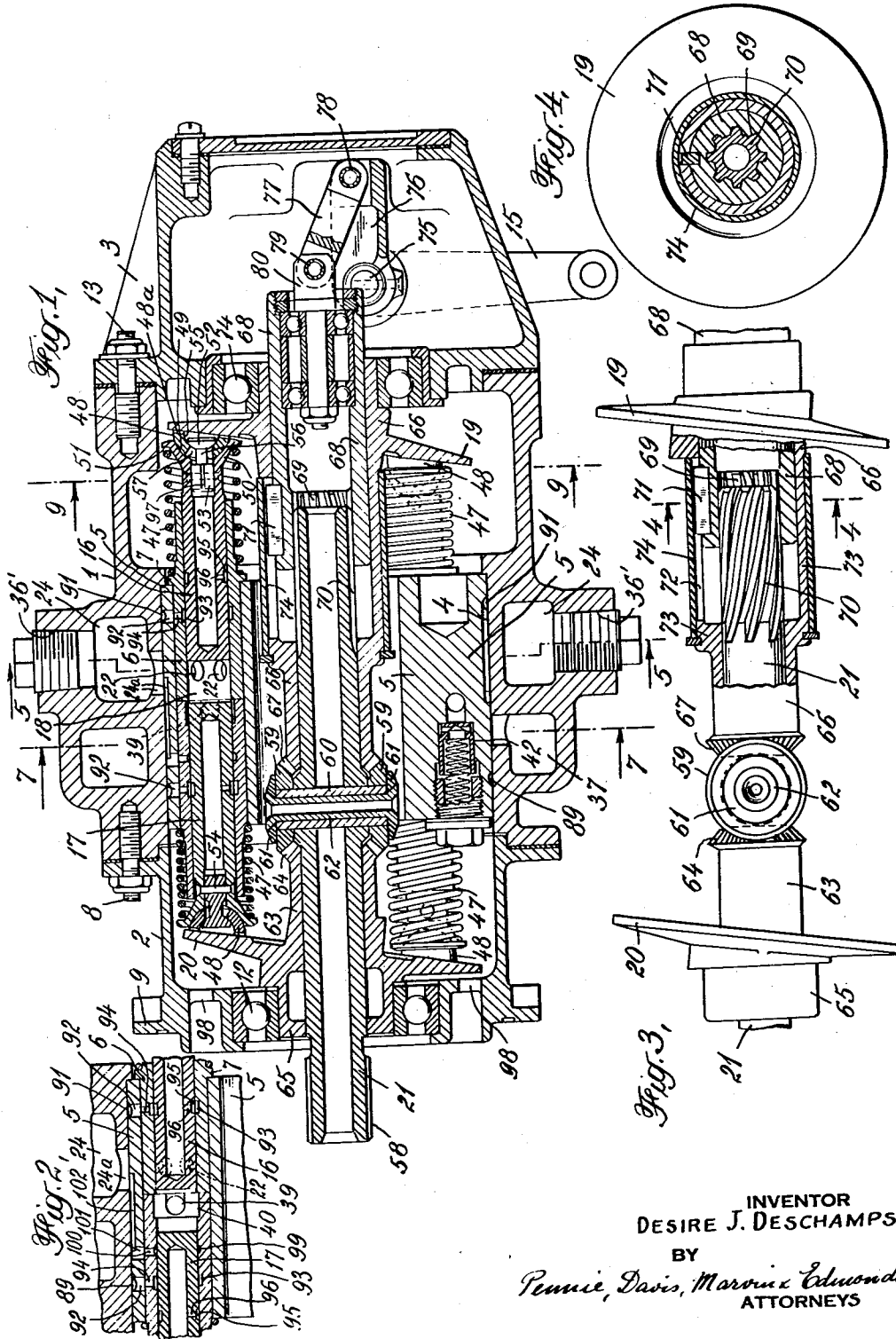


Dec. 2, 1947.

D. J. DESCHAMPS  
VARIABLE CAPACITY PUMP  
Filed July 21, 1943

2,431,686

6 Sheets-Sheet 1



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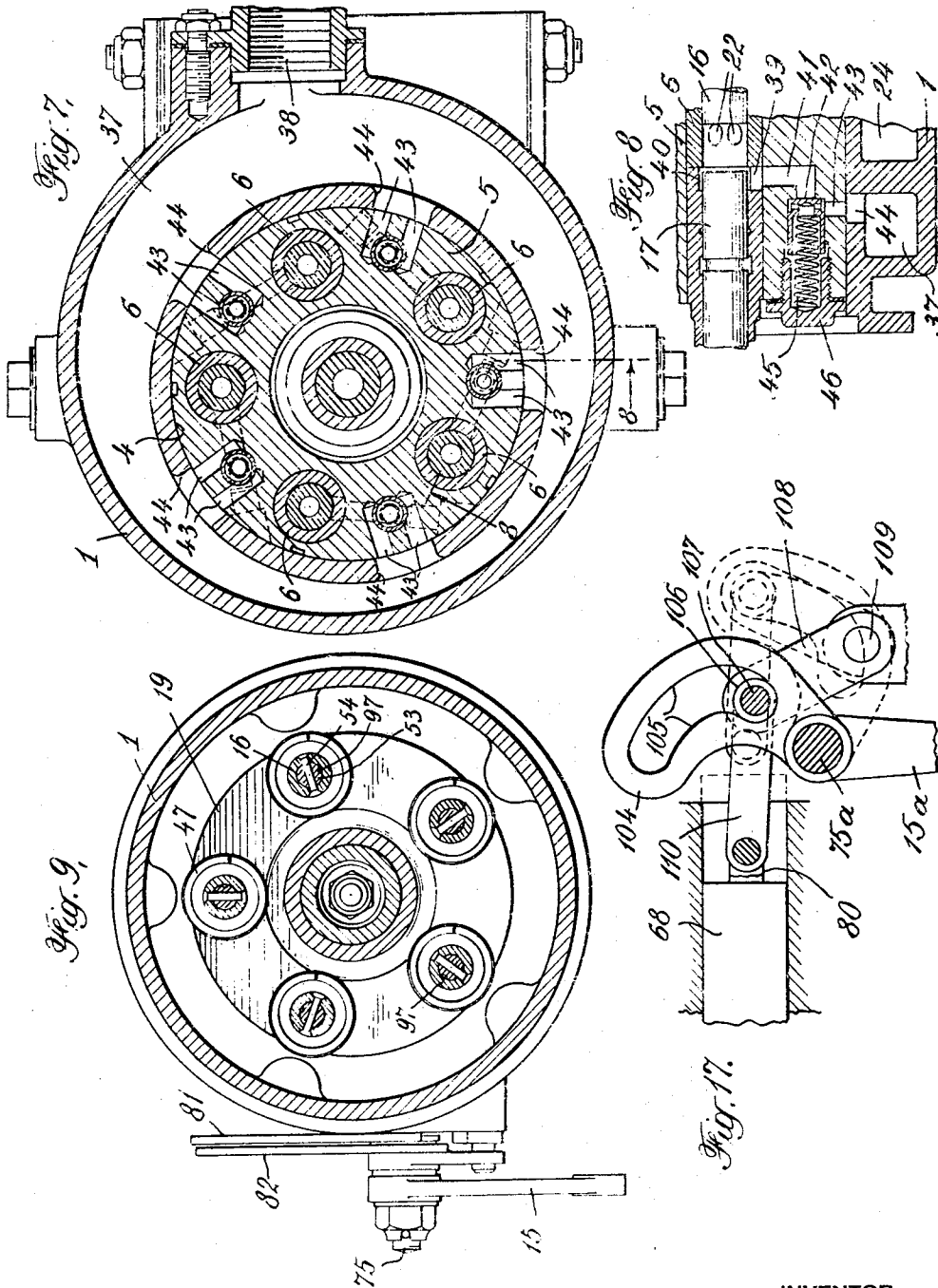
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VARIABLE CAPACITY PUMP

