United States Patent

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[54] **HYDRAULIC CONTROL MEANS**

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[52] **U.S. Cl.**.....**91/438,** 91/1, 91/411 R

[51] **Int. Cl.**.....**F15b 11/16**

[58] **Field of Search**.....91/438, 439, 1

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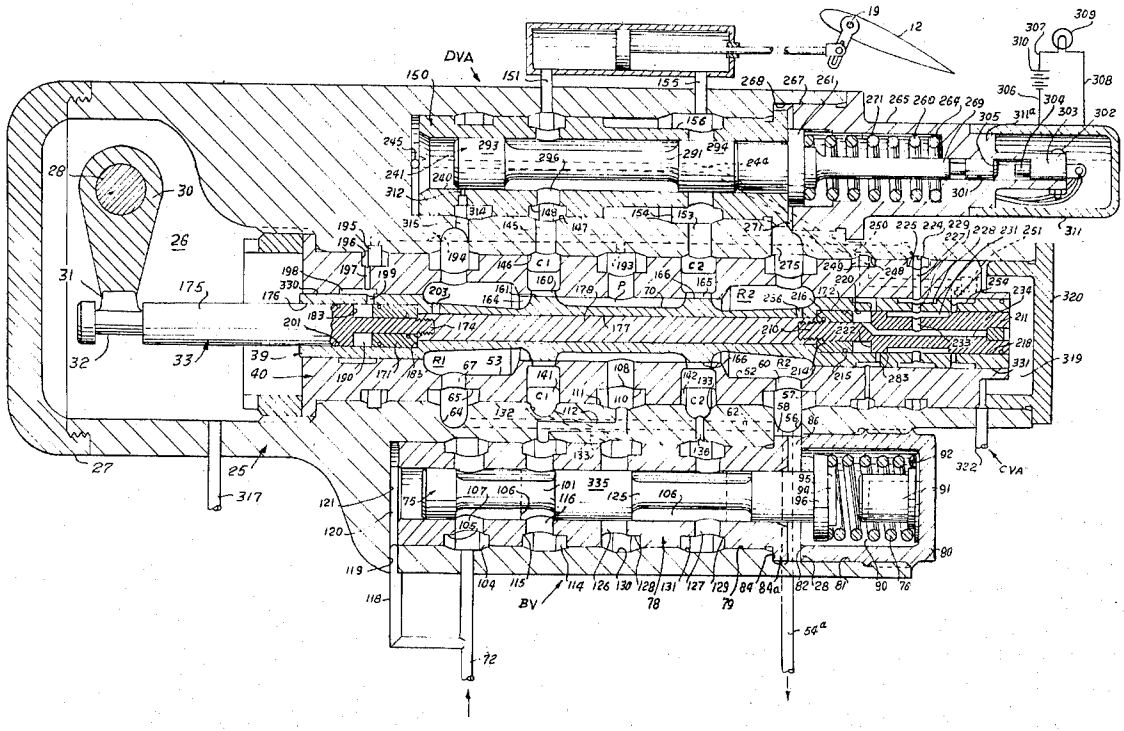
[57] **ABSTRACT**

A hydraulic control device for controlling the operation of a reversible hydraulic motor device, such as a hydraulic ram, which has a deactivating valve assembly which provides a fluid bypass passage across the fluid inlet and passages of the ram cylinder to render the hydraulic ram inoperative in the event of malfunction of the control device. An apparatus for operating a controlled member, such an aileron, spoiler or the like, of an aircraft which includes a plurality of hydraulic motor devices having separate control means for individually controlling the motor devices, the control devices having means for deactivating the motor devices upon the malfunction of the control devices so that the motor device whose control device has malfunctioned or is inoperative will not impede the operation of the controlled member by the other motor devices whose control devices still function properly.

5 Claims, 4 Drawing Figures



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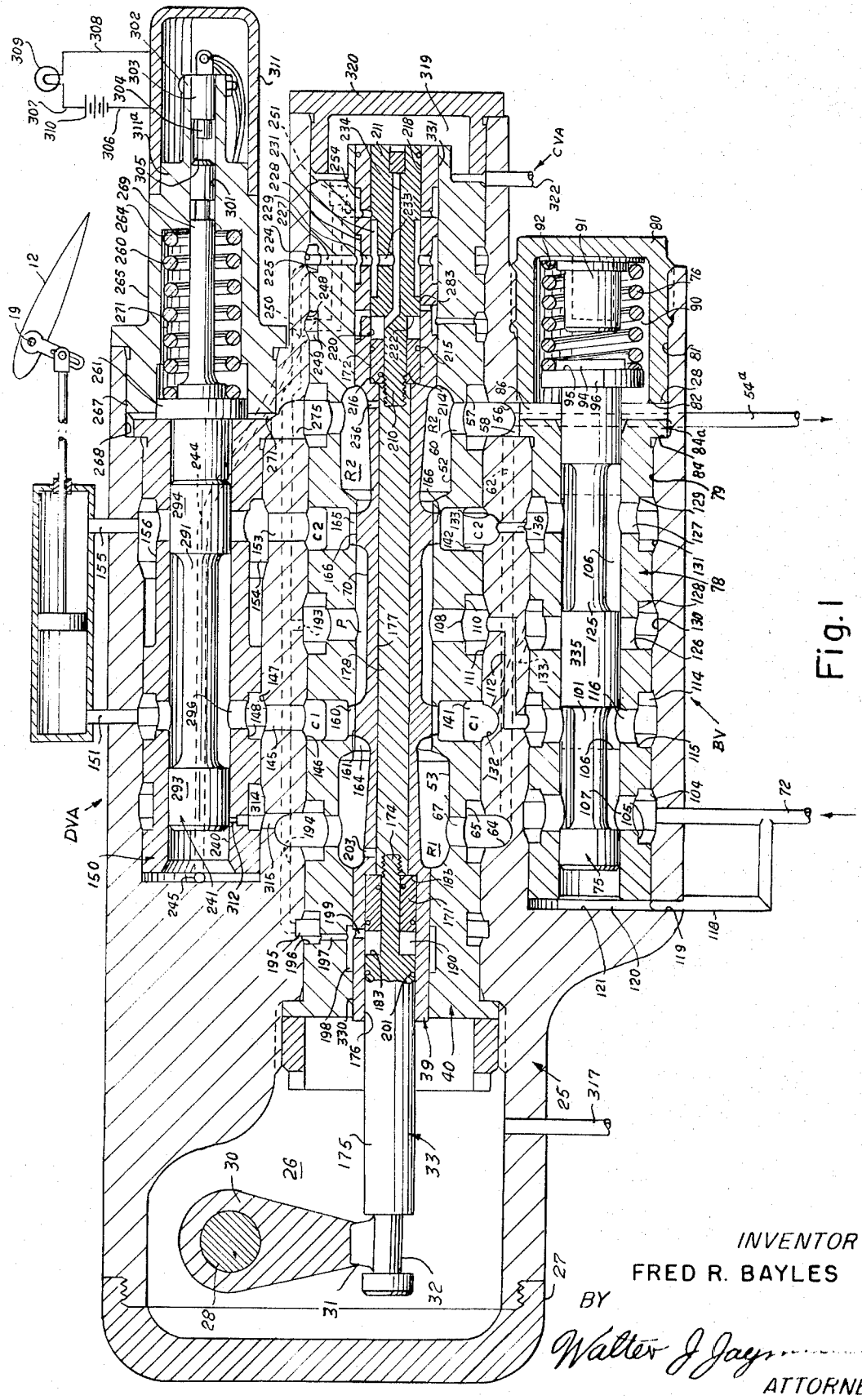

