United States Patent [19]

Chanal

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[45] **Aug. 20, 1974**

[54] **HYDRAULIC PUMPS WITH DOUBLE AXIAL PISTONS**

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July 8, 1968 France 68.50192

[52] **U.S. Cl.**........................ **417/203,** 91/506, 91/486

[51] **Int. Cl.**.. **F04b 23/64**

[58] **Field of Search**....... 103/162; 91/199, 499, 506, 60/53; 417/201–206

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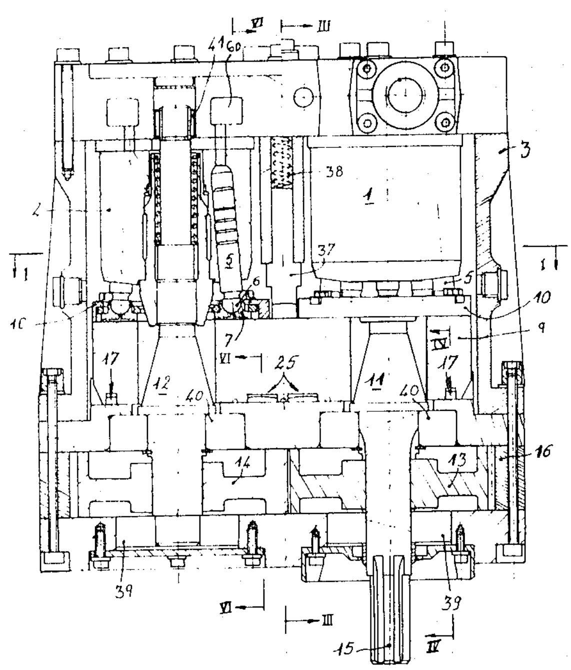
[57] **ABSTRACT**

Two swash plate pumps each of which are provided with axially directed piston chambers and pistons, are provided in a common housing in operative engagement with a single swash plate. The two pumps are driven synchronously by two meshing gears which in turn are driven from a single input power source. The two meshing gears cooperate with the housing to provide a low pressure feed pump for the two high pressure swash plate pumps. Each swash plate pump is arranged to supply an independent circuit and a common power regulator is operably connected to each pump output to control the position of the swash plate in response to the output pressure.

5 Claims, 10 Drawing Figures



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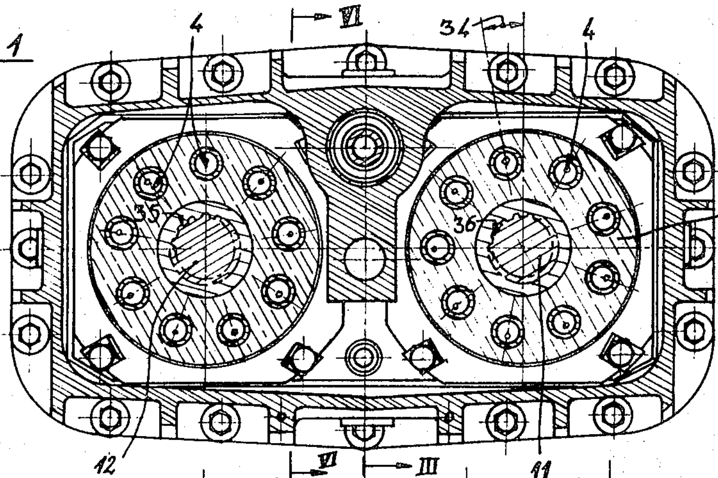


