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AXIAL PISTON PUMP WITH BALANCED
DRIVE PLATE
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This invention relates to piston pumps and more particu-
larly to fluid pumps having a rotor carrying the pistons
and in which the pistons reciprocate.

It is a feature of this invention to provide a pressure-
balancing arrangement whereby fluid under pressure is
directed from a high-pressure source through a fixed
laminar restriction and to the antipumping end of the
piston where it is conducted to a reaction surface such as
a bearing so that bearing forces are reduced.

It is another feature of this invention to provide the
above pressure balancing in an axial piston pump having
a fixed reaction bearing surface.

It is another feature of this invention to provide a
predetermined spacing between the piston and piston wells
to form a fixed restriction which connects in turn to an
annulus around the piston for subsequent communica-
tion with passages in the piston rod which lead to the
reaction surface.

It is still a further feature of this invention to provide
means for maintaining a fluid film between the fixed reac-
tion bearing surface and unitary drive plate surface so
that the high friction normally associated with bearing
surfaces is reduced to a minimum during starting regimes
of the pump.

It is another feature of this invention to provide a unitary
drive plate that has axial motion relative to the fixed thrust
bearing so that relative distance therebetween forms a
variable fluid escape path.

It is another feature of this invention to provide an
axial piston pump having a thrust member which oper-
tively receives the antipumping ends of the piston rods
and includes a surface comprising a plurality of pres-
sure wells receiving the metered fluid under pressure for
pressure balancing the pump, these wells forming pressure
chambers in relation to the adjacent flat bearing or reac-
tion surface.

It is a further feature of this invention to provide pres-
sure wells which are so located with respect to their respec-
tive piston rods such that the resultant center of pressure is
coincident with or radially spaced outwardly with respect
to the location of the major force resisting this pressure
load.

It is a further feature of this invention to provide a
plain axial bearing and a plain radial bearing with the
radial bearing being particularly aligned to avoid eccen-
tric loading.

These and other features of this invention will become
readily apparent from the following detailed description of
the drawings in which:

FIG. 1 is a detailed cross-sectional illustration of the
pump assembly embodying the features of this invention;

FIG. 2 is an enlarged detailed cross-sectional showing
of the piston rod assembly including its connection to the
thrust plate;

FIG. 2a is an enlarged detail of a portion of FIG. 2
showing the parts in a slightly exaggerated position;

FIG. 3 is an enlarged detailed showing of the bottom
of the unitary thrust plate; and

FIG. 4 is a partial showing of a side view of FIG. 3
schematically illustrating the tilt-balancing forces.

Referring to FIG. 1, the pump is shown as having an
upper casing 10 and a lower base casing 12 from which
protrudes at the left side a toothed member 14 for driv-
ing the pump. The member 14 includes a shaft 16 having
splines 18 for driving the unitary thrust or drive plate 20.

The unitary thrust plate 20 includes a number of pe-
ripherally spaced ball-receiving sockets 22 which receive
the balls 24 at the antipumping end of each piston rod
26. The unitary drive plate adjacent its left end includes
an elongated spline 30 which also through the spline 32
drives a coupling 34 carrying a beveled gear 36. The
beveled gear 36 engages a cooperating gear 38 for driving
the shaft extension 40 which via the splines 42 drives bar-
rel-like rotor 44. The axis of the rotor 44 is at an angle
with respect to the drive plate 20 and its adjacent bearing
220 such that as the barrel rotates the piston rods 26 are
reciprocated thereby inducing a pumping motion to the
pistons 50. A valve plate 60 is suitably held into engage-
ment with the top pumping end of the rotor 44 and is held
against continued rotation by means of a spline connection
62 leading to a control shaft 64. The control shaft 64 is
mounted on suitable bearings 65 and 68 and carries a
pinion 70 which is engaged by one or more racks 72 which
is in turn actuated by a suitable servo unit.

The servo unit is intended to rotate the valve plate 60 so as
to interconnect one or more pistons either to the inlet 80
or the outlet 82 or to connect certain pistons to each
other. A control mechanism of this type is more clearly
illustrated and described in copending patent application
Serial No. 821,180, filed June 18, 1959, by Richard N.
Sullivan.

