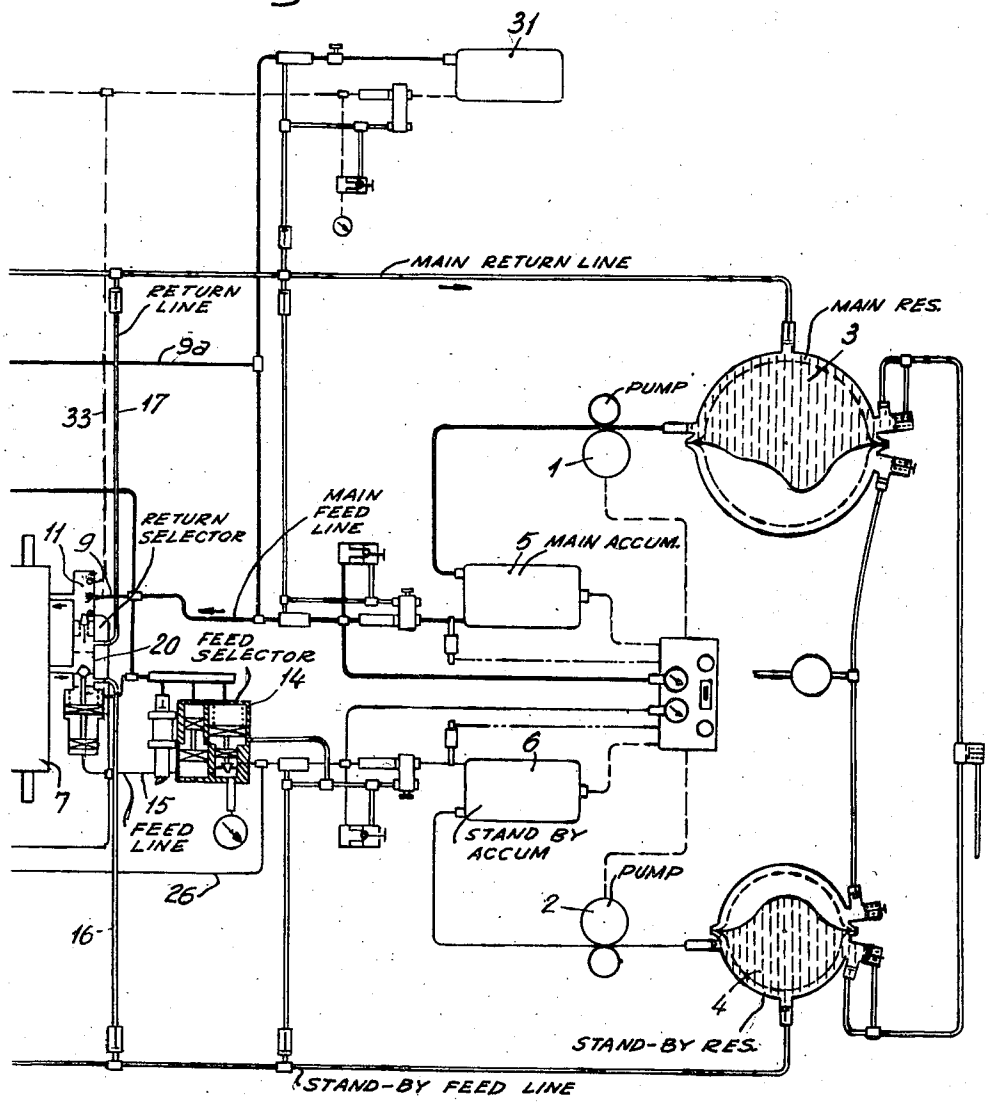
Sept. 3, 1957 R. LEDUC 2,804,753

HYDRAULIC SERVO-SYSTEM

Filed March 27, 1956 4 Sheets-Sheet 1

Fig. 1