Fig. 1

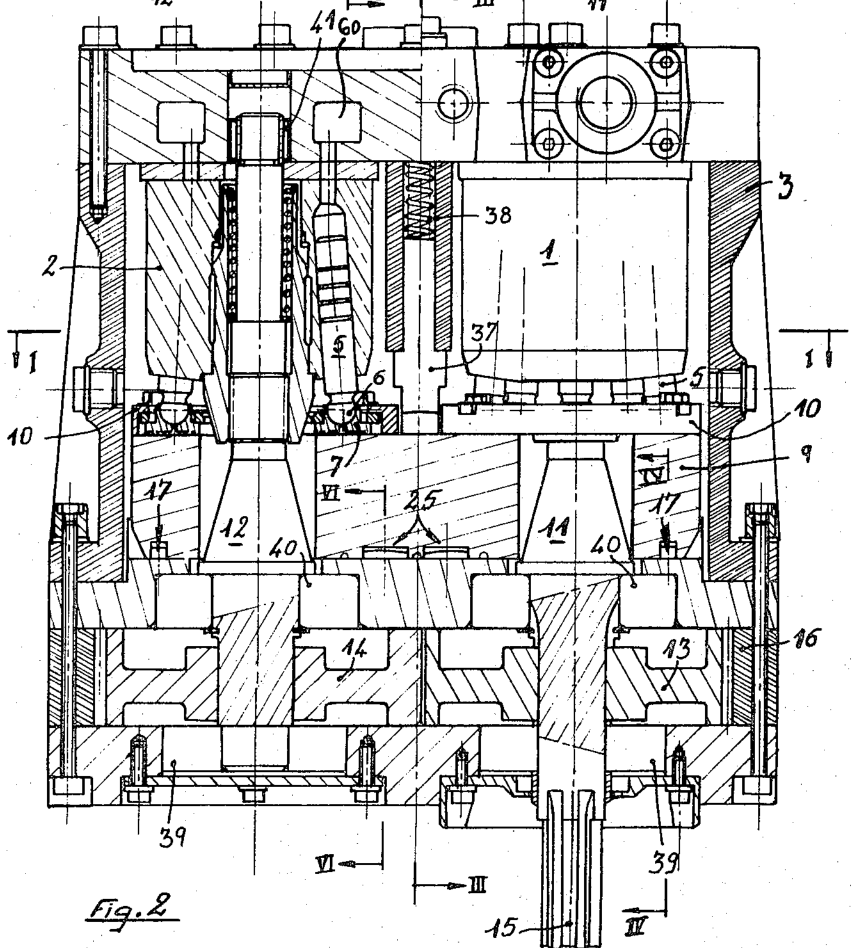


Fig. 2

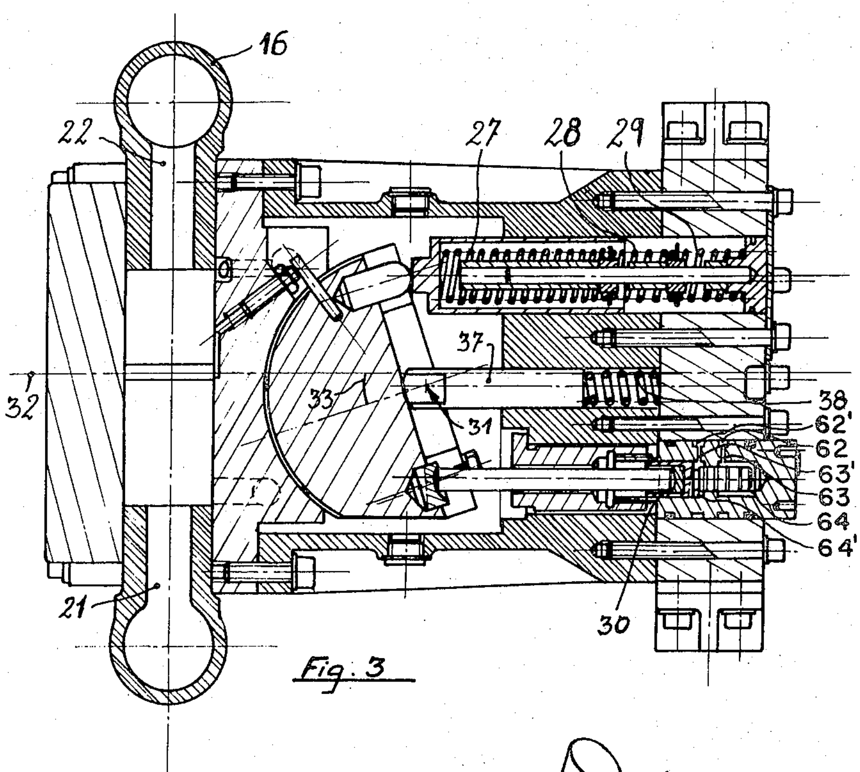


Fig. 3

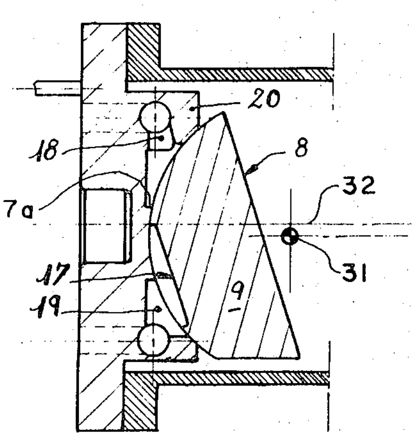


Fig. 4

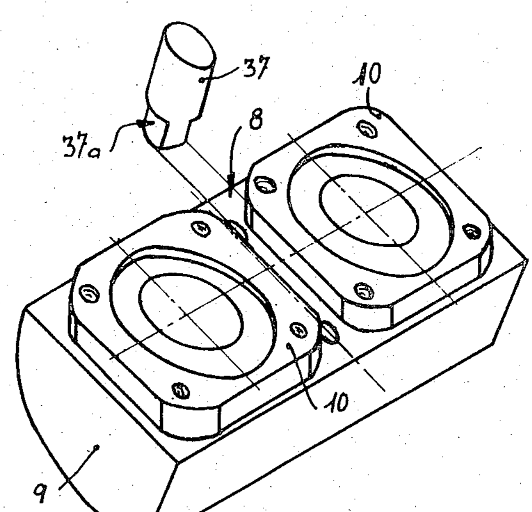