Fig. 1

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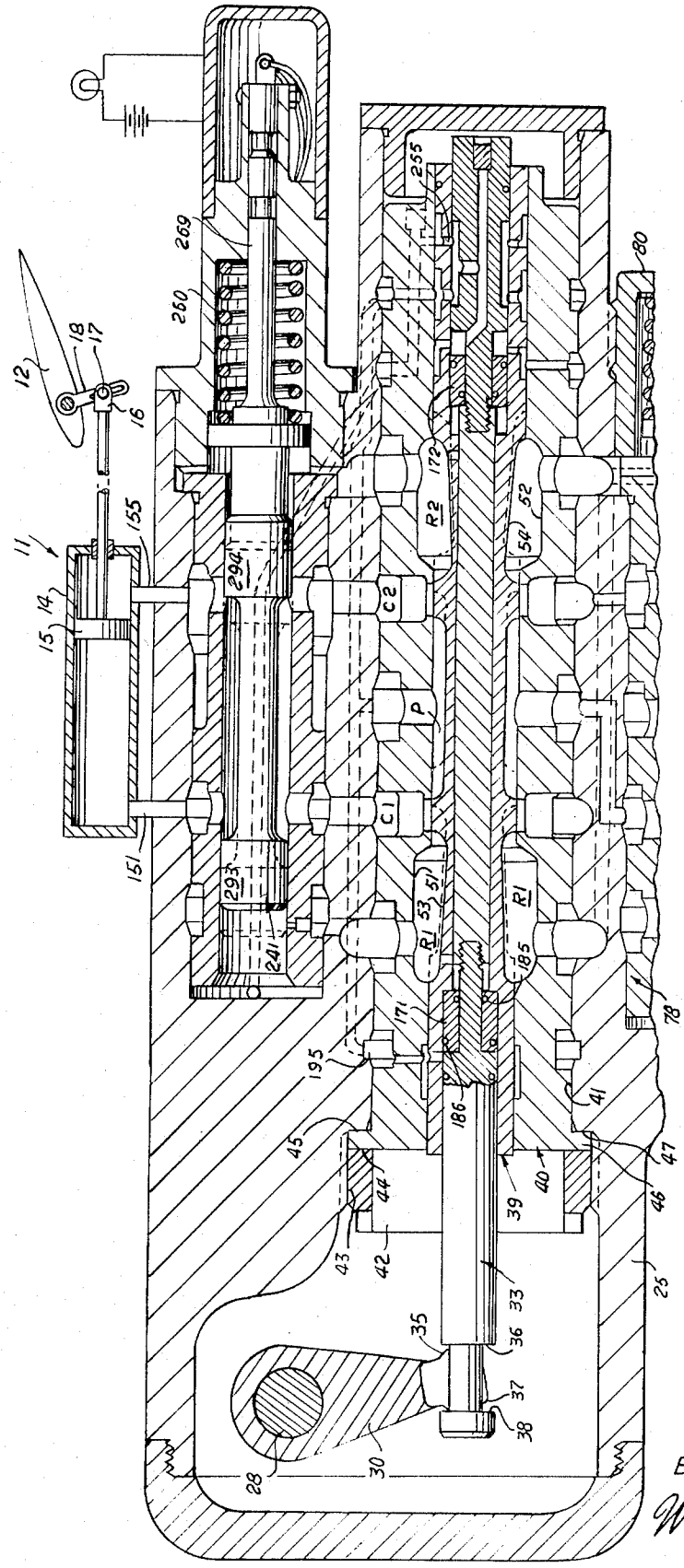

Fig. 2

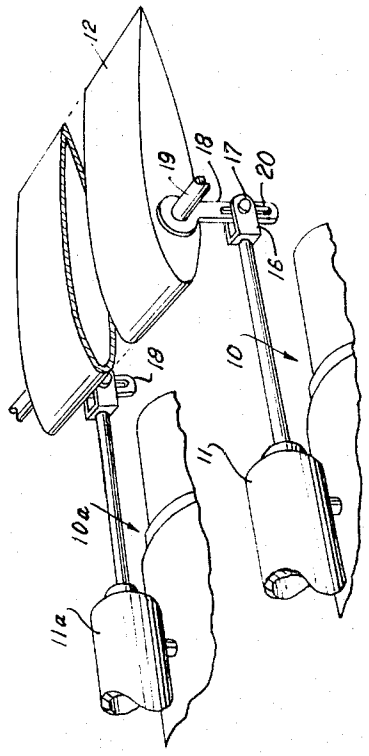

Fig. 4

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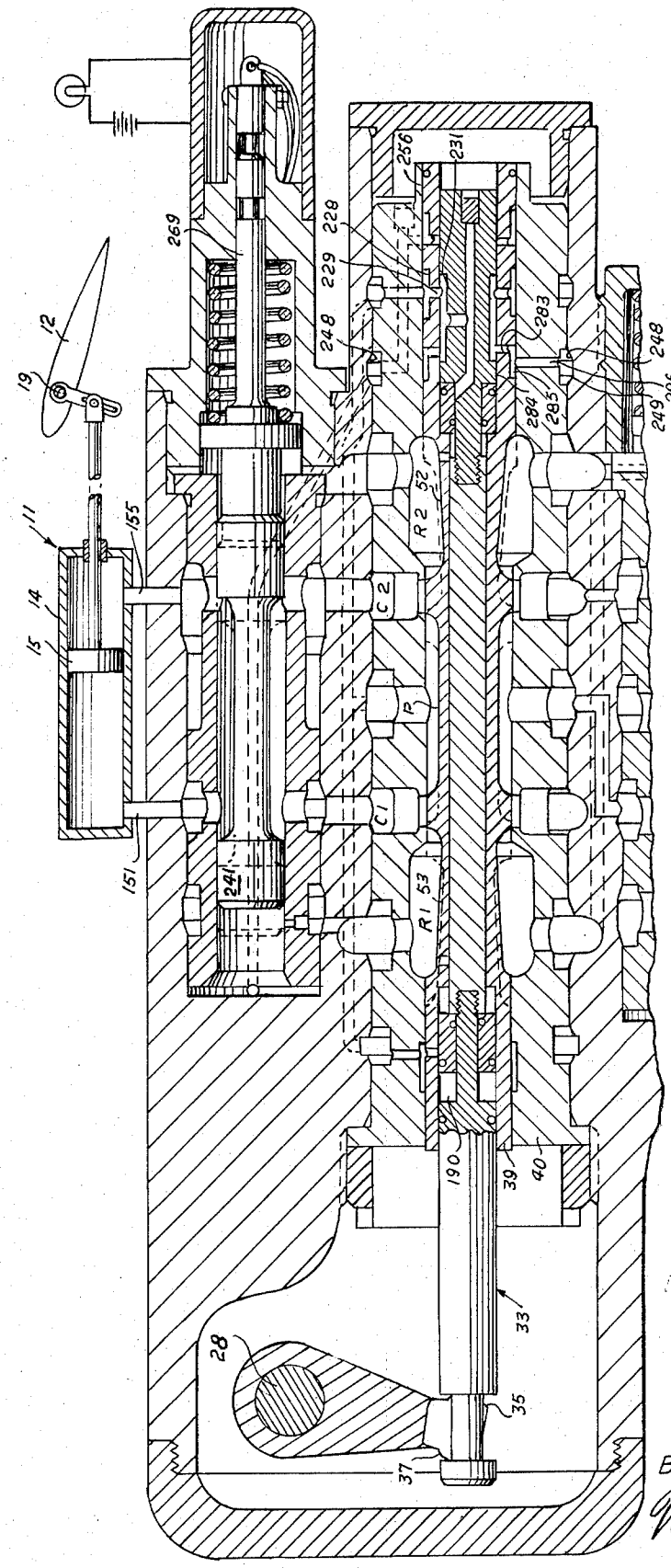

Fig. 3

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HYDRAULIC CONTROL MEANS

This invention relates to hydraulic control devices and to hydraulic apparatus for controlling the operation of a plurality of hydraulic motor devices used to operate a controlled member.