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2,431,686

VARIABLE CAPACITY PUMP

Filed July 21, 1943

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Fig. 10,

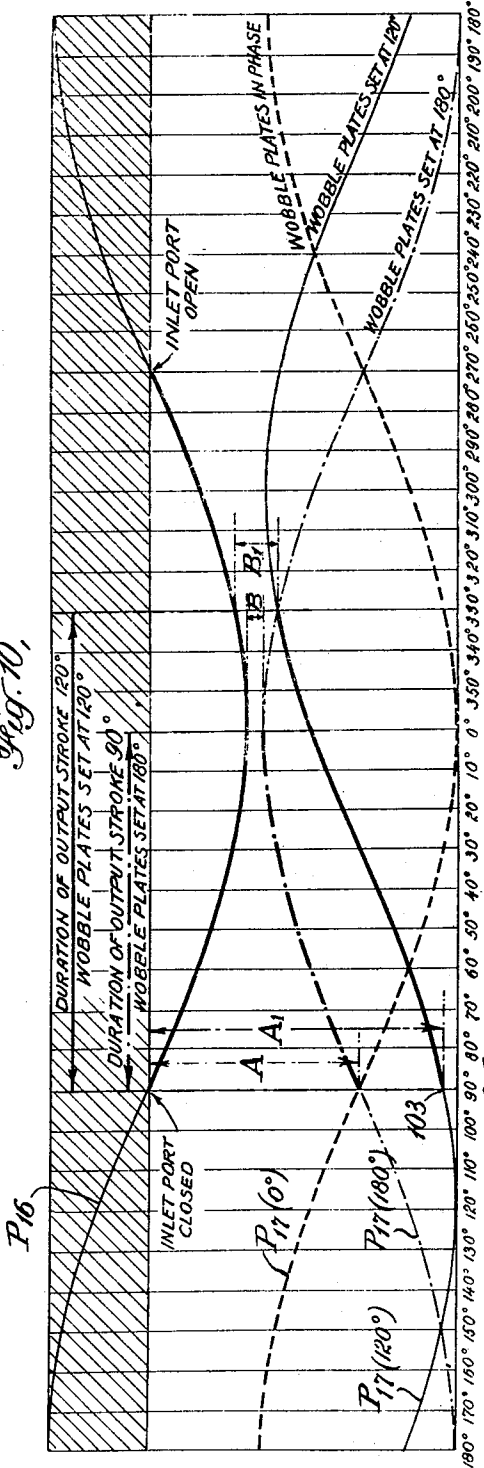


Fig. 11,

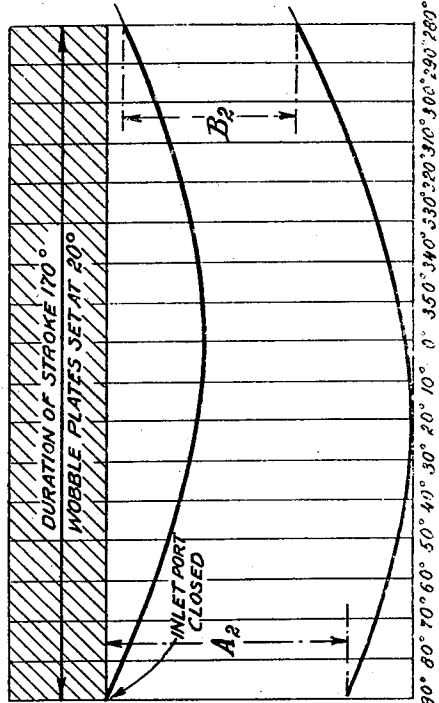
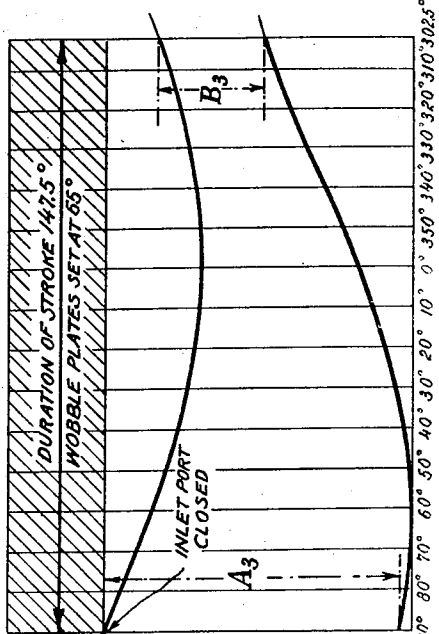


Fig. 12,



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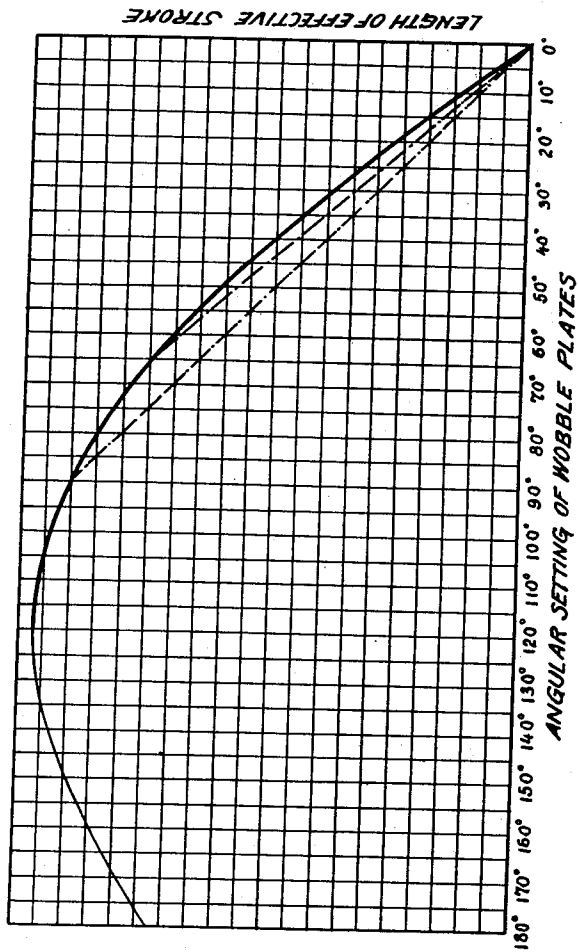
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VARIABLE CAPACITY PUMP

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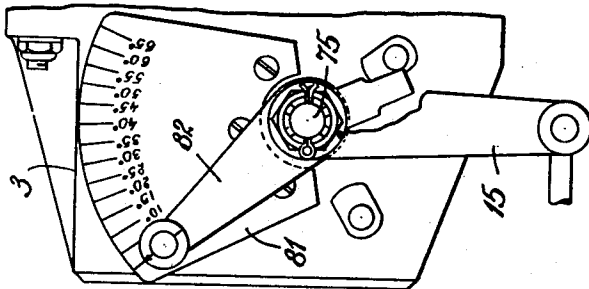
Filed July 21, 1943