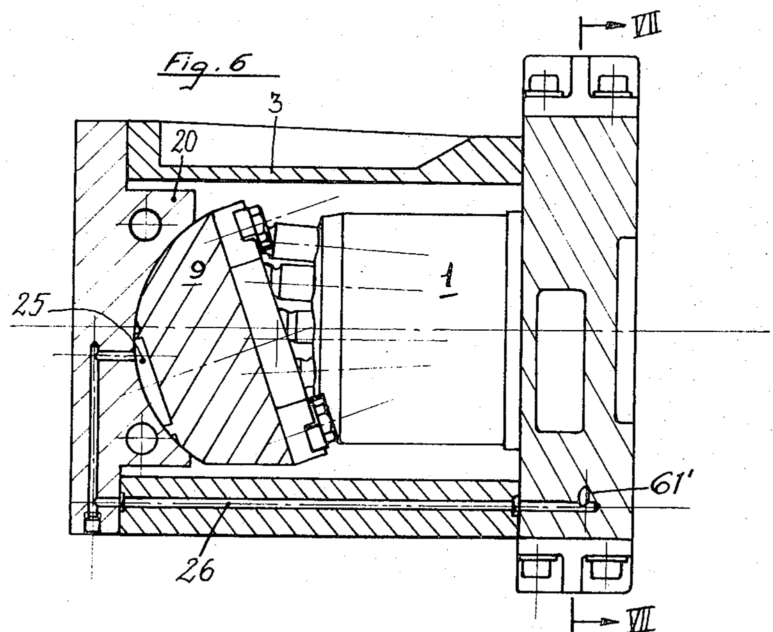


Fig. 5

Fig. 6


VII
3
20
9
1
25
61'
26
VII

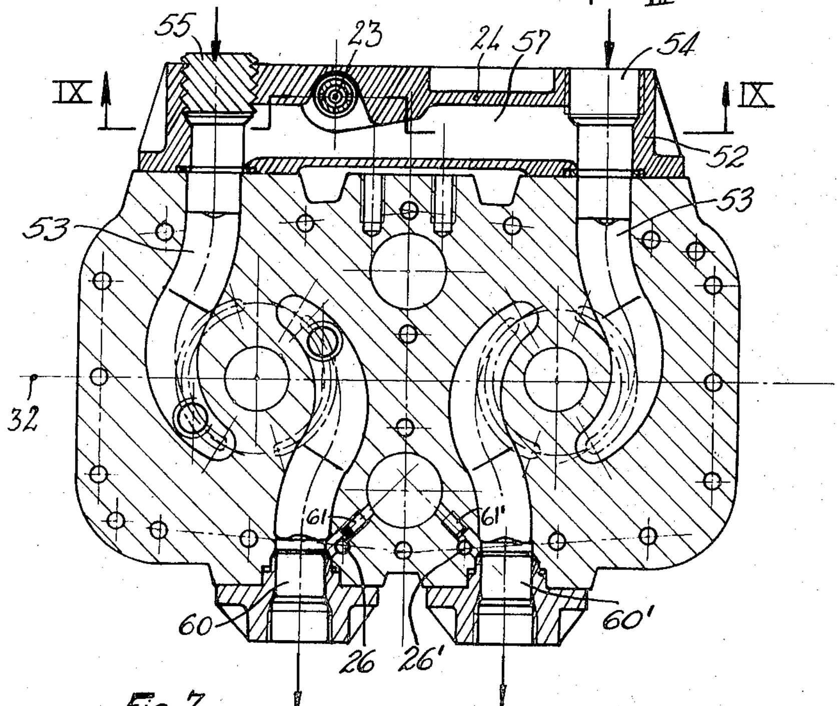

55
23
24
57
54
IX
IX
52
53
53
32
61
61'
60
26
26'
60'

