United States Patent [19]

Florjancic

[11] **3,841,786**

[45] **Oct. 15, 1974**

[54] **METHOD AND COOLING SYSTEM FOR COOLING CENTRIFUGAL PUMPS**

[75] Inventor: **Dusan Florjancic**, Winterthur, Switzerland

[73] Assignee: **Sulzer Brothers Ltd.**, Winterthur, Switzerland

[22] Filed: **June 28, 1971**

[21] Appl. No.: **157,438**

[30] **Foreign Application Priority Data**

July 1, 1970 Switzerland 9960/70

[52] **U.S. Cl.** **415/114**, 415/178, 416/97

[51] **Int. Cl.** **F04d 7/00**, F04d 7/06, F04d 9/00

[58] **Field of Search** .. 415/1, 112, 178, 116, DIG. 1, 415/177, 176, 114; 417/901; 416/95–97

[56] **References Cited**

UNITED STATES PATENTS

2,018,144	10/1935	Mesinger	417/901 A
2,149,510	3/1939	Darrieus	415/DIG. 1
2,292,617	8/1942	Dana	417/901
2,576,814	11/1951	Stalker	415/178
2,720,356	10/1955	Erwin	415/115
2,988,325	6/1961	Dawson	415/178
2,990,779	7/1961	Reinecke	415/116 X
3,237,564	3/1966	Hartland	415/116
3,240,468	3/1966	Watts	415/178
3,600,890	8/1971	White	416/95
3,623,825	11/1971	Schneider	416/231

FOREIGN PATENTS OR APPLICATIONS

673,393	6/1952	Great Britain	415/178
475,711	5/1929	Germany	415/116
319,020	2/1930	Great Britain	415/112
920,234	11/1954	Germany	415/112
350,836	1/1961	Switzerland	415/1

OTHER PUBLICATIONS

Flight; Mar. 16, 1956; Vol. 69, No. 2460; p. 293–294.
The Gas Turbine; R. Hodge et al.; A Review of Blade-Cooling Systems; Feb. 1958; p. 396–398.

Primary Examiner—Henry F. Raduazo
Attorney, Agent, or Firm—Kenyon & Kenyon Reilly Carr & Chapin

[57] **ABSTRACT**

The pump zone exposed to the risk of vapor bubble formation is cooled to eliminate or substantially reduce the risk. The cooling is accomplished in some embodiments by cooling the surfaces of the impeller blades from within or without, or in some other embodiments by cooling the medium being conveyed through the zone.