An object of the invention os to provide a new and improved hydraulic control device for controlling the operation of a hydraulic motor device.

Another object is to provide a hydraulic control device for a reversible hydraulic motor means which is caused to operate in one direction when hydraulic fluid under pressure from a hydraulic pressure system is circulated thereto in one direction and to operate in the opposite direction when the hydraulic fluid is circulated thereto in a second direction, and which is held against operation in either direction when the circulation of hydraulic fluid to or from the motor means is prevented.

Still another object is to provide a hydraulic control device, of the type described, having a control valve assembly which is operable selectively to admit fluid under pressure to a first or second fluid passage means of a hydraulic motor means and permit exhaust of hydraulic fluid from the other of the first and second flow passage means, or to prevent flow of hydraulic fluid to or from either of the first and second flow passage means of the hydraulic motor means; and a deactivating valve assembly which is responsive to malfunction of the control valve assembly for providing a first bypass flow passage between the first and second flow passage means of the motor control hydraulic motor means to deactivate the motor means and permit a controlled member normally operated by the motor means to be moved by other forces.

A further object is to provide a hydraulic control device, of the type described, which also has a bypass valve assembly, operatively associated with the control valve assembly and operable when the hydraulic pressure source or system fails to provide hydraulic fluid under predetermined pressure to the hydraulic control device, for establishing a second bypass flow passage between the first and second passage means of the hydraulic motor means.

A further object is to provide a new and improved hydraulic control device for controlling the operation of a hydraulic ram having a piston reciprocable in a cylinder and first and second passage means at opposite side ends of the cylinder and opening to the cylinder on opposite sides of the piston, the control device being operable selectively to admit hydraulic fluid under pressure to either of the passage means and permit exhaust of the fluid from the other of the passage means, in order to cause movement of the piston in one or other direction in the cylinder, and to prevent flow of hydraulic fluid to or from both of the passage means to prevent flow of hydraulic fluid to or from either end of the cylinder through the passage means whereby the piston is effectively locked in any adjusted position thereof relative to the cylinder, the control device including a deactivating valve assembly which is operable by fluid pressure upon the malfunction of the control valve assembly to provide a first bypass flow passage between the opposite ends of the cylinder whereby the piston is freed for movement in either direction in the cylinder.

A still further object is to provide a hydraulic control device of the type described wherein the control valve assembly includes a valve member or spool longitudinally movable in a body means of the control device by means of a reciprocable control member or rod by pistons exposed to hydraulic pressure which exert predetermined forces on the valve spool to cause the valve spool to move with the control rod, the control rod being movable relative to the valve spool if the valve spool is held against movement by a force which exceeds the predetermined value, the control rod and the valve spool having cooperative means for providing hydraulic fluid under pressure to the deactivating valve assembly upon occurence of relative movement between the control rod and the valve spool.

An important object of the invention is to provide a hydraulic apparatus or system for controlling operation of a plurality of hydraulic motor devices used jointly to operate a controlled member which apparatus employs separate control devices for individually controlling operation of the individual motor devices.

Another object is to provide a hydraulic apparatus or system, of the type described, wherein each control device has means for deactivating the motor device controlled thereby upon the malfunction of the control device in order that a motor device whose associated control device has malfunctioned or is inoperative will not impede or hinder the operation of the controlled device by the other motor devices whose control devices are functioning properly.

Additional objects and advantages of the invention will be readily apparent from the reading of the following description of a device constructed in accordance with the invention, and reference to the accompanying drawings thereof, wherein:

FIG. 1 is a sectional partly schematic view, with some parts such as seal means omitted for clarity of illustration, of the hydraulic control device embodying the invention for operating a hydraulic ram and showing the control device in position preventing flow of fluid from either end of the cylinder and causing the piston of the hydraulic ram to be held against movement by the hydraulic fluid;

FIG. 2 is a view similar to FIG. 1 showing the valve spool of the control valve assembly of the device held against movement in the body means of the device and its control rod displaced to the right relative to the valve spool, and the deactivating valve assembly being in actuated position and providing a bypass passage between opposite ends of the cylinder of the hydraulic ram;

FIG. 3 is a view similar to FIG. 2 showing the control rod displaced to the left relative to the valve spool and the deactivating valve assembly in actuated position; and,

FIG. 4 is a fragmentary perspective view, with some parts broken away, showing the control devices embodying the invention in use for controlling separate hydraulic rams for actuating a controlled member, such as the illustrated aileron on an aircraft.

Referring now to the drawings, each hydraulic control device **10** embodying the invention is shown as used to control the operation of a hydraulic motor. Two or more such motors **11** and **11***a*, FIG. **4**, individually controlled by separate devices **10** and **10***a*,

respectively, are shown in use to operate a control member of an aircraft, such as an elevator **12**, spoiler or the like. The hydraulic motors are of the hydraulic ram type having cylinders **14** in which are reciprocable pistons **15** whose rods are pivotally connected by means of clevises **16** and pins **17** to levers **18** rigidly connected to a rotatable shaft **19** to which the control member is rigidly secured. The pins **17** extend through suitable slots **20** of the levers.

It is desirable and necessary in the event of a malfunction of a control device **10** of one of the motors, that such motor be deactivated or rendered inoperative so that it will not interfere with the operation of the aircraft control member by the other motor or motors whose control devices are still in operative condition.

Each of the control assemblies includes a control valve assembly CVA, operable by the usual auto pilot and a pilot manual override control of an aircraft, not shown, which selectively causes hydraulic fluid under pressure, from the hydraulic fluid circulating system of the aircraft, to be admitted into one end or the other end of the hydraulic cylinder **14** while allowing flow of the hydraulic fluid from the other end of the cylinder back to the fluid return line of hydraulic system when the valve assembly is in either of its opposite operating conditions and which prevents flow of hydraulic fluid from either end of the hydraulic cylinder when the valve assembly CVA is in its neutral or intermediate position; a bypass valve assembly BV which isolates the control valve assembly CVA from the pressure side of the aircraft hydraulic system when the pressure of the hydraulic fluid is below a predetermined value; and a deactivating valve assembly DVA which, when the control valve assembly is damaged or malfunctioning, provides fluid communication between opposite ends of the hydraulic ram cylinder **14** so that the piston is free to move within the cylinder.

Each of the control assemblies **10** includes a housing **25** having a chamber **26** which is closed at one end by a closure **17**. A control shaft **28** suitably journaled in opposite walls of the housing extends through the chamber **26**. The control shaft is rotatable about its central longitudinal axis, being connected at a location externally of the housing to the autopilot linkage and also to the pilot manual override control. The control shaft has rigidly secured thereto an arm **30** whose outer end is bifurcated to provide a pair of legs **31** which are disposed in an external annular recess **32** of a reciprocable control rod **33**. It will be apparent that when the control shaft **28** is rotated in a counter-clockwise direction through a limited angle, the engagement of the cam surfaces **35** of the legs **31** with the annular shoulder **36** of the control rod defining one end of the annular recess **32** of the control rod causes the control rod to move to the right and that when it is pivoted in a counter-clockwise direction the engagement of the cam shoulders **37** of the legs with the annular shoulder **38** of the control rod defining the other end of the annular recess **32** causes the rod to be moved to the left.

