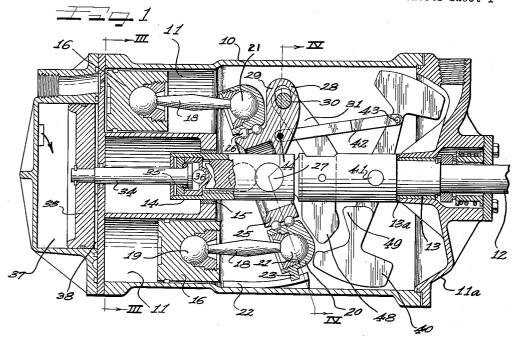
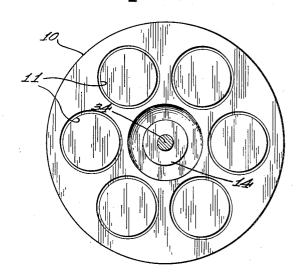
CONSTANT CLEARANCE VOLUME COMPRESSOR

Filed May 13, 1954

2 Sheets-Sheet 1







Inventor
Peter B. Loomis, III

Hill Shenman Merais Chase Vinger

Dec. 13, 1960

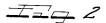
P. B. LOOMIS III

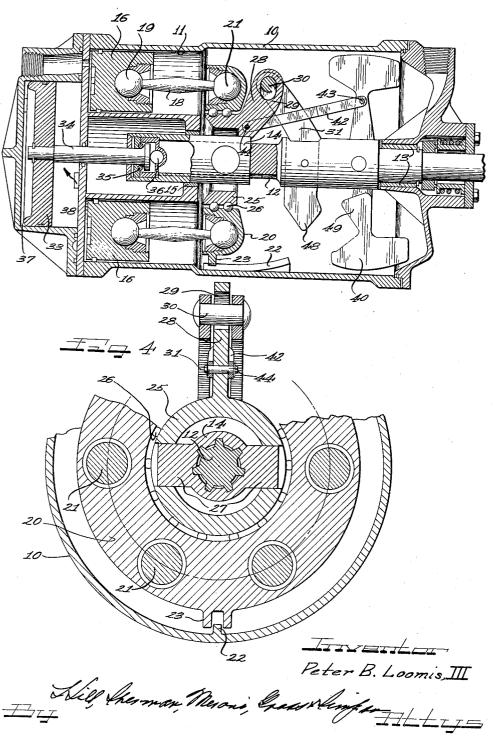
2,964,234

CONSTANT CLEARANCE VOLUME COMPRESSOR

Filed May 13, 1954

2 Sheets-Sheet 2





1

2,964,234

CONSTANT CLEARANCE VOLUME COMPRESSOR

Peter B. Loomis III, Birmingham, Mich., assignor to Houdaille Industries, Inc., a corporation of Michigan

> Filed May 13, 1954, Ser. No. 429,660 1 Claim. (Cl. 230—20)

The present invention relates to variable displacement 15 compressors, and more particularly, to a novel means for balancing, and for adjusting capacity, and to a novel result of sustained high volumetric efficiency with minimal stroke and wear.

Swash plate pumps have, of course, been used for 20 many years. Pumps of this type vary in structure over a wide range, but are all similar in that they operate reciprocating pistons from a rotary power input shaft by means of a swash plate or ring driven by a tilted crank associated with the power input shaft.

Although the use of such a swash plate, as above described, has been commonly used in the prior art, to my knowledge none of the prior art pumps utilizing this method of pump piston reciprocation have provided a constant minimum piston clearance. In the prior art 30 structures with which I am familiar, the pump stroke, or the distance which the pump pistons travel, is varied by tilting the power shaft and its swash plate with respect to the rotating block of cylinders, or if a stationary cylinder block is used, by tilting the swash plate on trunnions fixed to the power shaft. Either of these dictates, a pump operation in which the pistons approach their respective piston heads at the ends of the piston stroke, to a varying degree depending upon the angle of swash plate adjustment. In such an arrangement, the piston clearance, or distance between the piston and the end of the cylinder when the piston is at the end of its compression stroke, is a minimum when the swash plate is tilted for full capacity and is a maximum when the plate is normal to the axis of the block, and displacement is zero.