3 Claims, 8 Drawing Figures

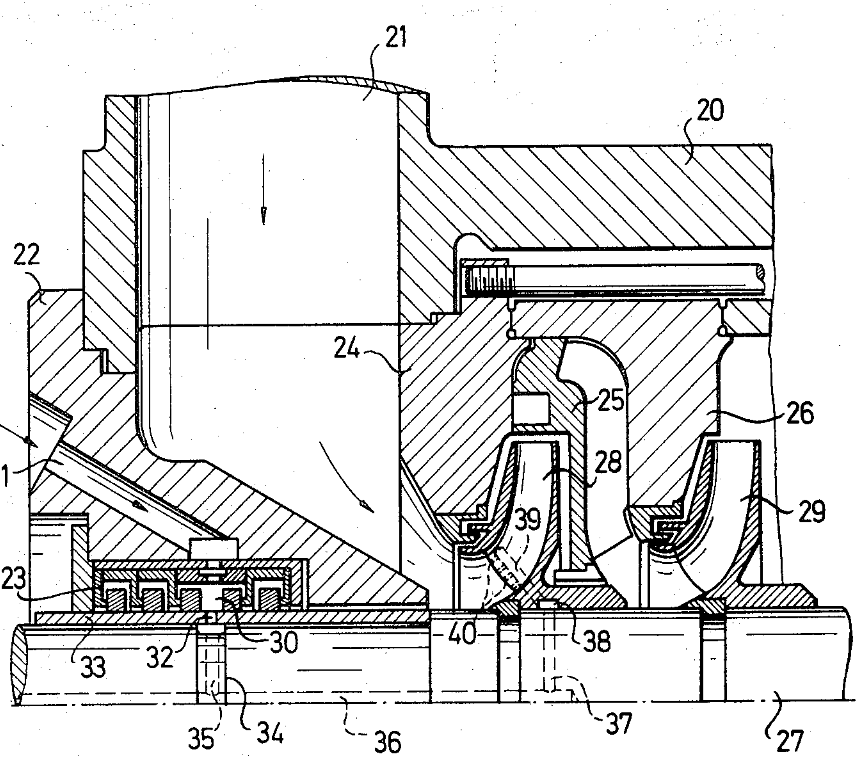
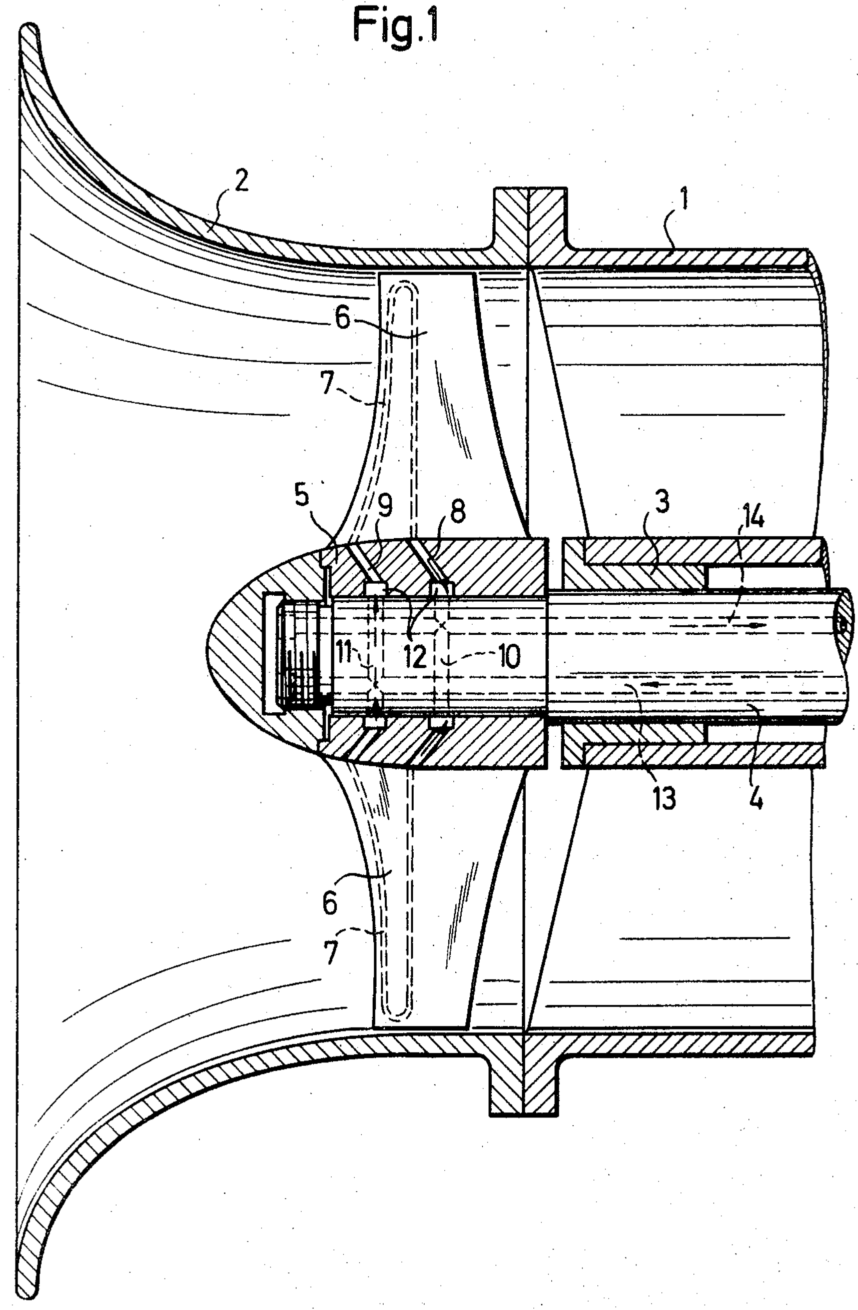