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HYDRAULIC SERVO-SYSTEM

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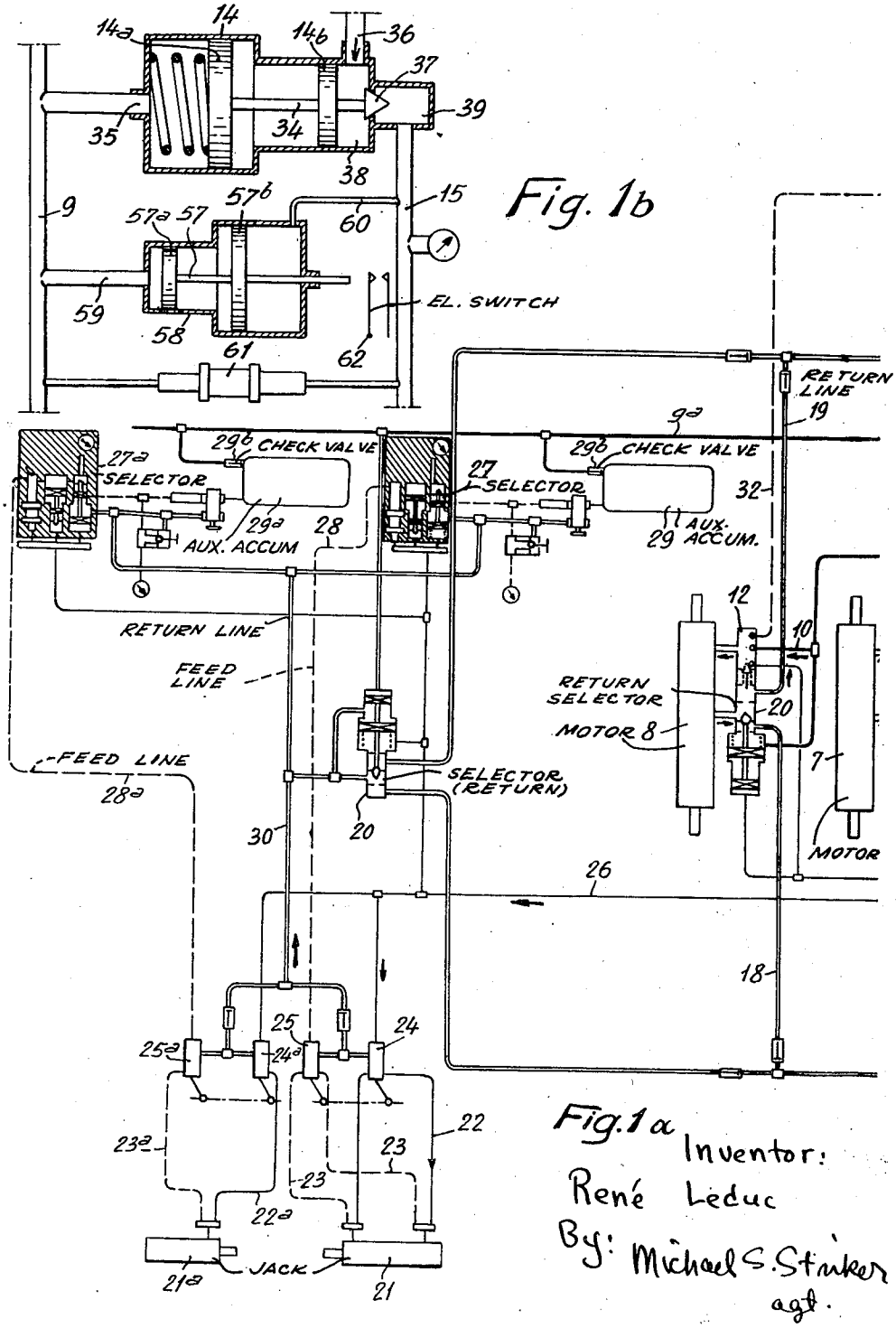

