United States Patent [19]

Ryall et al.

[11] **3,801,217**

[45] **Apr. 2, 1974**

[54] **FLUID MACHINES**

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[73] Assignee: **Weir Pumps Limited,** Glasgow, Scotland

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[21] Appl. No.: **216,960**

[30] **Foreign Application Priority Data**

Feb. 3, 1971 Great Britain 3851/71
June 18, 1971 Great Britain 28654/71

[52] **U.S. Cl.** ..... **415/199 A,** 415/219 C
[51] **Int. Cl.** **F04d 17/12,** F04d 29/44
[58] **Field of Search** ..... 415/219 C, 199 A, 198

[56] **References Cited**

UNITED STATES PATENTS

1,837,873	12/1931	Macmeeken	415/199 A
2,108,786	2/1938	Bigelow et al.	415/198
2,843,048	7/1958	Tapp	415/199 A

FOREIGN PATENTS OR APPLICATIONS

168,058	8/1922	Great Britain	415/199 A
526,732	9/1940	Great Britain	415/199 A
645,921	11/1950	Great Britain	415/219 C
838,317	6/1960	Great Britain	415/199 A
398,640	3/1909	France	415/199 A

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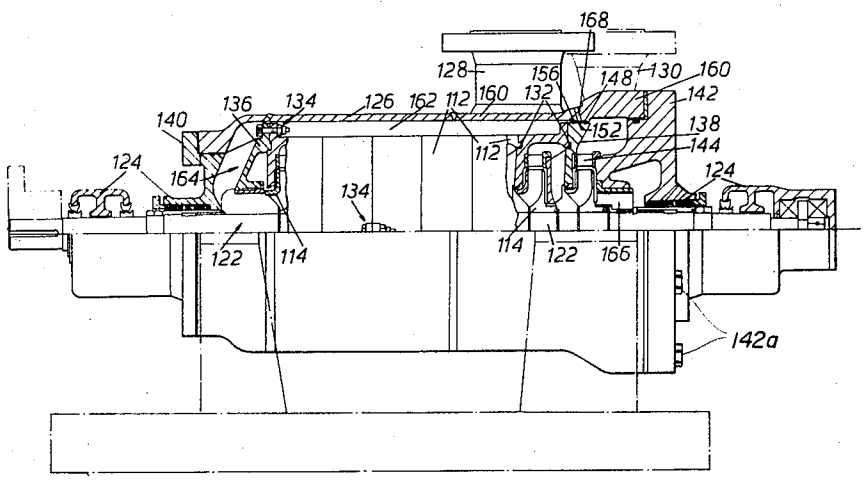
Attorney, Agent, or Firm—John E. Becker

[57] **ABSTRACT**

A multi-stage centrifugal pump which includes a plurality of stages the impellers of which are mounted on a shaft common to all stages. All the stages are mounted within a tie-frame carrying pump inlet and delivery connections and are arranged between an inlet end member and a delivery end member. The end members and the casings of each stage are arranged in abutting relationship so that they are urged in a direction towards the inlet member by the delivery pressure acting on a combination of a delivery end cover and the delivery end member, the inlet end member being held against movement relative to the tie-frame while the delivery end member is capable of movement relative to the tie-frame, sealing means being provided between the tie-frame and the movable member.