Fig. 7

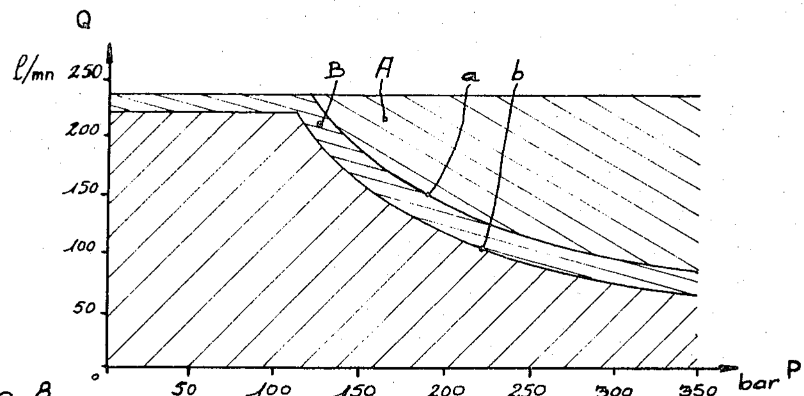


Fig. 8

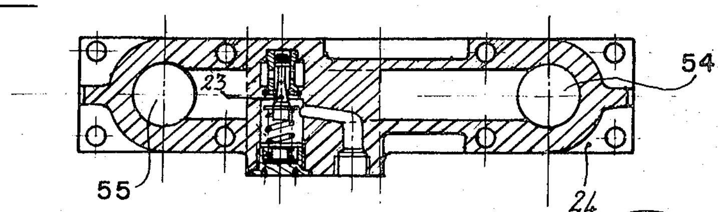


Fig. 9

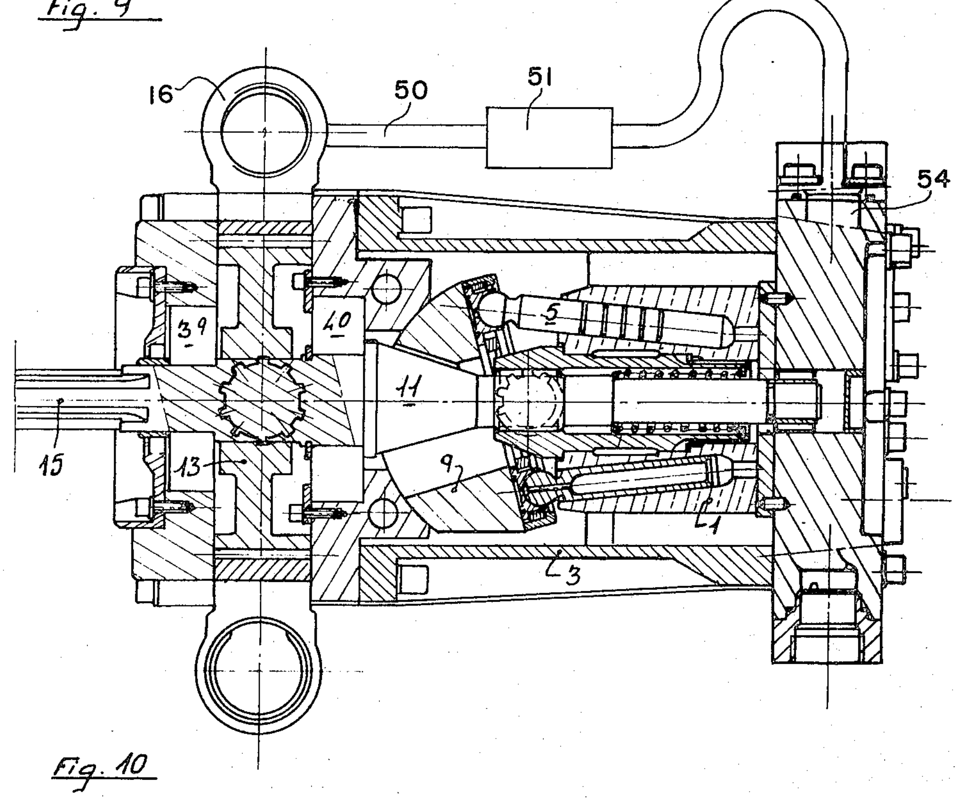


Fig. 10

HYDRAULIC PUMPS WITH DOUBLE AXIAL PISTONS

The present invention relates to a high pressure hydraulic pump which has variable output and is capable of feeding two independent circuits. More especially, the invention is applicable to swash plate pumps.

It is known that in various branches of industry, particularly in the equipment of certain machinery for public works, it is necessary to use independent hydraulic circuits. The method usually adopted up to the present consists in providing a pump on each circuit, which complicates the control manoeuvres as well as the regulation conditions, since the total power required by the pumps must remain approximately constant and equal to the power furnished by the driving motor of the machine.

The present invention has the aim of resolving this problem by means of a single hydro-mechanical assembly which comprises two swash plate pumps, with axial piston chambers and pistons, with variable output, each of these pumps feeding an independent oil circuit at high pressure. Moreover, these two pumps are driven synchronously by means of two meshing gears built into the pump, and therefore it is possible to hold constant the total power of the apparatus, even if the output pressures in each of the two hydraulic circuits vary independently one from the other.