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HYDRAULIC SERVO-SYSTEM

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Fig.2

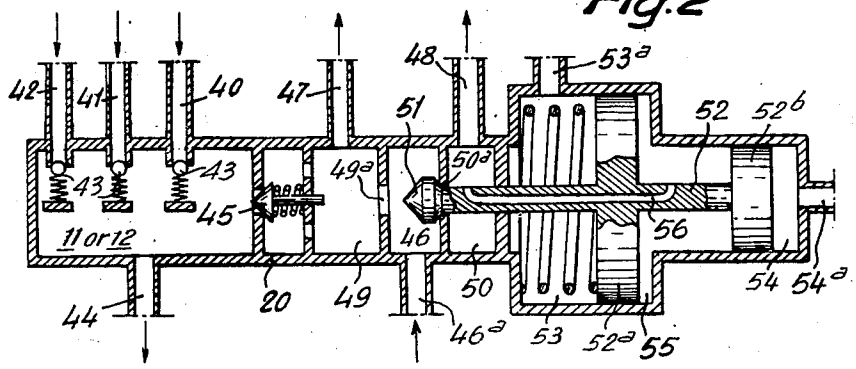


Fig.4

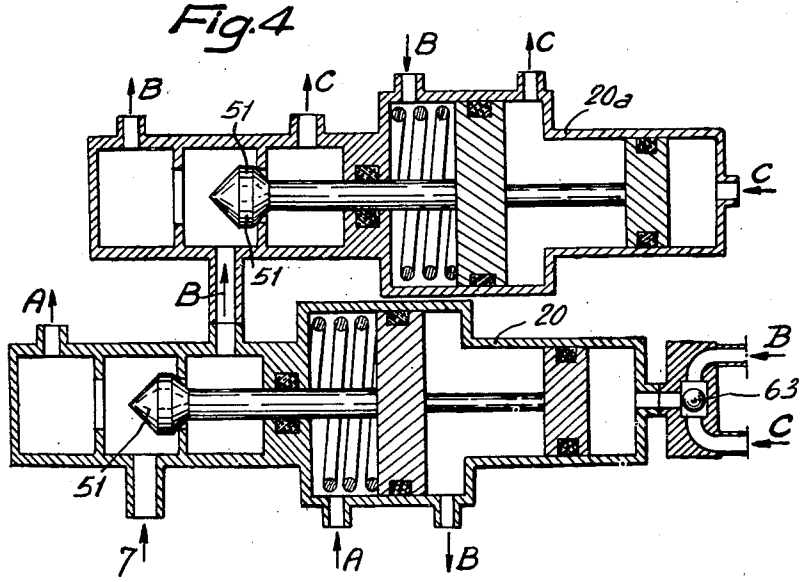
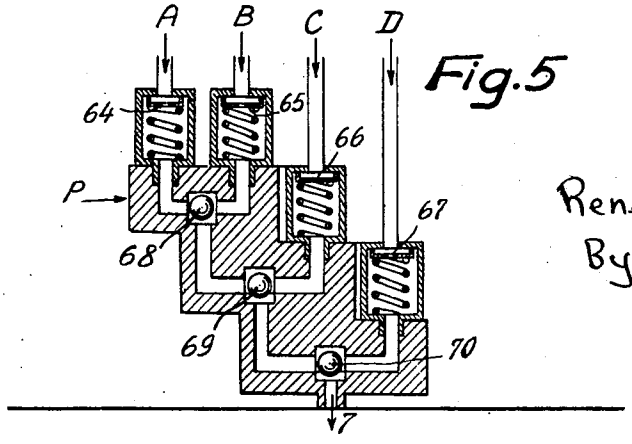