The control rod **33** extends through a tubular valve spool **39** slidably mounted in a tubular valve body **40** disposed in a longitudinal passage **41** of the valve body which extends perpendicularly to the axis of rotation of the control shaft **28**. The valve body is held in proper position in the passage **41** by a nut **42**, threaded in the enlarged portion **43** of the passage **41**, whose inner surface bears against the outer end surface **44** of the valve body and holds the inner annular surface **45** of the external annular flange **46** of the valve body against the annular stop shoulder **47** of the housing.

The valve body is provided with a pair of internal annular grooves **51** and **52** which are aligned with the external annular grooves **53** and **54**, respectively, of the valve spool **39**. The aligned pairs of grooves **51** and **53** and **52** and **54** define annular hydraulic fluid return passages R1 and R2, respectively. The hydraulic fluid return line or conduit **54***a* of the hydraulic system of the aircraft is connected to the housing **25** and opens to the internal annular groove **56** of the housing which is aligned with and in communication with an external annular groove **57** of the valve body **40**. The groove **57** is maintained at all times in communication with the fluid return passage R2 by a port **60** of the tubular valve body **40** which opens to its external and internal grooves **57** and **52**, respectively.

The housing is also provided with a longitudinal passage **62** which opens at its right end to the internal groove rt of the housing **25** and at its left end to a similar external groove **64** of the housing which is aligned with and therefore in communication with an external annular groove **65** of the valve body **40**. A port **67** of the valve body provides communication between the return passage R1 and the groove **65** as it opens to the grooves **65** and **53**.

The fluid return passages R1 and R2 are thus at all times connected to the exhaust line **54***a* of the hydraulic system. The tubular valve spool **39**, intermediate its external recesses **53** and **54**, is provided with an external annular recess or groove **70** which defines with the valve body an annular pressure passage P to which hydraulic fluid under pressure is transmitted from the pressure line **72** of the hydraulic system of the aircraft through the by-pass valve assembly BV when the piston **75** of the by-pass assembly BV is in the actuated position illustrated in FIG. **1** and held therein by the pressure of the hydraulic fluid against the resistance of the spring **76**. The piston **75** is slidable in a tubular valve body **78** which is held in a longitudinal passage **79** of the housing **25** by cap **80** threaded in the external enlarged portion **81** of the passage. The internal annular end surface **82** of the cap engages the external end surface **83** of the valve body to hold the valve body against outward movement in the passage. Inward movement of the valve body in the passage **79** is limited by the engagement of its external end flange **34***a* with the annular surface **84** of the valve body defining the inner end of the enlarged portion of the passage **79**. The flange **84***a* is provided with a diametric slot **86** which is in communication with a port **58** of the housing **25** which opens to the internal groove **56** thereof. As a result of the provision of this slot **86** and the port **58**, the bore **90** of the retainer cap **80** is at all times in communication with the fluid return passage R2 and therefore with the hydraulic fluid exhaust line **54** of the hydraulic system.

The spring **76** which biases the piston **75** toward its non-actuated position has an end portion telescoped over the spring guide **91** of the cap **80**, the outer end portion of the spring engaging the annular surface **92** of the cap **80** and its other end telescoping over the spring

retainer extension **94** of the piston and engaging the annular shoulder **95** provided by an external annular flange **96** of the piston.

The piston **75** is provided with an external annular recess **101** which, when the piston is in the actuated position illustrated in FIG. **1**, provides communication between the pressure fluid conduit **72** and the pressure passage P since the fluid pressure conduit **72** is connected to the housing **25** and opens to an internal annular groove **104** of the housing in the passage **79** which is aligned with and therefore in communication with an external annular groove **105** of the valve body **78**. The groove **105** is in communication with the internal bore or passage **106** of the tubular valve body through the ports **107**. The pressure passage P is in communication with passage defined by the external recess **101** of the piston **106** through ports **108** of the valve body which open to the passage P and to an annular recess or groove **110** of the valve body **40** which is aligned with an annular groove **111** of the housing, a passage **112** which opens to the groove **111** and **114** of the housing, an external groove **115** of the valve body **78** which is aligned with the recess **114** and the ports **116** of the valve body **78** which open to the groove **115** and the internal passage or bore **106** of the valve body **78**.

The hydraulic pressure conduit **72** is in fluid communication with the extreme left end portion of the passage or bore **106** of the valve body **78** by means of a branch duct **118** which is connected to the housing **25** at its bore **119** and which opens to the space **120** between the internal annular surface **121** of the housing defining the inner end of the passage **79** and the inner end of the valve body **78**.

When the pressure of the fluid of the hydraulic system of the aircraft exceeds a pre-determined value, the force exerted thereby against the inner end of the piston **75** is sufficient to overcome the resistance of the spring **76** and the piston is moved to and held in its actuated position illustrated in FIG. **1**.

The piston **75** also has a second external annular recess or groove **125** which, when the piston moves to the left to its non-actuated position, indicated in broken lines in FIG. **1**, provides fluid communication between two sets of ports **126** and **127**, for a purpose to be described below, which open to the external annular recesses **128** and **129**, respectively, of the valve body **78** aligned with the passages **130** and **131**, respectively, of the housing and within the passage or bore **79** thereof. The groove or recess **130** is in fluid communication with a groove **132** of the housing by a passage **133** thereof and the groove **131** is in fluid communication with the groove **135** of the housing by a passage **136** for a purpose to be described below.

The grooves **132** and **135** are aligned with external annular grooves **141** and **142**, respectively, of the valve body **40** and define therewith annular control passages C1 and C2, respectively.

The control passage C1 is always in fluid communication with the rear end of the cylinder **14** of the motor device **11** through a port **145** which extends between the annular recesses **146** and **147** of the housing which are aligned respectively with the recess **141** of the housing **25** and an external annular groove **148** of the valve body **150** of the deactivating valve assembly DVA, and a conduit **151** which opens to the groove **147** and the rear end of the ram cylinder **14**.

Similarly, the control passage C2 is always in communication with the front end of the cylinder **14** by means of a port **153** which extends between the annular grooves or recesses **142** and **154** of the housing and a conduit **155** which opens to the annular groove **154**. The valve body **150** has an annular groove **156** aligned with the groove **154**.

The housing **25** has a plurality of ports **160** which open to the groove **141** of the valve body **40**. The ports **160** are closed by an annular land **161** of the valve spool **39** when the valve spool is in the intermediate position illustrated in FIG. **1**, the land sealingly engaging with the intermediate seal surface **164** of the valve body **40** to close the ports **160**.

The valve body **40** has similar ports **165** which open to the annular recess **142** of the valve body **40** and which are closed by the land **166** of the valve spool. When the valve spool is in the intermediate position illustrated in FIG. **1** of the drawing, the land sealingly engages the seal surface **164** of the valve body to close the ports **165**.

It will now be apparent that if the valve spool **39** is moved to the right relative to the valve body **40**, as to the broken line position indicated in FIG. **4**, the control passage C1 is placed in fluid communication with the fluid return passage R1 since its ports **161** will now open to the recess **53** of the valve spool and thus the rear end of the cylinder **14** is placed in communication with the exhaust duct **54** of the aircraft hydraulic system. Simultaneously, the control passage C2 will be placed in communication with the pressure passage P since its ports **165** will now be in communication with the external recess **70** of the spool and therefore the hydraulic fluid under pressure is simultaneously allowed to flow into the front end of the hydraulic cylinder **14**. As a result, the piston **15** will be moved to its retracted position thus pivoting the control led member **12** in a clockwise direction about the axis of its shaft **19**.