According to this invention a composite pump comprises two swash plate pumps each of which has a rotating barrel with a plurality of pump pistons slidable axially within piston chambers formed in the barrel, the two barrels being disposed side-by-side in a stationary casing, and the two sets of pistons engaging on the flat face of the same swash plate which is adapted to cause oscillation of the pistons, the driving shafts of the two barrels being synchronised by a pair of meshing gears which are arranged in a stationary casing so that they constitute a feed pump which assures the fluid supply to the two swash plate pumps. Preferably the feed pump is adapted to operate at a lower pressure than the swash plate pumps.

According to a preferred feature of the invention, the swash plate has a part cylindrical base which slides on the seating of a fixed cradle whilst ports in this cradle co-operate in a hit-and-miss fashion with by-pass grooves provided in the cylindrical face of the plate, in such a way as automatically to short circuit the feed pump the pressure output of which remains constantly slightly higher than the output necessary to feed the high pressure swash plate pumps. The final adjustment between these two outputs may be carried out by a discharge valve the small dimensions of which guarantee operation substantially without inertia.

Finally by staggering the two barrels through an angle in respect to one another, there is obtained for the assembly of the composite pump an operation with a practically constant couple, whilst suppressing the oscillations to which the oscillating plates of known type are subject.

One construction of a pump in accordance with the invention will now be described by way of example only, with reference to the accompanying drawings, in which:

FIG. 1 is a sectional view along the line I—I in FIG. 2 of a pump according to the invention,

FIG. 2 is an axial section along the line II—II in FIG. 1,

FIG. 3 is a section along the line III—III in FIG. 2,

FIG. 4 is a view along the line IV—IV in FIG. 2,

FIG. 5 is a perspective view of the swash plate, by itself and fitted only with the return yokes of the piston shoes,

FIG. 6 is a section along the line VI—VI in FIG. 1,

FIG. 7 is a section along the line VII—VII in FIG. 6,

FIG. 8 is a diagram illustrating the supply operation of the valve interposed between the feed pump and the high pressure pumps,

FIG. 9 is a section along the line IX—IX in FIG. 7, and

FIG. 10 is a longitudinal section along the axis of the drive shaft.

The composite pump according to the invention has two piston barrels **1** and **2** which revolve within a fixed casing **3.** These two barrels are identical one to the other and each is formed with, for example, nine cylindrical bores **4** in which pistons **5** slide in the normal way. Each piston **5** ends at its lower extremity in a ball joint **6** seated in a shoe **7.** The 18 shoes **7** of the assembly of the two piston barrels **1** and **2** all bear on the upper flat face **8** of a swash plate **9** (FIGS. **2, 4** and **5**). Two collars or yokes **10** hold the shoes **7** on to the face **8.**

One of the principle characteristics of the invention consists in having the two revolving pistons barrels **1** and **2** placed side by side, the control of the variable output of the pumps being made by a single swash plate **9** of elongated form (FIG. **5**).

The assembly therefore comprises two high pressure pumps with axial pistons and variable output, of the same kinematic and the same bore capacity. The piston barrel **1** (primary piston barrel), is adapted to be rotated by a splined drive shaft **11** which projects at one end outside the fixed casing **3.** On the other hand, the piston barrel **2** (secondary piston barrel) is driven by a shaft **12** which does not extend outside the casing **3.** Synchronization of the two barrels is ensured by two large gears **13** and **14** keyed respectively on to the shafts **11** and **12.** The secondary pump is therefore driven by the primary pump.

The two linking gears **13** and **14** are mounted between the swash plate **9** and a drive portion **15** of the control shaft **11**; these gears being placed inside a fixed casing **16** which closely envelopes the gears so that, together with this casing, the gears constitute a gear pump of low pressure (relatively to the operating pressure of the swash plate pumps). The cylindrical capacity of the low pressure gear pump is slightly higher than the maximum capacity of the total of the two swash plate pumps of high pressure and variable capacity.

This low pressure pump **13, 14, 16** may be used for auxiliary functions. In particular, it may be used to ensure the circulation of the hydraulic liquid through a cooler, or to serve as a pressure source for different types of servo mechanism, or yet again to constitute a feed pump for the feeding of the two high pressure pumps.

The gear pump **13, 14** pumps the fluid through output channel **22** in the housing member through external conduit **50** and filter **51** to either inlet **54** or **55** in the fluid distribution plate **52** (FIGS. **7** and **10**). If inlet **54** is used, passage **55** may be blocked by a plug **56** or vice versa. A cross channel **57** interconnects the inlets **54** and **55** and is disposed in communication with the pressure regulating valve **23.** The cross channel **57** communicates with the pump inlet passages **53** and **53'** leading to the two swash plate pumps. Since the capacity furnished by the gear pump **13, 14, 16** is constant, it is adjusted to the capacity consummed by the high pressure pumps by means of a device the function of which is illustrated in FIG. **8.** This device comprises on the one hand the system of escape ports shown on FIG. **4,** and on the other hand by an adjustment valve shown in FIGS. **7** and **9.**

