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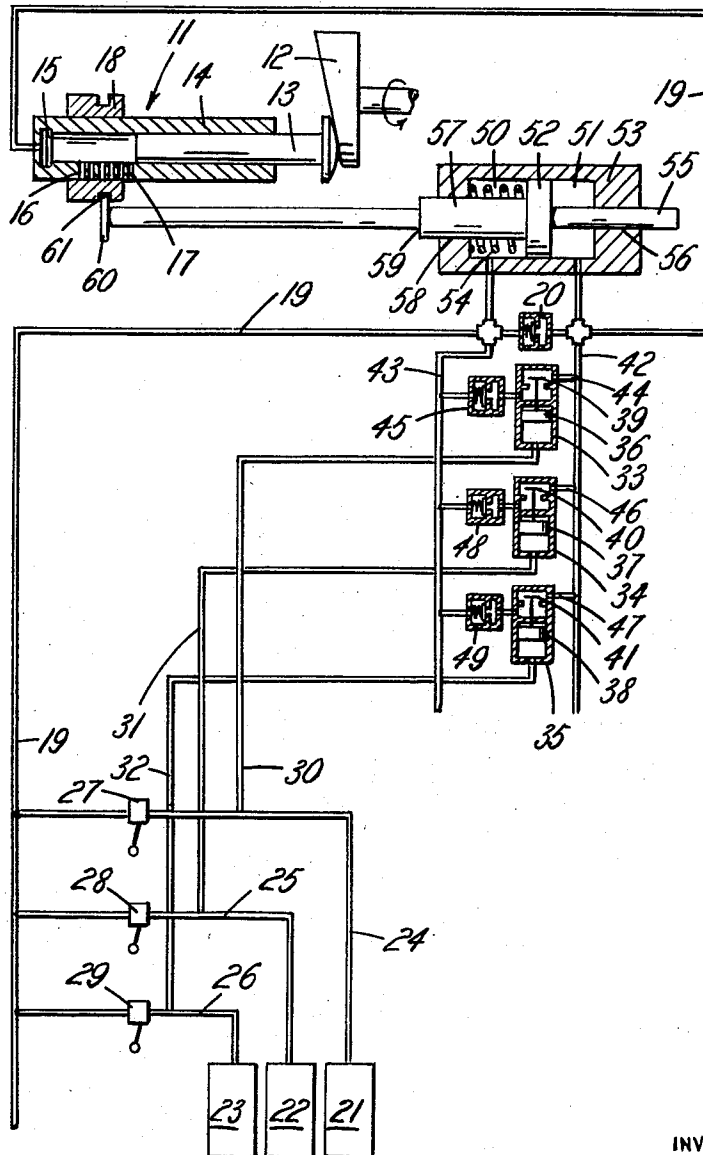
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HYDRAULIC SYSTEMS

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FIG. 1.



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HYDRAULIC SYSTEMS

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This invention relates to hydraulic operating systems, and is concerned with the kind of system in which the delivery of the pump supplying the pressure fluid is variable in accordance with the requirements of the services being operated. An object of the invention is to provide a delivery-regulating arrangement suitable for a pump that is required both to maintain substantially constantly a supply of pressure fluid to a circuit feeding intermittently-operating hydraulic units, and also to provide operating fluid when required for one or more additional services each of which can be brought into operation by use of its own selector valve and needs a volume of fluid to operate it that is substantially the same on each occasion but at a pressure varying according to the load on the service.

According to the present invention in its broadest aspect, there is provided in a hydraulic system, a supply pump, means for varying the delivery of the pump, restriction means in the pump delivery line with a flow area adjustable in accordance with the pressure fluid requirements of the system, said flow area increasing when the system requirements increase and reducing when they reduce, and means for comparing the pressures in the delivery line on opposite sides of the restriction means and for operating the pump delivery-varying means so as to reduce the pump delivery when the pressure difference increases and vice versa, irrespective of pump input speed.

In a system in which the pump supplies a plurality of services each with a selector valve to control the admission of pressure fluid thereto, the restriction means may comprise a plurality of orifices connected in parallel, one or more of the orifices having associated control-valve means coupled for operation with one or more of the selector valves for the services whereby opening of a selector valve to admit pressure fluid to the service controlled thereby results automatically in the opening of a control-valve associated with a corresponding orifice to permit flow through the orifice and so increase the flow area of the restriction means as a whole.