Conversely, if the valve spool **39** is moved to the left, as to the broken line position indicated in FIG. **3**, relative to the valve body **40**, the control passage C1 is placed in communication with the fluid return passage R2. Fluid under pressure is now admitted to the rear end of the cylinder from the pressure supply duct **72** of the hydraulic system and simultaneously the front end of the ram cylinder is connected to the exhaust duct **54** since the passage C1 is now placed in communication with the pressure passage P through its ports **161** and the control passage C2 is placed in communication with the fluid return passage R 2 through its ports **165**. As a result, the piston **15** is moved toward its extended position and pivots the control member **12** in a counter-clockwise direction about the axis of its shaft **19**.

The valve spool, during normal operation of the control valve assembly CVA is caused to move longitudinally with the control rod **33** by the force of the fluid pressure from the pressure passage P which acts on the outer end surfaces of opposed tubular pistons **171** and **172**.

The piston **171** is slidably mounted on a reduced portion **174** of the front end section **175** of the control rod **33** and is slidable in the enlarged left end portion **176** of the bore **177** of the valve spool **39**. Inward movement of the piston **171** on the control rod is limited by the en-

gagement of its inner annular end surface with the annular left end surface of the middle section **178** of the control rod. The treaded end portion **181** of the end section **175** is threaded in a suitable threaded bore in the left end of the middle section **180**. Outward movement of the piston **171** or the control rod is limited by the engagement of its outer annular end surface with the annular shoulder **183** of the end section **175** of the control rod. Inward movement of the piston **171** relative to the control rod and the valve spool is limited by the engagement of its inner annular end surface with the annulaer end surface of the central section **178** of the control rod and the internal annular stop shoulder **185** of the valve spool defining the inner end of the enlarged portion **176** of its central bore **177**. Suitable O-rings **185** and **186** disposed in annular recesses of the piston **171** seal between the control rod and the valve spool, respectively.

When fluid under pressure from the pressure passage P is transmitted to the annular chamber **190** between the control rod shoulder **183** and the outer end of the piston **171** by means of a passage **193** of the housing **25** which opens to the recess or groove **111** of the housing, a passage **194** which communicates with the passage **193**, an annular groove or recess **195** of the housing **25**, an external annular recess **196** of the valve body **40** aligned with the annular recess **195**, a port **197** of the valve body, an internal annular recess **198** of the valve body and a port **199** of the valve spool which opens to the recess **198** and the chamber **190**. An O-ring **201** seals between the piston and the valve spool outwardly of the port **199**.

A plurality of ports **203** of the valve spool open to the fluid return passage R1 inwardly of the shoulder **185** of the valve spool so that the outer annular end surface of the piston **171** is exposed to the high pressure from the pressure passage P while its inner end surface is exposed to the low pressure in the fluid return passage R1. As a result, the force exerted on the piston due to this pressure differential, and in turn exerted on the valve spool due to the engagement of the inner end surface of the tubular piston with the shoulder **185** of the valve spool causes the valve spool to move to the right with the control rod when the control rod is moved to the right if the valve spool is held against movement in the valve body with a force greater than the force exerted thereon by the piston.

The other tubular piston **172** similarly is mounted on the reduced end portion **210** of the right hand end section **211** of the control rod, secured to the right hand end of the middle section **178** by an inner end portion threaded in a suitable bore of the middle section. The piston is provided with O-rings **214** and **215** which seal between the piston and the control rod and the valve spool, respectively. Inward movement of the piston **172** relative to the spool valve is limited by the engagement of its annular inner end surface with the internal annular shoulder **216** of the valve spool defining the inner end of the right end enlarged portion **218** of the central bore **177** of the valve spool. Pressure fluid is transmitted to the annular chamber **220** between the outer end of the piston **172** and the annular shoulder **222** defining the inner end of the reduced portion **210** of the control rod right hand end section **211** through the housing passage **193**, the passage **194**, an internal annular recess **224** of the housing to which opens the right end of the passage **194**, an external annular recess **225** of the valve body which is aligned with the recess **224**, a port **227** of the valve body which opens to the groove **225**, an external recess **228** and ports **229** of the valve spool which open to the recess **228**, an external annular recess **231** of the control rod end portion **211** to which the port **229** opens, ports **233** which open to the recess **231**, and a passage **234** to which the ports **233** also open. The outer end of the passage **234** is closed by suitable plug **235**. The annular inner end surface of the piston is exposed to the pressure in the fluid return passage R2 through the ports **236** of the valve spool which open to the flow return passage R2 and the internal bore **177** of the valve spool inwardly of the valve spool shoulder **216**.

It will now be apparent that if the control rod is moved from its intermediate position, FIG. **1**, to the left, the force of the pressure of the hydraulic fluid exerted on the outer annular end surface of the piston **171** will cause the valve spool to move with the control rod to the left due to the engagement of the annular inner end surface of the piston **172** with the shoulder **216** of the valve spool if the force resisting the movement of the valve spool to the right in the valve body is less than a predetermined valve which is less than the force exerted by the hydraulic fluid on the piston **172**.

If the valve spool is seized in the valve body, as due to galling of the lands of the valve spool or presence of extraneous particles between the valve spool and the valve body so that the normal operating longitudinally acting force exerted thereon by either the piston **171** or **172** cannot move it to the left or to the right as the control rod is moved to the left or to the right, the control rod will move longitudinally relative to the valve spool. In the case of the movement of the control rod to the left relative to the valve spool from the position illustrated in FIG. **1** to the position illustrated in FIG. **3**, the force exerted by the pressure fluid on the tubular piston **171** will initially resist such movement. Similarly, if the valve spool due to some malfunction is seized in the valve body and cannot be moved to the right therein by the normal operating force, the control rod will be moved to the right from the position illustrated in FIG. **1** to the position illustrated in FIG. **2**, relative to the valve spool against the force being exerted by the fluid pressure on the outer end of the other piston **172**.

When the control rod is moved to the right, as illustrated in FIG. **2**, relative to the valve spool, fluid under pressure from the external annular recess **231** of the control rod is introduced to the left end of the cylindrical bore **240** of the valve body **150** of the deactivating valve assembly DVA to cause a piston **241** slidable in the bore **240** to move from its non-actuated position, illustrated in FIG. **1**, to its actuated position, illustrated in FIGS. **2** and **3**, through a passage or conduit means which includes an external conduit **244**, one end of which is connected to the housing **25**, as at **245** and opens at the inner end of the bore **246** of the housing in which is disposed the valve body **150** and whose other end is connected to the housing **25** and opens to an internal annular groove **248** of the housing, an external annular groove **249** of the valve body **40**, a passage **250** of the valve body which opens to the groove **249**, a port **251** which opens to the passage, an external annular

recess **254** of the valve spool to which the port **251** opens, and ports **255** which open directly to the recesses **254** and **231** when the control rod is in the position illustrated in FIG. **2**. The ports **255** are closed by the sealing surface **256** of the control rod when the control rod is in the positions relative to the valve spool illustrated in FIGS. **1** and **3**.