Fig.5



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HYDRAULIC SERVO-SYSTEM

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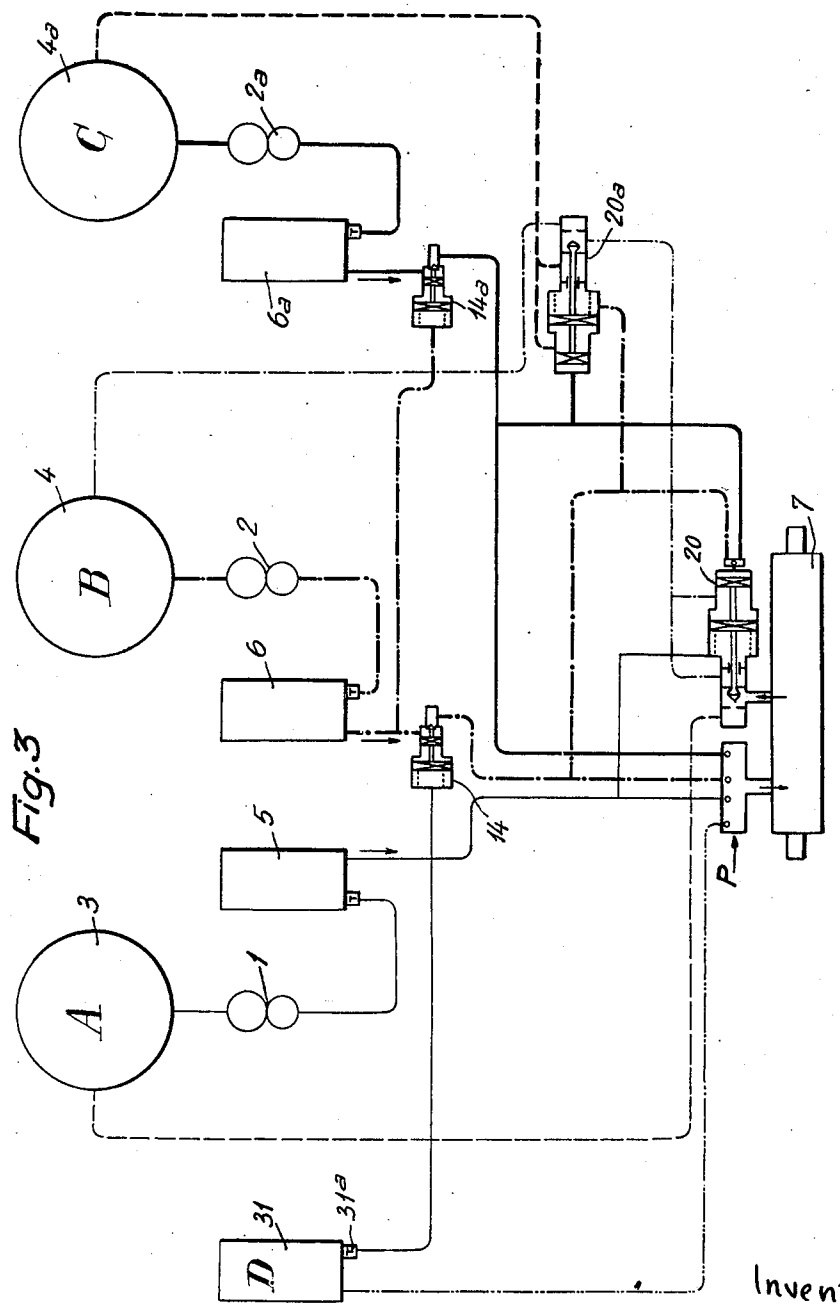

Fig. 3

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2,804,753

HYDRAULIC SERVO-SYSTEM

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6 Claims. (Cl. 60—97)

This invention relates to hydraulic servo-motor systems and is more especially applicable to hydraulic servo-controls for aircraft, for which substantially perfect reliability is essential.

It is an object of this invention to provide a hydraulic servo-motor, or a number of such servo-motors operating different services, e. g. different aircraft controls, with duplicated or multiple feed and return circuits, so automatically controlled that circuits not in use are positively isolated and that on the failure, complete or partial, of the circuit in use, a stand-by circuit is immediately brought into use and that the action of the servo-motor or motors are not interrupted even momentarily.

