12 are located at a level above the point 8, water which forms the stream 52 automatically expels air from the chambers which accommodate the sealing units 2 when the reactor pump is started, i.e., when the shaft 1 is set in motion.

If desired, the reactor pump can embody an auxiliary or intermediate cooler 13 which is provided in the flow path of the stream 52 between a pair of sealing units 2 to reduce the temperature of water in the stream 52 before the water reaches the next-following sealing unit or units. The cooler 13 is deaerated in a fully automatic way when the reactor pump is started because the coolant rises from the lowermost sealing unit 2 through the coil of the cooler 13 and toward the intermediate cooling unit.

When the reactor pump is at a standstill, the coolers 5, 13 produce a thermosiphon action which causes water to circulate in the same direction as when the shaft 1 rotates. This prevents penetration of hot water from the point 11 toward the radial bearing 4 and upwardly into the sealing units 2. The amount of water which circulates by thermosiphon action is selected in such a way that it exceeds considerably the amount of leak fluid which flows upwardly beyond the topmost sealing unit 2 and leaves the pump at 8*a*. The surplus of cold water which circulates by thermosiphon action flows downwardly from the point 8 along the shaft 1, through the radial bearing 4 and mixes with hot water at 11 in the same way as when the shaft 1 rotates. The resulting mixture enters the main cooler 5 at 10 and is recirculated through the pump housing 50. In order to assist the thermosiphon action, the apparatus comprises a second auxiliary cooler 14 which is mounted in or on the housing 50 in the region of the innermost (lowermost) sealing unit 2 and is in series with the auxiliary cooler 13. Furthermore, the apparatus comprises means for preventing a mixture of hot and cold water from flowing along the shaft 1 in the region between the radial bearing 4 and impeller 55. The impeller 55 has a hub 56 which is located at its pressure side and is surrounded by a chamber 15 which is supplied by a chamber 15 which is supplied with cold water by a further circuit 16 in a second system of channels provided in the housing 50. The contents of the circuit 16 are cooled and circulated by a heat-blocking cooler 17 which is located at a level above metallic heat-sealing sheets 18. The chamber 15, which is constantly filled with cold water, prevents penetration of hot water into the radial bearing 4.

In order to prevent penetration of particles of solid matter from the pump chamber 58 into the space which accommodates the sealing units 2 when the pump shaft 1 is idle or rotates at a reduced speed, the apparatus further comprises an injector nozzle 19 which is installed in the conduit between the outlet 9 and inlet 10. This nozzle 19 insures that sealing liquid 59 which entrains the mainstream 51 flows through a cyclone separator 20 which can be installed upstream or downstream of the main cooler 5 and delivers the stream 51 to the inlet 7. When the reactor pump is idle, and in the absence of the nozzle 19, the direction of liquid flow could be reversed or the solid particles could travel counter to the direction of liquid flow.

The auxiliary pump 3 (FIG. 2) comprises a rotor 3*a* which is keyed to the pump shaft 1, as at 3*b*, and an annular stator 3*c* which is mounted in the housing 50. The adjoining surfaces of the stator and rotor are provided with threads 3*d*, 3*e* (FIG. 3) one of which is a left-hand thread and the other of which is a right-hand thread whereby such threads force water (stream 53) to flow toward the radial bearing 4 when the pump shaft 1 rotates. For example, each of the parts 3*a*, 3*c* can be provided with 20 threads.

The main cooler 5 is shown in detail in FIG. 4. It comprises a cylindrical shell 5*a* which accommodates a coil 5*b* one end of which is connected with a source of low-pressure coolant, as at 5*c*. Coolant flowing through the coil 5*b* exchanges heat with the main stream 51 which flows from the inlet 6 toward the outlet 10 of the shell 5*a*. The numeral 5*d* denotes the outlet for low-pressure coolant. The numerals 5*e*, 5*f* respectively denote a venting nipple and a normally sealed liquid-evacuating opening of the shell 5*a*.

The details of the auxiliary coolers 13 and 14 are shown in FIG. 5. The cooler 13 comprises a coil 13*a* installed in a casing 13*b* which has an inlet 13*c* for a coolant and an outlet 13*d* connected with the inlet 14*a* of the cooler 14. The coolant exchanges heat with the stream 52 which flows through the coil 13*a*. The coolant which leaves the cooler 14 at 14*b* flows into the cooler 17. FIG. 6 shows certain further details of the cooler 14.

FIGS. 7 and 8 illustrate the details of the cooler 17. This cooler includes two concentric arcuate channels 17*a*, 17*b* one of which receives water from the cooler 14, as at 17*c*. The water flows through the one channel, into the other channel, through the other channel, and leaves the housing 50, as at 17*d*.