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*Fig. 13,*



*Fig. 14,*



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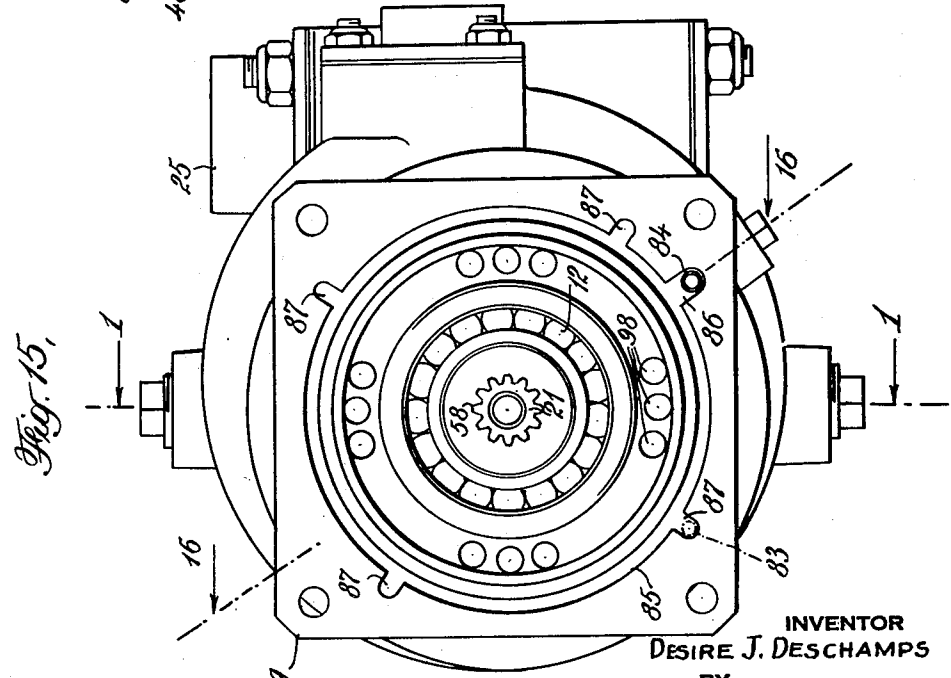
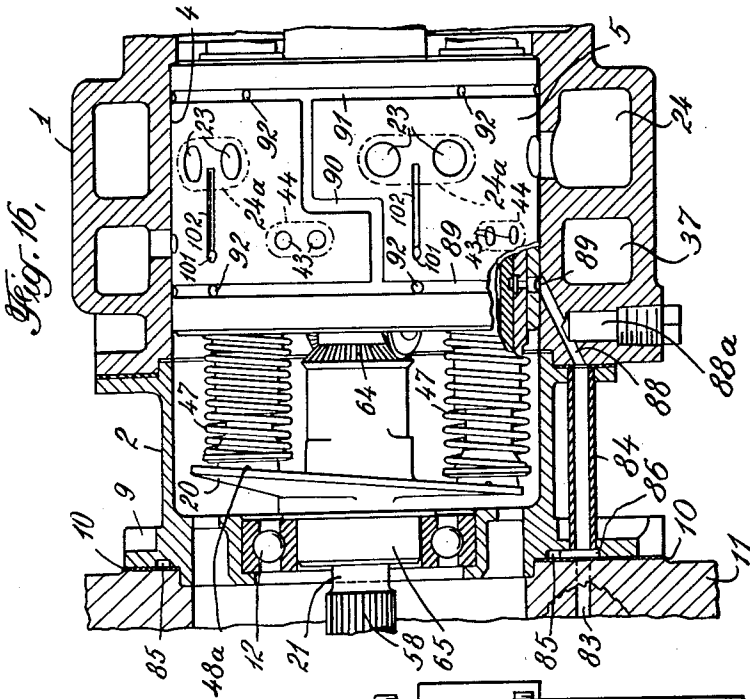
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6 Sheets-Sheet 6



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# UNITED STATES PATENT OFFICE

2,431,686

## VARIABLE CAPACITY PUMP

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Application July 21, 1943, Serial No. 495,541

23 Claims. (Cl. 103—173)

1

This invention relates to variable capacity hydraulic pumps of the positive displacement type, and, more particularly, to pumps provided with one or more cylinders and cooperating pistons or plungers and which are capable of operation at either low or high pressures, the general object of the invention being to provide an improved variable capacity pump.

The invention aims to provide a piston-and-cylinder type of pump in which the capacity or output of the pump can be continuously varied and controlled with great accuracy while the pump is in operation.

Another feature of the invention is the provision of a construction by which an accurate metering of the pump output is obtained not only when pumping near the rated capacity of the pump but also when the pump is delivering small quantities of liquid.

Another object of the invention is to provide a pump construction in which the output varies in equal amounts for equal changes in the setting of the pump capacity control member.

An object of the invention also is to provide a positive displacement pump in which very little force is required to actuate the control member to vary the output from zero to maximum.

Another object of the invention is to provide a pump with substantially a "straight-line" delivery, meaning that for a given setting of the capacity control member, the output increases and decreases substantially in a straight ratio with speed.

Pumps of the type contemplated by the invention have a variety of applications, one of their important uses being to supply fuel to the air intake pipe of an internal combustion engine in conjunction with appropriate control mechanism to proportion the fuel and air in accordance with the demands of the engine, as is done, for example, in supplying fuel mixtures to certain types of aircraft engines—the so-called non-timed injection. The invention will be described as embodied in a pump intended for such use.

Difficulty has been experienced in the operation of such engines with non-timed injection because the pulsating character of the flow from the fuel pump was reflected in the performance of the engine when operating at low speeds, causing the engine to surge.

An additional object of the invention is, therefore, to overcome such difficulty and to provide a variable output positive displacement hydraulic pump which delivers a substantially non-pulsating flow regardless of the pump's output adjust-

2

ment from the maximum output down to substantially zero output.

In connection with pumps for handling fuel such as gasoline it is important to prevent the leakage of the fuel into the lubricating system of the pump and engine. In view of the fact also that such pumps are required to operate at such substantial pressures as above mentioned and to deliver sizable quantities of fuel in gallons per minute when the engine is operating at full power output, and even when the engine is operating at cruising power, difficulties are encountered in connection with adequate lubrication. It is also an object of the present invention to overcome such lubrication difficulties and to prevent the dilution of the lubricant by the fuel.

The invention will be understood from a consideration of the accompanying drawings exemplifying one of its embodiments. In these drawings:

Fig. 1 is a view of the pump in central longitudinal section taken on line 1—1 of Figs. 5 and 15;

Fig. 2 is a fragmentary section similar to Fig. 1 showing the plungers in different position;

Fig. 3 is a detailed view of the pump shaft and its associated parts with certain parts shown in longitudinal section;

Fig. 4 is a transverse section taken on line 4—4 of Fig. 3;

Fig. 5 is a central transverse section taken on line 5—5 of Fig. 1 showing the inlet passages;

Fig. 6 is a view of the pump in side elevation with parts broken away and showing a vertical section taken on line 6—6 of Fig. 5;

Fig. 7 is a transverse section taken on line 7—7 of Fig. 1 showing the outlet passages;

Fig. 8 is a sectional view taken on broken line 8—8 of Fig. 7 showing the outlet valve for one of the cylinders;

Fig. 9 is a transverse section taken on line 9—9 of Fig. 1 looking in the direction of the arrows;

Fig. 10 is a diagram showing the travel of the two plungers of a cylinder with the wobble plate plunger driving cams set at three different angular (or phase) positions and also indicating the effective strokes for these different settings;

Figs. 11 and 12 are diagrams showing the effective strokes for two additional angular settings of the wobble plate cams;

Fig. 13 is a diagram showing the variation of the length of the effective stroke (or output) of the pump with change of the angular setting of the wobble plate cams;

Fig. 14 is a fragmentary vertical section looking

3

from the rear of the pump at the right hand end as shown in Fig. 1;

Fig. 15 is a view of the pump in end elevation looking from the driving end;

Fig. 16 is a view partly in section on the line 16-16 of Fig. 15 showing the lubricating oil inlet passages; and

Fig. 17 is a view showing a modification of the mechanism for adjusting the angular setting of the wobble plate cams.