While the swash plate pump has been successful in handling liquids which are practically incompressible, its use as a compressor is negligible to date because of its lost motion at any setting below maximum capacity. In a typical compression cycle, the gas in the cylinder does not reach discharge pressure and force open the discharge valve until approximately 70% of the stroke is completed. The output capacity at 70% of full stroke may under such circumstances therefore be zero. In automotive air conditioning, particularly, it is often desirable to operate the compressor at very high speed but to maintain a capacity equal to that of full displacement at idling. If this requires 73% of full stroke, the inertia forces and wear are high.

In the present compressor, a small fraction of full stroke can deliver the rated capacity at top speed, with low forces and wear, and automatic control is greatly simplified. The need for by-pass valve, variable ratio drive, and disconnect clutch is also eliminated. By thus providing for a constant, small, clearance volume, a high volumetric efficiency is retained.

Another serious drawback to the swash plate pump structures of the prior art is the presence of relatively large unbalanced forces found therein. While a tilting swash plate is, of course, statically balanced, it will become dynamically unbalanced as soon as it is tilted

2

relative to the input shaft. Thus, as the tilt occurs a couple is set up, as a result of centrifugal force, tending to cause the swash plate to assume its untilted or neutral position. At the same time, the force couple set up tends to cause an unbalanced load on the bearings of the drive shaft causing vibration and wear. The structure of the present invention therefore contemplates the provision of dynamic balancing apparatus linked to the swash plate for automatic controlled movement thereby to provide an oppositely acting balancing couple on the rotating shaft, and the bearings thereof.

In overcoming the disadvantages found in the prior art, and as discussed above, the present invention contemplates the provision of a swash plate supported on a rotating drive shaft by means of trunnions mounted for reciprocation on the drive shaft axially thereof. Axial movement of the trunnions of the swash plate causes tilting movement of the plate about a control point adjacent the periphery of the swash plate as well as a tilting about the trunnions themselves. This combined tilting action causes the end of the piston stroke to occur at substantially the same spot irrespective of the angular adjustment of the swash plate.

Elimination of the unbalance found in prior art structures is accomplished in the present invention through the pivotal mounting of counterweights on trunnions extending parallel to the support trunnions of the swash plate by a connecting linkage such that the adjustment of the swash plate to a particular angle relative to the rotating drive shaft will simultaneously cause an adjustment of the angular position of the counterweights to provide a substantially identical, counteracting, force couple.

It is therefore an object of the present invention to provide a novel constant clearance volume compressor of the swash plate type.

A further object of the present invention is to provide a swash plate type pump having a substantially constant clearance volume under all pump stroke adjustments.

Still a further object of the present invention is to provide an improved stroke-adjusting apparatus for swash plate pumps or compressors.

Yet another object of the present invention is to provide a novel piston stroke adjustment and counter-balancing apparatus for swash plate pumps whereby dynamic unbalance is eliminated at all adjusted conditions of the pump stroke.

A feature of the present invention is an adjusting actuator operable to vary the swash plate angle of a pump by movement of the swash plate trunnions axially along the longitudinal axis of rotation.

Yet a further feature of the invention is the incorporation in a swash plate type pump of an adjustment actuator mounted coaxially with the swash plate drive shaft for adjusting the angle of the swash plate relative thereto.

Another feature of the invention resides in the provision of a dynamic balancing apparatus connected to the swash plate for simultaneous but opposite tilting action relative thereto.

Still further objects and features of the present inven-60 tion will at once become apparent to those skilled in the art from a consideration of the attached drawings wherein:

Figure 1 is a side elevational view in cross-section illustrating the pump in its maximum stroke condition;

Figure 2 is an elevational view of the pump of the present invention in cross-section and showing the adjustment of the parts to their neutral condition;

Figure 3 is a cross-sectional view taken along the line III—III of Figure 1; and

Figure 4 is a cross-sectional view of the swash plate taken along the line IV—IV of Figure 1.

As shown on the drawings:

As illustrated in Figures 1 and 2, the pump of the present invention comprises a pump housing 10 having a plurality of radially spaced, axially extending cylinders 11 integral with, or fixedly secured, to one end thereof. The drive shaft 12 is rotatably supported in bearings 13 in the housing end cap 11a. The opposite end of the shaft 12 is slidably splined to the sleeve 14 which is rotatably mounted within the bearing 15 thereby providing a bearing support for the left hand end of the shaft 10 12.

Pistons 16 are reciprocably mounted within the cylinders 11 and are reciprocated by means of connecting rods 18 universally secured to the pistons 16 at 19 and universally secured to a common drive ring 20 at 21. The ring 20 is prevented from rotation relative to the housing 10 by means of a splined connection comprising a generally arcuate spline 22 extending longitudinally of the housing, and a clevis 23 fixedly secured to the ring 20. It is to be understood, of course, that a plurality of splines may be utilized if so desired.

The ring 20 is caused to reciprocate the several connecting rods 18 with their associated pistons 16, by means of the swash plate 25 which is mounted therein for antifrictional rotation therewith through the balls 26. The swash plate 25 is caused to rotate with the sleeve 14 by means of the trunnions 27 which are secured to the sleeve and upon which the plate 25 is pivotally mounted.

It will be seen that rotation of the swash plate 25, when lying in a plane perpendicular to the axis of the shaft 12 as shown in Figure 2, will not cause any reciprocation of the pistons 16. However, as the swash plate 25 assumes a gradually tilted condition, the extreme of which is shown in Figure 1, rotation thereof will cause the ring 20 to nutate thereby successively reciprocating the pistons 16 into the furthest left hand position as viewed in Figure 1.

Reciprocation of the pistons 16 will cause a pumping action, carried out in a conventional manner not illustrated. It is to be understood, however, that each of the cylinders 11 may be connected to a common source by means of a check valve, and to a common outlet by means of an oppositely acting check valve so as to provide a conventional force pumping action. It is to be understood that various valve arrangements may be utilized with the present invention without departing from the novel concepts thereof.

Adjustment of the angularity of the swash plate 25, which will vary the stroke of the pistons 16, is accomplished in a novel manner. As shown in Figures 1, 2, and 4, the sleeve 14 is slidably mounted on the shaft 12 thereby permitting axial movement of the trunnions 27. The swash plate 25 is provided with a radially extending control arm 28 having an arcuate slot 29 adjacent the outer end thereof and in cooperation with a pin 30 carried by the clevis 31. The clevis 31 is integral with, or affixed to the shaft 12 for rotation therewith, and the center of the arc of the slot 29 is coincident with the center of the ball connection 21 shown adjacent the pin 30 in Figure 1. It will be understood that the centers of the plurality of balls 21 which connect the rods 18 to the annular ring 20 lie on a circle and that the center point of the arc of radius of the slot 29 lies on that circle.

In view of the relationship set out above between the sleeve 14 and the shaft 12, it will be observed that reciprocation of the sleeve 14 from an extreme left hand position, shown in Figure 2, to an extreme right hand position shown in Figure 1, will cause the swash plate 25 to pivot about its trunnions 27 and also to pivot and 70 slide relative to the pin 30 passing through the control arm 28. By placing the pin 30 substantially at the same distance from the center of rotation of the shaft 12 as the end 21 of the connecting rods 18, it will be found that the point on the ring 20 which is positioned instan-

taneously adjacent the control arm 28 will maintain a substantially constant axial position. This is achieved through the provision of the arcuate slot in the arm 28 and may be controlled in a rather precise manner through control of the shape of the slot 29.

4

In effect, the linkage shown causes the plane of the swash plate 20 to tilt about a point on the circular line upon which the centers of the ends 21 of the connecting rods 18 lie when in their respective furthermost left-hand position.

As a result of this action, the clearance volume between the left-hand end of the pistons 16 and the left-hand end of the cylinders 11, when the pistons 16 are in their furthermost left-hand, or compression stroke, position remains substantially constant irrespective of the length of the piston stroke. Thus, it is possible to provide a very small volume clearance and cause substantially all of the fluid entering the respective cylinders on the suction stroke to be exhausted on the compression stroke, thereby permitting short stroke, high speed operation with high volumetric efficiency. Such operation, as explained above, minimizes wear and possible piston seizure by reducing piston speeds and reducing operating friction losses and at the same time provides satisfactory output volume at high speeds.