When fluid pressure is transmitted to the left end of the bore **240** of the deactivating valve assembly DVA, the piston **241** is moved to the right to its activated position against the resistance of a spring **260**, one of whose ends bears against the annular surface of an external flange **261** of the piston and whose other end bears against an annular stop shoulder **264** of a cap **266** whose enlarged end portion **267** is threaded in the enlarged portion **268** of the bore of the valve body **150**. The piston flange **261** and an extension **269** of the piston are disposed in a cavity or chamber **271** of the cap **265**. The chamber **271** is in communication with the fluid return passage R2 by means of a slot **274** which opens at its outer end to the chamber and at its inner end to a port **275** of the housing which in turn opens to the housing recess **56**.

It will thus be apparent that as the piston is moved to the right from the position illustrated in FIG. **1** to the position illustrated in FIGS. **2** and **3**, any hydraulic fluid present in the chamber and displaced by the movement of the piston may flow outwardly to the fluid return passage R2 and thus to the fluid return or withdrawal line **54** of the hydraulic system of the aircraft.

When the control rod is moved to the left relative to the spool valve **39**, FIG. **3**, the external recess **231** of the control rod is placed in communication with the housing groove **248** through ports **283**, which are closed by the seal surface **284** of the control rod when the control rod is in its normal operative position relative to the valve spool illustrated in FIG **1**, the external annular recess **285** of the valve spool to which the ports **283** open, a port **286** which opens to the recess **285**, and the recess **249** of the valve body **40**.

It will thus be apparent that if the control rod is moved either to the left or to the right from its normal operating position illustrated in FIG. **1**, the pressure of the hydraulic fluid from the pressure inlet conduit **72** of the aircraft hydraulic system is transmitted to the left end of the bore **240** of the valve body **150** and moves the piston **241** from its non-actuated position illustrated in FIG. **1** to its actuated position illustrated in FIGS. **2** and **3**.

The piston **241** has an intermediate annular recess **291** between its external seal surfaces **293** and **294** which sealingly engage the internal surface of the valve body **150** defining its bore **240**. The seal surface **293** is always disposed to the left of ports **296** of the valve body which open to the external recess **148** and the seal surface **294** closes ports **297** of the valve body **150** when the piston is in its normal non-actuated position illustrated in FIG. **1**.

It will be apparent that when the piston is moved to the right to its actuated position illustrated in FIGS. **2** and **3**, fluid communication is established between opposite ends of the cylinder **14** since the ports **296** and **297** are placed in communication through the cylindrical passage provided by the external recess **291** of the piston and the internal surface of the valve body defining its bore **240**.

The extension **269** of the piston rod extends slidably through a longitudinal passage **301** of the cap **265** of the deactivating valve assembly DVA. A bolt **302** rigidly secures the housing of a normally open switch **303** in the outer end of the passage **301**. The actuator button **304** of the switch is engageable by the outer end surface **305** of the piston extension when the piston moves to the right to the position illustrated in FIGS. **2** and **3** to cause closure of the switch. The switch by means of conductors **306**, **307** and **308** connects a signal lamp **309**, which may be located on the control panel of the aircraft, in series with a source of current, such as the battery **310**, to give a visual signal or indication to the pilot of the aircraft that the particular control valve assembly CVA is inoperative, as will be explained in greater detail below.

The valve body **150** is also provided with a restricted orifice **312** which opens to an external annular recess or groove **314** of the valve body **150** which is in communication with the annular groove **64** of the housing. The restricted orifice **312** allows the hydraulic fluid displaced from the left hand end of the bore **240** of the valve body **150** as the piston **241** moves from its actuated position, illustrated in FIGS. **2** and **3**, to its non-actuated position, illustrated in FIG. **1**, to flow to the fluid return passage R1.

A dome shaped cover **311** is press fitted on the reduced portion **311a** of the cap **265** and protects the outer end of the cap and the switch. The conductors **306** and **308** are of course led out of the cover through a suitable opening of the cover **311**.

Hydraulic fluid which may leak into the chamber **26** is returned to the pressure return fluid return conduit **54** by any suitable means such as a conduit **317** connected to the housing **25** and the return conduit **54**. For the same purpose, the chamber **319** of the housing defined by a cap **320** threaded in the outer end of the housing bore in which the valve body **40** is disposed and is in communication with the pressure return duct **54** through a duct **322** connected to the housing which opens to the chamber **319** inwardly of the closure **320**.

Suitable seal means, not all of which are shown in the somewhat schematic drawings, are provided between the various operative elements of the hydraulic control device **10** at required locations. For example, O-rings may be disposed in suitable external recesses of the three valve bodies **39**, **78** and **150** for sealing between the valve bodies and the housing at opposite sides of the external recesses of the valve bodies. The lands **161** and **166** and the opposite end surfaces **330** and **331** of the valve body **39** provide a metal to metal seal with the internal surfaces of the valve spool **40** which they engage.

The sealing surfaces of the pistons **75** and **241** also provide a metal to metal seal with the valve bodies **78** and **150**, respectively.

Assuming now that the hydraulic pressure system of the aircraft is continuously supplying an incompressible hydraulic fluid under a predetermined pressure to the hydraulic fluid inlet or pressure line or conduit **72** and that the hydraulic fluid return conduit **54a** is connected to the return inlet of such hydraulic pressure system, the bypass valve assembly BV piston **75** is held in its actuated position illustrated in FIG. **1** by the force exerted by the pressure of the hydraulic fluid on the area on the left hand end surface of the piston **75** against the

resistance of the spring **76**. The hydraulic fluid in the recess **101** of the piston **75** does not tend to move the piston in either direction since it exerts equal or balanced oppositely acting forces on the facing surfaces of equal area defining opposite ends of the recess **101**. In this actuated position the piston **75** of the bypass valve assembly BV provides communication between the inlet conduit **72** and the pressure passage P. The pressure of the hydraulic fluid is communicated through the various passages, ports and annular recesses of the elements of the control valve assembly CVA as described above to the chamber **190** in which the tubular piston **171** is movable so that the pressure of the hydraulic fluid exerted on the annular piston **171** will tend to cause the annular piston **171** to move the valve spool **39** to the right with the control rod **33** as the control rod **33** is moved to the right and also to the chamber **220** in which the tubular piston **172** is movable so that the pressure of the hydraulic fluid exerted on the annular piston **172** will tend to cause the valve spool **39** to move to the left with the control rod **33** when the control rod **33** is moved to the left.

Assuming further that the control valve assembly CVA is now in proper operational condition and in the position illustrated in FIG. **1**, the pressure of the hydraulic fluid is now not communicated to the left hand end of the bore **240** of the valve body **150** of the deactivating valve assembly DVA since the ports **255** and **286** of the valve spool are now closed. The various passages of the chambers are of course filled with the hydraulic fluid. Hydraulic fluid is now present in the cylinder **14** on both sides of the piston **15** of the motor device **11** and hydraulic fluid cannot flow either into or out of the opposite ends of the cylinder since the lands **161** and **166** of the valve spool now close the ports **160** and **165**, and thus the control fluid passages C1 and C2. As a result, the piston is now held against movement in either direction in the cylinder **14**, and the controlled member **12** is held against movement by the piston, since the hydraulic fluid is of course incompressible. Each of the other motor devices **11** each of the other hydraulic control devices **10**, **10** *a* – **10***n* which control the operation of the other motor devices **11**, **11***a* – *11n* for moving the controlled member **12** have control shafts which are linked to the control shaft **28** of the control device **10** and to one another or a single common control shaft **28** operates all control devices **10**, **10***a* – *10a* so that the control rods **33** of the control valve assemblies will be operated simultaneously by the autopilot or by the pilot himself utilizing the usual autopilot override linkage.