Fig.1



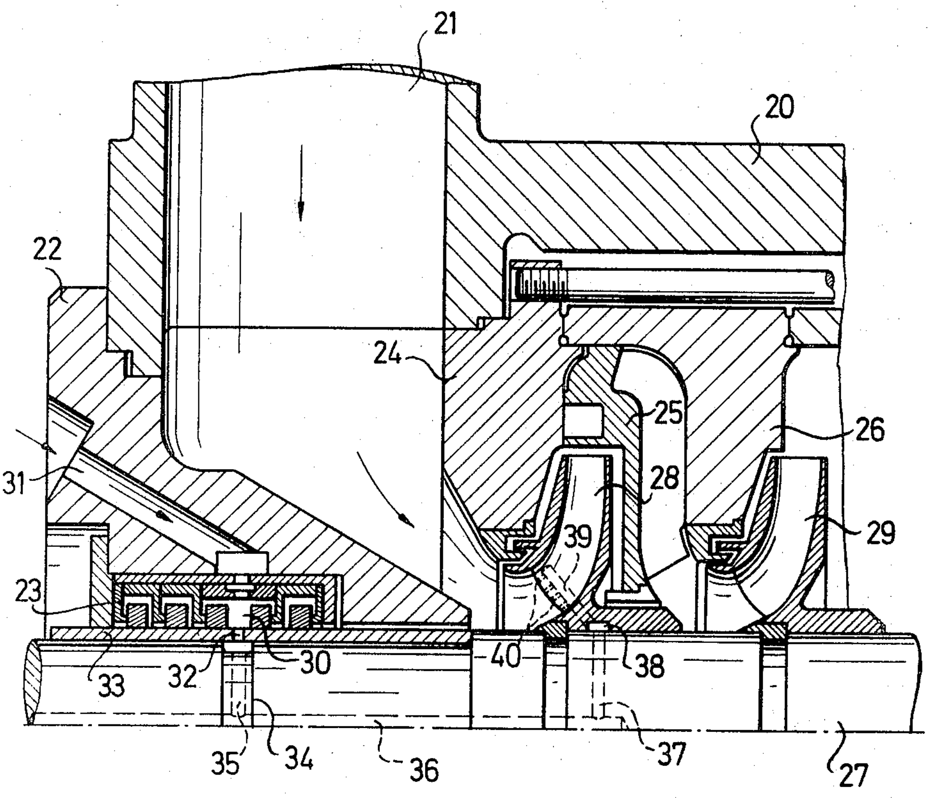
Inventor:

DUSAN FLORJANCIC

BY

Kenyon & Kenyon Reilly Carr & Chapin

Fig. 2



Inventor:
DUSAN FLORJANCIC
BY
Kenyon & Kenyon Reilly Carr & Chapin

Fig.3

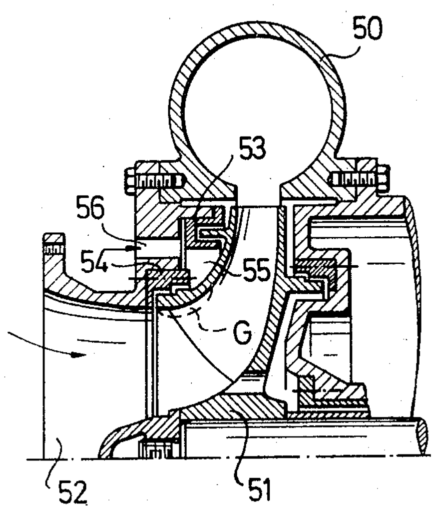


Fig.4

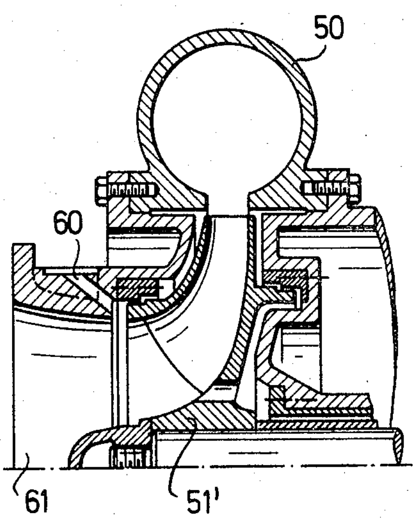


Fig.5

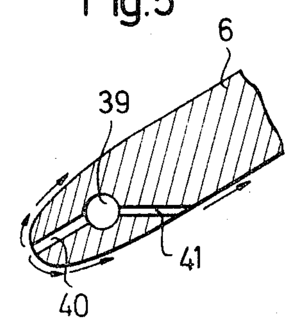


Fig.6

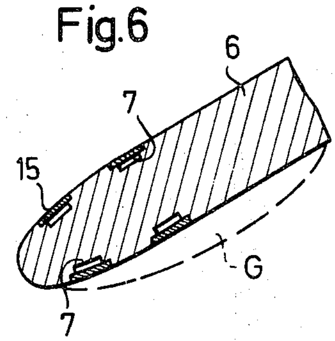
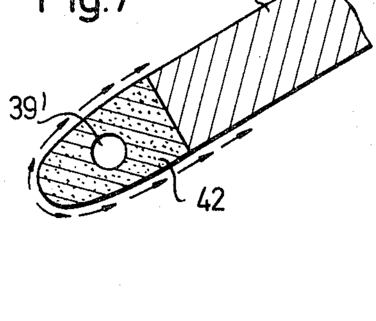


Fig.7



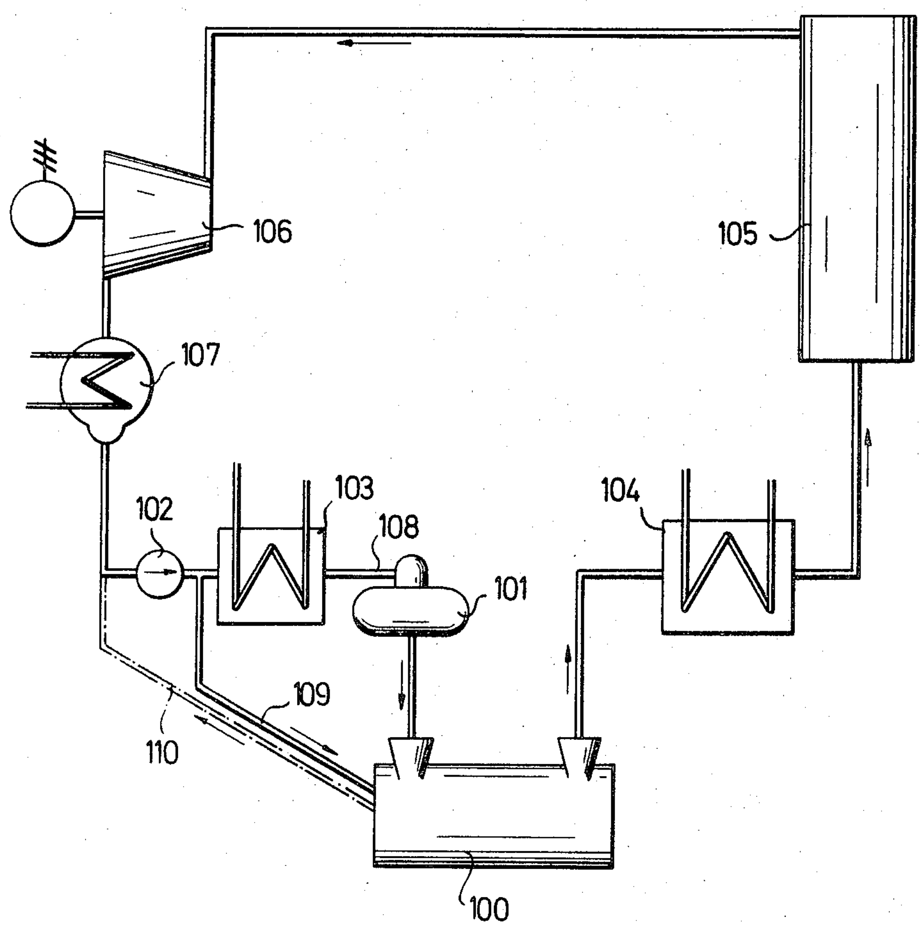
Inventor:

Dusan Florjancic

By

Kenyon & Kenyon Reilly Carr & Chapin

Fig. 8



Inventor:

DUSAN FLORJANCIC

BY

Kenyon & Kenyon Reilly Carr & Chapin

METHOD AND COOLING SYSTEM FOR COOLING CENTRIFUGAL PUMPS

This invention relates to centrifugal pumps and more particularly to a method of improving the suction performance of centrifugal pumps.