When the pressure of the return circuits of the swash plate pumps is high, these high pressure pumps have little output. The low pressure pump **13, 14, 16** therefore furnishes more liquid than the high pressure pumps can absorb, and the excess output must be evacuated. For this purpose, known systems consist in utilizing a pressure release valve. Nevertheless, such a valve has to be large and bulky, with a large opening area which varies in relation to the output which it is necessary to let pass. This has the disadvantage of causing pressure at the intake of the high pressure pumps to vary considerably. The avoid these disadvantages, the invention replaces a large release valve of known type by the mechanism shown in FIGS. **4** and **5.**

It is known that, in order to vary the output of swash plate pumps, it is sufficient to adjust the angle of the plate in its cradle. Now it will be observed that transverse grooves **17** are formed in the cylindrical face of the plate **9** (see FIG. **2**) and that there is a "land" **17***a* formed on the cradle **20.** Moreover, there are ports **18** and **19** on opposite sides of the "land" **17***a* and these communicate respectively with the return channel **21** and the output channel **22** of the low pressure pump **13, 14, 16.** So long as part of the plate **9** seals with the "land" **17***a* as shown in FIG. **2,** the ports **18** and **19** are isolated, but when the plate **9** is tilted nearer to the vertical so that the stroke of the pistons is reduced, then the grooves **17** cross the "land" **17***a* and put the ports **18** and **19** in communication which short circuits the low pressure pump. This part is shown on the diagram of FIG. **8** by the shaded area A. This diagram shows in abscissa the return pressure in bars of the high pressure pumps and in ordinates the total output which they expel expressed in litres per minute.

The output expelled by the feed pump **13, 14 16** is shown by the curve *a*. It will be seen that it is very little higher than the output necessary to feed the high pressure pumps, this utilised output being shown by the curve *b*. The variations of the output *a* furnished by the feed pump follow very closely the variations of the utilized output *b*. The excess output remains constantly very small and it is shown by the shaded area B. It will be seen that in order to evacuate this excess it will suffice to use a relief valve of small dimensions which is easily accommodated and has a very low cost price. This valve **23** (FIGS. **7** and **9**) is incorporated in a feed collar **24** which is attached on the side of the fixed casing **3.** The small dimensions of this valve **23** obviate any large variation in the feed pressure of the high pressure pumps. In addition the fact of having sited the valve in a detachable collar **24,** allows of using only a single standard type of casing **3** to group low pressure and high pressure pumps, the simple exchange of the collar **24** permitting the fitting of valves **23** of various dimensions in relation to the performances required for the pump. This advantage is particularly important with high pressure pumps of which the total output is large, for example above 200 litres per minute.

In order to allow the plate **9** to swing freely on the cradle **20,** in spite of the large pressures to which it is subjected, there are provided on the cylindrical portion of this cradle **9** in the region where the center of thrust of the pistons occurs, chambers **25** (FIGS. **2** and **6**) which receive liquid under pressure from the hydraulic circuits by means of two channels **26** and **26'**.

There corresponds to each of the two swash plate pumps a chamber **25** which behaves like a jack tending to thrust the plate **9** from its cradle **20** which diminishes the pressures between these two components. The lifting of the plate **9** is thus facilitated, especially since a film of oil under pressure penetrates between the surfaces in contact which assures a lubrication under pressure of the sliding surface.

This case of sliding has the effect of providing for a very flexible operation and the possibility of great precision of the angular position of the plate **9**: this furnishes a very clear definition of the curve of regulation output, with very little hysteresis.

It may be noticed that this balance is defined with precision by the judicious choice of dimensions for the section of the chambers **25** since the corresponding reaction represents precisely a certain percentage of the operation pressure of the circuit. At the same time, this balance remains strictly proportional to the operating pressure of the pump. Each of the two swash plate pumps is thus balanced separately in ratio of its return pressure.

The regulation system common to the two high pressure pumps is situated between them, parallel to their axes of rotation. This regulation system, of the type known as "regulation of power," allows the plate **9** to be positioned in such a way that the sum of the two outputs expelled by the pumps, multiplied by the sum of the pressures obtaining in each hydraulic circuit shall correspond to a constant power. This is expressed by the ratio:

$$Q\ (P\ 1 + P\ 2) = \text{constant.}$$

The above ratio is obtained as follows:

The power W necessary for driving a hydraulic pump is:

$$W_{(h.p.)} = Q_{(1./s.)}\ x\ P_{(bars)}/450$$

Therefore, for the double pump according to the invention, it is desired to have a total power W kept constant. Said power is:

$$W_{total} = W_{pump\ 1}\ W_{pump\ 2}$$

wherein:

pump **1** corresponds to the right hand barrel **1**

pump **2** corresponds to the left hand barrel **2.**

Or:

$$W_{total} = W_1 + W_2 = QP_1/450 + QP_2/450 = \text{constant}$$

wherein:

Q = outlet flow (the same for both elementary pumps **1** and **2,** since they have the same tilting swashplate **9**).