An important advantage of my apparatus is that the coolers produce a thermosiphon action which insures that cooling water circulates in a predetermined direction when the pump shaft is idle. Another important advantage of the apparatus is that the streams 52, 53 branch from a single mainstream 51 which is caused to flow through the main cooler 5. The circuit 16 prevents penetration of hot water into the bearing 4 when the shaft 1 is idle while the main circuit of the pump (including the contents of the pump chamber 58) contains hot water.

As stated before, the circuit which contains water for cooling of radial bearings is independent of the circuit for cooling of seals in the housing of a conventional reactor pump. In the apparatus of my invention, such circuits have a common branch (from the outlet 9, through the cooler 5 and to the point 8). Furthermore, the stream 52 not only performs the function of insuring satisfactory distribution of pressure at the sealing units 2 but also as a means for cooling such sealing units. Since the stream 52 also expels air from the spaces which accommodate the sealing units 2, the temperature and pressure at these sealing units can be regulated with a high degree of precision. The thermosiphon action insures proper cooling of bearing 4 and sealing units 2 when the pump shaft 1 is idle; therefore, the apparatus need not be provided with a feed for sealing water which is needed in conventional apparatus including hydrostatic seals for the pump shaft.

The nozzle 19 insures that the streams 51 and 59 are circulated at a predetermined minimum speed when the shaft 1 is idle or when this shaft rotates at a reduced speed. Thus, the nozzle 19 insures that the cyclone separator 20 is effective at all times, as well as that the flow of cooling liquid in the gaps between the shaft 1 and housing 50 takes place at a speed which suffices to prevent penetration of hot water from pump chamber 58 and upwardly along the shaft 1. Such hot water could entrain solid particles into the bearing 4 and/or sealing units 2. The likelihood of penetration of solid particles is particularly pronounced if the pump is mounted in inverted

position so that the chamber **58** is located at a level above the bearing **4** and sealing units **2**. It will be seen that some or all of the aforediscussed features can be embodied in a high-pressure pump which is mounted in upright, inverted or another position.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can, by applying current knowledge, readily adapt it for various applications without omitting features which fairly constitute essential characteristics of the generic and specific aspects of my contribution to the art.

I claim:

1. In an apparatus which circulates a fluid at an elevated pressure, particularly in a nuclear reactor pump, a combination comprising a housing; a shaft rotatably mounted in said housing; radial bearing means surrounding said shaft in said housing; impeller means mounted on said shaft in said housing at one side of said bearing means; a plurality of axially spaced sealing units mounted in said housing at the other side of said bearing means and surrounding said shaft; auxiliary pump means mounted on said shaft between said bearing means and said sealing units to force cooling water to flow through said bearing means when said shaft rotates; and coolant circulating means for supplying cooling water to said auxiliary pump and said sealing units by thermosiphon action when said shaft is idle, comprising a main cooler having an outlet connected to channel means provided in said housing and arranged to supply water to said auxiliary pump and to said sealing units.

2. A combination as defined in claim **1**, wherein said channel means includes an inlet connected with the outlet of said main cooler, a first portion which conveys a first stream of water along said sealing units and to an outlet of said housing, and a second portion which conveys water from said inlet to said auxiliary pump and from the latter through said bearing means to another outlet of said housing, said other outlet being connected with an inlet of said main cooler.

3. A combination as defined in claim **1**, wherein said housing defines second channel means for circulation of cooling water along a portion of said shaft between said impeller means and said bearing means to prevent penetration of the contents of the pump chamber into said bearing means.

4. A combination as defined in claim **3**, wherein said second channel means comprises a chamber adjacent to said impeller means and further comprising a second cooler provided in said housing adjacent to said last mentioned chamber to cool the liquid in said second channel means and to effect circulation of such liquid.

5. A combination as defined in claim **4**, further comprising a package of metallic sheets interposed between said second cooler and said second channel means.

6. A combination as defined in claim **2**, further comprising injector nozzle means provided between the inlet of said main cooler and the other outlet of said housing to effect flow of water into and through said main cooler at a speed exceeding a predetermined minimum speed.

7. A combination as defined in claim **6**, further comprising cyclone separator means provided between said nozzle means and the inlet of said housing.

8. A method of cooling the bearing and seals for the shaft of a pump which circulates fluid at an elevated pressure and wherein the shaft rotates in a housing and the bearing is located between the seals and the pump impeller, comprising the steps of conveying through the housing a first stream of cold water along the seals while the shaft rotates, simultaneously conveying through the housing a second stream of cold water which flows through the bearing, cooling said streams externally of the housing, and conveying such streams through the housing by thermosiphon action when the shaft is idle so that the direction of flow is the same as when the shaft rotates.

9. A method as defined in claim **8**, further comprising the step of circulating a stream of cold water along a portion of the shaft between the bearing and the impeller to prevent penetration of hot fluid from the pump chamber into the bearing.

10. A method as defined in claim **8**, further comprising the steps of accelerating the water upstream of the point where the streams are cooled, and separating solid particles from the thus cooled streams prior to admission into the housing.