

May 26, 1953

R. HADEKEL
PUMP OR MOTOR

2,639,673

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2 Sheets-Sheet 1

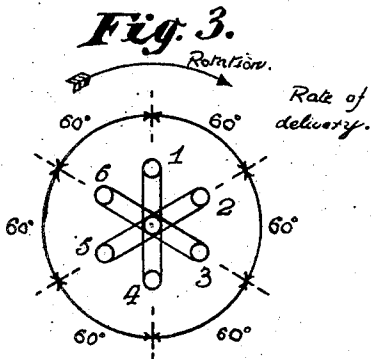
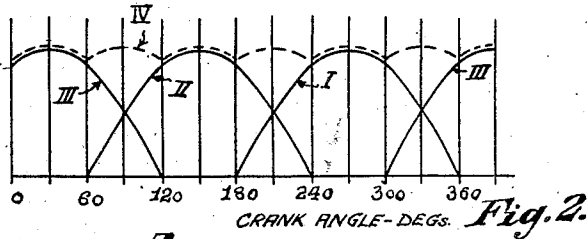
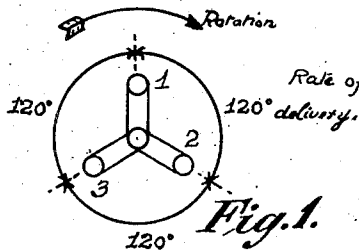


Fig. 4.

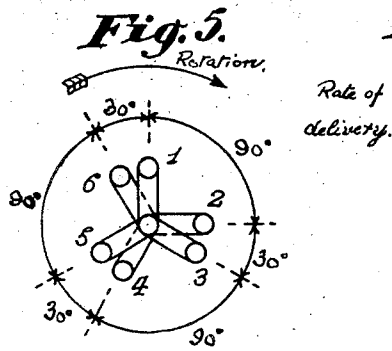
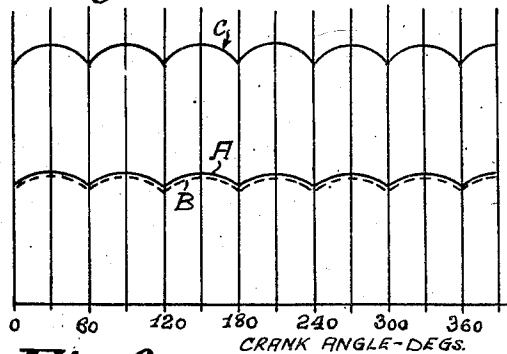


Fig. 6.

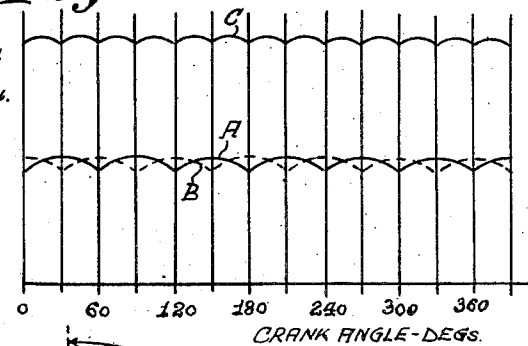
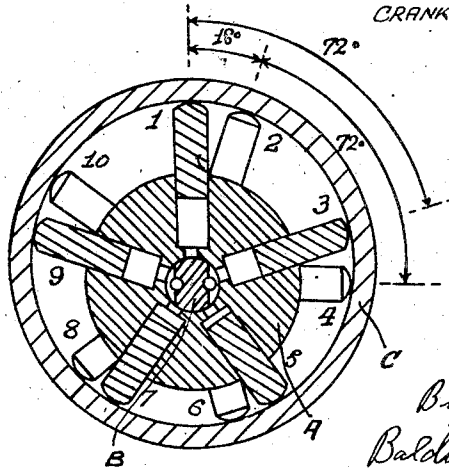


Fig. 7.



Inventor:
Ruben Hadekel,
By his attorneys:
Baldwin, Wright & Perrot

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2 Sheets-Sheet 2

Fig. 8.

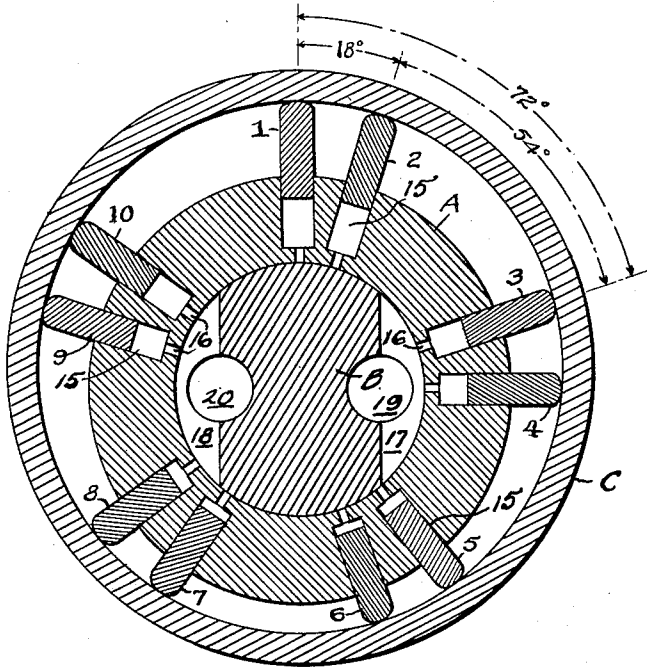
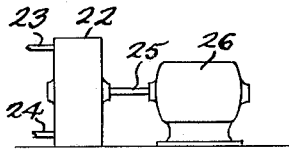


Fig. 9.

INVENTOR: /
/

Ruben Hadekel;

BY Baldwin & Wright

HIS ATTORNEYS

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PUMP OR MOTOR

Ruben Hadekel, Warrington, England, assignor
to Electro-Hydraulics Limited, Warrington,
England, a British company

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1 Claim. (Cl. 103—161)

1

This invention relates to gas or liquid multi-piston pumps or motors, the terms pumps or motors hereinafter being used broadly to include multi-cylinder gas or liquid pumps, internal combustion engines and other devices wherein rotary motion is converted into gas or liquid pressure or vice versa.

In such devices, a constant rotational crankshaft speed corresponds to a pulsating variation in each cylinder and although the outputs of the cylinders are additive, the resultant still contains a substantial pulsating component or ripple.

Such pumps or motors usually have a plurality of piston-cylinder or equivalent pairs, so arranged as to deliver fluid in determinate sequence. For instance in a four cylinder piston pump the pistons may be driven by cranks set at 90° apart, so that one piston is "phased" with respect to another, that is to say, one piston commences to deliver one quarter of a crank revolution before the preceding one. This "phasing" of the pistons may correspond to actual physical angles between crank throws if the pistons are crankshaft driven and set in line; in a crank mechanism with radial arrangement of cylinders it may correspond to angles between the axes of the cylinders.

With such piston pumps or motors as at present known, the difference in phase between each piston and the next piston is equal; for example, in a seven piston pump the difference in phase between each piston and the next is

$$\frac{360}{7}$$

degrees. It is known that such pumps having an even number of pistons are markedly inferior in point of smoothness of delivery to those pumps having an odd number of pistons.

This invention relates to that type of pump or motor in which the fluid chamber is caused to change its volume according to an approximate sinusoidal law and is applicable more particularly to that type comprising a number of chambers the volume of which varies approximately according to a simple harmonic law and includes, for example mechanism in which each piston performs two complete to-and-fro motions for one complete revolution of the driving member.

The object of this invention is to reduce what may be termed "the overall resultant ripple amplitude" for a given number of pistons the object being achieved by so arranging the phasing of the pistons as to increase the overall resultant ripple frequency.

In a pump or motor of the type described according to the present invention an even number of pistons is provided which is not divisible by 4, the pistons being so arranged that the phase difference between succeeding pistons is

2

alternately one half and one-and-a-half times the average phase difference, the latter being equal to 360° divided by the total number of pistons.

The pistons may, if desired, be arranged in two banks.

The term "phase angle" or "phase difference" as used according to this invention, is intended to cover the measurement of displacement of a piston in such a manner that 360° represent a complete "cycle" or to-and-fro motion, irrespective of the actual rotation of the driving member.

In order to explain the mode of functioning of a pump or motor constructed according to this invention, reference will now be made to the accompanying diagrammatic drawing, in which

Fig. 1 is a diagrammatic representation of portions of a conventional three cylinder pump or motor showing an angle between adjacent crank throws of 120°.

Fig. 2 is a diagrammatic representation showing the rates of delivery from the cylinders of the same.

Fig. 3 is a view similar to Fig. 1 showing a six cylinder motor or pump wherein the crank throws are 60° apart.

Fig. 4 is a diagrammatic representation showing the rate of delivery from the cylinders of the same.

Fig. 5 is a diagrammatic view similar to Figs. 1 and 3 showing the cranks of a six cylinder engine arranged in accordance with the present invention.

Fig. 6 is a diagrammatic representation showing the rate of delivery from a pump of the type shown in Fig. 5.

Fig. 7 is a sectional view of a ten cylinder motor embodying the present invention wherein the pistons are radially slidable and wherein the pistons are arranged in two banks arranged in two different planes.

Fig. 8 is a similar view wherein the pistons are all arranged in the same plane, and

Fig. 9 is a diagrammatic showing of the present invention, primarily operating as a pump and driven by an electric motor.

For the sake of clarity, it is assumed that, except in Fig. 7, the cylinders are arranged in line and are driven by an orthodox form of crankshaft.

Referring to Figs. 1 and 2, the pistons and corresponding crank throws are numbered 1, 2 and 3 the angle between the crank throws being 120°, which is the phase angle between the successive pistons. The movement of the pistons being approximately simple harmonic, the rate of delivery from each cylinder can be represented by the positive portion of a sine curve; thus the rates of delivery from cylinders 1, 2 and 3 are shown by curves I, II and III respectively in

Fig. 2. The total rate of delivery is obtained by adding the above curves, and is therefore given by curve IV of Fig. 2. It will be noted that this last curve is a series of ripples, each of which spans 60° of crank angle, i. e. one sixth of a revolution. In this sense a three-cylinder pump has virtually six cylinders.

Referring to Figs. 3 and 4 showing a six-cylinder pump of orthodox construction, the end view of the crank is shown in Fig. 3, the crank throws (1 to 6) being 60° apart. Now pistons 1, 3 and 5 can be considered as forming a three-cylinder pump, and their total rate of delivery will therefore be given by curve IV of Fig. 2. Similarly pistons 2, 4, and 6 form another three-cylinder pump, and their delivery is represented by a similar curve, but dephased by 60°. This is curve B of Fig. 4, which is seen to be coincident with curve A. The resultant rate of flow is obtained by adding the two curves, and is shown in curve C of Fig. 4. This is merely twice curve A (or B) and it is apparent therefore that the flow of a six-cylinder pump of the type described is no smoother than that of a three-cylinder pump. The same comparison holds between a pump with any odd number of cylinders and a pump with twice that number.

Referring now to Figs. 5 and 6 which show a six-cylinder pump according to this invention, the crank throws are so arranged that the angle between successive throws is alternately 30° and 90°, that is, one half and one-and-a-half times the average phase difference which is

$$\frac{360}{6} = 60^\circ$$

The cylinders 1, 3 and 5 can be considered as forming a three-cylinder pump giving a rate of delivery shown by curve A, Fig. 5. Similarly, cylinders 2, 4 and 6 constitute another three-cylinder pump, the rate of delivery being given by a curve B similar to A, but displaced relatively to the latter by thirty degrees instead of sixty as Fig. 4. The total rate of delivery is now given by curve C which is the sum of curves A and B. Curve C now has twelve (instead of six) ripples for each crank revolution, the amplitude of the ripples being very much smaller. Thus a construction according to the invention gives a much smoother resultant output.

In Figures 3 and 5, the cylinders are arranged in two banks positioned in the same plane.

Another example of pump according to the invention is shown in Fig. 7 in which the banks are arranged in two different planes. This consists of a rotor A rotating on a shaft B, and carrying pistons the outer extremities of which bear against a track C eccentric to the rotor axis; the shaft B is provided with slots which are arranged to connect the cylinders to "suction" or "delivery" according to direction of motion of the pistons, in known manner.

The pistons are ten in number and arranged in two banks, the first consisting of pistons 1, 3, 5, 7 and 9 all spaced 72° apart from each other. The two banks (which may be in different planes, as shown) are offset by 18° relatively to each other, that is to say the phase difference between succeeding pistons is alternately one half and one-and-a-half times the average phase difference.

In Fig. 8 of the drawings a pump or motor similar to that illustrated in Fig. 7 is shown with the pistons arranged in the common plane with the ends of the pistons bearing against the track C or surrounding eccentric shell whereby rota-

tion of the rotor A about the stationary shaft C causes radial reciprocation of the pistons to provide the desired pumping action. The showing in Fig. 8 is somewhat enlarged and it will be noted that each of the pistons, which are indicated by the same numerals as in Fig. 7, is reciprocal in a cylinder 15 provided at its inner end with a port 16 adapted to communicate successively with chambers 17 and 18 formed by transversely grooving the shaft B. This shaft is provided with a pair of longitudinal passages 19 and 20 communicating with the respective chambers 17 and 18. It will be apparent that these passages will be inlet and outlet passages depending on the direction of rotation of the rotor A.

In Fig. 9 the pump as a whole is indicated by the numeral 22 and is provided with inlet and outlet connections 23 and 24. Used as a pump, the rotor A is adapted to be driven by a shaft 25 connected to a motor 26. When the device is used as a motor, the driving motor 26 is of course omitted and the connections 23 and 24 used for the admission and exhaust of pressure fluid to such motor.

When the invention is applied to hydraulic motors, the arrangement which gives smooth delivery when the machine is used as a pump will give smooth torque when the machine is used as a motor. When the expression "driving means" occurs in the claim, it will be understood that this driving means is the motor 26 of Fig. 9. Where the apparatus is employed as a motor, the driving means would be means for supplying pressure fluid or an explosive charge to such motor.

It will, of course, be appreciated that the coupling together of the two pumps having an odd number of cylinders in such a way that the phase difference of the even number of cylinders thus provided fulfills the requirements of this invention and falls within the scope of this invention.

What I claim is:

A fluid pump or motor comprising a plurality of cylinders and pistons arranged in two sets, inlets and outlets for respective cylinders, and driving means for said pistons, each of said sets consisting of an uneven number of pistons, so arranged that the space phase difference between succeeding pistons is alternately one-half and one and one-half times the average phase difference, the latter being equal to 360° divided by the total number of pistons.

RUBEN HADEKEL.

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