Referring now to the accompanying drawings, the pump housing or casing comprises a center section 1, a front section 2 and a rear section 3. Center section 1 of the housing has a cylindrical bore 4 within which is mounted a cylindrical cylinder block 5. Block 5 is hollow at the center for the passage of the pump shaft and surrounding this central opening there is a plurality (in this instance 5) of pump cylinder members, or liners, or bushings, 6. These are each provided at their right hand ends with a flange 7 and are forced into suitable openings formed in cylinder block 5.

The front section 2 of the pump housing is secured to center section 1 by means of a series of tap bolts 8 and is provided with a flange 9 having appropriate bolt holes, as shown in Fig. 15, by means of which the pump is mounted upon a suitable support, such as the mounting pad 10 (Fig. 16) which is provided on the frame 11 of the aircraft engine. Front casing section 2 also supports the front ball bearing 12 of the pump.

Rear casing section 3 of the pump is mounted upon the center section 1 by means of a series of tap bolts 13 and supports the rear pump bearing 14. It also houses the pump capacity varying mechanism which is actuated by the capacity-changing or output lever 15.

The pump cylinders 6 are identical with one another and a description of one of these cylinders and its associated parts is applicable to all. Each cylinder 6, as shown in Fig. 1, is provided with two pistons or plungers 16 and 17 whose inner ends cooperate to define between them a common working or pumping space 18. These plungers are actuated by means of two fixed stroke wobble plate cams 19 and 20 which are mounted on the pump main shaft 21 in such a way as to be adjustably rotatable on this shaft to vary the phase angle of the cams while the pump is in operation. The change in the operation of plungers 16 and 17 thus produced varies the effective stroke of the pump.

This may be readily understood by observing that in Fig. 1 the wobble plate cams 19 and 20 are positioned in phase with each other or, in other words, at 0° with one another. Plungers 16 and 17 therefore also move in phase with one another, plunger 16, for example, moving simultaneously with plunger 17 in the same direction and to the same extent so that there is no change in the volume of space 18, the liquid contained therein being simply moved back and forth within cylinder 6. That is to say, the effective stroke is zero.

If, however, the wobble plates 19 and 20 are placed at some angle other than 0° with respect to each other, plungers 16 and 17 will not move in phase with each other and the volume of pumping space 18 will shrink and expand with each rotation of shaft 21; in other words, the pump will have an effective stroke and its amount will depend upon the relative angular positions of wobble plates 19 and 20.

4

In order to admit liquid into the pumping space 18, cylinder 6 is provided with four inlet ports 22 (see Figs. 1 and 5) which open into two drilled passageways 23 in the cylinder block 5 which, in turn, open into a circular inlet chamber 24. The liquid to be pumped, such as gasoline, enters the pump through an inlet connection 25 (Fig. 6) and enters the open end of a cup-shaped filter element 26. After passing through the walls of the filtering element it is received within a surrounding space 27 and flows through a connecting passage 28 into circular inlet chamber 24.

Filter element 26 is arranged to be removed for cleaning and replacement and for this purpose is attached at its closed end to a supporting cover member 29 (Fig. 6) which closes an opening 30 in central casing section 1 which is in axial alignment with the cylindrical filter element. The filter element is attached to cover member 29 by means of a threaded post 31 which projects inwardly from the cover, and washers 32 of rubber or other suitable material are provided on post 31 on opposite sides of the filter element in order to prevent the leakage of unfiltered liquid through the filter.

Cover member 29 is held in position by one or more nuts 33 which clamp the member in opening 30 against a suitable washer 34, and simultaneously force the inner cylindrical end of filter element 26 against a washer 35 which is mounted on a flange member 36 placed inwardly of inlet connection 25.

When the pump is used for pumping volatile fluids, as in conjunction with an engine fuel system, it is necessary to remove air and vapor because their presence in pumping chambers 18 would cause irregular operation and inaccurate control of the pump output. The greater part is removed by a vapor eliminator, and two outlets 36' are provided, both of which are shown in the drawings with plugs in them. These two outlets enable the pump to be mounted in either of two positions on the mounting pad of the engine, and the plug which is at the top is to be removed and a connection made to the vapor eliminator.

Alongside of circular inlet chamber 24 is an outlet chamber 37. The main pump outlet connection 38 is shown in Fig. 7. Each of the cylinders 6 is provided with an outlet port 39 (see Figs. 8 and 2). This opens out of a circular groove 40 surrounding the inner end of plunger 17 when it is at the inner end of its stroke in order to prevent plunger 17 from closing outlet port 39, for although plunger 16 controls the opening and closing of the inlet ports 22, plunger 17 does not control outlet port 39.

In a variable output positive displacement hydraulic pump used for fuel injection it is important to prevent side thrust of the plunger against the walls of the cylinders or bushings, as this would ultimately interfere with the accurate metering ability of the pump. Circular groove 40 extends entirely around the mid-section of the cylinder and for a substantial distance lengthwise adjacent the end of plunger 17, when it is near the inner end of its stroke, having substantially the same width as port 39. Thus it provides a free path for the flow of the liquid towards port 39 and also places the end of the plunger in hydraulic balance.

Outlet port 39 communicates with an L-shaped passage 41 in cylinder block 5 and, mounted in the outer leg of this passage, there is an automatic outlet valve (or check valve) 42. This is a cup-shaped member which seats upon a shoul-

5

der formed in the outer leg of L-shaped passage 41 and when lifted from this seat by the pressure of the liquid, permits the liquid to flow through a pair of drilled passages 43 (Fig. 7) in cylinder block 5 which register with an opening 44 in housing 1. Thus the liquid enters the circular outlet chamber 37.

A helical spring 45 serves to bias valve 42 against its seat and is held in position by means of a removable plug 46 threaded into cylinder block 5. It will be understood that there is an outlet valve 42 and the connecting passages just described for each of the five cylinders 6.

It will be understood that the plungers 16 and 17 are moved inwardly by the respective wobble plate cams 19 and 20 and are moved outwardly by means of helical springs as shown at 47 in Figs. 1 and 16. For the purpose of transmitting the actuating force from cams 19 and 20 to the plungers, each of the plungers is provided at its outer end with a slipper or shoe 48 which is so mounted on the plunger as to maintain its bearing surface in contact with the flat face of its cooperating wobble plate cam regardless of the angular position the plunger may have with respect to the cam during a complete revolution.

In a pump of this type in which the output of each cylinder is very accurately controlled and wherein such accurate control of the output must be maintained throughout a long period of service, it is not only important but very necessary to prevent tilting of the bearing surface of the slipper with respect to the face of the wobble plate. If such tilting is permitted the bearing face of the slipper will be caused to wear unevenly, even to such an extent that the face of the slippers may become convex in shape. Such a condition would make accurate metering impossible.

To bring about absence of a tilting moment on slippers 48 they are arranged to have a center of oscillation on the plunger which is substantially in the plane of the wobble plate bearing face. Slippers 48 are made semispherical in shape and are so mounted that the center of the semispherical surface of the slipper lies in, or substantially in, the plane of the bearing surface of the slipper on the face of the wobble plate. The semispherical surface of slipper 48 is received in a similarly shaped socket 49 formed on the inside of a head member 50 which is preferably formed integrally with the body of plungers 16 and 17 at their outer ends. Head portion 50 has a rim 51 against which bears the operating spring 47.

In order to retain the slipper 48 in the socket thus formed, the slipper is made hollow at the center to receive the head 52 of a retainer 53 which is fitted within a bore in the outer end of the plunger and held therein by means of a cross pin 54. Retainer head 52 also has a semispherical under surface which is concentric with the socket surface 49 of head 50. The interior surface 55 of slipper 48 is of semispherical shape to cooperate with the head 52 so that both the interior and exterior surfaces of slipper 48 are concentric. Head 52 is attached to retainer 53 by a narrow neck portion 56 which passes through a larger opening 57 in slipper 48 in order to permit the necessary freedom of movement to the slipper.

The mounting of the wobble plate cams 19 and 20 and the mechanism for adjusting their relative angular positions on shaft 21 while the pump

6

is operating in order to vary the output or capacity will now be described.

Main shaft 21 of the pump is splined at its outer end as indicated at 58 to provide a driving connection with the aircraft engine when the pump is mounted thereon. Shaft 21 extends into the pump to a point a short distance to the left of the right hand bearing 14 and about midway of its length is provided with two oppositely positioned bosses against which lie the inner faces of two bevel gears 59 which might be said to form the planet pinions of a differential gear mechanism. Gears 59 rotate on a hollow shaft 60 which passes through a cross bore in shaft 21 at the centers of the two bosses previously referred to. The gears are retained in place on hollow shaft 60 by means of washers 61 and a hollow rivet 62. Shaft 21 is preferably made hollow in the interest of lightness.

The wobble plate cam 20 at the left hand end of the pump is integral with or fixed to a sleeve 63 which closely fits the exterior surface of shaft 21, this sleeve being provided at its inner end with bevelled teeth 64 which engage the teeth of bevel gears 59. Sleeve 63 has at its outer end an enlarged hub portion 65 which serves to strengthen wobble plate 20 and also to support the inner race of ball bearing 12.

Wobble plate cam 19 at the right hand end of the pump is fixed near the outer end of a second sleeve 66 which closely fits the surface of pump shaft 21 but is longer than sleeve 63 and extends for a considerable distance beyond the end of shaft 21. Sleeve 66 at its outer or right hand end beyond cam 19 supports the inner race of the right hand pump bearing 14. At its inner end sleeve 66, like sleeve 63, is provided with teeth 67 which engage the teeth of bevel gears 59.

With such a construction the torque for driving or rotating the wobble plate cams 19 and 20 is transmitted from shaft 21 through the differential gear mechanism comprising bevel gears or planet pinions 59 and sun gears 64 and 67, but the wobble plates will tend to rotate to the position where they are in phase with one another, or, in other words, where the output of the pump is zero. At this position the wobble plates may be said to have an offset of 0°.

With the arrangement just described, the rotation of one of the wobble plate cams 19 with respect to shaft 21 in a given direction will cause an equal and opposite rotation of the other wobble plate cam 20. Mechanism is provided for rotating the wobble plates in this manner with respect to one another so as to adjust their offset angle away from the 0° position to cause the pump to produce the desired output and to maintain the wobble plates in such position.

This mechanism includes an offset adjusting member 68 in the form of a hollow sleeve having internal helical splines 69 which engage similar splines 70 provided on the outside of main shaft and extending to the left from its right hand end to enable offset adjusting member or sleeve 68 to be moved axially on shaft 21 to cause it to rotate with respect to the shaft through a predetermined angle.

Such rotation of offset adjusting member 68 is transmitted to sleeve 66 by means of a key 71 fixed in a groove in member 68 of the same length as the key. Key 71 slides longitudinally in an elongated slot 72 cut in an enlarged portion 73 of sleeve 66, this enlargement being provided in order to accommodate offset adjusting member 68. Key 71 is held in place by a thin walled

7

sleeve 74 which is slipped over enlarged portion 73.

The offset adjusting member 68 is movable longitudinally by the output control lever 15 and the connections between them are shown in Fig. 1. Lever 15 is fixed upon the outer end of a shaft 75 which projects through the wall of the rear section 3 of the pump housing (see also Figs. 9 and 14). A yoke 76 is fixed to the inner end of shaft 75 and has a link 77 pivoted to it at its outer end at 78. The other end of link 77 is pivoted at 79 to a member 80 which is connected to offset adjusting member 68 by means of a pair of ball thrust bearings thereby enabling member 68 to be moved longitudinally by member 80 while member 68 is rotating with the pump shaft 21.

From this description it will be understood that movement of output control lever 15 from the position shown in Fig. 1, in a counterclockwise direction, will cause offset control member 68 to slide toward the left on shaft 21, with the result that wobble plate cam 19 will be rotated with respect to shaft 21 and through the differential gearing wobble plate 20 will be rotated an equal amount in the opposite direction. This movement will therefore place wobble plates 19 and 20 out of phase with each other and cause the pump to deliver liquid, the output being at a maximum when the left hand end of offset adjusting member 68 is in contact with the shoulder formed at the bottom of enlargement 73.

The arrangement of the parts can be made to utilize any desired angular movement of output control lever 15, but in order to suit a particular automatic control mechanism with which this embodiment of the improved pump is intended to be used, lever 15 is arranged to have a total angular movement of 65° which, if desired, may be indicated on an indicator dial 81 (Figs. 14 and 9). An indicator 82 affixed to shaft 75 may be arranged to show the position of the output control mechanism on this dial.

It has become almost universal practice in manufacturing aircraft engines to make provision to use oil under pressure from the main engine lubricating system for lubricating engine-driven accessories, such for example, as this pump. The mounting pad 10 (Fig. 16) on the engine thus has an oil supply passage 83 which usually would be located in the position indicated in Fig. 15. Because of the construction of the pump, however, it is more convenient to locate the oil inlet to the pump at 84. To connect the engine supply passage 83 with oil inlet 84 a circular groove 85 is machined in the face of pump mounting flange 9; then a short slot 86 is milled in flange 9 to connect this groove with the oil inlet tube 84 and another short slot 87 to connect inlet 83 with groove 85. In order to allow the mounting of the pump in four different angular positions and have communication with the oil supply 83 at each, three additional short slots 87 are milled in flange 9.

From inlet tube 84 the oil flows through a drilled passage 88 in the central section 1 of the pump housing, to a circular groove 89 formed in the cylindrical surface of cylinder block 5. In case the mounting pad on the engine has not been drilled for an oil connection, the oil is supplied to passage 88 through an outside oil line which is connected to passage 88a. When the mounting pad is provided with an oil supply port 83, then passage 88a is closed by means of a plug as shown in Fig. 16.

8

From groove 89 the oil flows through one or more Z-shaped cross grooves 90 to a second circular groove 91 similar to groove 89 but located near the opposite end of the cylinder block. From these two circular grooves 89 and 91 oil is distributed to each of the sets of plungers 17 and 16 by means of holes 92 drilled in cylinder block 5 opposite each of the cylinder liners 6 and at appropriate locations spaced appropriate distances from each side of the centers of the cylinders (see Figs. 2 and 1). Holes 92 communicate with circular grooves 93 in the cylinder walls through holes 94 in the cylinder liners thereby lubricating the surfaces of the plungers 16 and 17.

The plungers are hollow in order to save weight and the slippers 48 and their mounting sockets are lubricated by oil under pressure supplied through the hollow plungers from grooves 93. To accomplish this, each of the plungers 16 and 17 has a circular groove 95 cut in its surfaces, which for an instant during each reciprocation registers with cooperating grooves 93 and permits a small volume of oil to enter the hollow plunger through a hole 96 at the bottoms of groove 95. The oil from the interior of the plunger flows through a shallow longitudinal groove 97 (see Fig. 1 at the right) in the surface of the body of retainer 53 for holding the slipper 48 in place. The oil passing through this groove lubricates both the socket surface of the slipper and its bearing surface with the wobble plate. Small radial grooves 48a cut in the slipper bearing face with the wobble plates (Figs. 1 and 16) allow the oil to escape without building up pressure under the slipper which otherwise may lift it away from the wobble plate, causing an undesirable modification of the linear movement of the plunger.

The oil escaping around the plungers and from the slippers is thrown about by the rotation of the wobble plates and forms a mist which lubricates the ball bearings 12 and 14 supporting the drive shaft and the wobble plates. This oil collects at the bottom of the pump housing, the oil at the rear part being allowed to drain to the front section 2 through holes (not shown) drilled longitudinally through the cylinder block 5. The oil accumulating at the bottom of the front housing section 2 finally drains back to the lubricating system of the engine through holes 98 drilled in the web supporting the front ball bearing 12.