In the preferred embodiment, the pressures on opposite sides of the restriction means act on opposite faces of a control piston that is operatively connected to the means for varying the pump delivery. The pump may be of the type in which a plurality of plungers are reciprocated in parallel cylinder bores by a swash plate, each plunger-and-cylinder having radial spill ports in the cylinder wall, or in the plunger, for the escape of pressure fluid from the cylinder chamber to exhaust, with a sleeve or the like around the cylinder, or the plunger as the case may be, axially adjustable to obturate said ports to varying extents during the plunger stroke and thereby vary the pump delivery. The system, in addition to being volume sensitive, is pressure sensitive as are conventional hydraulic pump systems.

Embodiments of the invention will now be described by way of example with reference to the accompanying diagrammatic drawings of which:

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Figure 1 shows in section a simplified type of pumping system according to the invention,

Figure 2 shows in section a further system which incorporates a differential overbalance valve, and

Figure 3 shows in section details of the overbalance valve.

Referring to Figure 1 a swashplate type variable displacement hydraulic pump generally indicated at 11 comprises a rotatable swashplate 12 operatively engaging a plurality of plunger-type pump pistons 13 (one only being shown) which are each reciprocable under the control of the swashplate, in a cylinder 14. A non-return valve 15 is provided at the lefthand end of each cylinder and the wall of each cylinder is provided with a number of radially disposed apertures 16 and 17. Slidably mounted around the exterior of the cylinder is a spill control ring 18.

A fluid delivery line 19 is taken from the lefthand end of the cylinder 14 to an orifice 20 and thence to a hydraulic system. Further, this line 19 is connected with a number of additional services 21, 22 and 23 through branch lines 24, 25 and 26. Whereas the hydraulic system is intermittently operable, these additional services are such as to require substantially constant volumes of fluid supplied at varying pressure according to load. Selector valves 27, 28 and 29, operable in any convenient manner, are provided in branch lines 24, 25 and 26, and downstream of each selector valve a branch line 30, 31, 32 is taken to a cylinder 33, 34, 35. Each cylinder accommodates a piston 36, 37, 38 slidable therein and connected to a poppet valve 39, 40, 41 working in a valve chamber beyond one end of the cylinder. The arrangement is such that when pressure fluid enters the cylinder 33, 34 or 35 from the line 30, 31, or 32, the piston 36, 37 or 38 moves in a direction to open the valve 39, 40 or 41.

A line 42 is tapped from the line 19 just upstream of the orifice 20, while a line 43 is tapped from the line 19 just downstream of the orifice 20. A branch line 44, which includes the valve 39, is taken from the line 42 to the line 43, and an orifice 45 is provided in this line 44 between the valve 39 and the line 43. Similarly branch lines 46, 47 are taken from the line 42 through valves 40 and 41 to the line 43, orifices 48, 49 being provided in the lines 46, 47 between the valves 40 and 41 and the line 43. The lines 42 and 43 respectively also have branches which connect with chambers 50 and 51 on either side of a piston 52 working in a cylinder 53. A coil spring 54 is interposed between the left-hand side of the piston and the left-hand end of the cylinder. A piston rod 55 extends from the right-hand side of the piston through an aperture 56 in the end of the cylinder 53, while a piston rod 57 of larger diameter extends from the left-hand side of the piston through an aperture 58 in the other end of the cylinder to the exterior thereof where it is stepped down in diameter at 59. The extreme left-hand end of the rod 57 is provided with a head 60 which engages a peripheral slot 61 in each of the spill control rings 18. It will be appreciated that the effect of the pressure fluid on the piston 52 is always to urge it toward the left, in opposition to the effort of the spring 54, since firstly, the right-hand working area of the piston is greater than the left-hand area by an amount corresponding to the difference in the cross-sectional areas of the piston rods 55, 57 and secondly there is a pressure drop across the orifice 20.

In operation, when all services are inoperative it is desirable that the pump should be offloaded. Under this condition, the maximum effort is applied by the pressure fluid to urge the piston 52 to the left, the load of spring 54 is overcome and the piston moves fully to the left. Consequently the spill control rings 18 also move to the left to effect maximum spill from the pump 11 through the apertures 16, 17 in the cylinders 14, as

the pistons 13 are reciprocated under the control of the rotating swashplate 12. Thus under these conditions the volumetric delivery of fluid from the pump through the line 19 is at a minimum.

