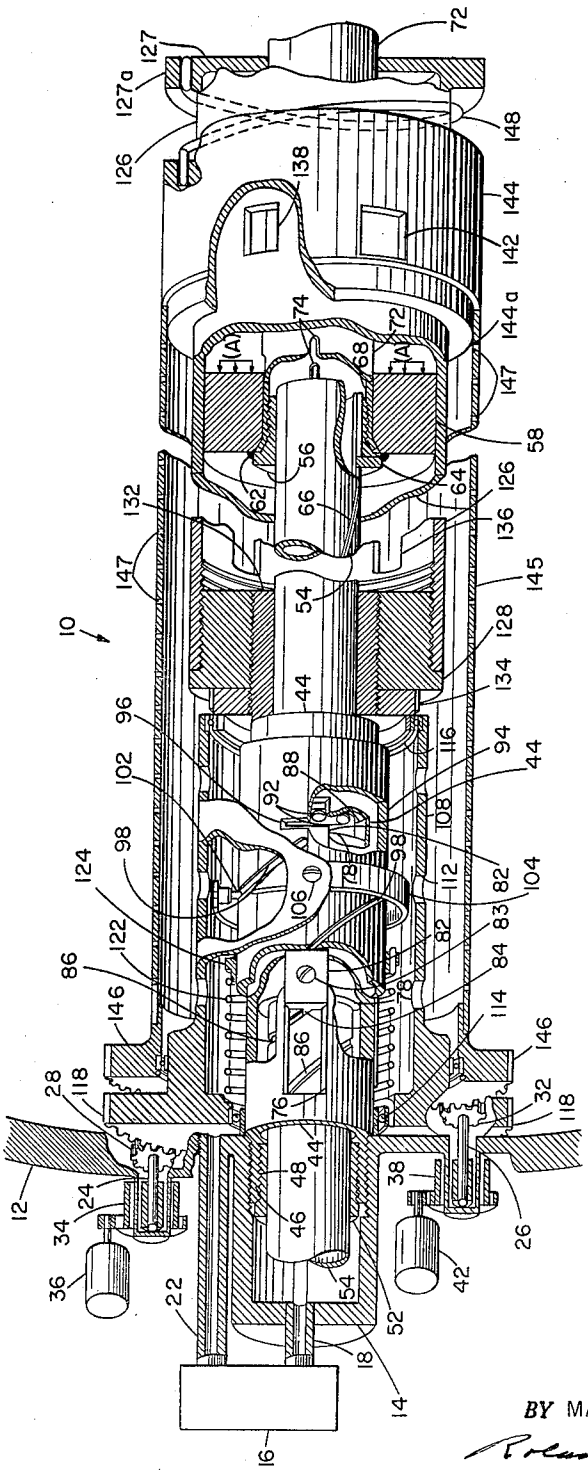
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HYDRAULIC SERVO CONTROL MECHANISM

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INVENTOR.

RUSSELL B. HUSSEY

BY MARCUS J. GOTTSCHE, JR.

Roland A. Anderson

Attorney

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HYDRAULIC SERVO CONTROL MECHANISM

Russell B. Hussey, East Longmeadow, and Marcus J. Gottsche, Jr., Hampden, Mass., assignors to the United States of America as represented by the United States Atomic Energy Commission

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The present invention relates to a hydraulic servo control mechanism of compact construction and reduced fluid requirements.

Devices used for the drive and control of control rods in nuclear reactors have typically combined mechanical and hydraulic arrangements in which a compromise is made between compactness and reliability, as well as other advantages generally associated with each of these two general types of systems. Hydraulic drive and control systems are ordinarily preferred where extremely heavy loads exist and where there are severe space limitations. However, hydraulic systems heretofore available do not have the reliability as well as the ease of maintenance usually associated with mechanical configurations.

The present invention has to do with a hydraulic drive and control mechanism suitable for use with nuclear reactor control rods and other applications capable of obtaining benefits of heavy load capability, compactness and trouble-free operation which up to now was not thought to be possible in hydraulic systems. In accordance with this invention, a main hydraulic piston comprising the drive output is connected for feedback purposes to move a servo piston through a so-called readout rod which is connected by key and helical groove arrangement to both of the servo and main pistons. A control sleeve containing the control slots for the system encloses the servo piston while a key engaged with the servo piston as part of the mechanical feedback acts to cover or uncover the control slots to provide the means by which the system is controlled. This arrangement permits a highly compact system which eliminates jamming and improves control over the whole system as well as other advantages as will hereinafter be made evident.

It is, therefore, a first object of this invention to provide a hydraulic arrangement for the drive and control of control rods in a nuclear reactor.

Another object of this invention is the provision of a hydraulic servo control mechanism utilizing mechanical feedback between the main and servo control pistons incorporating a unique fluid pressure control.