Finally:

$$Q.\ (P_1 + P_2) = \text{constant}$$

Thus, the output Q of the two pumps which depends upon the angle of inclination of the common swash plate **9** is directly variable under the action of the pressures P_1 and P_2.

Such a result is obtained by subjecting the angular position of the plate **9** to a regulating system which comprises:

a flexible component of which the flexibility is rendered variable by superposing three or more springs **27, 28, 29** (FIG. 3).

an assembly of two jacks **30** (FIG. 3) the mounting of which may be coaxial, each one of them being sensitive to the pressure obtaining in one of the circuits.

Fluid under pressure is supplied to the jack assembly **30** and to the channels **26** and **26'** by a network of passages best shown in FIGS. **3, 6** and **7.** From the lefthand pump **2**, the fluid passes through the outlet passage **60.** Auxiliary passage **61** interconnects the outlet passage **60** with the annular groove **62** which is in communication with the jack chamber **64** through passage **63.** Fluid is likewise supplied to jack chamber **64'** from outlet passage **60'** through auxiliary passage **61'** annular groove **62'** and passage **63'**. Channels **26** and **26'** communicate directly with auxiliary passages **61** and **61'**, respectively. Thus, the pressure of each pump acts on the jack assembly **30** to control the position of the plate **9.**

This defines an output curve of hyperbolic characteristic if there is shown in abscissa the return pressure in bars and as ordinate the output in litres per minute.

The axis of tilting **31** of the plate **9** (FIG. **3**) is situated outside the plane **32** containing the two axes of rotation of the pump barrels. This is the opposite of what is usual in known pumps. It is known that the normal arrangement, which would have consisted of placing the axis **31** in the plane **32,** has disadvantages in pumps the barrel of which is furnished with an odd number of pistons. In effect the number of the pistons under pressure corresponds alternately to three and to four when there are seven of them to five and to four when there are nine of them and so on. In consequence, the counter pressure resulting from the pistons on the swinging plate posses above or below a line perpendicular to the line of the dead points and containing the centre of rotation (axis **32** on the FIG. **7**). Therefore, if the normal arrangement has been used, the plate **9** would swing alternately forward and backwards at a frequency which is in ratio to the number of pistons **5** and to the speed of rotation of the pump. The vibration which would result from this would cause abnormal fatigue in the control components of the inclination of the plate and would cause, as is often observed, local failures by hammering or by breakage.

On the contrary the system according to the invention where the axis of oscillation **31** is situated outside the plane **32,** ensures a polarity which remains always the same at the moment of swing. This moment may be made totally positive or negative according to the required purpose, which at the same time suppresses the alternating tendencies mentioned above. If care is taken to situate this axis **31** outside the point of the extreme position of the total resultant of the reactions of the pistons, there is a swing movement which is variable in intensity, but the direction of which remains always the same. The plate **9** therefore becomes stable and the operation of regulation is improved.

The magnitude of the displacement **33** may be chosen according to the desired application.

Further to improve the regularity of the operation of the double swash plate pump according to the invention, and to supress the appearance of large disturbing forces at the level of the control of inclination of the plate **9,** the swinging movements of the two high pressure pumps are coordinated by dephasing angularly the two piston barrels **1** and **2** in order to find the most regular value of the resultant moment. The size of this angular dephasing depends mainly on the number of pistons **5** under the value **33** defined above.

In the case of the two pumps of which each piston barrel **1** and **2** carries nine pistons **5,** calculation shows that the angular displacement between the piston barrels **1** and **2** which is most advantageous is about 10°, to ensure the maximum regularity of the couple. This displacement has been shown on FIG. **1** by the reference **34.** It is advantageous not only as regards the moment of swing of the plate **9,** but also as regards the regularisation of the driving couple of the motor shaft **11.** The variations in couple to be transmitted by this first shaft are less important and more spread out in time.

In order to obtain this practical result, while still preserving identical components on the two high pressure pumps, all the geometrical differences have been made on the secondary shaft alone. It is sufficient that on this shaft **12,** the drive splines **35** for the barrel **12** should be displaced by the desired amount with relation to the splines **36** of the primary shaft **11.**

The plate **9** is held on to its cradle **20** by means of a push rod **37** (FIGS. **2** and **3**) the pressure of which is defined by a calibrated spring **38.** The end of this push rod **37** bears on the plate **9** and it has a rounded profile centered on the theoretical axis **31,** so that the plate **9** revolves around the end of the push rod **37** when it tilts. The push rod holds the plate **9** in position and prevents it from rising under the action of the pistons **5** which are in the recoil strike during the intake phase.