If, however, one of the additional services is brought into operation, let us say service 21, by opening its associated selector valve 27, pressure fluid is delivered to service 21 through the line 24. This would tend to produce a fall in pressure in the line 19 on the downstream side of the orifice 20 and therefore an increase in the pressure drop across the piston 52 tending to urge the piston toward the left. However, pressure fluid is also delivered to the cylinder 33, through line 30 and this opens the valve 39 so that the orifice 45 is effective in parallel with the orifice 20 in the delivery line 19; hence the total flow area through the orifice is increased, which tends to reduce the pressure drop across the piston 52. At the same time the pressure on the upstream side of the orifice 20 and acting on the right-hand side of the piston 52 will have dropped. The correct balance of these effects, and the effort of the spring 54, causes the sleeves 18 to reduce the volume of spill from the pump cylinders by an amount related to the demands of the service 21, and the pump delivers the correct volume of fluid required irrespective of pressure.

In like manner if either of the services 22 or 23, or both of them, are brought into operation by opening their associated selector valves 28 and 29, then the orifices 48, 49 are effective in the delivery line from the pump to tend to reduce still further the pressure drop transmitted to the piston 52. Thus the spill from the pump cylinders 14 is reduced still further and the volumetric delivery from the pump is accordingly increased to cater for the demands of the services 22 and/or 23.

It will be understood that, within the scope of the invention, variation in volumetric delivery of fluid from the pump may be effected in any convenient manner and is not limited to the spill rings described. Furthermore, although the above description refers to hydraulic transmission for operating the valves 39, 40, 41, this may be alternatively accomplished by mechanical, electrical or pneumatic transmission from the selector valves 27, 28, 29.

Referring now to Figure 2, a swashplate type variable displacement hydraulic pump generally indicated at 111 comprises a rotatable swashplate 112 operatively engaging a plurality of plunger type pump pistons 113 (one only being shown) which are each reciprocable under the control of the swashplate, in a cylinder 114. A non-return valve 115 is provided at the left-hand end of each cylinder. Each piston 113 is provided with a bore 116 which extends from its left-hand end to a point approximately midway along its length. The wall of the hollow part of the piston is provided with two sets of apertures 117 and 118 which open into the bore 116. Slidably mounted upon each piston is a spill control ring 119. A fluid delivery line 120 is taken from the left-hand end of the cylinder 114 and branch lines 121, 122, 123 and 124 are taken respectively therefrom to orifices 125, 126, 127 and 128. A further line 129 branches from the line 120 and is taken to a chamber 130 on the left-hand side of a piston spool 131 slidably mounted at the right-hand end of a casing 133. The casing 133 is disposed with its axis in line with the pump axis and on the same side (the left-hand side) of the swashplate as the pump cylinders, the right-hand end of the casing being among the cylinders.

From the downstream side of the orifice 125 a line 134 is taken to the normal hydraulic system. Three lines 135, 136 and 137 are branched from line 134 and lead respectively to additional services 138, 139 and 140, each having a substantially constant fluid flow requirement at variable pressure, according to load. Selector

valves 141, 142 and 143 are provided in the lines 135, 136 and 137 respectively, which valves may be operated independently in any convenient manner to bring any of the services 138, 139 or 140 into operation. Each selector valve is electrically connected through a transmission 141a, 142a, and 143a with an associated valve 144, 145, 146, such that when a selector valve is opened, its associated valve is simultaneously opened. The valves 144, 145, and 146 are respectively incorporated in lines 147, 148 and 149 which lead from the downstream sides of orifices 125, 127 and 128 into a line 150 which connects the line 134 with a chamber 132 on the right-hand side of the piston spool 131.

The piston spool 131 comprises a piston 131a having an orifice 131b through it, and a piston rod 131c which extends to the right of the piston, through an aperture 151 at the right-hand end of the casing 133, and to the left of the piston through an aperture 152 to project into a cylinder 153 of larger diameter than the chambers 130, 132. Externally of the casing 133, a disc member 154 is secured to the right-hand end of the piston rod 131c by means of a nut 155, and a coil spring 156 is interposed between the right-hand face of this disc member and a fixed seating within the pump structure. The peripheral edge of the disc member engages a peripheral slot 157 in each spill control ring 119.

