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H. A. DE LANEY

2,923,251

ROTARY ENGINE

Filed April 2, 1956

2 Sheets-Sheet 1

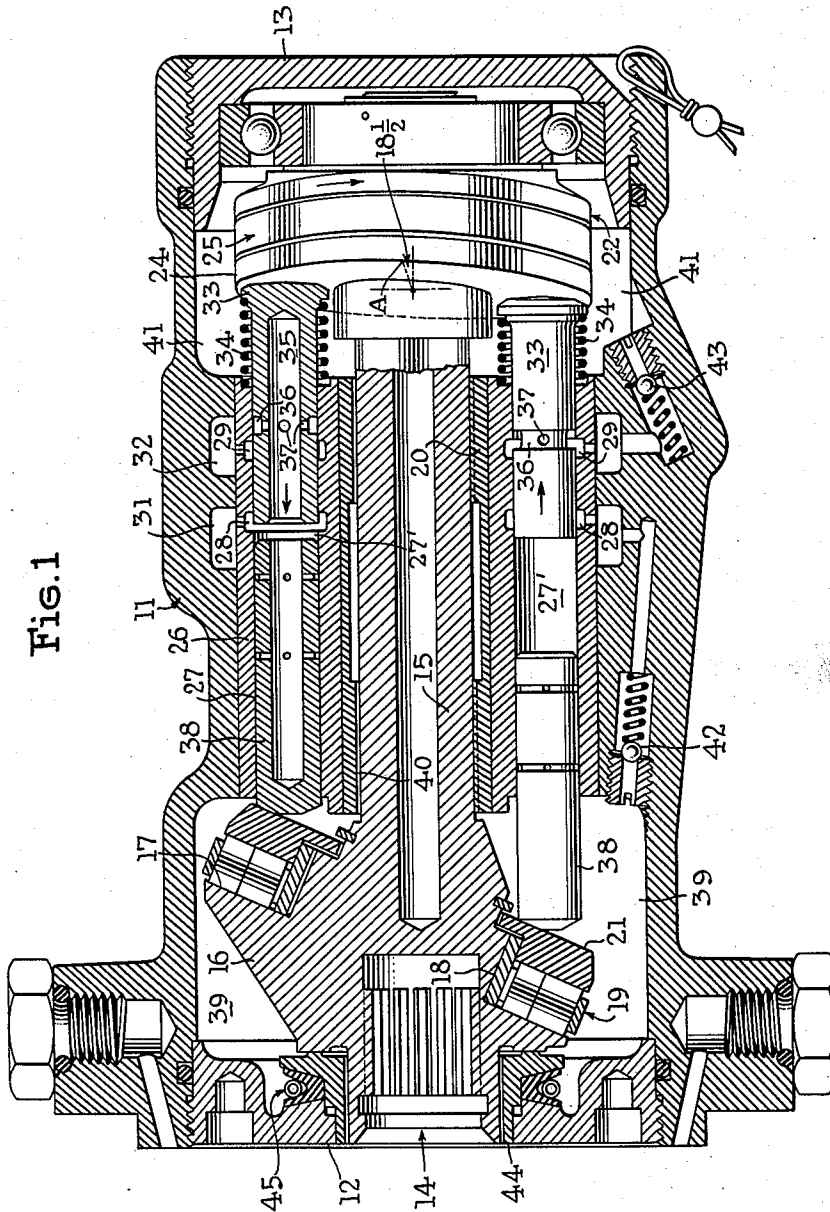


Fig. 1

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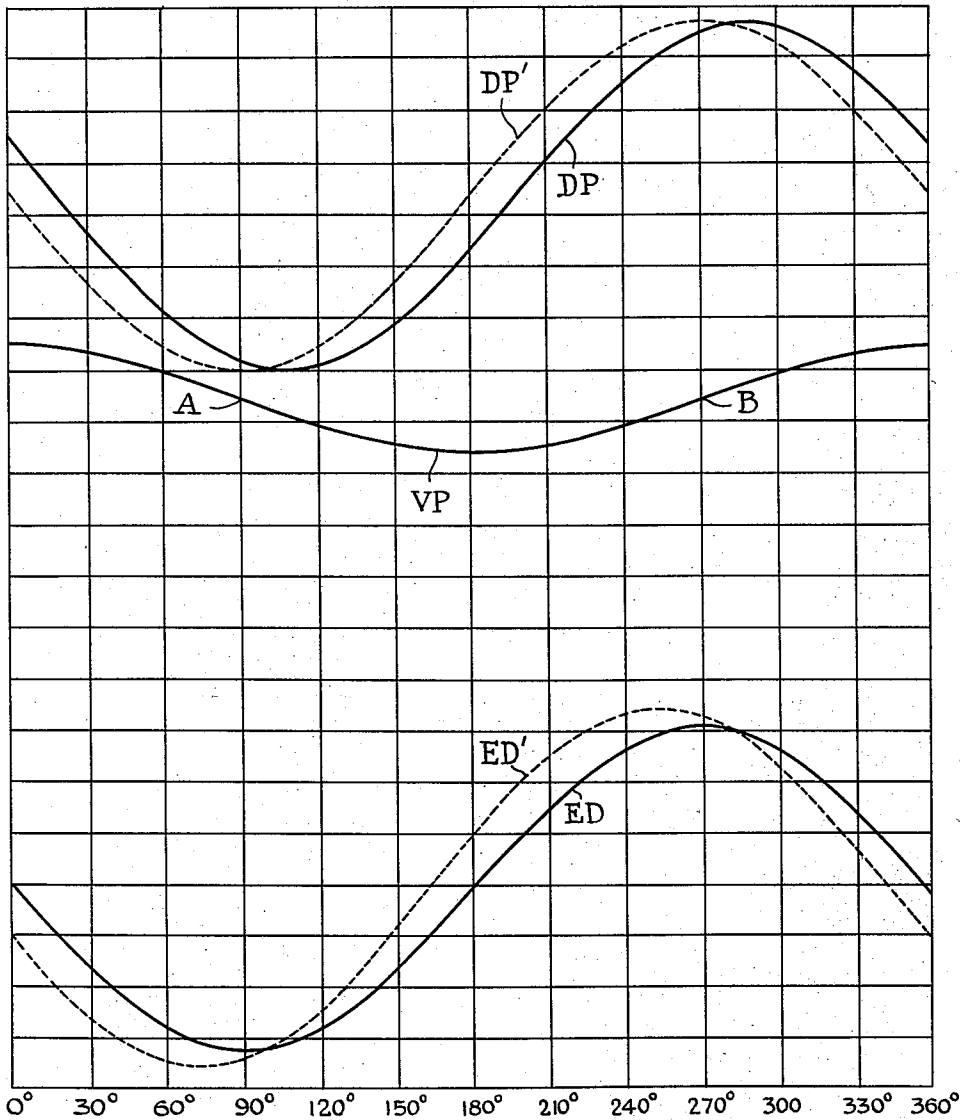
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FIG. 2



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ROTARY ENGINE

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Application April 2, 1956, Serial No. 575,400

3 Claims. (Cl. 103—173)

This invention relates to rotary hydraulic engines. Specifically it relates to an improvement to the engine described and claimed in the Huber patent, No. 2,391,575, dated December 25, 1945, and assigned to applicant's assignee.

The structure of the engine in a preferred embodiment of the present invention is basically similar to that shown in the Huber patent. The engine comprises a multipart housing having a centrally located cylinder block secured therein. The cylinder block is provided with a circular series of through cylinder bores which are parallel with one another and with the axis of a rotary shaft which extends through central bearings formed in the cylinder block. The axial position of the shaft is determined by adjustment of a screw threaded abutment in one end of the housing. This feature of the preferred embodiment is more fully described and claimed in the application of M. W. Huber, Serial No. 576,670, file April 6, 1956, and now Patent No. 2,785,639, dated March 19, 1957, and assigned to applicant's assignee.

Formed in the block and communicating with each of the cylinder bores are axially spaced inlet and exhaust ports. Two swash plates are mounted on the shaft and are provided with different degrees of inclination. A piston type distributing valve is reciprocable in each of the cylinder bores and is arranged with its projecting end in contact with the swash plate having the smaller degree of inclination. These distributing valve pistons control the flow of liquid through the axially spaced inlet and exhaust ports and are designed so that the ports are closed with zero lap when the distributing valve pistons are at midstroke. A displacement piston is reciprocable in each cylinder bore and its projecting end is in contact with the other swash plate. The working space defined between the displacement pistons and the piston valves is connected alternately with an exhaust or an inlet port. The change-over between connection to an inlet or an exhaust port occurs as the piston valve passes through the zero lap position defined above.

According to the Huber patent the two swash plates were arranged so that the high point of one cam was removed substantially 90° from the high point of the other cam. If this phase relationship between the cams exists and if the distributing valve pistons have a negligible displacement, the admission and exhaust of liquid from the working space is properly timed. Of course the displacement of liquid by the distributing valve pistons, while it may be small, does make up a measurable part of the total displacement of the engine and therefore the timing resulting from this phase relationship is not entirely correct. This inherently incorrect timing was recognized by the patentee.

Since the Huber engine is a reversible engine, it was necessary that the valves be timed as nearly correctly as possible for both directions of rotation and the 90° phase relationship, though a compromise, was believed to represent the best timing available.

The present invention involves the recognition of the

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fact that the piston valves and the displacement pistons are each reciprocated by their swash plates with substantially sinusoidal motion and that as a result the displacement of the liquid from the working space between these two pistons is also sinusoidal in character.

5 This characteristic results from the fact that the periods of the sine waves representing respectively the motion of the distributing valve pistons and the displacement pistons are identical. Two sine waves which have the same 10 period will produce a resultant sine wave having the same period and whose amplitude at any point is equal to the algebraic sum of the amplitudes of the two sine waves of which it is the resultant.

The ideal condition involving the displacement of fluid 15 from each working space in the present engine is achieved if port reversal occurs when the displacement from the working space is zero. Therefore it is desirable that the zero lap condition, occurring at midstroke of the distributing valve pistons, occur when this displacement is zero. This condition is realized when the sine wave representing the displacement from the working space is precisely 90° out of phase with the sine wave representing the motion of the distributing valve piston. This result can be achieved by changing the phase relationship 25 between the two swash plates. If this phase angle is made greater than 90°, improved valve timing results. The amount of increase in the phase angle between the two swash plates is dependent upon the amplitude of motion of the distributing valve pistons and the displacement pistons. Of course the motion of the valve pistons must be adequate to assure an adequate flow of liquid to and from the working space at all times during operation of the engine, but this motion should be reduced to a practicable minimum. The ideal condition would occur 35 if the two swash plates could be arranged 90° out of phase with one another and still preserve proper valve action. Unfortunately this condition cannot be achieved because the distributing valves must move in order to perform their function and this motion contributes to the displacement of liquid in the engine.

In the illustrated embodiment of the invention, the distributing valve pistons have a displacement which is slightly less than 1/3 of the displacement of the displacing pistons. Under these conditions, ideal valve timing 45 is achieved by providing a phase angle of approximately 108 1/2° between the high points of the two swash plates. This timing is correct regardless of the direction of rotation of the swash plates.

A clearer understanding of the invention will be had by reference to the following description which refers to the accompanying drawings in which:

Fig. 1 is an axial section partly in elevation of a motor embodying the invention.

Fig. 2 is a graphic representation of the displacement characteristic of the motor of the present invention and also showing in dotted line a graphic representation of a motor having the characteristic of the above-mentioned Huber patent.

As shown in Fig. 1 the motor comprises a housing comprising a generally cylindrical central portion 11 closed at its opposite ends by screw-threaded abutments 12 and 13. The abutment 12 is provided with a central aperture through which one end of the shaft assembly 14 projects. This end of the shaft assembly 14 is counter-bored and the counterbore is provided with splines whereby the assembly may be attached to a driving means.

The shaft assembly 14 includes a central shaft 15 which extends end to end through the housing and a swash plate 16 formed integrally with the shaft 15. Swash plate 16 is provided with an inclined thrust face 17. Projecting normal to the thrust face 17 is a cylin-

dric al abutment 18 which sustains the cage of a roller thrust bearing assembly 19. A wear plate 21, parallel with the thrust face 17, is sustained by the bearing assembly 19.

A second swash plate 22 is releasably attached to the opposite end of the shaft 15. This swash plate 22 is provided with a thrust face inclined to the axis of the shaft 15 but at an angle less than the angle of inclination of the thrust face 17 of the swash plate 16. An annular wear plate 24 is mounted parallel to this thrust face and sustained by roller thrust bearing assembly 25. The bearing assemblies 19 and 25 are fully described and claimed in the Huber application Serial No. 573,420, filed March 23, 1956, and assigned to applicant's assignee.

A cylindrical cylinder block 26 is pressed into the housing 11 between the swash plates 16 and 22. Cylinder block 26 has a central aperture in which is mounted a bearing bushing 20 in which the shaft 15 is journaled. A circular series of open-ended cylinder bores 27 is provided in the cylinder block 26. Each of the bores 27 is encircled by spaced annular grooves 28 and 29. The cylinder block 26 is encircled by two annular chambers 31 and 32 formed in the housing 11. The annular chambers 31 and 32 are in communication respective with each of the annular grooves 28 and 29 by means of drilled passageways as shown.

A distributing valve 33 of the piston type closes one end of each bore 27. The projecting ends of the distributing valves 33 are encircled by springs 34 which bias the outer ends of the distributing valves into thrust engagement with the wear plate 24.

A counterbore 35 is provided in each of the distributing valves. Each of the distributing valves 33 is provided with an encircling groove 36 which is in communication with the counterbore 35 by means of drilled cross ports 37.

The opposite end of each of the bores 27 is closed by a displacement piston 38. The projecting ends of the pistons 38 are in thrust engagement with the wear plate 21. The piston valves 33 and the displacement pistons 38 define a working space 27' between them.

A plurality of axial grooves 40 are formed in shaft bearing bushing 20. In this way fluid may flow from the swash-plate chamber 39 to the swash-plate chamber 41. The chamber 39 is in one-way flow communication with the encircling chamber 31, a check valve 42 being arranged to prevent flow from the chamber 31 to the chamber 39. Similarly one-way flow communication is afforded from the chamber 41 to the encircling chamber 29. A check valve 43 inhibits reverse flow through this communication.

An oil seal encircles the projecting end of the shaft assembly and comprises an axially movable sealing member 44 which is biased in sealing engagement with swash plate 16 by the combined sealing ring and garter spring assembly 45.

Solely for the purpose of describing the operation of the device it will be assumed that the liquid is admitted through chamber 32 so that the motor rotates in the direction of the arrow on the swash plate 22. Liquid is discharged from the engine through chamber 31. For purposes of simplifying the illustration it has been illustrated as though the motor included an even number of cylinder bores and only two sets of distributing valves and pistons are illustrated.

The displacement pistons 38 are shown in their extreme positions and the plane of section of Fig. 1 passes through the high and low points of swash plate 16. As illustrated the low point of the swash plate which actuates the valve pistons is at "A" and is $108\frac{1}{2}^\circ$ out of phase with the swash plate 16, i.e. $18\frac{1}{2}^\circ$ more than the 90° phase angle recommended in the Huber patent.

Because of this phase relationship it will be apparent

that the upper piston valve 33, as shown in Fig. 1 is moving to the left as shown by the arrow and port reversal has not yet occurred. The lower piston valve 33 is moving to the right and port reversal has not yet occurred.

The upper working space 27' will be connected to the discharge chamber 31 while the lower space 27' is connected to high pressure chamber 32. Port reversal will occur when the swash plates have rotated an additional $18\frac{1}{2}^\circ$ from the position illustrated in Fig. 1. At this time the distance between the pistons, which is a function of the volume of the working space 27' will have achieved its maximum in the lower bore and its minimum in the upper bore. Since the pressure fluid is a liquid and substantially incompressible except for included gases it is desirable that the port reversal occur when the direction of displacement changes.

The 90° phase relationship disclosed in the Huber patent causes port reversal to occur too soon in one direction of rotation and too late in the other direction of rotation. Early port reversal means that a working space, whose volume is still increasing, is connected to the motor's discharge. A partial vacuum will be drawn in this working space and will cause the displacement piston to be separated from its swash plate momentarily until the volume of the working space starts to decrease. Reengagement between the swash plate and the displacement pistons occurs with an undesirable impact. In a working space whose volume is decreasing, the early port reversal results in the early connection to inlet pressure, which acts in opposition to the rotation of the motor. In the other direction of rotation, late port reversal results in the momentary creation of a partial vacuum in the working space whose volume is starting to increase, which results in a momentary separation of the displacement piston from its swash plate and the impact resulting from its reengagement. Late port reversal in a working space which has started to decrease means that inlet pressure acts in opposition to the motor's rotation. Precise timing as taught by this invention avoids both of these conditions.

The graphic presentation of Fig. 2 permits a more readily understood discussion. The curve DP represents the motion of a single displacement piston, the curve VP represents the motion of the corresponding piston type distributing valve. The curve ED represents the distance between the pistons. So long as this distance is increasing, the working space is receiving liquid and when it is decreasing, liquid is being displaced from the working space.

The points A and B on curve VP represent the points at which port reversal occurs. The curve ED is a curve which is the algebraic sum of the curves VP and DP. The curve ED under ideal conditions is 90° out of phase with the curve VP so that port reversal points, A and B, occur when ED has reached its maximum or its minimum. The phase relation between VP and DP is selected so that the proper phase relationship is achieved between VP and ED. The dotted curve DP' represents motion of a displacement piston which is 90° out of phase with the curve VP. The dotted curve ED' represents the piston separation which results from this phase relationship between DP' and VP. Since port reversal occurs at A and B, it will be apparent that it does not coincide with the points of maximum and minimum distance between the pistons. This is the condition characteristic of the Huber device, and the improvement achieved by the present invention is easily recognized by comparison of the two sets of curves.

Mathematically the solution may be stated:

$$\theta = 90 + \sin^{-1} \frac{T}{D}$$

in which:

θ is the phase angle between the motion of the valve pistons and the displacement pistons.

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T is the total displacement of the valve piston.
D is the total displacement of the displacement piston.

The phase angle will be correct regardless of whether liquid is supplied to the motor from chamber 32, as assumed in the description of operation or whether it is admitted at 31 to cause rotation in the opposite direction.

While the invention has been described as it is embodied in a motor, it will be obvious to one skilled in this art that it could also be embodied in a pump of the same type. The word engine is used in the appended claims in its generic sense and includes pumps and motors.

What is claimed is:

1. In an expansible chamber engine, the combination of a rotary shaft rotatable in either direction; a plurality of expansible chamber units each comprising an open-ended cylinder having supply and exhaust ports, a displacement piston closing one end of the cylinder, and a distributing valve of the piston type closing the other end of the cylinder, whereby an intervening working space is formed, the piston valve serving to connect the supply and exhaust ports alternately with the working space; and mechanical connections between the shaft and the displacement pistons and between the shaft and the valve pistons so arranged that the displacement pistons and valve pistons are reciprocated substantially sinusoidally and so that each valve piston is reciprocated 90° out of phase with the sinusoidal variation of the axial distance between it and the corresponding displacement piston.

2. In an expansible chamber engine, the combination of a rotary shaft rotatable in either direction; a plurality of expansible chamber units each comprising an open-ended cylinder having supply and exhaust ports, a displacement piston closing one end of the cylinder, and a distributing valve of the piston type closing the other end of the cylinder, whereby an intervening working space

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is formed, the piston valve serving to connect the supply and exhaust ports alternately with the working space; and mechanical connections between the shaft and the displacement pistons and between the shaft and the valve pistons so arranged that the displacement pistons and valve pistons are reciprocated substantially sinusoidally, the motion of the displacement pistons being out of phase with the motion of the valve pistons by an angle equal to

$$90^\circ \text{ plus } \sin^{-1} \frac{T}{D}$$

in which T represents the total valve piston displacement and D represents the total displacement of the displacement pistons.

3. In an expansible chamber engine, the combination of a plurality of expansible chamber units each including a working space and two cylinder bores communicating therewith, one of the cylinder bores having spaced supply and discharge ports, a piston type distributing valve reciprocable in the last-named bore and serving to connect said working space alternately with the supply and discharge ports, and a displacement piston reciprocable in the other cylinder bore; a shaft rotatable in either direction relatively to said units and mechanical connections between the shaft and the valve pistons and between the shaft and the displacement pistons so arranged that said displacement pistons and valve pistons are reciprocated substantially sinusoidally, and so that each valve piston is reciprocated 90° out of phase with the sinusoidal variation of the volume of said working space.

References Cited in the file of this patent

UNITED STATES PATENTS

2,391,575	Huber	Dec. 25, 1945
2,431,686	Deschamps	Dec. 2, 1947