7 Claims, 4 Drawing Figures



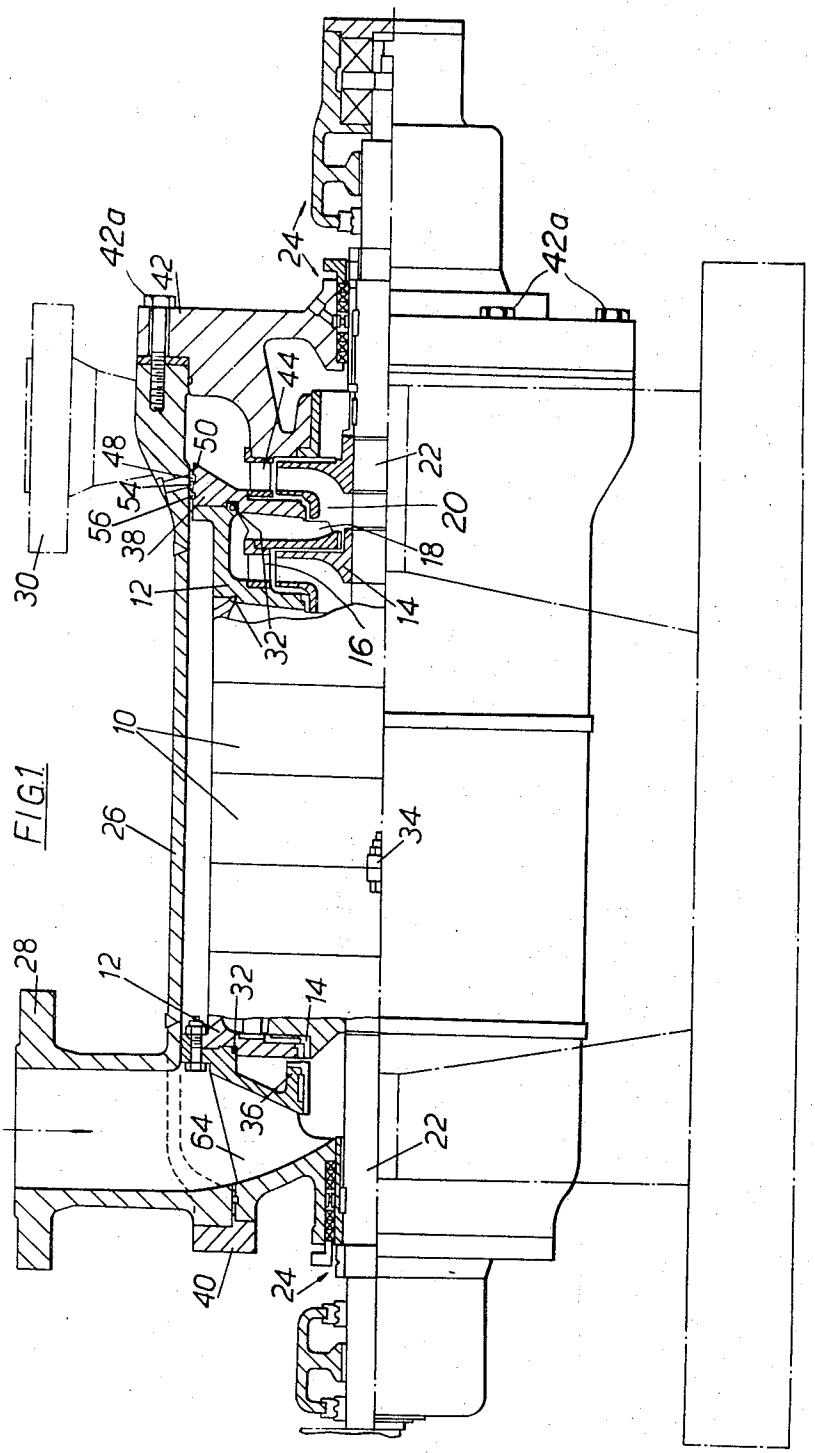

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FIG1