Referring now to both Figures 2 and 3, the cylinder 153 is stepped down at its left-hand end to a smaller diameter 158, a partition 159 with a through bore being provided therebetween. This smaller diameter part 158 is hereinafter termed the annular chamber 158. The annular chamber 158 is connected at its left-hand end and through a bore 160 to another part of further reduced diameter. This part is divided into two annular chambers 161 and 162 by a partition 163. The chamber 162 has a bore 164 at its left-hand end extending to the exterior of the casing 133.

An overbalance control 165 is incorporated in the casing 133. This control comprises a stepped valve spool having a rod-like extension 166 at its right-hand end which projects axially from a flanged part 167 of the spool member disposed in the greater diameter chamber of the cylinder 153. The right-hand face of the flanged part 167 is suitably stepped to seat a coil spring 168 interposed between this flange and a seating 169 at the right-hand end of the cylinder 153. The stepped part of the spool member extends to the left from the flanged part 167, passing slidably through the partition 159 and being reduced from diameter 170 to diameter 171 at 172 within the annular chamber 158. The spool member thereafter extends to the left through the bore 160, the annular chamber 161, and a bore in the partition 163, into the annular chamber 162 where it is stepped down to a new diameter 173 at 174. This part of diameter 173 extends slidably through the bore 164 to the exterior of the casing 133. A port 175 in the spool member at a point in the chamber 162 adjacent the step 174 opens into an axially disposed passage 176 within the spool member. A port 177, which, when the spool member is in its extreme leftward position is disposed roughly centrally with respect to the annular chamber 161, is provided in the spool member in the part of diameter 171, and opens into the right-hand end of the passage 176.

The arrangement is such that when the spool member of the overbalance valve is in its extreme leftward position, and the piston spool 131 is also in its extreme leftward position, there is a clearance 178 between the right-hand extremity of the rod-like extension 166 and the left-hand extremity of the piston rod 131c. From the chamber 132 on the right of the piston 131a a line 179 is taken to the annular chamber 158, whilst a line 180 is taken from the line 179 through a fixed orifice 181 to the annular chamber 162. Drain lines 182 and 183 are respectively taken from the greater diameter part of the cylinder 153 and the annular chamber 161.

In operation, when the hydraulic system and the additional services 138, 139 and 140 are all operative (i. e. the selector valves 141, 142 and 143 are open), and with the pump running at its lowest rated speed, it is desirable that the pump 111 should be pumping at maximum capacity. Since the selector valves are open, by virtue of the electrical transmissions 141a, 142a and 143a the associated valves 144, 145 and 146 are open also so that the parallel orifices 125, 126, 127 and 128 are all effective in the delivery line 120. The resultant pressure drop across these orifices is transmitted through the lines 129 and 150 to the piston 131a of the piston spool 131. This pressure drop is, under these conditions, at a predetermined value and the piston 131a is in its extreme leftward position, despite the hydraulic pressure differential across it, due to the bias of the coil spring 156. Hence the spill control rings 119 are in their extreme leftward position as shown.

The apertures 117, 118 constitute inlet ports for each pump cylinder during the stroke of the piston 113 to the right, and the port 118 also functions as a spill port through which a varying amount of spill can take place during the pumping stroke. A very small amount of fluid may spill through the port 117 as well at the commencement of the pumping stroke but this does not vary with the position of the spill control ring and may be neglected. Considering the case in which the spill control ring 119 is in its extreme leftward position, when the piston 113 has moved to its extreme right fluid passes into the cylinder through both ports 117 and 118. As the piston next moves into the cylinder a very small amount of fluid is initially spilled through ports 117 and 118, but these ports are quickly closed by the end of the cylinder 114 and the spill control ring 119 respectively. The piston moves further in to the end of its stroke, but under these full-load conditions the port 118 does not emerge beyond the left-hand end of the spill control ring so that there is no further spill.

Pressure fluid passes from the chamber 132 through the line 179 to the annular chamber 158 this pressure acting upon the annular area formed by the step 172 to tend to urge the spool member, forming the overbalance valve 165, to the right against the effort of the coil spring 168. This spring is, however, chosen to yield only when the pressure in the annular chamber 158 approaches the off-loading pressure. When this occurs, the valve 165, moves to the right, takes up the clearance 178 and moves the piston rod 131c also to the right, until the piston 131a abuts the right-hand wall of the chamber 132 which constitutes its limit of travel. This position of the piston rod 131c corresponds to the extreme rightward position of the spill control rings 119, in which said rings are on the right of the ports 118 during substantially the whole of the piston travel and the pump output is spilled through those ports throughout substantially the entire piston stroke to offload the system.

To cause this offloading to occur without hunting, pressure fluid passing normally through the line 180 and the orifice 181 into the annular chamber 162, and thereafter through the port 175, the passage 176, the port 177, the annular chamber 161 and the line 183 to drain, is prevented from taking this course when the overbalance valve 165 moves fully to the right as described above, the port 177 being closed by entering the bore 160. Pressure fluid then acts on the annular step area 174 and supplements the existing load on the overbalance valve 165, causing an increased bias in a rightwards direction. This offloading effect overrides that to be now described, obtained from the orifices 125, 126, 127, 128 and the piston 131a.

When, for example, the service 138 is no longer required to operate, the selector valve 141, and accordingly the associated valve 144, are closed so that the orifice 126 is no longer effective in the delivery line 120, and the pressure drop transmitted through the lines 129 and

150 to the piston 131a is increased (i. e. the pressure in the line 150, the chamber 132, the line 179, the annular chamber 158, the line 180 and the annular chamber 162 is reduced). Consequently the piston spool 131 moves a little to the right to a new position while the pressure acting upon the annular area 172 is insufficient to maintain compression of the coil spring 168 and the rod-like extension 166 remains out of contact with the piston rod 131c. On moving to the right, the piston spool 131 effects corresponding movement of the spill control rings 119 to the right. Thus as the pump pistons 113 move to the left during their pumping strokes a certain amount of fluid is caused to spill through the apertures 118 when they pass beyond the left-hand ends of the spill control rings 119 into the gaps between the cylinders 114 and the control rings. Such spill results in a reduction of the volume of fluid delivered by the pump, which reduction is related to the operative demands of the service 138.

It will be appreciated that when the pump is partially offloaded in this way the inlet area afforded by the port 118 of each piston 113, when the piston arrives at the right-hand end of its stroke, is reduced or eliminated owing to the port being obturated by the spill control ring 119. This effect may be counteracted, if desired, by providing additional inlet ports 184 in the wall of the cylinder 114 itself which additional ports are only uncovered when the piston reaches the right hand end of its stroke.

Supposing now both services 139 and 140 are no longer required to operate, the selector valves 142 and 143 and accordingly their associated valves 145 and 146 are closed so that the orifices 127 and 128 are no longer effective in the delivery line 120 and the pressure drop across the remaining orifice 125, assuming there to be flow to the hydraulic system, transmitted through the lines 129 and 150 to the piston 131a is still further increased (i. e. the pressure in the line 150, the chamber 132, the line 179, the annular chamber 158, the line 180 and the annular chamber 162 is further reduced in relation to the pressure in line 129 and chamber 130). The above action causes further offloading of the pump until its output flow is that predetermined by the design of the orifice 125.

It will be seen that an increase in pump speed to one higher than the minimum rated speed, will cause the mechanism to react in a similar way to that obtained when a service is switched off as described above. Any increase in output flow will correspondingly increase the pressure drop across one or more of the orifices 125, 126, 127, 128, causing movement of the control piston 131a as previously described.

The pump will thus give substantially constant output flow under varying conditions of speed and pressure, and related to the requirements of the system as signalled by the valves 144, 145, 146 coupled with the selectors 141, 142, 143. Complete offloading occurs only when, for any reason, the output pressure reaches a predetermined maximum value.

The orifice 131b in the piston 131a is included for damping and stabilization of the system; it is not an essential feature and can be omitted if desired.

It will be noted that each of the orifices 20, 45, 48 and 49 in the first embodiment, and 125, 126, 127 and 128 in the second embodiment, is provided with a spring-urged plate valve that gives it linear characteristics.

We claim:

1. In a hydraulic system, a supply pump, means for varying the delivery of said pump, a plurality of intermittently-operating services supplied by said pump, each said service having a selector valve to control the admission of pressure fluid thereto, restriction means in the pump delivery line with a flow area adjustable in accordance with the number of services to be supplied, said flow area increasing step-wise when the number

of services supplied increases and reducing step-wise when said number of services reduces, and means for comparing the pressures in the delivery line on opposite sides of said restriction means and for operating the pump delivery-varying means so as to reduce the pump delivery when the pressure difference increases and vice versa, irrespective of pump input speed.

2. A hydraulic system as claimed in claim 1, and comprising an overbalance control which is operable hydraulically upon reaching of a predetermined delivery line pressure to override the delivery varying means and to offload the pump irrespective of the pressure drop across the restriction means.

3. A hydraulic system as claimed in claim 1, wherein the pump is of the type in which a plurality of plungers are reciprocated in parallel cylinder bores by a swash-plate, there being radial spill ports in each cylinder wall for the escape of pressure fluid from the cylinder chamber to exhaust, and a sleeve around the cylinder, said sleeve being axially adjustable to obturate said ports to varying extents during the plunger stroke and thereby to vary the pump delivery.

4. A hydraulic system as claimed in claim 1, wherein the pump is of the type in which a plurality of plungers are reciprocated in parallel cylinder bores by a swash-plate, there being radial spill ports in each plunger for the escape of pressure fluid from the associated cylinder chamber to exhaust, and a sleeve around the plunger, said sleeve being axially adjustable to obturate said ports to varying extents during the plunger stroke and thereby to vary the pump delivery.

5. A hydraulic system as claimed in claim 1 further including a control piston that is operatively connected to the means for varying the pump delivery, the pressures on opposite sides of said restriction means acting on opposite sides of said control piston.

6. A hydraulic system as claimed in claim 5 comprising an over-balance control which comprises a spool member axially in line with the control piston and which is slidable endwise to engage a rod on said piston, said over-balance control being operable hydraulically upon reaching a predetermined delivery pressure to override the delivery varying means and to offload the pump irrespective of the pressure drop across the restriction means.

7. A hydraulic system as claimed in claim 6, wherein the spool member of the overbalance control has a working face that is subject to the pressure in the delivery line on the downstream side of the restriction means, whereby when said pressure reaches a predetermined maximum the spool member is driven endwise against the action of a return spring to engage the rod of the control piston and move said piston to its position corresponding to maximum spill of the pump delivery.

8. A hydraulic system as claimed in claim 7, comprising a fluid line leading from the delivery line to exhaust by way of a restricting orifice, a valve in said exhaust line downstream of the orifice and coupled to

the overbalance control, said valve being normally open but closing, when the overbalance control comes into action to offload the pump, and an additional working face on the spool member of the overbalance control which is subject to the pressure in said exhaust line on the downstream side of the restricting orifice and upstream of the valve, the arrangement being such that the pressure built up on said additional working face when the valve closes assists in holding the overbalance control in the offload position.

9. A hydraulic system as claimed in claim 8, wherein the valve in the exhaust line comprises a port in the spool member of the overbalance control, and a cooperating shoulder or land in the bore in which said spool member works.

10. A hydraulic system comprising a supply pump, means for varying the delivery of said pump, a plurality of intermittently-operating services supplied by said pump, each service having a selector valve to control the admission of pressure fluid thereto, restriction means in the pump delivery line, said restriction means including a plurality of orifices connected in parallel, said hydraulic system further comprising a plurality of control-valve means associated respectively with said orifices and coupled respectively for operation with the selector valves for the services whereby opening of a selector valve to admit pressure fluid to the service controlled thereby results automatically in the opening of a control-valve associated with a corresponding orifice to permit flow through the orifice and so to increase the flow area of the restriction means as a whole.

11. A hydraulic system as claimed in claim 10, wherein the pump also supplies, in addition to the aforesaid services, a hydraulic circuit requiring a supply of pressure fluid substantially constantly, and the restriction means includes as well as the valve-controlled orifices, a further orifice in parallel with the others and which is permanently in circuit.

12. A hydraulic system as claimed in claim 10 wherein the orifice control-valves are hydraulically coupled to their respective selector valves, in that an operating piston is provided for each orifice control-valve which piston is subject to the fluid pressure in a line communicating with the line supplying the respective service downstream of the selector valve, whereby when any selector valve is opened pressure fluid flows to act on the piston and open the corresponding orifice control-valve.

13. A hydraulic system as claimed in claim 10 wherein each orifice control-valve is electrically coupled with its associated selector valve controlling the respective service.

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