Another object is the provision of a simplified, compact hydraulic servo control mechanism having high load capability for controlling the movements of the main drive piston.

Still another object of this invention is the provision of a fail-safe hydraulic servo control mechanism which minimizes the possibilities of binding and whose performance will not deteriorate due to mechanical wear.

Other objects and advantages of this invention will hereinafter become more apparent from a reading of the following description of a preferred embodiment of this invention which is illustrated in the accompanying drawing showing an isometric view partially cut away and schematized.

Illustrated in the FIGURE is a portion of a pressure vessel **12** which may be part of a nuclear reactor whose control rods are to be driven and controlled by the hydraulic drive mechanism **10** of this invention. Of course, mechanism **10** may be used in other applications where it would be suitable. It should be pointed out at this point that the hydraulic mechanism **10** illustrated in the figure is oriented with the top at the left extending to the right,

or downwardly. Hence, in its customary and expected utilization, the unit would be vertically mounted, the axis from left to right in the drawing extending from top to bottom.

Extending up from the top of pressure vessel **12** is a cylindrical pressure vessel head **14** which is closed off at the top as shown. A so-called closed loop system **16** for providing system pressure is provided. System **16** provides hydraulic fluid under desired pressure through a tube **18** into pressure vessel head **14**. Suction or return of fluid from the interior of pressure vessel **12** is provided through a conduit **22** extending from vessel **12** to system **16**. Closed loop system **16** is a conventional arrangement for providing fluid pressure and would generally include a pump, means to drive the pump and quite often a reservoir for storing the fluid and controlling the fluid pressure. The fluid used here may be any suitable hydraulic fluid, and in the case of a reactor, the coolant within the reactor itself is quite often suitable for this purpose.

Also extending up from the top of vessel **12** into pressure vessel **12** are a pair of drive shafts **24** and **26** connected to pinion or drive gears **28** and **32**, respectively. Drive shaft **24** is driven through a magnetic coupling arrangement **34** by a piston control motor **36** while drive shaft **26** is similarly driven through a magnetic coupling arrangement **38** by a scram motor **42**, for a purpose to be later described. Clutches not illustrated may also be provided in these driving arrangements. While the transmission arrangements, generally designated as **34** and **38**, may be conventional in nature if suitable for the particular application, they are illustrated as magnetic couplings to avoid openings in the reactor containment. The purpose of these drive arrangements is for the control of mechanism **10**. Their specific connection and mode of operation will be described further below.

Within vessel **12** is a cylindrical main support member **44** having an extension threadably engaged into pressure vessel head **14** as illustrated. Extension **46** is also provided with internal threads **48** for engagement with a bearing **52** which supports rotatably one end of a hollow so-called readout rod **54**. The other end of readout rod **54** is supported slidably in a bearing **56**. The latter is supported by the main power piston **58** which is rigidly connected as indicated by ring weld **62** to bearing **56**. A key **64** mounted through bearing **56** is located to engage with a drive helical slot **66** along the outer surface of readout rod **54**. By this arrangement, movement of power piston **58** along the axis of readout rod **54** will cause readout rod **54** to rotate. Therefore, the rotational position of rod **54** will indicate the axial position of power piston **58** in mechanism **10**. It should be noted briefly here that power piston **58** is connected by way of a ring extension **68** to a hollow piston rod **72** which extends downwardly therefrom and is connected ultimately to the load or control rod (not shown). Piston rod **72** is provided with two pairs of oppositely facing slots **74** for a purpose to be later described.

At this point it will be seen that fluid pressure delivered from system **16** through tube **18** into the interior of pressure vessel head **14** enters an end opening (not shown) in readout tube **54**, travels the length of this tube, and exits to within piston tube **72**. The fluid under pressure leaves the interior of piston rod **72** through slots **74** and pressurizes one side of power piston **58** as indicated by arrows A.

Stationary main support member **44** contains a pair of oppositely facing, vertically elongated slots **76**, only one shown. In the annular space formed between support member **44** and readout rod **54** is located the servo piston **78** which has attached to it on opposite sides a pair of large servo piston keys **82** only one of which is illustrated.

One or mores crews **83** may be used to attach keys **82** to the outer surface of servo piston **78**. Each servo piston key **82** is rectangularly shaped to slide within a vertical slot **76** as illustrated. Each servo piston key **82** is provided with a key follower **84** to slide within a helical keyway **86** formed in the outer surface of readout rod **54**. It will be seen that rotation of readout rod **54** will cause servo piston **78** to slide axially as a result of this arrangement.

Main support member **44** is provided with an expanded internal section **88** below and spaced from servo piston **78**. A plurality of small holes **92** through the wall of rod **54** are provided in the annular space between piston **78** and section **88** to provide access for hydraulic fluid so as to pressurize the annular space directly below servo piston **78**. The hydraulic fluid under system pressure will tend to move servo piston **78** to the left, or upward, in the same direction that system pressure tends to move main piston **58** as indicated by arrows A.