It has been known that the suction performance of centrifugal pumps is limited by the vapor stress of the delivered fluid. This feature is particularly noticeable in pumps for delivering hot water, for example, boiler feed pumps or circulating pumps for nuclear reactor plants. For example, boiler feed pumps require relatively expensive inlet pumps in order to enable to the hot feed water to be supplied to the impellers of the feed pumps with an adequate positive pressure. However, if the pressure is too low, vapor bubbles will occur at hazardous positions of the pump. This results in a deterioration of the delivery rate of the pump and, in some cases, causes interruption of the delivery, quite apart from the associated cavitation damage. The vapor bubbles usually occur at the leading blade edges and, in pumps with radial impellers, the bubbles occur on the exterior of the impeller suction eye.

Accordingly, it is an object of the invention to suppress vapor bubble formation on the impeller blade surface of a pump.

It is another object of the invention to improve the suction performance of a centrifugal pump.

It is another object of the invention to use relatively small inlet pumps for a boiler feed pump.

It is another object of the invention to eliminate the need for inlet pumps in some boiler feed apparatus.

Briefly, the invention provides a method and a cooling system by which a pump zone of a centrifugal pump exposed to the risk of vapor bubbles is cooled.

The method of the invention resides in the improvement of the suction performance of a centrifugal pump by cooling the pump zone at an impeller blade in which there is a risk of vapor bubble formation. The method, in one embodiment, cools the surfaces of the impeller blades exposed to the risk by passing a cooling medium through the interior of the blade. The cooling medium can either be discharged out of the blades for recirculation or can be discharged into the pump zone to flow over the external surfaces of the blades. In another embodiment, the cooling medium can be injected into the pump zone from the exterior of the pump casing to admix with the heated medium being conveyed through the zone so as to cool the conveyed medium. Also, in another embodiment, the medium being conveyed can be used for cooling purposes. For example, a portion of the medium can be extracted from the medium flow upstream of the pump and then injected into the flow in the pump zone while at a lower temperature.

The cooling system, in one embodiment, utilizes cooling elements such as a plurality of ducts which pass through the impeller blades and carry a cooling medium supplied from any suitable means. These ducts can be connected with return means for recirculation of the cooling medium or can be connected to discharge ducts in the blades for discharging the cooling medium in the pump zone over the external blade surfaces. In another embodiment, the cooling elements can be in the form of passages which pass through the pump casing to inject the cooling medium into the pump zone from outside the pump. In still another embodiment, the cooling elements can be connected in parallel by-pass relation with the ducts for directing a medium to be conveyed through the pump. These elements then direct a portion of the conveyed medium through a separate path wherein this portion is maintained at a cooler temperature than the remainder of the flow and inject the cooled portion back into the flow in the pump zone.

These and other objects and advantages of the invention will become more apparent from the following detailed description and appended claims taken in conjunction with the accompanying drawings in which:

FIG. 1 illustrates a cross-sectional view of an axial-flow pump with a duct cooling system for the blades according to the invention;

FIG. 2 illustrates a cross-sectional view of a radial-flow pump with film cooling according to the invention;

FIG. 3 illustrates a cross-sectional view of a pump with provision for cooling the fluid which flows through the hazardous zone according to the invention;

FIG. 4 illustrates another embodiment of a pump according to FIG. 3 modified in accordance with the invention;

FIG. 5 illustrates a partial section of a leading blade edge of a blade with film cooling according to the invention;

FIG. 6 illustrates a partial section, corresponding to FIG. 5 and relating to a blade with duct cooling according to the invention;

FIG. 7 illustrates a section of a leading blade edge in which the fluid required for forming the film flows outwardly through porous material from the interior of the blade according to the invention; and

FIG. 8 diagrammatically illustrates the circuit of a boiler feed pump constructed in accordance with the invention.

It is noted that in this application "centrifugal pumps" refers to all pumps having blades over which delivered fluid flows, for example, axial-flow pumps, radial-flow pumps and diagonal pumps. The same flow principles apply to all these pump types.

Referring to FIG. 1, an axial-flow pump which may, for example, function as the circulating pump for a boiling-water reactor is provided with a tubular casing **1** defining a central inlet for flow of a fluid therethrough, a suction branch **2** adjoining the casing and a bearing **3** in which a drive shaft **4** is journalled. In addition, a boss **5** of an impeller having blades **6** extending therefrom is mounted on the end of the drive shaft **4** within the suction branch **2**.