A further object of the invention is to provide means for "exercising" a stand-by circuit, by arranging that it shall operate services which are only required intermittently, e. g. undercarriage retraction and extension mechanism in aircraft.

How these objects and such others as may hereinafter appear are attained and in what manner the invention may be performed will be more fully understood from the following description having reference to the accompanying drawings of an embodiment of the invention together with a modification thereof, given by way of example only and without implied limitation of the scope of the invention which is defined in the hereto appended claims.

In the drawings,

Figures 1 and 1*a* is a schematic view illustrating the general arrangement of a two-circuit servo-motor operating hydraulic system;

Figure 1*b* is a detail view in section of the component **14** of Figure 1 on an enlarged scale;

Figure 2 is a detail view in section of the component **20** of Figures 1 and 1*a*;

Figure 3 is a simplified schematic view or pictorial circuit diagram of a three-circuit, servo-motor operating hydraulic system;

Figure 4 is a detail view in section of the components **20**, **20***a* of Figure 3 on an enlarged scale; and

Figure 5 is a view similar to Figure 4 of the component P of Figure 3.

The system illustrated in Figures 1 and 1*a* comprises a main and a stand-by hydraulic circuit, each capable independently of operating a number of servo-motors of which two only, designated **7** and **8**, are illustrated. The main circuit comprises a reservoir **3**, a pump **1**, an accumulator **5**, parallel feed lines **9**, **10** and return lines **17**, **19**. The stand-by circuit likewise comprises a reservoir **4**, a pump **2**, an accumulator **6**, a branched feed line **15** and return lines **16**, **18**. Each servo-motor has a feed collector chamber **11**, **12** receiving the main and stand-by feed lines **9**, **10** and **15**.

The stand-by feed is controlled responsively to the main feed pressure by a single feed selector device **14** common to all the servo-motors, while a separate return selector device **20** controls the disposal of the liquid returned from each servo-motor to the reservoir **3** via lines **17**, **19** or to the reservoir **4** via lines **16**, **18**, responsively to the main feed pressure.

The feed selector **14** (Fig. 1*b*) comprises a needle valve **37** controlling communication between a chamber **38**, which communicates via a port **36** with the accumulator **6**, and a chamber **39** communicating with the stand-by feed line **15**. Valve **37** is actuated by a differential piston **34** whose larger diameter part **14***a* is subjected, via a port **35** communicating with the main feed line **9**, to the main feed pressure supplied by accumulator **5** and acting in the sense to seat the valve **37**, and whose smaller diameter part **14***b* is subjected in the opposite sense to the pressure in chamber **38** supplied by accumulator **6**. The accumulators **5**, **6** are adjusted to maintain equal pressures and consequently the effort of piston part **14***a* is normally predominant and the valve **37** is kept closed, thus isolating the stand-by feed line **15**; but if the main feed line **9** suffers a loss of pressure exceeding a critical value, determined by the relative areas of the piston parts **14***a* and **14***b*, the effort of the smaller piston part **14***b* will predominate and open valve **37** thus activating the stand-by feed line **15**.

The selector devices **20** act to divert the liquid returned by the servo-motors from the main return lines **17**, **19** leading to reservoir **3** to the stand-by return lines **16**, **18** leading to reservoir **4** when the stand-by feed takes over from the main feed.