Axial adjustment of the sleeve 14 may be accomplished in various manners, one of which is shown in the figures. As may be seen from Figures 1 and 2, a hydraulically operated piston 33 is connected to a reciprocal piston rod 34 carrying thrust bearings 35, 36 which cooperate with the left-hand end of the sleeve 14. By pumping an incompressible fluid into the chamber 37, or, alternatively, chamber 38, the axial position of the piston 33 may be accurately controlled. With the piston 33 in a fixed, adjusted position, the sleeve 14 will be maintained securely in an axial adjusted position relative to the shaft 12 by the thrust bearings 35 and 36. In such adjusted position, the sleeve 14 will absorb a portion of the axial load imposed upon the system by the reciprocating pistons 16 and the remainder of the load will be absorbed through the clevis 31 and bearing 13 which is provided with a thrust surface 13a.

The entire rotating system of the pump described above is both statically and dynamically balanced by means of a novel balancing linkage automatically adjustable with adjustment of the swash plate. As may be seen in Figures 1 and 2, weight 40 is pivotally mounted as at 41 to the shaft 12 to rotate with the swash plate 25. A connecting link 42 secures the ring 40 to the control arm 28 by means of the clevis pins 43 and 44, respectively, such that movement of the sleeve 14, and hence movement of the pin 44 will cause tilting of the annular ring 40 in a direction opposite to the tilt of the swash plate 25. Thus, the force couples associated with the swash plate 25 and weight 40, respectively, will balance each other out relative to the respective support bearings 14 and 13, thereby minimizing the tendency of the shaft 12 to vibrate within those bearings.

Static balancing of the system may be simply achieved through the addition of the weight 48 disposed at 180° relative to the clevis 31. Additional weight to balance the link 42, both statically and dynamically, is provided at 49 on the annular ring 40. It will be seen that adjustably positioning the weights 40 and 49, in the manner above described, will substantially balance, both dynamically and statically, the rotating system of the present pump in all conditions of stroke adjustment. It will also be perceived that this system is unusually simple and that simplicity is achieved, in part, through the extremely simple, single, link 42 which acts to tilt the plate 25 and weight 40 in opposite directions. The single link may be used in the present invention since the swash plate 25 tends to pivot, on its adjustment, about an outer peripheral edge rather than about its central axis, while the weight 40 pivots about its central -

•

10

axis. In view of this arrangement, the positioning of the single link 42, as shown, provides a cross over effect without adding a bulky or complex balance weight control which crosses over the axis of the shaft 12.

It will be understood that other and further variations may be made in the structure described above without departing from the novel concepts of the present invention and it is therefore intended that the scope of the present invention be limited only by the scope of the appended claim.

I claim as my invention:

A constant clearance volume swash plate actuated pump comprising a rotating shaft, a swash plate, a sleeve mounted for rotation with said shaft in slidable relationship thereto and carrying radially extending trunnions pivotally supporting said swash plate, a plurality of axially disposed pistons circumferentially surrounding said shaft, a ring mounted on said swash plate with said swash plate being journalled therein, each of said pistons having a connecting rod having a pivotal connection therewith and with said ring, the connections with said ring being aligned in a circle, an arm member secured to said swash plate having a slot in the end thereof extending in generally radial alignment with said swash plate and formed in register with the pivotal connections of said connecting rods and said ring, a second arm member secured for rotation with said shaft in fixed axial relationship thereto, pin means secured to the

end of said second arm member and positioned in said slot whereby relative axial movement of said sleeve and said trunnions relative to said shaft causes tilting of said swash plate about a point adjacent the periphery thereof, said point being defined by said pin and being in register with said circle to afford said constant clearance volume, and means for moving said sleeve and said trunnions relative to said second arm member.

References Cited in the file of this patent UNITED STATES PATENTS

	803,149	Clark Oct. 31, 1905
15	1,825,691	Hall Oct. 6, 1931
	1,869,189	Eggert July 26, 1932
	2,031,346	Wahlmark Feb. 18, 1936
	2,231,100	Wahlmark Feb. 11, 1941
	2,337,511	Wahlmark Dec. 21, 1943
	2,451,453	Tuxhorn Oct. 12, 1948
20	2,513,083	Eckert June 27, 1950
	2,520,632	Greenhut Aug. 29, 1950
	2,706,384	Schott 1950
		Schott Apr. 19, 1955
	2,737,900	Smith Mar. 13, 1956
25		FOREIGN PATENTS
	276,072	Great Britain Aug. 18, 1927
	493,976	Italy May 12, 1954
	605,215	France May 21 1926