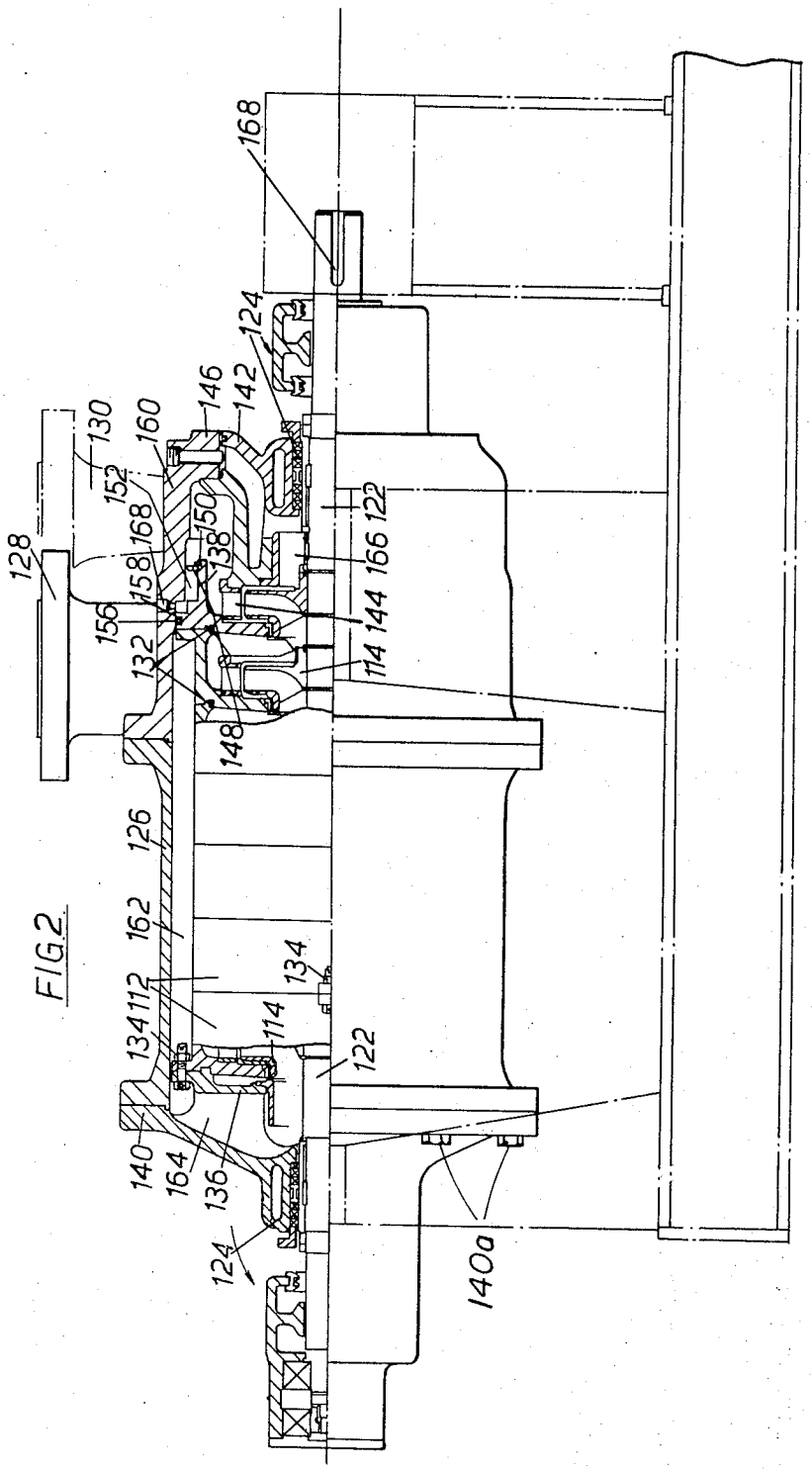
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FIG 2