In order to cool the blades, a cooling system is provided. This system has cooling ducts **7** formed in the blades **6** which connect through respective ports **8, 9** in the boss **5** to ports **10, 11** at the end of the shaft **4**. The connection may be obtained, for example, in the illustrated manner, by circumferential grooves **12**. The ports **10, 11**, in turn, communicate with longitudinal bores **13, 14** in the shaft **4** which are connected, in a manner not shown, to ducts for the supply and discharge of a coolant, for example a cooling fluid.

Referring to FIG. 6, the ducts **7** on the leading edge or forward flow impinging edge of the blade **6**, against which the flow impinges, can alternatively be constructed by being milled into the surface of the blade **6**. In this case, the ducts **7** are covered with metallic closure strips **15**, affixed by soldering.

In operation, there is a risk of a drop below the vapor pressure of the fluid and consequent formation of vapor bubbles G at hazardous positions, which may, for example, have the form illustrated in broken lines in FIG. 6.

According to the invention, the formation of such vapor bubbles G is counter-acted by cooling of the zone in which there is a risk of such bubbles being formed. To this end, a coolant, for example water, is supplied through the bores 13 at a temperature which is lower than that of the pumped water. The coolant flows from the bore 13 through the port 11 and the port 9 into the ducts 7 and is discharged from the ports 8, 10 and the bore 14. The coolant thus serves to cool the blade 6 via a heat exchange along and adjacent the path of the ducts 7.

Referring to FIG 2, a radial-flow pump, for example, the feed pump of a boiler installation, has a pump casing 20 with a suction branch 21, a casing cover 22 with a shaft seal 23, integral casing parts 24, 25, 26 with the first casing part 24 defining a central inlet and a shaft 27 with radial flow impellers 28 and 29. It will be understood that the impellers of further stages may adjoin the impeller 29 but would not normally require any cooling. Further, each impeller 28, 29 carries a plurality of blades as is known.

The cooling system for this pump cooperates with the shaft seal 23 in that the shaft seal 23 is formed of two parts which define a chamber 30 therebetween. This chamber 30 connects to a supply line 31 for coolant. The chamber 30 also communicates through bores 32, formed in a shroud bush 33 of the shaft 27, with a circumferential groove 34 of the shaft 27. Radial bores 35 extend from the groove 34 into an axial bore 36 of the shaft 27. The axial bore 36 communicates through a radial bore 37 with a circumferential groove 38 in the first impeller 28.

As viewed, the flow-receiving leading blade edges of the impeller 28 are provided with bores 39 which adjoin on the circumferential groove 38. In addition, bores or ducts 40 extend outwardly from each bore 39 to the tip edge of the impeller 28. This is more clearly shown in FIG. 5 wherein a section through a leading blade edge is taken to disclose the construction of the bores 39 and 40. This illustration also shows further bores 41 which extend rearwardly into the zone which is hazarded by the formation of vapor bubbles.

In the embodiment according to FIGS. 2 and 5, the coolant is preferably the same fluid as the pump fluid but at a lower temperature. For example, in a boiler feed pump, it is possible for the coolant, supplied through the duct 31 and the bores 35, 36, 37 to the bore 39 to be feed water at a temperature lower than that delivered by the pump.

In this embodiment, the coolant is intermixed with the delivered fluid by emerging outwardly through the bores 40 and 41 from the blade and flowing in the form of a fluid film, indicated by arrows in FIG. 5, along the surface of the blade before being intermixed with the pumped fluid. In this way, the zone, hazarded by the formation of gas bubbles, may also be cooled.

Referring to FIG. 7, film cooling can also be obtained by means of the coolant. For example, the coolant forming the coolant film can flow through the pores of a sintered material of which the leading edge of the blade 6 is constructed. The sintered material may form a strip which extends along at least part of the leading edge of the blade 6 and is provided with a bore 39', corresponding to the above described bore 39, for supplying the coolant.

Referring to FIGS. 3 and 4, instead of cooling along the leading edges of the blades as in the preceeding cases, the external circumferential zones of the flow can be supplied from stationary sources to achieve the cooling effect. For example, in the radial flow pumps of the kind illustrated in FIGS. 3 and 4, the zones in which there is a risk of vapor bubble formation are disposed mainly on the external circumference of the inlet cross section of the impeller. FIG. 3 shows a vapor bubble G of this kind.