When pumping liquid of extremely low viscosity which readily penetrates minute passages and which also adversely affects the lubricating qualities of oil, it is important to prevent contamination of the engine and pump lubricating oil by such liquid. Accordingly the cylinders 6 at their ends in which plungers 17 operate are provided with leak-off grooves 99 which are placed a suitable distance from the lubricating oil grooves 93 as shown in Fig. 2. Grooves 99 are placed in communication with inlet openings 24a by holes 100 and 101, drilled through the wall of cylinder 6 and the outer portion of cylinder block 5, and by a longitudinal groove 102 cut in the surface of cylinder block 5 and extending to opening 24a.

Any gasoline which leaks past the end of plunger 17 towards the lubricating oil grooves 93 is thus trapped by leak-off grooves 99, which being at inlet pressure, provide an escape for the gasoline and prevent any tendency for it to leak beyond grooves 99. In connection with the plunger 16 which controls the inlet ports 22 there is no such tendency for the gasoline to leak to the oil pressure grooves 92 because the only time

leakage may occur is when the inner ends of these plungers have closed ports 22 so that if any leakage occurs it merely goes back to these inlet ports.

Referring again to the effect of varying the offset angle of the fixed stroke wobble plates 19 and 20, it will be understood that change in this offset angle produces a change in the relative motion of the two opposed plungers 16 and 17 and that such relative motion determines the extent of shrinkage and expansion of the pumping space 18. This relative motion, that is, the extent to which plungers 16 and 17 approach and recede from each other during each revolution of the pump shaft determines the amount of shrinkage and expansion of the pumping space and measures the effective output of the pump. The maximum relative motion of plungers 16 and 17 occurs when the wobble plates are offset by an angle of 180° so that the plungers are moving inwardly at exactly the same time, the ends of the two plungers coming together as close as is permissible according to good construction and manufacturing practice.

Such maximum relative motion of the two plungers does not, however, produce the maximum pump output because of the intake ports 22, these ports having to be closed by the advance of plunger 16 before the effective stroke of the pump can commence.

This is illustrated in the diagram shown in Fig. 10 in which the vertical distance from the top horizontal line to the bottom horizontal line represents the maximum separation of the inner ends of plungers 16 and 17. The distance horizontally from the left to right in the diagram is laid out in degrees of angular movement for a complete rotation of the pump shaft. The shaded portion at the top represents the width of inlet ports 22. The upper, continuous line curve, indicated by reference numeral P16 represents the motion of the inner face of plunger 16 and the lower curves represent the motion of the inner face of plunger 17 with the wobble plates offset at different angles. The dotted lower curve P17 (0°) represents the movement of the inner face of plunger 17 when the offset angle of the wobble plate is 0°, or in other words, when the wobble plates are in phase with each other. Comparing this curve with curve P16 it will be seen that they are parallel at all points and consequently that there is no relative motion between them and the pump has no effective stroke.

It will be understood that when the wobble plates are set at some angle other than 0°, the effective stroke commences at the point where the inlet ports 22 are closed by the end of plunger 16, and terminates when the two plungers 16 and 17 have reached their point of closest proximity and commence to recede from one another. Between these two points liquid is being forced through the outlet port 39 and check valve 42 into outlet chamber 37. Hence, referring to the dot-and-dash curve P17 (180°) of Fig. 10 and comparing this with curve P16, at the instant the inlet ports 22 are closed by plunger 16, the inner face of plunger 17 is at the position represented by numeral 103 and the faces of the two plungers at this instant are separated by a distance indicated by the reference character A. The pump continues to deliver liquid until the pump shaft has rotated through an angle of 90°, at which instant the two plungers have approached one another until they are separated only by the distance B, after which the plungers commence

to recede from each other. The effective stroke, therefore, with the wobble plate set 180° out of phase, is indicated by the difference between the lengths A and B, that is, effective stroke=A-B.

If, however, we reduce the offset angle of the wobble plates from 180° to 120° as shown by curve P17 (120°) of Fig. 10, the distance A<sub>1</sub> which separates the faces of the plungers at the beginning of the effective stroke is considerably more than the distance A which separated them when the wobble plates were offset 180°. Although the distance B<sub>1</sub> which separates the plungers at the end of the effective stroke is somewhat greater than the distance B, the effective stroke, A<sub>1</sub>-B<sub>1</sub>, is greater than when the wobble plates were set 180° apart. In other words, by decreasing the phase angle of the wobble plates the pump output is increased.

Figs. 11 and 12 show diagrams similar to the central part of Fig. 10 illustrating the length and duration of the effective stroke of the pump at two other offset angles of the wobble plates. In Fig. 11, A<sub>2</sub>-B<sub>2</sub> indicates the effective stroke of the pump with the wobble plates set at 20°, the duration of the output stroke being 170° of pump shaft rotation. In Fig. 12, A<sub>3</sub>-B<sub>3</sub> indicates the effective stroke with the wobble plates set at 65° and the duration of output being 147½°.

It will be noticed that the length in degrees of the delivery period varies inversely with increase in output (from just below 180°, at output nearly zero, to 120° of rotation at maximum output). This results in a smooth, substantially non-pulsating flow at all pump outputs, even down to its lowest output and even when operating at slow speed; the increase in the delivery period with decrease in pump output brings about longer overlapping of the delivery periods of the several cylinders when the pump is operating at low outputs than when operating in its upper capacity range.

The variation in the effective stroke of the pump with change in offset angle of the wobble plates is shown in Fig. 13, the vertical distances of the diagram indicating the effective stroke and the horizontal distances the phase displacement of the plates. From this curve it will be seen that the output reaches a maximum when the wobble plates are offset at an angle of 120° and after that decreases, the output with the wobble plates at 180° being substantially the same as when the wobble plates are at an angle of about 62½°.

It will also be observed that with an offset angle of from 0° to about 65° the variation of the curve from a straight line is substantially negligible. With a pump having such an inherent characteristic, therefore, the simple linkage mechanism shown in Fig. 1 for adjusting the movement of the offset adjusting member 68 can be successfully used. Hence this mechanism is so constructed as to provide a change in the offset angle of the wobble plates 19 and 20 from 0° to a maximum of about 65° with an angular movement of output control lever 15 from 0° to 65°.

It may also be desired to obtain a larger output without increasing the size of the pump, by using, for instance, an offset angle of 90° of the wobble plates or even by using the maximum possible effective stroke by offsetting the wobble plates by 120°. If, for such an application, it is important that even increments in output be obtained for each degree of rotation of the capacity control shaft, then the modified form of control

mechanism shown in Fig. 17 can be employed. This mechanism may be arranged to move offset angle adjusting member 68 a sufficient distance to produce a maximum of 120° offset of the wobble plates although, like the mechanism of Fig. 1, it may also be arranged to produce smaller maximum offset angles.

In the modified control mechanism of Fig. 17 the output control lever 15a is fixed on the end of shaft 75a, which, like shaft 75, projects through the wall of the rear housing section 3. Inside the housing there is fixed to shaft 75a a cam arm 104 having a slotted cam 105. Cam 105 engages a roller 106 mounted on a pin 107 which is fixed near the outer end of an arm 108 pivoted at its lower end at 109 to a boss formed on the inside of housing section 3. In its opposite end arm 108 is also connected by means of a link 110 to member 80 on offset adjusting member 68.

As cam arm 104 is rocked from the full line position shown in Fig. 17 to the dotted line position by the movement of lever 15a, offset adjusting member 68 is shifted from one end of its range of movement to the other. The full line position corresponds to maximum pump output and the dotted line position to zero output. The shape of cam surfaces 105 are such as to compensate for the deviation of the curve shown in Fig. 13 from a straight line so that for equal increments of angular movement of lever 15a the output of the pump will be increased or decreased by exactly the same amount.

In connection with the general arrangement of the pump mechanism, it will be understood that sleeves 63 and 66 which support the wobble plate cams 20 and 19 fit closely the exterior surface of pump shaft 21 and are of sufficient length to prevent any longitudinal rocking movement of the sleeves on the shaft due to the unbalanced forces operating near the peripheries of the cams caused by the operating resistance of the pump plungers. In other words, the structure is substantially rigid. Also it will be understood that the main pump ball bearings 12 and 14 are of a type which will resist the end thrust which is caused by the operating resistance of the plungers. These bearings therefore prevent the outward shift of sleeves 63 and 64 and maintain the teeth of sun gears 64 and 67 in engagement with gears 59 of the differential mechanism.

Due to the fact that the wobble plate cams 19 and 20 tend to rotate to the in-phase, or 0° offset position, it will always require the application of a degree of force to the output control lever 15 in order to maintain the pump setting at any angle other than the zero output position. The lead angle of the helical splines 69 and 70, however, is very small and consequently the end thrust or pressure which must be maintained on offset adjusting member 68 is not objectionable.

When pumping volatile fluids, such as gasoline, in order to obtain accurate control of the output it is important that the pumping space be filled with "solid" liquid (that is, all liquid and no vapor) when the delivery of liquid through the outlet valve commences. The vapor eliminator previously referred to removes the bulk of the vapor, but pressure variations, the velocity of the fluid within the pump itself, and temperature affect the vapor formation in the pump passages and in pumping space 18 of each cylinder. If not removed, such vapor may cause

appreciable variation in the volumetric output of the pump.

By admitting the fluid through ports 22 in the cylinder walls and controlled by one of the plungers, such vapor is given an opportunity to leave pumping space 18 before delivery through the outlet valve commences. These ports are of considerable size relative to the size of the pumping space and, as these ports remain open during the first part of the compression stroke of this plunger, some of the fuel and substantially all of the vapor are forced out so that when the plunger closes the ports there remains only "solid" liquid within pumping space 18.

When used as a fuel injection pump the pump of the present invention may develop a pressure of from about 200 to about 400 pounds per square inch, depending upon the characteristics of the engine with which it is to be used. For other hydraulic applications, however, the pump may be arranged to develop very much higher pressures if desired. There is substantially no limit to its operating pressure.

The pump of the present invention is inherently balanced and can be operated at high rotative speeds, for example, in the neighborhood of 5,000 R. P. M. Consequently the pump has a high volumetric output per unit of weight.

When a pump of this sort, that is, a variable output positive displacement pump, is used as a fuel injection pump, one of the most important considerations is the maintenance of accurate metering under varying conditions. In other words, it is not only important that the output shall be accurately under the control of the capacity-varying member but that straight line delivery, or equal increase in delivery with equal increases of speed, shall be maintained. One of the sources of interference with such operation in pumps of this kind is the formation of vapor within the working space of the pump on the intake stroke which changes its volumetric efficiency.

In the pump of the present invention such change is substantially prevented because of the unusually large inlet port area in relation to the volume of the working space or pump displacement. This keeps down the velocity of liquid flow through the inlet ports thereby preventing such a drop of pressure within the working space during intake as would tend to cause vapor formation. In addition, plungers 16 are arranged so as to move at high velocity during both the opening and closing of inlet ports 22, thereby providing especially quick opening and closing of the inlet ports. Consequently the pump has a substantially straight line delivery with change of speed. Because of the good "breathing" ability of the cylinders there is substantially no change in volumetric efficiency with change in speed.

It will be understood that the foregoing disclosure has been made for the purpose of explaining the construction and operation of the pump and that changes can be made without departing from the spirit and scope of the invention which are set forth in the appended claims.

I claim:

1. A pump comprising a pair of plungers, stationary cylinder walls to receive the plungers, the inner ends of said plungers cooperating in a common working space, a rotary fixed stroke wobble plate cam to drive each plunger, said cams having a common axis of rotation, pump operating means to rotate said cams, and means actuable while said cams are rotating for varying

the phase relationship of said rotating cams thereby varying the output of the pump.

2. A pump comprising a pair of plungers, stationary cylinder walls to receive the plungers, the inner ends of said plungers cooperating in a common working space, two fixed stroke cams to drive the respective plungers, a common driving shaft for said cams, means actuatable while said shaft is rotating for turning one of said cams on the shaft and means operatively connected therewith for turning the second cam by a like amount in the opposite direction to change the phase relation of the plungers and vary the pump output.

3. A pump comprising a pair of plungers, cylinder walls to receive the plungers, the inner ends of said plungers cooperating in a common working space, a pump operating shaft, a pair of fixed stroke wobble plate cams to drive the respective plungers and means for adjustably mounting the cams on the pump shaft comprising a differential gear spider carried by the shaft, a planet pinion rotatable thereon, a pair of sleeves on the shaft on opposite sides of the spider, each of said sleeves having a sun gear whose teeth mesh with said planet pinion, one of said wobble plates being secured to each of said sleeves, and an adjusting member longitudinally movable with respect to said shaft and having a cam connection therewith to cause rotation of said member with respect to the shaft during such longitudinal movement, and a connection between said member and one of said sleeves to impart such rotational movement thereto, said differential gearing causing the second sleeve and the wobble plate cam thereon to rotate a corresponding amount in the opposite direction.

4. A pump comprising a stationary cylinder, a pair of plungers operating from the opposite ends thereof and defining the pump working space between their inner ends, a fixed stroke rotary wobble plate cam to drive each plunger, said cams having a common driving shaft, and means actuatable while the pump is operating for varying the phase relationship of said cams thereby varying the output of the pump.

5. A pump comprising a cylinder, a pair of plungers operating from the opposite ends thereof and defining the pump working space between their inner ends, two fixed stroke cams to drive the respective plungers, a common driving shaft on which said cams are mounted, means actuatable while the pump is operating for varying the angular position of one of said cams on said shaft and means operatively connected therewith for changing the angular position of the second cam by a like amount in the opposite direction to change the phase relation of the plungers and vary the pump output.

6. A pump comprising a cylinder, a pair of plungers operating from the opposite ends thereof and defining the pump working space between their inner ends, a pump operating shaft, a pair of fixed stroke wobble plate cams to drive the respective plungers and means for adjustably mounting the cams on the pump shaft comprising a differential gear spider carried by the shaft, a planet pinion rotatable thereon, a pair of sleeves on the shaft on opposite sides of the spider, each of said sleeves having a sun gear whose teeth mesh with said planet pinion, one of said wobble plates being secured to each of said sleeves, and an adjusting member longitudinally movable with respect to said shaft and having a cam connection therewith to cause rotation of said member with respect to the shaft during such longitudi-

nal movement, and a connection between said member and one of said sleeves to impart such rotational movement thereto, said differential gearing causing the second sleeve and the wobble plate cam thereon to rotate a corresponding amount in the opposite direction.

7. In apparatus of the class described, a wobble plate cam having a plane bearing face, a shaft therefor, and a member driven by said cam having a slipper engaging said bearing face, said slipper having a center of oscillation on said driven member which is substantially in the plane of said bearing face.

8. In apparatus of the class described, a wobble plate cam having a plane bearing face, a shaft therefor, a member mounted to reciprocate in a path parallel to said shaft, and a slipper to interconnect said cam and driven member coacting with the bearing face of the cam, said slipper having with the driven member a universal connection whose center of oscillation is substantially in the plane of said bearing face.

9. In apparatus of the class described, a wobble plate cam having a plane bearing face, a shaft therefor, and a member driven by said cam having a slipper engaging said bearing face, said slipper having a semispherical socket connection with said driven member, the center of said socket being substantially in the plane of said bearing face.