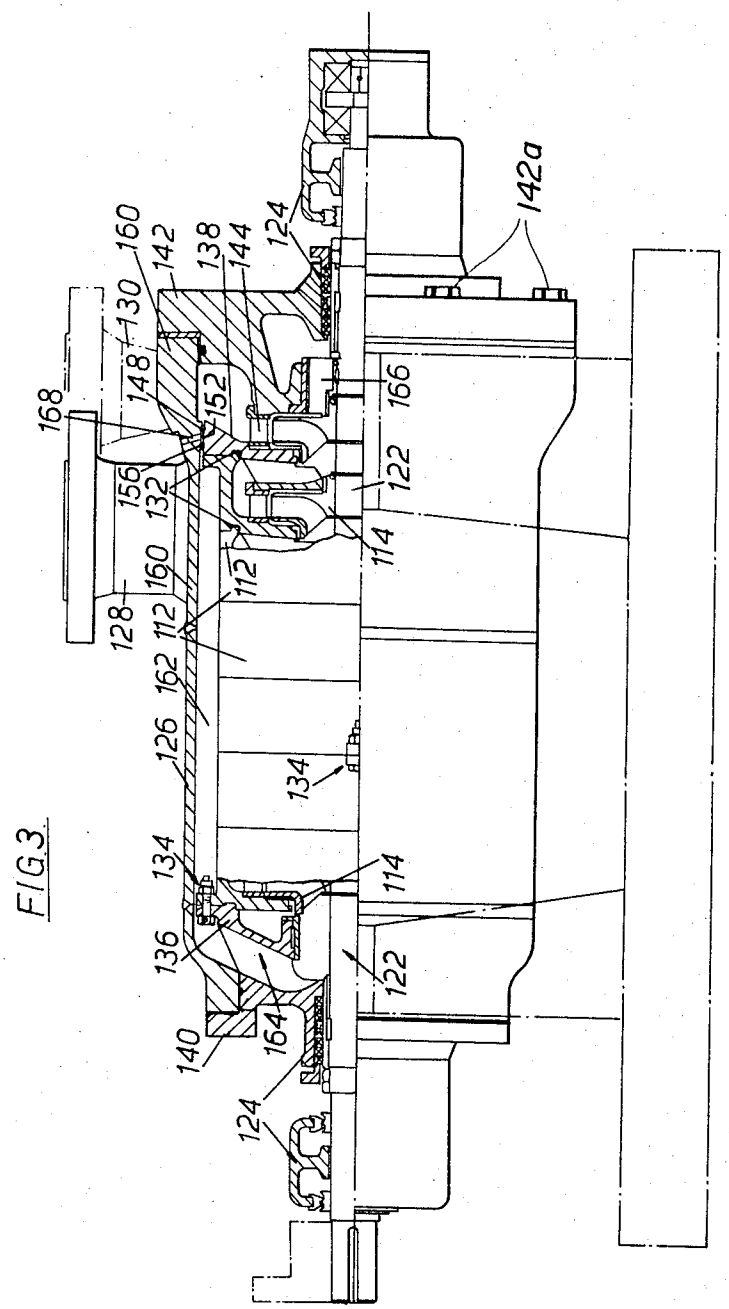
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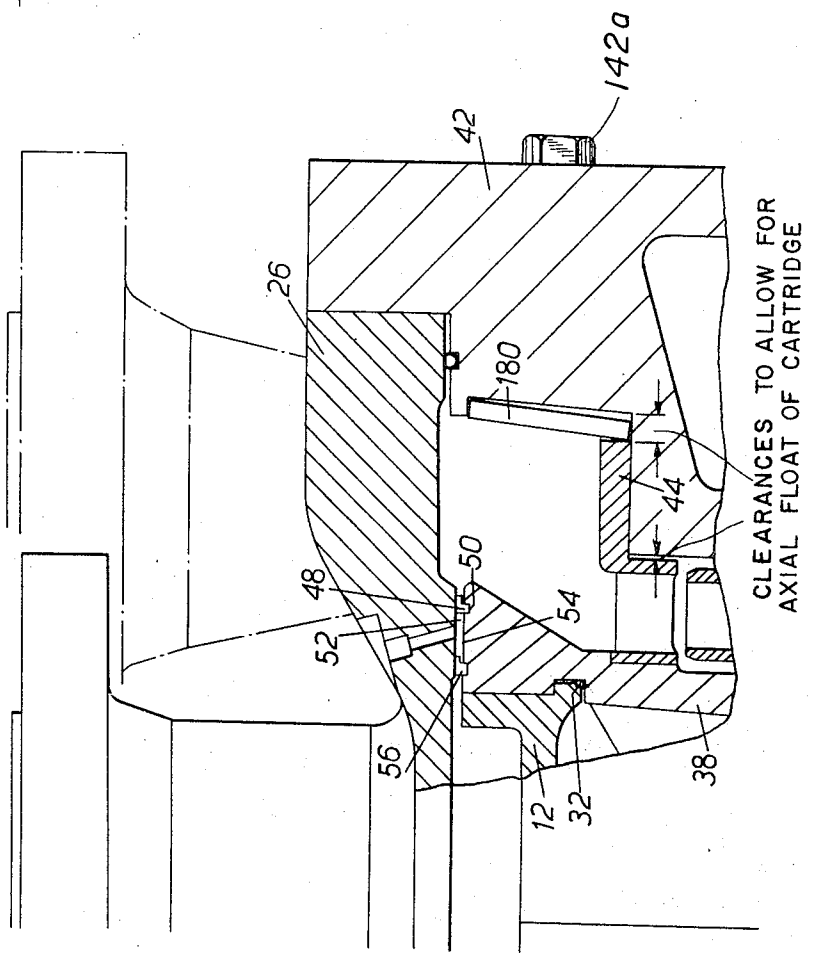
FIG.3