If it is determined either by the autopilot or the pilot that the controlled member **12** should be pivoted in a clockwise manner about the axis of the shaft **19**, as the control shaft **28** is rotated in a counter-clockwise manner, the control rod is moved to the right and the force of the pressure fluid exerted on the outer end of the annular piston **171** causes the valve spool to move to the right with the control rod, as to the broken line position thereof indicated in broken lines in FIG. **2**, to place the pressure passage P in communication with the control passage C2 through the ports **165** which now open to the recess **70** of the valve spool, hydraulic fluid under pressure will now flow from the inlet conduit **72** to the right end of the cylinder **14** through the conduit **155**.

The pressure of the hydraulic fluid from the pressure inlet conduit communicated to the control fluid passage C2 and thus to the ports **297** of the valve body **150** does not tend to cause movement of the piston **241** in either direction since these ports are now open only to the circumferential seal surface **294** of the piston.

Simultaneously, such longitudinal movement of the valve spool to the right places the return fluid passage R1 in communication with the control passage C1 as the recess **53** of the valve spool moves into alignment with the ports **160**. As a result the piston will be moved to the left as hydraulic fluid flows into the right end of the cylinder **14** through the conduit **155** and flows out of the left end of the cylinder through the conduit **151**. As the control member pivots in a clockwise manner about the axis of the shaft **19** and approaches the desired position, the control shaft **28** is rotated in a clockwise direction and the control rod **33** and the valve spool **39** move back to the left to the intermediate position illustrated in FIG. **1**, the force of the fluid pressure in the chamber **220** causing the tubular piston **172** to move the valve spool with the control rod. Once the valve spool is again in the intermediate position, hydraulic fluid can neither enter into nor exit from either end of the cylinder **14** and therefore the control member **12** will be held locked in the new position.

Conversely, if it is desired that the control member **12** be moved in a counter-clockwise manner about the axis of its shaft **19**, the control shaft **28** will be rotated in a clockwise direction, as illustrated in FIG. **3**, and the control rod **33** and the valve spool **39** will move to the left, the valve spool assuming a position such as that indicated by the broken lines in FIG. **3**. As a result, the recess **52** moves into communication with the ports **165** so that the fluid from the right end of the cylinder **14** may flow through the fluid return passage R1 and the various passages described above to the exhaust conduit **54a** and simultaneously the recess **70** of the valve spool moves into the communication or alignment with the ports **160** so that fluid under pressure from the pressure passage P will flow into the left hand end of the cylinder **14**. As a result, the piston will be moved to the right in the cylinder and the control member **12** will rotate in a counter-clockwise direction about the axis of its shaft **19**. The high pressure hydraulic fluid which is now present in the recess **291** of the piston **241** will not tend to move the piston **241** in either direction since its force is exerted on equal opposite facing areas of the piston defining the opposite ends of its annular recess **291**. As the control member reaches its desired position, the control shaft **28** is again moved to position the control rod **27** and the valve spool **39** in the position illustrated in FIG. **1** and the controlled member **12** will then be locked in such position by the hydraulic fluid in the opposite ends of the cylinder **14**.

Should the valve spool **39** of the control valve assembly CVA, due to some malfunction as for example, the presence of a particles of foreign matter between the engaging surfaces of the valve spool **39** and the valve body **40** be held against longitudinal movement in the valve body with a force greater than that exerted by the fluid pressure on the outer ends of the tubular piston **171** and **172**, when the control shaft **28** is rotated in one direction or the other, the control rod will move relative to the valve spool. If, as illustrated in

FIG. 2, the control shaft is rotated in a counterclockwise direction and the valve spool cannot be moved by the force of the hydraulic fluid pressure exerted on its outer annular end surface, the control rod will move to the right relative to the valve spool, the recess **231** of the control rod will move into alignment with the ports **255** of the valve spool and the pressure hydraulic fluid will be communicated to the left end of the bore **240** of the deactivating valve assembly DVA, as explained above, and its piston **241** will be moved to its actuated position illustrated in FIG. **2**. As the piston **241** moves to its actuated position against the force exerted by the spring **260**, its extension **269** will engage the push button **304** of the switch **303** and will cause energization of the signal lamp **309** which will then indicate to the pilot that the control valve assembly **10** is inoperative and that, as will be explained below, the motor device **11** which it controls has also been rendered inoperative.

As the piston **241** moves to its actuated position, its outer recess **291** moves into communication with the ports **297**. As a result, a bypass passage between opposite ends of the cylinder **14** is established through the conduit **151**, the aligned recesses **147** and **148** of the valve body **150** and the housing **250**, respectively, the ports **296**, the cylindrical passage defined by the external recess **291** of the piston **241** and the bore **240** of the piston, the ports **297**, the aligned recesses **154** and **156** of the housing and the valve body **150**, respectively, and the conduit **155**. As a result, the piston of the motor device **11** will now be free to move in the cylinder in either longitudinal direction as the control member **12** is pivoted about the axis of the shaft **19** by the other motor devices.

Since the orifice **312** is of very relatively small dimensions, it will allow a hydraulic fluid under pressure to continuously flow therethrough at a low rate to the fluid return passage R1 but provides enough of a restriction that a pressure in the bore **240** will remain high enough value that the piston will be held in its actuated position thereby against the resistance of the spring **260** as long as the recess **231** is in communication with the ports **255**.

Should the force with which the valve spool **39** is held against movement to the right in its valve body **40** decrease below that of the force of the fluid pressure on the piston **171** the force of the fluid under pressure exerted on the tubular piston **171** will of course move it back to the right in the valve body. In that case, as the control rod recess **231** moves out of communication with the valve spool ports **255**, the left end of the bore **240** will be placed out of communication with the pressure hydraulic inlet conduit **72** and the force exerted by the spring **260** will be effective to move the piston back to its non-actuated position illustrated in FIG. **1**, the hydraulic fluid trapped to the left of the piston in the bore **240** flowing outwardly through the restricted orifice passage **312** back to the fluid return passage R1.

Conversely, as illustrated in FIG. **3**, if for one reason or another the force resisting the movement of the valve spool to the left in the valve body **40** exceeds the force exerted by the tubular piston **172** on the valve spool, as the control shaft **28** is rotated in a clockwise manner and moves the control rod **33** to the left, the valve spool will remain stationary in the valve body and the control rod recess **231** will move into communication with the ports **283**, the pressure of the hydraulic fluid from the inlet conduit **72** is communicated to the left end of the bore **240** of the valve body **150**. As explained above, the piston **241** is moved into its actuated position, the piston **15** of the motor device **11** is freed to move in either direction in the cylinder **14**, and operation of the controlled member **12** by the other motor devices **11***a*–**11***n* . . . *n* will not be hindered or impeded by the motor device **11**.

The annular recesses **231**, **254** and **285** of the valve spool **39** are of such lengths that should the valve spool be seized or held against movement relative to the valve body **40** when in either of its extreme right or left positions, indicated in broken lines in FIGS. **2** and **3** of the drawings, if the control rod is moved longitudinally relative to the valve spool while it is in such extreme right or left positions relative to the valve body, hydraulic fluid under pressure will be communicated to the left end of the bore **240** in the same manner as when the control valve spool is in its intermediate position and the piston **241** of the deactivating valve assembly will be moved to its actuated position.