10. In apparatus of the class described, a pair of plungers, cylinder walls to coact therewith, the inner ends of said plungers cooperating in a common working space, a wobble plate cam to drive the outer end of each of said plungers, means for mounting said cams on the shaft for angular adjustment thereon with respect to one another while the pump is operating to change the phase relation of the pistons and thereby vary the pump output, and a slipper to drive each of said plungers from its adjacent wobble plate cam coacting with the bearing face thereof, said slipper having a universal connection with the outer end of its plunger, the center of oscillation of said universal connection being substantially in the plane of the respective bearing face of the wobble plate cam.

11. In apparatus of the class described, a cylinder, a pair of plungers operating from the opposite ends thereof and defining between their inner ends a pumping space, a shaft parallel with the axis of said cylinder, a wobble plate cam to drive the outer end of each of said plungers, means for mounting said cams on the shaft for angular adjustment thereon with respect to one another while the pump is operating to change the phase relation of the pistons and thereby vary the pump output, and a slipper to drive each of said plungers from its adjacent wobble plate cam coacting with the bearing face thereof, said slipper having a universal connection with the outer end of its plunger, the center of oscillation of said universal connection being substantially in the plane of the respective bearing face of the wobble plate cam.

12. In apparatus of the class described, a pair of plungers, cylinder walls to coact therewith, the inner ends of said plungers cooperating in a common working space, an inlet port controlled by one of said plungers, oil grooves in the cylinder walls surrounding each of said plungers, means for supplying oil under pressure to the oil grooves to lubricate the plungers, and a second groove surrounding the plunger which does not control the inlet port, said groove being disposed inwardly from the oil groove for said plunger, and means placing

15

said second groove in communication with the inlet port to return liquid leaking along the surface of the plunger to the inlet and prevent it from mixing with the lubricating oil.

13. In apparatus of the class described, a cylinder, a pair of plungers operating from the opposite ends thereof and defining between their inner ends a pumping space, the cylinder having an inlet port controlled by one of said plungers, oil grooves in the cylinder walls surrounding each of said plungers, means for supplying oil under pressure to the oil grooves to lubricate the plungers, and a second groove surrounding the plunger which does not control the inlet port, said groove being disposed inwardly from the oil groove for said plunger, and means placing said second groove in communication with the inlet port to return liquid leaking along the surface of the plunger to the inlet and prevent it from mixing with the lubricating oil.

14. In apparatus of the class described, a cylinder, a plunger adapted to reciprocate therein, a pump shaft parallel with the axis of the cylinder, a wobble plate cam rotated thereby for actuating the plunger, a slipper universally pivoted on the outer end of the plunger to interconnect the plunger and the wobble plate cam, and means for lubricating said slipper comprising an interior longitudinal passage in said plunger in communication with said slipper, a passageway through the wall of the cylinder supplying oil under pressure to the surface of the plunger, and an opening from the surface of the plunger to said interior longitudinal passage adapted to register with said oil pressure passageway at each reciprocation of the plunger so as to introduce a small quantity of oil into the interior of the plunger at each reciprocation thereof.

15. In apparatus of the class described, a housing having a central longitudinal bore, a circular inlet passage for liquid to be pumped and a circular outlet passage arranged parallel with one another within said housing, a plurality of inlet ports spaced around the interior of said bore and communicating with said inlet passage, a plurality of outlet ports similarly spaced and connected to said outlet passage, a cylinder block positioned within said bore having a central axial opening therethrough, a plurality of cylinders in said block arranged axially thereof in a circular row outside the central axial opening therein, a pump shaft passing through said axial opening, a pair of plungers operating from the opposite ends of each cylinder and defining between their inner ends a pumping space, a pair of wobble plate cams carried by said shaft, one disposed on each side of the cylinder block and cooperating with the plungers projecting therefrom to actuate the same, each of said cylinders having an inlet passage and an outlet passage adapted to register respectively with said inlet and outlet ports.

16. A pump comprising a pair of plungers, cylinder walls to receive the plungers, the inner ends of said plungers cooperating in a common working space, an inlet port arranged to be opened and closed by the inner end of one of said plungers, the second plunger constituting a movable cylinder head defining with the first plunger the extent of said working space, and an outlet passage communicating with said working space unaffected by the movement of either plunger and having therein a pressure operated outlet valve.

17. A pump comprising a pair of plungers, cylinder walls to receive the plungers, the inner ends

16

of said plungers cooperating in a common working space, mechanism for reciprocating said plungers, an inlet port arranged to be opened and closed by the inner end of one of said plungers, the second plunger constituting a movable cylinder head defining with the first plunger the extent of said working space, and an outlet passage communicating with said working space unaffected by the movement of either plunger.

18. A pump comprising a pair of plungers, cylinder walls to receive the plungers, the inner ends of said plungers cooperating in a common working space, an inlet port arranged to be opened and closed by the inner end of one of said plungers, the second plunger constituting a movable cylinder head defining with the first plunger the extent of said working space, and means for operating the plungers in adjustable phase relationship to vary the pump output, the length of the delivery period of the pump increasing with decrease of said output.

19. A pump comprising a plurality of pairs of axially aligned plungers, cylinders to receive each of said pairs of plungers, the inner ends of the plungers of each pair cooperating in a common working space, an inlet port arranged to be opened and closed by the inner end of one of said plungers of each pair, the second plunger of each pair constituting a movable cylinder head defining with the first plunger the extent of said working space, common means for reciprocating all of the plungers which control the inlet ports of said cylinders, common means for reciprocating all the other of said plungers, and means for adjusting said reciprocating means to vary the phase relationship between the plungers of each of said pairs to vary the pump output, the delivery periods of said cylinders overlapping one another and said overlap being greater throughout the lower range of pump output than in the higher range.

20. A pump comprising a pair of plungers, cylinder walls to receive the plungers, the inner ends of said plungers cooperating in a common working space, an inlet port arranged to be opened and closed by the inner end of one of said plungers, the second plunger constituting a movable cylinder head defining with the first plunger the extent of said working space, means for operating the plungers in adjustable phase relationship to vary the pump output, a groove surrounding the end of said second plunger when at the inner end of its stroke, and an outlet port communicating with said groove.

21. A pump comprising a pair of plungers, stationary cylinder walls to receive the plungers, the inner ends of said plungers cooperating in a common working space, two rotary cams to drive the respective plungers, a common driving shaft for said cams, means actuatable while said shaft is rotating for turning one of said cams relatively to the other on the shaft and thereby changing the phase relation of the plungers and varying the pump output.

22. A pump comprising a cylinder, a pair of plungers operating from the opposite ends thereof and defining the pump working space between their inner ends, a pump operating shaft, a pair of fixed stroke wobble plate cams to drive the respective plungers, and means for adjustably mounting the cams on the pump shaft including a differential gear mechanism carried by the shaft, a pair of sleeves on the shaft each having operatively connected therewith a gear whose teeth coact with said differential mechanism, one

of said wobble plates being operatively connected with each of said sleeves, an adjusting member longitudinally movable with respect to said shaft and having a cam connection therewith to cause rotation of said member with respect to the shaft during such longitudinal movement, and a connection between said member and one of said sleeves to impart such rotational movement thereto, said differential gearing causing the second sleeve and the wobble plate cam operatively connected therewith to rotate a corresponding amount in the opposite direction.

23. A pump comprising a stationary cylinder, a pair of plungers operating from the opposite ends thereof and defining the working space between their inner ends, a pump operating shaft, two rotary fixed stroke wobble plate cams carried by said shaft to drive the respective plungers, a differential gear mechanism operatively associated with said shaft and serving to interconnect said cams, and means actuatable while said shaft is rotating to adjust said mechanism to turn one of said cams relatively to the other to change the phase relation of the plungers and vary the pump output.

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