Each selector **20** (see Figure 2) has a chamber **46** which receives the liquid returned by the servo-motor through a port **46***a*, and two chambers **49**, **50** communicating respectively with the return line **17** (or **19**) and the return line **16** (or **18**) via ports **47**, **48**. Orifices **49***a*, **50***a* connecting chamber **46** with chambers **49**, **50** respectively are selectively closable by a valve member **51** actuated by a differential piston **52**. The variable volume chamber **55** between the large and small parts of the piston **52** is vented by a passage **56** in the piston stem to chamber **50**, and the variable volume chambers **53** and **54** which are respectively to the left of the large diameter piston part **52***a* and to the right of the small diameter piston part **52***b* communicate via ports **53***a*, **54***a* with the main and stand-by feed lines **9** (or **10**) and **15** respectively. Normally, the feed pressure applied to chamber **53** and acting on the piston part **52***a* causes the valve member **51** to close the orifice **50***a* and open the orifice **49***a* so that the liquid returned by the servo-motor is directed to return line **17** (or **19**). When however, the main feed pressure fails, feed line **15** is activated through the action of selector device **14** and the stand-by feed pressure is thus applied to chamber **54** to act on the piston part **52***b*, and since the pressure in chamber **53** has fallen below the critical value, the piston **52** is moved to the left to open orifice **50***a*, and close orifice **49***a*, thus directing the liquid returned by the servo-motor to the stand-by return line **16** (or **18**).

Figure 2 also illustrates the detail of the feed collector chamber **11** (or **12**) which has a single outlet **44** leading to the servo-motor's feed port and two inlets **40**, **41** connected respectively to the feed lines **9** (or **10**) and **15** and a third inlet **42** connected by means of a reserve feed line **32** or **33** to a low pressure reserve accumulator **31** (see Figure 1) chargeable by the main accumulator **5** before the complete system is put to use, i. e. in the case of an aircraft servo-control system before flight. Inlets **40**—**42** have non-return valves **43** and since the accumulator **31** is charged to a lower pressure than the main and stand-by accumulators **5**, **6**, the non-return valve **43** of inlet **42** shuts off the feed line **32** or **33** and keeps accumulator **31** in reserve as long as either the main or stand-by accumulator **5** or **6** is operative. The collector chamber **11** (or **12**) also has a spring-loaded

relief valve 45 communicating via chamber 49 and port 47 with return line 17 (or 19).

In normal circumstances, when the main circuit is in operation, the stand-by circuit 2, 6, 15, 16 or 18, 4 is completely idle; and since complete idleness is detrimental to stand-by systems and introduces a hazard of failure when the stand-by system is required, provision is made for the operation of certain services which are only required intermittently, e. g. in an aircraft installation the undercarriage retraction and extension mechanism, by the stand-by accumulator 6.

Figure 1 includes two such intermittently operable hydraulic jacks 21, 21*a* connected to a feed line 26 and to a return line 30 through selector valves 24, 24*a* and connections 22, 22*a*. The feed line 26 is branched from the feed line 15 upstream of the device 14. The jacks 21, 21*a* are further provided with a stand-by system comprising selector valves 25, 25*a*, connections 23, 23*a* and feed lines 28, 28*a*. The latter are connected to a branch 9*a* of the feed line 9, supplied by accumulator 5, through selector devices 27, 27*a* of similar construction to the device 14, but so connected that the master pressure (corresponding to the pressure in line 9 in the case of device 14) is that in line 26 derived from accumulator 6. Consequently, so long as there is no failure of pressure in line 26, lines 28 and 28*a* are isolated. The feed connections of selectors 27, 27*a* to the feed line 9*a* include auxiliary accumulators 29, 29*a* in series with and charged by accumulator 5 and protected by non-return valves 29*b*, so as to be capable of providing pressure for emergency operation of the jacks 21, 21*a* in the event of failure of both feed systems supplied respectively by accumulators 6 and 5. A single selector device 20 controlled by the pressure in feed line 26 connects the return line 30 by jacks 21, 21*a* selectively to reservoir 4 or 6 through return lines 30*a*, 30*b* respectively according to whether the feed line 26 is active or not.