With high pumping loads, normally, the antipumping
end of the piston, piston-rod assembly would have to be
engaged and supported by thrust bearings of substantial
weight and size. However, provision is made for pressure
balancing the assembly so that a lightweight plain bearing
can be utilized in place of the much heavier anti-friction
type ball bearings or the like. To this end, each piston 50
(see also FIG. 2) has a land portion 90 which is
meticulously machined and lapped with respect to its ad-
ja-cent cylinder wall so as to form a first fixed orifice 92,
better seen in FIG. 2. The fixed orifice 92 thus formed
is continuously wiped during the piston reciprocation
which tends to make it a self-cleaning capillary restric-
tion. The restriction 90 is of a predetermined size and length
so that under maximum pressure operation of the pump
a predetermined pressure drop will occur thereacross.

During operation, high-pressure fluid from the pumping
chamber 94 flows through the fixed restriction 90 and
there is an annulus 96 leading to a transverse passage
98 in the piston. This passage in turn connects with a
passage 100 drilled centrally of the piston rod 26. The
ball joint 24 at the antipumping end of the piston rod 26
includes a flat portion 104 so that continuous communi-
cation is provided with the drilled passage 106 in the socket
22, regardless of the rotary or tilted position of the piston
rod in the pumping cycle.

The bottom or reaction face (FIG. 2) 110 of the
unitary drive plate 20 contains a plurality of circular
wells or recesses 112 which, as seen also in FIG. 3, may
have their centers eccentrically located or spaced in an
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The wells or recesses 112 form pressure-balancing areas which form a liquid-type bearing surface to reduce the friction loading on the adjacent cooperating plain bearing 120.

The construction of the pump is such that there is a limited relative axial movement of the thrust drive 20 with respect to the plain bearing 120 so that there is provided therebetween a variable orifice depending upon the pressure and the loading of the pump parts.

The pressure wells 112 and the remaining radial areas of the juxtaposed surface 110 and the bearing 120 form the total balancing force depending upon the pressure across this region. Thus, in order to maintain a balance between the wells 112 but there is a drop across the cooperating surfaces as the leakage flow passes outwardly to the substantially low casing pressure. The total force is an integration of the particular pressures over their respective areas which, at the balanced position of the parts, are equal to the total force acting on the piston heads. Thus, the variable orifice formed by the space in between the reaction surface 110 of the drive plate 20 and the bearings 120 determines the outflow of the bleed fluid and hence the pressure level necessary to achieve equilibrium and balance. For example, if the combined fluid pressure in the well and between the cooperating surfaces is at a level whereby the force acting on the thrust bearing is less than the force generated by the piston, the unitary drive plate will be urged toward the thrust bearing and effectively reduce the area of the variable orifice which effects a reduction in fluid flow and hence builds up the pressure in the well and the cooperating surfaces until the forces created by this newly increased pressure will substantially equal and cancel out the forces generated by the piston. And conversely should the combined fluid pressure in the well and between the cooperating surfaces generate a force which is greater than the force generated by the pistons, the unitary drive plate will be urged away from the thrust bearing, effecting an increase in effective area of the variable orifice so as to increase the flow therethrough and hence reduce the pressure in the well and cooperating surfaces. In this manner the movement of the unitary drive plate with respect to the thrust bearing will automatically adjust itself to maintain a fluid pressure level in the well and between the cooperating surfaces so that the forces generated thereby will substantially match or equal the forces generated by the piston.

It is thus apparent that during starting, the unitary drive plate will be moved away from bearing 120 so as to form a lubricant film immediately to avoid starting friction.

The bleed fluid from the radial variable orifice can flow through a chamber 130 leading to the casing. Another passage 132 is provided for receiving leakage fluid from the annular chamber 134 leading from the inside or axial end of the variable orifice.

Returning to FIG. 1, the radial pump forces are absorbed through an annular plain bearing 150 which engages an outer peripheral surface 152 on the drive plate 20. The size of the bearing 150 is materially reduced by locating its supporting pedestal 154 in a plane containing the centers of pivotation of each of the balls 24 at the antipumping end of the piston rods 26. In this way the radial loads are symmetrical, thus avoiding any cocking tendency which would require larger and higher strength bearings and supports. With this particular bearing arrangement and the pressure balancing, the size and weight of the pump of this invention are materially reduced.