In addition this push rod **37** has the function of holding in position the plate **9** while it is moving for it simply rests on its cradle **20.** Two flats **37***a* are cut on the end of the push rod **37** and serve as stops for the opposite faces of the collars **10** (FIGS. **3** and **5**).

The drive shaft according to the invention that is to say the primary shaft **11** is maintained in position by means of three bearings **39, 40** and **41,** in the same way as the secondary shaft **12** (FIG. **2**). It will be noticed that a single bearing, that is to say the bearing **40** ensures the longitudinal position of each shaft **11** or **12.**

The plate **9** which defines the unit cylinder capacity of each high pressure pump is common to these two components. This ensures that the two swash plate pumps will have cylinder capacities strictly identical since, by construction their components elements are also identical. This is particularly important when it is a question of carrying out precisely simultaneous movements at different pressures on each return hydraulic circuit. It is on the other hand useful to have a swinging plate **9** common to the other two pumps in order to:

1. reduce the bulk by abolishing all means of connection between two pump plates, these means being necessary if one was limited to mounting side-by-side in the same case two pumps with piston barrels of known

types. The connecting components in question would always be subject to the development of play or to the possibility of mistiming relatively to each other;

2. to allow for easy machining; pressures;

3. to have a plate **9** of increased rigidity and of which the bearing on the cradle **20** is at maximum because it renders possible reduced contact pressures:

4. to arrange on the cylindrical face of the plate **9** grooves or pockets **17** which have a control function of the output of the low pressure pump **13, 14, 16** as well as the balancing chambers **25**;

5. to have a single system of regulation of output which operates on the plate **9** directly, and symmetrically with regard to each swash plate pump.

To sum up, the composite pump according to the invention presents the following advantages:

great robustness;
reduced price;
high power to weight ratio;
the possibility of regulation of the power;
case of regulation;
case of maintenance.

I claim:

1. A double hydraulic pump comprising a casing, first and second barrel means mounted in side by side parallel relation for rotation about their respective axes within said casing, at least one reciprocal piston means mounted within each of said barrels, a common swash plate pivotally mounted within said casing and having a flat surface disposed in contact with said piston means, first and second shaft means drivingly connected to said first and second barrel means respectively, a pair of gears mounted on said first and second shaft means respectively, disposed in meshing engagement with each other and coacting with said casing to provide a feed pump for said double hydraulic pump, one of said shaft means extending outside said casing for connection to a suitable power source, spring biased push rod means disposed intermediate said first and second barrel means and bearing against said swash plate, and flange means mounted on said swash plate adjacent each of said barrel means, said push rod having two parallel flat surfaces on opposite sides thereof disposed intermediate said flange means.

2. A double hydraulic pump comprising a casing, first and second barrel means mounted in side by side parallel relation for rotation about their respective axes within said casing, at least one reciprocal piston means mounted within each of said barrels, a common swash plate pivotally mounted within said casing and having a flat surface disposed in contact with said piston means, first and second shaft means drivingly connected to said first and second barrel means respectively, a pair of gears mounted on said first and second shaft means respectively, disposed in meshing engagement with each other and coacting with said casing to provide a feed pump for said double hydraulic pump, one of said shaft means extending outside said casing for connection to a suitable power source, and cradle means fixed to said casing and having a concave cylindrical portion formed therein, said swash plate having a convex cylindrical portion adapted to be received in the concave cylindrical portion of said cradle, said swash plate having grooves therein disposed transversely to the pivotal axis of said swash plate for simultaneously uncovering fixed ports formed in the concave cylindrical surface of said cradle, said ports connecting inlet and outlet channels of said feed pump.

3. A double hydraulic pump as set forth in claim **2** further comprising chamber means located in the convex cylindrical surface portion of said swash plate and means for transmitting fluid under pressure from the output of said double pump to said chambers.

4. A double hydraulic pump comprising a casing, first and second barrel means mounted in side by side parallel relation for rotation about their respective axes within said casing, at least one reciprocal piston means mounted within each of said barrels, a common swash plate pivotally mounted within said casing and having a flat surface disposed in contact with said piston means, first and second shaft means drivingly connected to said first and second barrel means respectively, a pair of gears mounted on said first and second shaft means respectively, disposed in meshing engagement with each other and coacting with said casing to provide a feed pump for said double hydraulic pump, one of said shaft means extending outside said casing for connection to a suitable power source, and power regulating means disposed in said casing intermediate said first and second barrel means, said power regulating means comprising spring means operably bearing against said swash plate on one side of the pivot axis thereof and hydraulic jack means operatively bearing on said swash plate on the opposite side of said pivot axis.

5. A double hydraulic pump as set forth in claim **4** further comprising fluid passage means operatively connecting the output of each of said double hydraulic pumps to said hydraulic jack means.

* * * * *