To guard against the risk of stand-by circuit being put out of action the device 14 (Figure 1*b*) has means for triggering a warning device of any suitable kind, comprising a cylinder 58 containing a differential piston to the smaller diameter part 57*a* of which the pressure in line 9 is applied through a branch 59, the pressure in line 15 being applied in the opposite sense to the larger diameter part of piston 57 through a branch 60. Lines 9 and 15 are further interconnected by a bridge line containing a cock 61. Before commencing operations, e. g. in the case of an aircraft installation before flight, cock 61 is opened momentarily to pressurize line 15 (which is otherwise isolated by the valve 37) and thereby drive piston 57 to the left as seen in Figure 1*a* to the end of its stroke. When cock 61 is re-closed to isolate line 15 a hydraulic lock is created which holds piston 57 in the above mentioned position. If however line 15 is ruptured or develops an appreciable leak the hydraulic lock will be released and the pressure in line 9 will move piston 57 to the right to trigger a warning device, e. g. by closing an electric switch 62. The area and stroke of piston 57 are so selected that the amount of minor leakage from the line 15 which is normally to be expected during a period of use, e. g. in an aircraft installation during a single flight, will be insufficient to cause the warning signal to be triggered.

Figure 3 illustrates an arrangement comprising three alternative feed and return systems for servo-motors of which one is shown at 7. In addition to a main circuit comprising a pump 1, reservoir 3 and accumulator 5, a first stand-by circuit comprising a pump 2, reservoir 4 and accumulator 6, a feed selector 14 and a return selector 20, all as illustrated and described with reference to Figures 1 and 1*a*, a second stand-by circuit comprising a pump 2*a*, reservoir 4*a*, and accumulator 6*a* is provided. Selection of this circuit on successive failure of the main and first stand-by circuits is effected by a feed selector 14*a* and a return selector 20*a*, which are respectively similar to selectors 14 and 20. Whereas the selectors 14, 20 are controlled by the main feed pressure supplied by accumulator 5 so as to isolate the first stand-by accumulator 6 and reservoir 4 from the servo-motor 7 as long as the main feed pressure is maintained, but to connect the servo-motor to accumulator 6 and reservoir 4, while isolating it from reservoir 3, on failure of the main feed pressure, the selectors 14*a* and 20*a* are controlled by the feed pressure supplied by the first stand-by accumulator 6 to isolate the second stand-by accumulator 6*a* and reservoir 4*a* unless and until the feed pressure in the first stand-by circuit fails, in which event the selectors 14*a*, 20*a* connect the servo-motor to accumulator 6*a* and reservoir 4*a* and isolate it from reservoir 4.

The selectors 20 and 20*a* are disposed in series in the return lines of the servo-motor 7 to the stand-by reservoirs 4, 4*a* (see also Figure 4) so that liquid returned by the servo-motor to reservoir 4 or 4*a* must pass through both selectors 20, 20*a*.

It is therefore necessary that when the feed pressure of the first stand-by circuit fails the selector 20 should be maintained in its previous position in which returned liquid is directed to selector 20*a*. Now in the form of construction of the selectors 20, 20*a* illustrated (see more especially Figure 4) the selector valve 51 (Figure 4) is operated by a differential piston, which in the case of selector 20 is subjected on one side to the main feed pressure and on the other to the stand-by feed pressure, which latter pressure acts to throw-over the selector to direct the return liquid to reservoir 4 or 4*a* and must therefore be maintained at all times. This is achieved by connecting the feed lines of both stand-by circuits to the selector 20 through a ball valve 63 as shown in Figure 4, so the smaller diameter part of the differential piston of selector 20 is subjected to the feed pressure supplied by either of the accumulators 6 or 6*a*, whichever is the higher.

The system illustrated in Figure 3 also includes a reserve accumulator 31 charged by accumulator 3 through a non-return valve 31a.