FIG 4


142a
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CLEARANCES TO ALLOW FOR AXIAL FLOAT OF CARTRIDGE

FLUID MACHINES

The present invention concerns improvements in or relating to fluid machines.

According to the present invention there is provided a multi-stage centrifugal pump including a plurality of stages each of which includes a casing and an impeller rotatable therein, the pump including a shaft having an impeller of each stage mounted thereon, a tie frame carrying pump inlet and delivery connections and surrounding said casing to define an annular passage therearound, fluid communication means to connect said annular passage with said pump inlet connection, an inlet end member and a delivery end member, said end members and casings being arranged in abutting relationships so that they are urged in a direction towards the inlet end member by the delivery pressure acting on the delivery end member, holding means being provided to hold the inlet end member, against movement relative to the tie frame in said direction and seal means being provided between the delivery end member and the tie frame to permit relative movement therebetween.

Embodiments of the present invention will now be described by way of example with reference to the accompanying drawings in which:

FIG. 1 is a partial sectional elevation of a first pump;

FIG. 2 is a similar view of a second pump;

FIG. 3 is a similar view of a third pump; and

FIG. 4 shows a modification which can be made to any one of the pumps shown in FIGS. 1 to 3, but is shown here as a modification at the delivery end cover 42 of FIG. 1.

In the embodiments shown in FIG. 1 a multi-stage centrifugal pump has a plurality of stages 10 which are arranged in series fluid communication, each stage including a casing 12 and an impeller 14, the impeller being rotatable within the casing which defines a diffuser section 16 and a fluid return section 18 directing fluid from the diffuser to the eye 20 of the impeller of the next stage. The impellers 14 of each stage are mounted on a common shaft 22 which is supported at either end of the pump in bearings 24, and the normal glands, thrust bearings, balance rings, etcetera associated with this type of pump are provided for the shaft. An assembly which comprises the shaft 22, impellers 14, and casings 12, is housed within a non-pressurised barrel 26, including inlet and delivery connections 28 and 30 respectively, the barrel serving as a tie frame, as will be described in more detail hereinafter. When assembled the casing 12 of each stage abuts the casings of the neighbouring stage or stages and resilient sealing means 32 are provided to ensure a fluid tight connection between the casings. To facilitate assembly and to hold the stages together when the pump is not working under full operating conditions bolts 34 are provided to connect the stages.

An inlet end member 36 and delivery end member 38 are provided to co-operate between the tie frame 26 and the assembly of stages. The inlet end member 36 is fixed to an inlet end cover 40 which closes the tie frame 26 and is rigidly bolted thereto. The projections from cover 40 define passages providing fluid communication between the inlet connection and the eye of the impeller of the lowest pressure stage. Similarly fluid communication between the diffuser 44 of the last or highest pressure stage and the delivery connection 30 is provided also.

At the delivery end of the pump the delivery end member 38 abuts the casing 12 of the highest pressure stage. A delivery end cover 42 is provided also and closes the delivery end of the tie frame 26 at the same time having bearings, glands and balance means for the shaft 22 which passes therethrough.

The delivery end cover 42 is retained in position against the end of the tie frame by bolts 42*a*.

The inlet end cover 40 and inlet end member 36 are rigidly mounted against movement. The delivery end member 38, however, is slidably mounted in the tie frame 26 (note the slight axial space between components 38 and 44) and when the pump is fully assembled the delivery end member abuts the casing 12 of the last stage while the casing of the first stage abuts the inlet end member. Thus, in operation delivery pressure acting upon a portion of the delivery end cover 42 and the delivery end plate 38 forces this plate into closer engagement with the casing of the last but one stage and this force is transmitted through the casings to the inlet end cover.

Seal means 48 are provided between the delivery end member and the tie frame or barrel 26 to allow relative movement between these components without leakage of fluid therebetween. The seal means conveniently comprises a suitable sliding packing which abuts an annular surface 50 formed on the delivery end member, the outer and inner sides of the packing abutting the sides of an annular passage 52 defined by the tie frame 26 and a cylindrical surface 54 of the delivery end member.

A secondary seal 56 between the delivery end member and the tie frame is provided, this seal taking the form of a piston ring mounted in a groove cut in the cylindrical surface 54 of the delivery end member. Thus, the assembly of casings is free to float axially and is held together by the delivery pressure so that the tie frame carries only small loads and need not cater for very large differential expansion stresses.

In assembly, the assembly of stages end members and end covers is entered into the tie frame 26 at the delivery end thereof and preferably the driving unit, for example, a motor a steam turbine or other machine, is located at the delivery end.

In the embodiment described above the tie frame 26 has been described as a non-pressurised barrel. The frame, however, since it is not pressurised or subjected to great stresses may take other convenient forms, for example, a plurality of bars connecting suitable inlet and delivery branches.

Since the barrel of the embodiment is not pressurised and, in fact, is connected to atmosphere, it is possible by including a pressure gauge (not shown) between the sliding joint packing and the piston ring to detect and measure leakage past the packing.

In further modifications, it is possible also to replace the sliding joint packing with other suitable cylindrical joints, bellows joints or other pressure holding devices.

In the embodiment shown in FIG. 2 a multi-stage centrifugal pump includes a plurality of stages arranged with the outlet from one stage in fluid communication with the inlet to the next adjacent stage, each stage including a substantially cylindrical casing 112 and an impeller 114 mounted for rotation within the casing,

each impeller being carried by a shaft **122**, common to all the stages.

The assembly of stages is mounted within a tie frame comprising a tubular barrel portion **126** and a branch vessel **160** rigidly fixed in a fluid tight manner at one end thereof. The branch vessel **160** is substantially tubular and includes fluid inlet and outlet connections **128** and **130** respectively, the inlet **128** connection communicating with an annular space **162** defined by the exterior of the stage casings and the interior of the vessel while the outlet branch **130** communicates with the outlet **144** from the last stage.

The end of the tubular barrel portion **126** of the tie frame remote from the branch vessel **160** is closed by an inlet end cover **140** rigidly fixed thereto by bolts **140***a*, said cover carrying bearings and glands **124** for the shaft, having an inlet end member **136** formed integrally therewith and being provided with fluid passages **164** which guide fluid from the annular space **162** surrounding the casings of the stages to the inlet to the first or lowest pressure stage.

The branch vessel **160** is effectively closed by a delivery end cover **142** which has components assembled thereon including a balancing disc or drum **166** for the pump and a gland device and journal and thrust bearings **124** for the pump shaft **122** which passes therethrough, the shaft terminating in a coupling **168** adapted for attachment to a suitable driving unit.

A delivery end member **138** is provided also, this member being formed as part of the casing **112** of the highest pressure stage. This member **138** is a sliding fit in the branch vessel **160.**

To prevent leakage of fluid across the delivery end member a resilient and slidable sealing means **148** such as a sliding packing or O-rings is housed in an annular passage **152** defined between the end member **138** and the branch essel **160,** the sealing means **148** being held against movement out of this housing by a ring fitted **150** in a radial recess in the member.