If the aircraft hydraulic system is rendered inoperative so that fluid under pressure is not transmitted through the inlet conduit **72**, the force of the spring **76** will be effective to move the piston **75** of the bypass of valve assembly BV to its inoperative position, illustrated in broken lines in FIG. **1**. In this inoperative position, the seal surface **335** of the piston closes the ports **116** and opens the ports **126** as the piston recess **125** moves into communication therewith. As a result, the pressure passage P is placed out of communication with the pressure inlet conduit **72** and the control passages C1 and C2 are placed in communication with one another through the cylindrical passage provided by the annular external recess **125** of the piston **75** and the internal bore **106** of the valve body **78** and a bypass passage path for hydraulic fluid is provided between opposite ends of the cylinder **14**. The control member **12** will be free to move since the piston **16** of the motor device can now move in either direction since the hydraulic fluid being free to circulate between opposite ends of the cylinder as the piston is moved therein.

It will now be seen that a new and improved hydraulic control device **10** has been illustrated and described which is used to control the operation of a hydraulic reversible motor device, such as the motor device **11**, which operates in one direction when hydraulic fluid under pressure is transmitted to a first fluid passage thereof and allowed to exhaust from a second fluid passage thereof, operates in an opposite direction when the fluid under pressure is transmitted to its second passage and allowed to exhaust from its first passage, and is held against operation when flow of fluids to or from both passages is prevented.

It will further be seen that the control device **10** includes a control valve assembly CVA having a valve member or spool **39** movable longitudinally in a body means, such as that formed by the housing **25** and the valve body **40**, the valve member and the body means cooperating selectively to permit flow of hydraulic fluid under pressure to one of the first and second passages and permitting the exhaust from hydraulic fluid from the other of the first and second passages and per-

mitting the exhaust from hydraulic fluid from the other of the first and second passages when the valve member is in opposite extreme longitudinal positions, and preventing the flow of fluids through the passages in either direction when the valve member is in intermediate position relative to the body means.

It will further be seen that the valve member is movable in the body means by a control means, such as the control rod **33** and the tubular pistons **171** and **172** which are operatively associated with the valve member, the tubular piston exerting oppositely directed forces on the valve member whose values are predetermined by the pressure of the hydraulic fluid and the areas of the surfaces of the tubular pistons exposed to the fluid pressure, on the valve member tending to cause the valve member to move with the control rod.

It will further be seen that the control device **10** includes a deactivating valve assembly DVA, actuated upon the occurence of relative movement between the control rod and the valve member, which occurs when the longitudinal movement of the valve member is resisted by a force greater than the forces exerted thereon by either of the tubular pistons, for providing a bypass fluid passage or path for hydraulic fluid between the two passages of the motor device.

It will further be seen that a new and improved apparatus for operating a control member, such as an aileron **12**, spoiler or the like, of an aircraft has been illustrated and described which has a plurality of simultaneously operable motor devices, such as the motor devices **11**, **11***a* . . . **11***n* whose operation is individually controlled by separate control devices **10**, **10***a* . . . **10***n*, respectively, and that each control device has means for de-activating the motor device **11** controlled thereby in the event of malfunction of the control device so that the operation of the control member **12** by the other motor devices, whose control devices **10** are still functioning properly, will not be impeded or hindered by the motor devie whose control device is inoperable or has malfunctioned.

The foregoing description of the invention is explanatory only, and changes in the details of the construction illustrated may be made by those skilled in the art, within the scope of the appended claims, without departing from the spirit of the invention.

What is claimed and desired to be secured by Letters Patent is:

1. A control device for controlling operation of a hydraulic motor device having first and second passage means and operating in one direction when fluid under pressure is allowed to flow to one of the passage means and exhaust from the other and operating in an opposite direction to said one direction when fluid under pressure is allowed to flow to said other passage means and exhaust from said one of the passage means, and being prevented from operating in either direction when fluid flow through both passage means is prevented, said control device including: body means having inlet means connectible to a source of fluid under pressure and fluid outlet means; a control valve assembly for selectively transmitting fluid under pressure from said inlet means to one of said flow passages of a hydraulic motor device permitting flow of fluid from the motor device from its other flow passage means to said outlet means, and preventing flow through both of said flow passage means, and a deactivating valve assembly operatively associated with said control valve assembly and said motor device responsive to the malfunction of said control valve assembly for providing a bypass flow passage between said passage means of the motor device upon malfunction of the control valve assembly, said body means having first and second passages in communication with said first and second flow passage means of said motor device, and a valve member movable in said body means for selectively placing said first and second flow passages in communication with said inlet and outlet means and preventing fluid flow between said first and second flow passages; said control valve assembly including a control member operatively associated with and movable relative to said valve member, and piston means operatively associated with said control member and said valve member and biased by hydraulic pressure from said inlet means for exerting a force on said valve member tending to cause said valve member to move with said control member, said control member and said valve member having passage means communicating said inlet means with said deactivating valve assembly upon movement of said control member relative to said valve member to actuate said deactivating valve assembly when the movement of said valve member is resisted by a force greater than the force exerted thereon by said piston means.

2. The control device of claim **1**, wherein said valve member comprises a tubular valve spool having a central longitudinal bore therein and said control member includes a rod longitudinally slidable in said bore of said valve spool, said piston means comprising a pair of longitudinally spaced tubular pistons, said pistons and said valve spool and said control member having co-engageable means limiting longitudinal movement of said piston means relative to said control member and said valve spool.

3. The control device of claim **2**, wherein said co-engageable means permit limited longitudinal movement of said pistons relative to said valve spool and said rod.

4. The control device of claim **3**, and means responsive to the actuation of said deactivating valve assembly for providing a signal at a location remote from said control device.

5. The control device of claim **1**, and means responsive to the actuation of said deactivating valve assembly for providing a signal at a location remote from said control device.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,683,749 **Dated** August 15, 1972

Inventor(s) Fred R. Bayles

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Abstract, line 8 [Pg. 1, ln. 9] after "such" insert --as--.
Column 1, line 6 [Pg. 1, ln. 24] "os" should be --is--.
Column 3, line 42 [Pg. 5, ln. 7] "17" should be --27--.
Column 7, line 6 [Pg. 11, ln. 14] "or" should be --on--.
Column 8, line 57 [Pg. 14, ln. 20] "position" should be --positions-
Column 11, line 49 [Pg. 19, ln. 28] "10a-10a" should be --10a-10n--.
Column 12, line 66 [Pg. 22, ln. 5] "piston" should be --pistons--.
Column 14, line 28 [Pg. 24, ln. 25] after "bypass" delete "of".

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(5/69)

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,683,749 **Dated** August 15, 1972

Inventor(s) Fred R. Bayles - 2 -

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 4, line 25 [Pg. 6, ln. 18] "rt" should be --56--;
line 53 [Pg. 7, ln. 10] "34a" should be --83--.
Column 6, line 21 [Pg. 10, ln. 1] "164" should be --166--;
line 25 [Pg. 10, ln. 5] "FIGURE 4" should be --FIGURE 2--
line 30 [Pg. 10, ln. 9] "54" should be --54a--;
line 48 [Pg. 10, ln. 25] "54" should be --54a--.
Column 7, line 17 [Pg. 11, ln. 22] after "O-ring" delete "185 and".
Column 9, line 14 [Pg. 15, ln. 9] "266" should be --265--.
Column 10, line 35 [Pg. 17, ln. 21] "54" should be --54a--;
line 36 [Pg. 17, ln. 23] "54" should be --54a--;
line 41 [Pg. 17, ln. 26] "54" should be --54a--.
Column 12, line 53 [Pg. 21, ln. 27] "27" should be --33--.
Column 13, line 26 [Pg. 22, ln. 28] "250" should be --25--.
Column 14, line 43 [Pg. 25, ln. 5] "16" should be --15--.

Signed and sealed this 23rd day of January 1973.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents