UNITED STATES PATENT OFFICE

2,678,606

CENTRIFUGAL PUMP OR COMPRESSOR

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Application March 18, 1950, Serial No. 159,435

7 Claims. (Cl. 102—108)

This invention relates generally to multi-stage centrifugal pumps and compressors for fluids of high or varying temperature, and especially for liquids of high delivery pressure, possibly in excess of a thousand pounds per square inch, and provides novel means for minimizing longitudinal forces in the casing and its end closure joints, in spite of differential thermal expansion of its members, and also for minimizing leakage at the shaft seals in each end of the casing, while minimizing first cost and promoting easy inspection, repair and replacement of parts.

While this invention will be described and shown in connection with pumps for high temperature liquid such as those for boiler feed in high efficiency steam power plants, for petroleum products in oil refineries and other liquids in chemical industries, it is not intended to so limit this invention, which may be advantageously applied to multi-stage compressors in which the pressure ratio results in a substantial rise in temperature of discharge gases or vapors during compression.

My invention is preferably applied to those high pressure multi-stage pumps that are of double casing construction, in which there is an outer casing of generally cylindrical form without longitudinal joints subjected to the delivery pressure of the fluid, and inside of it, an inner casing of horizontal split type enclosing all of the pump impellers, and fluid passage between the impellers. Such pumps must have at least one end of the outer casing open, with a bolted closure member to permit insertion and removal of the inner casing assembly, and there must be a connection between these two members that will permit of independent longitudinal expansion and contraction due to changes in the fluid temperature, to minimize longitudinal stresses in the outer casing and limit the load on its end closure member and its fastening, with prevention of leakage of fluid at the delivery pressure. It is recognized that an outer round casing without longitudinal joints, and an inner casing having a longitudinal joint, with the fluid delivery pressure between them, tending to burst the outer casing and to collapse the inner casing, and to tighten its longitudinal joint, are advantageous and in actual use.

However, this construction has developed two main problems. First, since the discharge pressure acts on the end closure of the outer casing, heavy flanges and bolts must be provided to prevent leakage as well as rupture. These heavy flanges and bolts increase the cost of manufacture and create an awkward and heavy structure to handle when repairs are necessary. Second, the sealing structures between the shaft and the outer casing end closure member will be expensive or unsatisfactory if subjected to the delivery pressure that acts on the end closure member.

The present invention in a single embodiment contemplates a construction wherein the delivery pressure, which acts between the inner and outer casing, does not act on an appreciable area of the end closure members of the outer casing, and thereby does not load it, or longitudinally load the outer casing, and at the same time prevents the delivery pressure from acting on the shaft seal in the end closure member, and permits complete freedom of thermal expansion of one casing relative to the other.

Accordingly, it is an object of the present invention to provide a double case multi-stage centrifugal pump with the discharge pressure acting inside of the outer, and outside of the inner case, without producing any opposing longitudinal forces in the outer casing, or substantially none, or loading its end closure members.

It is another object of the present invention to provide a novel construction of a double case multi-stage centrifugal high pressure pump or compressor wherein the function of the outer casing will be simply that of a cylindrical internal pressure resisting element carrying primarily hoop stress instead of a combined hoop stress and axial stress.

It is another object of the present invention to provide a novel construction of a double case multi-stage high pressure pump with the discharge pressure acting on the inside of the outer cylindrical case, but caused to act on a relatively small axially projected area of the end closure.

It is another object of the present invention to provide a novel construction of a double case multi-stage centrifugal pump with the discharge pressure acting between the two cases, and the suction pressure acting on both shaft stuffing boxes or seals.

It is another object of the present invention to provide a novel construction of a double case multi-stage high pressure pump or compressor wherein the whole sub-assembly, including impellers, connecting passages and inner casing can be assembled with its bearings and checked for free rotation (before insertion into the outer casing or barrel).

It is another object of the present invention to provide a novel construction of a double case multi-stage centrifugal pump with the discharge
pressure acting between the two cases for a longitudinal distance limited to the space between two cylindrical piston-like extensions on the outside of the inner case in contact with a bored internal cylindrical surface on the inside of the outer case. It is a further object of the present invention to provide at least one or more slip joints between the contacting inner and outer cylindrical surfaces of the inner and outer casings, which permits relative axial thermal expansion, under variations in temperatures, between the inner and outer casing and also permits easy assembly and disassembly. With these and other objects in view, as may appear from the accompanying specification, the invention consists of various features of construction and combination of parts, which will be first described in connection with the accompanying drawings, showing a centrifugal pump or compressor of a preferred form embodying the invention, and the features forming the invention will be specifically pointed out in the claims.

In the drawings:

Figures 1A and 1B combined show a longitudinal section through a multi-stage centrifugal pump constructed in accordance with the present invention.

Figure 2 is a cross section through the pump casing taken on the line 2—2 of Figure 1, looking in the direction of the arrows.

Figure 3 is a cross section through the pump casing taken on the line 3—3 of Figure 1, looking in the direction of the arrows.

Figure 4 is a cross section taken on the line 4—4 of Figure 1, looking in the direction of the arrows.

Figure 5 is a longitudinal section through a slightly modified form of the invention.

Figure 6 is a fragmentary longitudinal section through a modified form of the pump embodying packing at the slip joint.

Figure 7 is a fragmentary longitudinal section through a modified form of the pump embodying rings at the slip joint or joints.

Figure 8 and Figure 1B combined show a longitudinal section through a modified form of the invention.

Referring more particularly to the drawings, Figures 1A and 1B combined, show a preferred form of the improved multi-stage centrifugal pump comprising an outer casing 1 which is preferably of the barrel type, that is, it is a cylindrical casing open at one end to receive the inner casing 2 of the pump and being without any longitudinal joint. It being understood that while this type of construction is called the preferred form, that it is not intended to so limit the invention as the outer casing 1 may be constructed with both ends open as is shown in the modified form of Figures 8 and 1B combined.

Thus, in the preferred form, outer casing 1 is open at the discharge end of the pump so that the inner casing 2 carrying the various impellers 3, 6 and 14 and having various flow passages 4 formed therein may be inserted longitudinally into the outer casing 1 with the suction eye 5 of the first-stage impeller 9 opening into the suction passage 7 formed in the end of the outer casing. A suitable sealing structure 8 for the impeller shaft 9 is carried by the outer casing 1 at the inlet end of the pump and a corresponding sealing structure 16 is detachably carried by the inner casing 2 at the discharge end of the pump. It is to be understood, of course, that bearings for the shaft 9 may be of any approved construction and are not shown in the present drawings.

The inner casing 2 is split longitudinally and has the various fluid passages 4 formed therein for the flow of the liquid to be pumped from stage to stage. The final stage impeller 14 discharges through the discharge outlet 16 of the inner casing 2 into and through the outlet 15 of the outer casing 1, across a gap or open space 17, in communication with the annular space 18 between the inner and outer casings.

In the preferred form of the invention the inner casing 2 has one or more diametral enlargements 18 and 29 substantially piston-like in construction and disposed so that there will be at least one of said piston-like members at each end of the inner casing 2. Thus the discharge outlets 16 and 18 and the space or gap 17 will be disposed between the piston-like enlargements 18 and 29 and the suction inlet 7 will be disposed outwardly thereof so that the suction inlet 7 and the discharge outlets 15 and 16 will be separated by at least one of said piston-like members, all of which is clearly shown in Figures 1A and 1B of the drawings.

The piston-like enlargements 18 and 29 are machined to make a sliding fit with corresponding inner circumferential bores 21 and 22, formed in the bored interior of the outer casing 1. The bores 21 and 22 may be of equal diameters with respect to each other but of lesser diameter than the inner circumference of the outer casing 1. However, in the preferred form, bore 22 at the open end of the outer casing will have a little larger diameter than bore 21, to facilitate the insertion and removal of the inner casing as a self-contained unit.

In addition, if the bores 21 and 22 are of equal diameters the delivery fluid acting between the piston members 18 and 29 by reason of the gap 17 cannot produce a longitudinal thrust in either direction. However, where the bore 22 and correspondingly the piston 20 are of slightly larger diameter, there is a thrust force toward the open end of the outer casing as small as may be desired.

This unbalance longitudinal end thrust may accordingly be adjusted to a predetermined limited magnitude whereby it will require only a relatively light flange and stud bolt to resist it. Figure 1B shows a relatively light flange 23 formed on the piston 20 which is substantially annular in shape and is adapted to engage studs 24 on the outer end of the outer casing and to be held thereto by means of nuts 25, thus closing the outer casing both axially and longitudinally and providing means for fixing the inner casing and its sub-assembly parts at only one end. This allows the inner casing and its subassembly to be free to bend when the piston 20 and the outer casing 1 under the pressure of the sliding of the piston 19 in the bore 21 formed in the outer casing between the suction inlet 7 and the discharge outlet 15 and 16 thereof, thus forming a relatively simple slip joint, all of which is clearly shown in Figures 1A and 1B of the drawings.

The finished outer surface of the piston 19 may be provided with pressure reducing grooves 26 to reduce the fluid leakage from the annular
space 18 between the inner and outer casings which receives discharge fluid pressure thereon by reason of gap 17, to the suction 7, it being understood that other suitable means may be utilized such as packing rings, O rings or soft packing as is shown at 28a in Figure 6 and 28b in Figure 7 of the drawings. This joint between the inner and outer casings is made possible, practical, and commercially acceptable, due to the recognition by the power and process industries that stainless steels around the waterways or liquid passages are preferable with present day boiler feedwaters and process industry liquids. Such stainless steels or materials are exceedingly resistant to corrosion and erosion, and as the inner casing is made of stainless material, any slight leakage developing at the slip joint between the high pressure and low pressure side would have a very low rate of erosion and the life of the pump will accordingly be acceptable, and accumulation of corrosion products that might resist sliding is unlikely.

To prevent action of the discharge pressure on it, and to alternatively subject the packing space 19 to the suction 17 which is of interest of good operation, and also to aid the balance of the axial thrust on the rotating element, the inner casing 2 is provided with a chamber 27 at its discharge end outwardly of the piston 23. The chamber 27 has communication with the suction 7 through a plurality of internal conduits or pipes 28 which, as shown in Figures 1A and 1B, extend longitudinally of the pump structure and have no communication with the fluid flow through the normal flow passages 4 of the pump excepting only the suction 7, but it is understood that while this type of communication is shown that other means such as external conduits may be utilized for this purpose.

In some instances of multi-stage centrifugal pump construction, it may be desirable either to provide for assembly and disassembly with a minimum amount of effort and allows for the complete removal of one unit and replacement thereof by a completely new unit without the necessity of completely disassembling the entire pump structure.

The modified form changes in particular the suction side of the pump as is shown in Figure 8 of the drawings. This outer casing 1' is a substantially cylindrically-shaped casing open at either end to receive therein the inner casing 2' of the pump.

The outer casing 1' is now provided with a suction inlet 3' and discharge outlet 15 shown in Figure 1B instead of a suction passage 7 as is shown in Figure 1A. It being understood that the suction inlet and discharge outlet may be varied in their respective lower than final discharge pressure of the pump, or to add inlets to introduce fluid into the pump from some source in the system in which the pump is employed where the pressure of the introduced fluid is in excess of the suction pressure. In both constructions, axial and/or radial O ring-like enlargements are formed on the inner casing to fit another outer casing bore to make a second slip joint and a second pressure chamber as more fully shown and described in my co-pending application, Serial No. 389,877, filed October 2, 1939.

Figure 3 of the drawings shows a slight modification in the pump structure wherein the first stage of the multi-stage centrifugal pump is a double suction impeller 46, the suction eyes 41 at each side of which receive the incoming liquid from the branches 42 of the inlet passage 43 formed in the inner casing 44. The inlet passage 43 in the inner casing 44 communicates with the inlet passage 45 in the outer casing 45 of the pump. An annular space 47 is provided between the suction passage 4' wherein such cylindrical bared surfaces 13' forming the outer casing 1' thus forming slip joints as is clearly shown in Figure 8 of the drawings. The pistons 1' and 12' and the cylindrical surfaces 13' forming the slip joints are substantially identical in construction with pistons 10' and 12' shown in Figure 1A of the drawings, above described. To effect better sealing against fluid leakage, however, O rings 14' have been added. It being understood that
other types of packing structures may be utilized as, for example, that shown in Figure 6 of the drawings. By providing the piston-cylinder slip joint between the outer barrel without longitudinal joints and the inner axially split casing of the pump, it is not necessary to provide a complicated seal construction to prevent damage to the pump under sudden temperature changes in service, and the discharge end flange of the outer casing in the present pump does not need to be made sufficiently heavy to carry the force resulting from the discharge pressure of the pump against the full area of the discharge end closure member as above described.

It will be understood that the invention is not to be limited to the specific construction or arrangement of parts shown, but that these may be widely modified within the invention defined by the claims.

What is claimed is:

1. In a multi-stage centrifugal pump or the like, a hollow cylindrical outer casing, an inner casing including a plurality of pumping stages having flow passages and impellers, said casing provided with communicating inlets and communicating discharge outlets, said outer casing bored internally to provide finished bores on the inner surface thereof disposed on either side of said discharge outlet, said inner casing having diametral enlargements therein corresponding to said finished bores and mounted for sliding contact with said bores to form at least one slip joint for expansion and contraction of said inner casing with respect to said outer casing, at least one of said diametral enlargements formed on the end of said inner casing outwardly of said discharge outlets and provided with means thereon for connecting said casing, at one end, a chamber formed between said casings when said casings are disposed to form said slip joint, said chamber located between said discharge outlets and at least one of said slip joints and open to receive fluid at discharge pressure from the discharge outlet of said inner casing whereby said slip joint will be responsive to pressure and temperature changes in said fluid being pumped, said inner casing having an opening at one end into said inlets and at the other end into said second chamber.

2. In a multi-stage centrifugal pump or the like as is claimed in claim 1 wherein said means providing communication between said second chamber and said inlet openings for said casings includes a conduit formed integrally with said inner casing having an opening at one end into said inlets and at the other end into said second chamber.

3. In a multi-stage centrifugal pump, a hollow cylindrical outer casing, an inner casing including a plurality of pumping stages having flow passages and impellers, said casings provided with communicating inlets and communicating discharge outlets, said outer casing having circumferential sealing surfaces on the inner surface thereof disposed on opposite sides of the discharge outlet therein, said inner casing having continuous circumferential enlargements thereon corresponding to said sealing surfaces to form at least one slip joint and at least one seal therewith, said outer casing, inner casing and circumferential enlargements forming a pressure chamber communicating with said discharge outlets, said slip joint and said seal having substantially equal diameters to present a relatively small net cross-sectional area subject to the full discharge pressure acting between said casing, and means for connecting said inner casing to said outer casing.

4. In the multi-stage centrifugal pump, a hollow cylindrical outer casing, an inner casing including a plurality of pumping stages having flow passages and impellers, said casings provided with communicating inlets and communicating discharge outlets, said outer casing having circumferential sealing surfaces on the inner surface thereof disposed on opposite sides of the discharge outlet therein, said inner casing having continuous circumferential enlargements thereon corresponding to said sealing surfaces to form at least one slip joint and at least one seal therewith, said outer casing, inner casing and circumferential enlargements forming a pressure chamber communicating with said discharge outlets, said slip joint and said seal having substantially equal diameters to present a relatively small net cross-sectional area subject to the full discharge pressure acting between said casing, and means for connecting said inner casing to said outer casing.

5. In a multi-stage centrifugal pump as claimed in claim 4 wherein means to reduce leakage is provided on said slip joint between said communicating inlets and said pressure chamber.

6. In a multi-stage centrifugal pump, a hollow cylindrical outer casing having an inlet and a discharge outlet, said outer casing having at least one circumferential sealing surface on the inner surface thereof disposed between said inlets and said discharge outlet, an inner casing including a plurality of pumping stages having flow passages and impellers and a suction inlet and discharge outlet for said inner casing communicating with said inlet and said discharge outlet of said outer casing, said inner casing having a continuous circumferential enlargement thereon for sliding contact with said circumferential sealing surface to form a slip joint therewith, said inner casing communicating with said slip joint and said seal having substantially equal diameters so that a relatively small net cross-sectional area will be subject to the full discharge pressure acting between said casings, and means connecting said inner casing to said outer casing.

7. In a multi-stage centrifugal pump, a hollow cylindrical outer casing having an inlet and a discharge outlet, said outer casing having at least one circumferential sealing surface on the inner surface thereof disposed between said inlets and said discharge outlet, an inner casing including a plurality of pumping stages having flow passages and impellers and a suction inlet and discharge outlet for said inner casing communicating with said inlet and said discharge outlet of said outer casing, said inner casing having a continuous circumferential enlargement thereon for sliding contact with said circumferential sealing surface to form a slip joint therewith, said inner casing communicating with said slip joint and said seal having substantially equal diameters so that a relatively small net cross-sectional area will be subject to the full discharge pressure acting between said casings, and means connecting said inner casing to said outer casing.
for contact with the inner surface of said outer casing on the side of the discharge outlet thereof opposite from said slip joint to form a seal therewith, said outer casing, inner casing and circumferential enlargements forming a pressure chamber communicating with said discharge outlets, said slip joint and said formed seal having substantially equal diameters so that a relatively small net cross-sectional area will be subject to the full discharge pressure acting between said casings, said second circumferential enlargement on said inner casing having means continuous therewith for connecting said inner casing to said outer casing.

References Cited in the file of this patent

UNITED STATES PATENTS

<table>
<thead>
<tr>
<th>Number</th>
<th>Name</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,017,226</td>
<td>Aisenstein</td>
<td>Oct. 15, 1935</td>
</tr>
<tr>
<td>2,058,017</td>
<td>Hollander</td>
<td>Oct. 20, 1936</td>
</tr>
<tr>
<td>2,161,685</td>
<td>Bigelow</td>
<td>June 6, 1939</td>
</tr>
<tr>
<td>2,374,122</td>
<td>Nelson</td>
<td>Apr. 17, 1945</td>
</tr>
<tr>
<td>2,480,382</td>
<td>Wislicenus</td>
<td>Nov. 4, 1947</td>
</tr>
</tbody>
</table>

FOREIGN PATENTS

<table>
<thead>
<tr>
<th>Number</th>
<th>Country</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>188,547</td>
<td>Great Britain</td>
<td>Nov. 16, 1922</td>
</tr>
<tr>
<td>498,970</td>
<td>Great Britain</td>
<td>Jan. 17, 1939</td>
</tr>
</tbody>
</table>