There are thus four alternative sources of supply to the servo-motor 7 giving virtually 100% reliability of operation. For convenience the four feed sources and their connections to the servo-motor and selectors 20 and 20*a* are designated A, B, C and D in Figures 3, 4 and 5. Figure 5 illustrates the detail of a common collector box P (Figure 3) corresponding to the collectors 11 and 12 of Figure 1 and receiving the feed lines from all four sources of supply A(3), B(4), C(4*a*) and D(31) and delivering the liquid supplied to the servo-motor 7. Each feed connection A, B, C, D, has a separate non-return valve 64, 65, 66 or 67, and three ball valves 68, 69, 70 which ensure that the feed connections in reserve are isolated. Thus if connection A is under full pressure and the other three are not, the ball valves 68—70 isolate connections B, C and D and, generally, whichever of the four connections is under full pressure, the others not being under full pressure, are isolated by the ball valves 68—70. One and one only of the four supply sources A, B, C, D, is therefore always connected to the servo-motor. This arrangement enables the relief valve 45 (see Figure 2) to be dispensed with.

It is to be understood that the foregoing description is given by way of example only and that all such modifications, alterations and changes of arrangement and constructional details as are within the competence of those skilled in the art may be made without departing from the scope of the invention. In particular the differential pistons of the selector devices 14, 20, 27 etc. may be replaced by simple spring-loaded pistons subjected only to the master feed pressure, e. g. the main feed pressure in the case of the selectors 14 and 20 of Figures 1 and 1*a*.

I claim:

1. In combination, an hydraulic servo-motor, a main feed line thereto, a stand-by feed line thereto, a separate source of hydraulic pressure supplying each said feed line, a feed selector device responsive to the pressure in the main feed line for isolating the stand-by feed line from its pressure source as long as the main feed pressure exceeds a predetermined value and for connecting the stand-by feed line to its pressure source when the main feed pressure falls below said predetermined value, a main return line and a stand-by return line from said servo-motor, and a return selector device responsive to the main feed pressure for directing liquid returned by said servo-motor into the main return line or into the stand-by return line, while isolating the other of such return lines, according as the main feed pressure exceeds or is less than a predetermined value.

2. In combination, at least two hydraulic servo-motors, a main source of hydraulic pressure, a main feed line from said source common to all said servo-motors, a stand-by source of hydraulic pressure, a stand-by feed line from said stand-by source common to all said servo-motors, a single feed selector device responsive to the pressure in said main feed line for isolating said stand-by feed line from its pressure source as long as the main feed pressure exceeds a predetermined value and connecting said stand-by feed line to its pressure source when the main feed pressure falls below said predetermined value, a main return line and a stand-by return line from each said servo-motor, and a return selector device associated with each such servo-motor and operative responsively to the main feed pressure to direct liquid returned by the servo-motor associated therewith into the main or the stand-by return line of such servo-motor, while isolating the other of such return lines, according as the main feed pressure exceeds or is less than a predetermined value.

3. The combination defined in claim 1, including further a reserve source of hydraulic pressure, such pressure being lower than that of the main pressure source, a direct connection from said reserve source to the servo-motor, and a non-return valve in said direct connection.

4. In combination with an hydraulic servo-motor, a series of at least three separate, progressively selectable hydraulic circuits for operating said servo-motor, each such circuit including an hydraulic pressure source and a return line, at least two feed selector devices and at least two return selector devices, each feed selector device being operative to isolate and connect the servo-motor from and to one of the circuits (other than the first of the series) responsively to the source pressure of the preceding circuit of the series according as such source pressure exceeds or is below a critical limiting value, and each return selector device being operative responsively to the source pressure of one of said circuits (other than the last of the series) to connect the servo-motor to the return line of the last-named circuit while isolating it from the return line of the next circuit of the series when said last-named source pressure exceeds a critical limiting value and to reverse the connections of the servo-motor to said last-named return lines when said last-named source pressure is below said critical value.

5. The combination defined in claim 4 including further a reserve source of hydraulic pressure, such pressure being lower than those of the pressure sources of the mentioned hydraulic circuits, a direct connection from said reserve source to the servo-motor, and a non-return valve in said direct connection.

6. The combination defined in claim 1 including further an hydraulic motor required to operate intermittently, an hydraulic feed connection to said hydraulic motor in constant communication with the source of hydraulic pressure supplying said stand-by feed line and a return connection from said hydraulic motor to said stand-by return line.

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