Further sealing means in the form of a piston ring **156** held in a radial groove formed in the end member downstream of the sealing means **148** is provided and a tapping **168** through the branch vessel is provided in communication with the space between the sealing means and piston ring so that leakage of fluid past the sealing means can be detected.

Thus in operation the stages of the pump of this second embodiment are held together by the delivery pressure acting upon a portion of the delivery end cover **142** and the delivery end member **138** and forcing the stages into closer engagement with each other and with the inlet end member **136,** sealing means **132** being provided between each stage casing.

Any movement of the assembly of stages relative to the tie frame **126, 160** is accommodated by the slidable resilient sealing means **148** and the piston ring **156.**

To facilitate assembly and to ensure the correct alignment of the stages at all times lugs are provided on the stages through which tie bolts **134** can be fitted to connect a stage with the next adjacent stage.

The flow of incoming hot or cold water passes in a symmetrical manner through the annulus **162** and the stages so that all pressure walls are treated uniformly in the circumferential and axial aspects thus minimising distortion and almost eliminating differential movement at the sliding joints.

The assembly of the pump of this second embodiment is similar to that of the first embodiment, that is the stages with the end members and end covers are assembled on the shaft but this assembly is fitted axially into the tie frame from the end thereof remote from the branch vessel **160.**

Thus in operation increase in delivery pressure causes not only a closer inter-engagement between the stages and the inlet end member but also a closer engagement of the self sealing delivery end cover **142** with a branch vessel flange **146.**

In the third embodiment shown in FIG. **3**, a pump having similar features to that of the first and second embodiments is shown, this pump however being assembled and dismantled through the delivery end of the tie frame.

As the features of the stages, inlet end cover and member and branch vessel are quite similar to those of the pump of the second embodiment shown in FIG. **2,** they will not be described in detail and have been given the same reference numerals on the drawing.

At the delivery end of the pump, as with the second embodiment, the casing of the highest pressure stage defines the delivery end member **138,** which in operation is also subjected to delivery pressure and tends to slide towards the inlet end member **136,** movement without leakage being permitted by seals **148** and **156.**

The delivery end cover **142,** in this embodiment, is bolted on to the end of the branch vessel **160** by bolts **142***a* to enable the assembly of shaft, stages, end plates and inlet end cover to be introduced to the interior of the barrel and branch vessel from the delivery end, this requiring the use of an erection cradle.

The pumps described above offer the advantages previously obtainable only from expensive barrel type pumps, for example, it has a very rigid pump casing which can carry large pipework loads and moments, it has the ability to withstand thermal shock and it provides the facility of removing the assembly of stages on the shaft without disturbing delivery and inlet pipework. Furthermore the pump is relatively economic when compared with normal barrel type pumps. In the normal barrel type pump, for example, the barrel which contains the stages is designed to withstand pump pressure and consequently the construction thereof is expensive.

A further important advantage of the pumps described above is the elimination of thermal distortion and the very high thermal stresses which may be involved in previous pump designs, when hot liquids are pumped.

The pumps of all the embodiments achieve this by providing a non-pressurised tie frame or a tie frame which is subjected only to inlet pressure which withstands only modest loads, for example, mechanical end loads particularly hydraulic axial loading on the end covers caused by the delivery pressure acting over the area of each stage, and in the case of the tie frame of the second embodiment, in addition by the relatively low inlet pressure; and by permitting the assembly of stages to expand and contract axially independently of the barrel.

In each embodiment the complete pump is suspended at or near its centre line by a system of keys and bolts to maintain correct alignment with the driver under all pressure and thermal conditions. The integral

construction of the barrel and branch piece and its attachment by bolts and keys to a bed-plate or foundation provides a rigid structure capsule of resisting the loadings imposed on the pump by the piping due to thermal and pressure conditions.