Another advantage of the radial bearing described is that the rotor of the pump does not have to absorb these radial loads. Instead the side loads are taken at the antipumping end of the connecting rods so that piston wear is avoided since they are not subject to eccentric loading.

In order to further reduce the weight requirements of the pump assembly, reference is made to FIGS. 3 and 4. As previously stated, the pressure wells 112 which are disposed about the center of the unitary drive plate 20 have their centers radially spaced from the centers of bleed passages 106 leading thereto. This moves the total center of pressure radially outwardly so that on the pumping side of the thrust plate, the resisting force will be located inwardly thereof as seen in FIG. 4. This resisting force and the center of pressure produce a force couple which can be balanced readily by a relatively small balancing force, as indicated in FIG. 4, because of its relatively large moment arm. It should be noted, however, that the center of pressure will travel radially as the valve plate 60 is adjusted since only certain pistons will be contributing to the final pumping output. In any case, the center of pressure should be coincident with or outboard of the major resistance vector.

As a result of this invention, it will be apparent that an extremely lightweight pump has been provided which can be made relatively small in size. This compactness makes it readily adaptable for aircraft and missiles where weight is of the essence. Thus, the bearings are reduced materially in size and weight permitting the entire structure to be manufactured at low cost.

Although one embodiment of this invention has been illustrated and described herein, it will be apparent that various changes may be made in the construction and arrangement of the various parts without departing from the scope of the novel concept. I claim:

1. In a multiple piston pump having a rotatably mounted rotor, a plurality of cylinders formed in said rotor, a corresponding number of pumping pistons mounted in said cylinders, a plate member connected to the anti-pumping end of said piston, a bearing member having a first bearing surface and a second bearing surface surrounding the first bearing surface, chamber means located between said bearing member and said plate means for receiving fluid from said cylinders so that said fluid acts on said first bearing surface, passage means extending through said piston including a fixed restriction connected to said cylinders for communicating with said chamber means, said plate member being movable relative linearly with respect to said plate member for defining a variable orifice, said variable orifice serving to control the leakage of fluid from said chamber means so that the leakage fluid acts on said second bearing surface, the combined first bearing surface and second bearing surface serving to counterbalance the thrust force created by the pumping piston, and means providing recesses in said plate member corresponding to said pistons respectively, for maintaining alignment of said plate member relative to said bearing member, said recesses being disposed eccentrically outwardly relative to the resultant axial forces of their respective pistons.

2. In a multiple piston pump according to claim 1, wherein said fixed restriction is defined by each piston having a portion of its length of reduced diameter smaller than that of its cylinder communicating with said passage means.

3. In a multiple piston pump according to claim 1, wherein each piston has a rod connected thereto, each rod having an end remote from its piston connected to said plate member by a swivel joint.

4. In a multiple piston pump according to claim 1, wherein each passage means includes a passage disposed transversely of said piston and a passage disposed axially of said piston.

5. In a multiple piston pump according to claim 1, wherein each piston has a rod connected thereto, each rod having an end remote from its piston connected to said plate member by a swivel joint, and said passage means
includes passages extending transversely of said piston, axially of said rod and through said swivel joint.

6. In a multiple piston pump according to claim 1 wherein each piston has a rod connected thereto, each rod having an end remote from its piston connected to said plate member by a movable joint, said passage means extending through said piston, said rod and said joint.

References Cited in the file of this patent

UNITED STATES PATENTS

2,241,701 Doe .......................... May 13, 1941
2,549,711 Ruben .......................... Apr. 17, 1951

604,168

1,114,641

Dietiker .......................... Apr. 21, 1951
Klopp .......................... Feb. 7, 1956
Postel et al. .......................... May 13, 1958
Bauer .......................... Dec. 2, 1958
Henrichsen .......................... Sept. 1, 1959
Sherman .......................... Dec. 22, 1959
Lucien .......................... Dec. 22, 1959

FORIEGN PATENTS

Great Britain .......................... June 29, 1948
France .......................... Dec. 19, 1955