As shown in FIG. 3, the pump has a casing 50 and an impeller 51 as well as a labyrinth seal 53 and a restrictor ring 54 on that side of the impeller 51 which is nearest to the inlet socket 52. A chamber 55 which is formed between the labyrinth seal 53 and the restrictor ring 54 communicates through a duct 56 with a coolant source (not shown). The coolant, in this case also preferably the same liquid which is being conveyed but having a lower temperature, flows from the chamber 55 past the restrictor ring 54 and is then entrained by the flow delivered by the pump. Under these conditions the coolant will move in a film along the outer wall of the duct of the impeller 51 to cool the zone in which there is a risk of a vapor bubble G being formed.

The pump shown in FIG. 4 differs from the pump illustrated in FIG. 3 solely by the fact that the coolant is supplied through circumferentially disposed ducts 60 which are formed in a suction branch 61 of the pump. In this case, there is no need to provide two seals or one seal and one restrictor position at the front of the impeller 51' of the pump. In use, the coolant supplied by the system to the pump cools the outer zone of the suction eye of the impeller 51', which correponds to the hazard zone G in FIG. 3.

Referring to FIG. 8, the circuit of a feed pump 100 which is, for example, constructed as illustrated in FIG. 2, and is disposed in a boiler plant connects with a cooling system so that cooling medium is supplied to the pump impeller of the first stage. The feed pump 100 is provided with feed water from a feed water tank 101 to which the feed water is supplied by a condensate pump 102. A low-pressure preheater 103 is disposed between the condensate pump 102 and the feed water tank 101 in order to preheat the condensate as is known. The feed pump 100 delivers feed water through a high-pressure preheater 104 into a steam boiler 105 in which the water is evaporated and super-heated. The steam passes from the steam boiler into a turbine 106, is expanded and then finally passes into a condenser 107. The condensate formed in the condenser 107 is returned by the condensate pump 102 into the feed water tank 101.

The cooling system utilizes a duct 109 which branches from a condensate duct 108 connecting the condensate pump 102 to the feed water tank 101 upstream of the low pressure preheater 103. Accordingly, the duct 109 conveys cool condensate which may be used for cooling the first stage of the feed pump in the manner described by reference to FIG. 2. If blade cooling is to be provided in accordance with FIGS. 1 or 6 respectively, a duct 110 may be employed for returning the heated coolant. This duct 110 would then extend into the condensate duct 108 upstream of the condensate pump 102 as shown in dash-dot lines.

What is claimed is:

1. A centrifugal pump for the conveyance of hot fluids wherein the formation of vapor bubbles in the hot fluids is avoided, said pump comprising

a casing for flow of a fluid therethrough;

a suction branch adjoining said casing;

an internal casing part defining a central inlet;

a drive shaft journalled in said casing and within said casing part on a longitudinal axis;

at least one radial flow impeller mounted on said drive shaft, said impeller having at least one blade extending radially of said shaft and transversely of the fluid flow, said blade having a forward flow impinging edge and surfaces within a pump zone adjacent said blade in which vapor bubbles formation can raise, said edge extending at an angle to said axis of rotation; and

a cooling system for cooling said zone, said system including at least one bore extending through said blade, a plurality of discharge ducts disposed in said blade in communication with said bore and extending to the surface of said forward flow impinging edge, and means for supplying coolant to said bore and said ducts to discharge the coolant out of said blade over said blade surface in a fluid film into said zone.

2. A centrifugal pump as set forth in claim 1 wherein said blade includes a porous material portion communicating with said duct and wherein said discharge ducts are formed in said portion.

3. A centrifugal pump for the conveyance of hot fluids having an improved suction performance wherein formation of vapor bubbles is avoided, said pump comprising

a casing defining a central inlet for flow of a hot fluid therethrough;

a drive shaft journalled in said casing and having bores extending therethrough;

at least one impeller mounted on said drive shaft, said impeller having at least one radial pumping blade extending therefrom within a pump zone adjacent said blade in which vapor bubble formation can arise, said blade having a forward flow inclined leading impinging edge and surfaces adjacent said pump zone; and

a cooling system for cooling said zone, said system including a plurality of ducts disposed in said blade at said forward flow inclined leading impinging edge, means connected to at least one of said bores in said shaft for supplying a coolant to said ducts to cool said blade surfaces in said zone, and means connected to said ducts for receiving the coolant from said blade and for discharging the received coolant into at least one other of said bores of said shaft.

* * * * *