In the second and third embodiments described above all hot or cold incoming water flow, all consequent heat flow and all metal stresses are therefore uniformly distributed about the circumference of any circle which is centred on and normal to the axis of the pump. Hence all pressure walls are treated uniformly in the circumferential and axial aspects thus minimising distortion and almost eliminating differential movement at the sliding joints.

With the pump design of the second embodiment a relatively short axial space to the inlet end of the pump is required when dismantling the pump in situ. Further the assembly of shaft stages etc., can be lifted by a sling at its centre of gravity thus obviating the cost of an erection cradle.

With the pump of the third embodiments it is necessary to employ an erection cradle, however, this embodiment has the advantage that the thrust bearing which is preferably situated at the delivery end of the shaft, is closer to the balance disc or drum.

In a modification of the pumps described above the assembly of shaft, casings etc., may include two half casings clamped together by a splitting flange in a plane containing the shaft axis.

In a further modification, illustrated in FIG. **4** and shown modifying the pump illustrated in FIG. **1**, but which can be employed on any of the pumps shown, a resilient member **180** in the shape of a conical washer is interposed between an extension from the highest pressure stage diffuser **44** (**144**) the delivery end cover **42** (**142**).

On assembly this member **180** is compressed so that after assembly, on attempting to return to its original undeformed state it tends to force the delivery end cover **42** (**142**) and the assembly of stages and inlet end cover away from each other and out of the barrel **26** (**126**).

Movement of these components out of the barrel beyond a certain point is prevented so that the resilient member maintains the stages and covers in close contact, especially when full delivery pressure is not being produced.

In this modification the interstage bolts **34** (**134**) may be dispensed with.

We claim:

1. A multi-stage centrifugal pump including a plurality of stages each of which includes a casing and an impeller rotatable therein, the pump including a shaft having an impeller of each stage mounted thereon, a tie frame carrying pump inlet and delivery connections, and including means surrounding said casings to define an annular passage therearound whereby said casings are subjected to only suction pressure, fluid communication means to connect said annular passage with said pump inlet connection, an inlet end member and a delivery end member, said annular passage extending between said delivery end members and enclosed by said tie frame so that during operation the delivery end member and said plural stage casings as interposed between said inlet and delivery end members are urged together in a direction towards the inlet end member by the delivery pressure acting on the delivery end member, holding means being provided to hold the inlet end member against movement relative to the tie frame in said direction, and seal means being provided between the delivery end member and the tie frame to permit relative movement therebetween.

2. A pump as claimed in claim **1**, wherein said seal means between the delivery end member and the tie frame comprises a sliding packing.

3. A pump as claimed in claim **1**, further including additional seal means in the form of a piston ring being provided downstream of said seal means between the delivery end member and the tie frame.

4. A pump as claimed in claim **3**, further including a pressure gauge provided between said seal means and said piston ring to detect leakage of fluid past said seal means.

5. A pump as claimed in claim **1** further including a resilient member interposed between the highest pressure stage and the delivery end member, said resilient member tending to force the highest pressure stage and delivery end member away from each other.

6. A pump as claimed in claim **5**, wherein said resilient member is an annular plate and wherein the elasticity of the metal of the plate urges the plate to or from a conical shape.

7. A pump as claimed in claim **1**, wherein said impellers, said casings, said inlet end member, said delivery end member and one end cover member are assembled around said shaft as a unitary assembly, fixing means being provided to removably connect said end cover member with said barrel such that on removal of said fixing means said unitary assembly is removable from the barrel.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,801,217 Dated April 2, 1974

Inventor(s) Michael Leslie Ryall, et al

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 19, delete the comma; line 20, insert a comma after "direction".

Column 2, line 42, after "stages" insert a comma; line 45, after "motor", insert a comma.

Column 3, line 37, "essel 160" should read --vessel 160--.

Column 6, line 4, delete the comma at the end of the line; line 11, delete "delivery"; line 13, delete "as".

Signed and sealed this 15th day of October 1974.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

FORM PO-1050 (10-69)

USCOMM-DC 60376-P69
* U.S. GOVERNMENT PRINTING OFFICE : 1969 O—366-334.