Surrounding stationary main support member **44** is a cylindrical control sleeve **94** which is keyed to member **44** (by means not illustrated) to permit axial movement only with respect to member **44**. Control sleeve **94** is provided with a pair of two oppositely facing control slots **96**, only one of which can be seen. Each of slots **96** is in alignment with a vertical slot **76** so that the lower end of key **82** partially covers a control slot **96** for a reason to be later explained. Control sleeve **94** is also provided with a pair of helical keyways **98** along the outer surface thereof for engagement with a pair of keys **102** mounted on the inside of a gimbal drive ring **104**. Gimbal drive ring **104** is pivoted by a pair of pins **106**, one of which can be seen, to a control sleeve drive gear tube **108**. Tube **108** is cylindrical in shape and is provided with a plurality of openings or holes **112** to avoid interfering with fluid flow therein. Tube **108** is supported at each end by a pair of roller bearings **114** and **116**, respectively. The upper end of control sleeve drive gear tube **108** terminates in a control sleeve drive gear **118** which engages with drive pinion **28**, previously identified. Hence, the connection between pinion **28** and control sleeve drive gear **118** makes it possible to position selectively control sleeve **94** axially and hence the position of control slot **96** with respect to the lower edge of servo piston key **82**. By positioning control slot **96** relative to the end of key **82**, it is possible to control the flow of fluid through control slots **96** and, as will be seen later, ultimately position the control rod or load which is connected to the bottom of piston **72**. An anti-backlash spring **122** is provided between drive gear **118** and the control sleeve **94** which has a stop **124** for this purpose. Spring **122** also returns control sleeve **94** to rod bottom position during a scram which is accomplished by a separate control arrangement as will be described below.

Surrounding main piston **58** is a cylinder **126** in which main power piston **58** slides. Cylinder **126** is threadably engaged at one end to a ring **128** which is provided with an internally threaded bearing member **132** for supporting readout rod **54** as illustrated. The other end of cylinder **126** terminates in a closed wall **127** having a flanged portion **127***a*, for a purpose to be later described. Returning to the other end of cylinder **126**, an adjustment and locking nut **134** is provided over bearing **132** immediately adjacent ring **128** to support bearing **116** previously described, and also to adjust and lock cylinder **126** in place. Cylinder **126** is provided with a plurality of displacement slots **136** above power piston **58** to insure that the upper side of piston **58** is not pressurized with fluid and to prevent the entrapment of fluid therein. Cylinder **126** is provided, below power piston **58**, with a plurality of scram openings **138** which are offset from scram sleeve dump ports **142** located in a scram sleeve **144** which encloses cylinder **126**. Openings **138** in cylinder **126** and ports **142** in sleeve **144** have the same vertical position, but they are staggered rotationally to prevent the loss of fluid pressure below power piston **58**. Scram sleeve **144** is cylindrical in shape and is connected through a tube **145** to a scram sleeve drive gear **146** which is engaged to pinion **32** which was previously described. Tube **145** is pierced with a plurality of holes **147**, to prevent entrapment of fluid, and fits over an expanded section or shoulder **144***a* of sleeve **144**.

A scram torsion spring **148** connecting scram sleeve **144** and flange **127***a* is provided to rotate scram sleeve **144** to a position where ports **130** and **142** interconnect to dump high pressure fluid.

For normal operation, scram motor **42** is energized to overcome spring **148** and rotate scram sleeve **144** to a position, where ports **138** and **142** are staggered, and thereafter hold this position. When it is desired to scram the control mechanism **10**, a clutch (not shown) will be actuated to disengage the transmission arrangement **38** and allow scram spring **148** to rotate scram sleeve **144** to a position where scram sleeve ports **142** are aligned with openings **138** in cylinder **126** thereby relieving pressure from below power piston **58** and permitting the control rods, or other load, to drop under the force of gravity.

In the control operation of the apparatus just described, pressurized fluid is delivered from closed loop system **16** through conduit **18** into the interior of pressure vessel head **14** as previously described. The pressurized fluid flows through hollow readout rod **54** into piston rod **72** and out through rod slots **74** to apply pressure to power piston **58** as indicated by arrows A. Some of the pressurized fluid is forced out through openings **92** in readout rod **54** to direct a vertical upward force against servo piston **78**, also in the direction of arrows A. Servo piston **78** is coupled through readout rod **54** to main piston **58** by means of helical keyways **66** and **86** as previously described. All backlash is removed by the continous hydraulic force which urges piston **78** in a vertical upward direction. The mechanical linkage between main piston **58** and servo piston **78** including readout rod **54** acts as a restraining stop on servo piston **78** during upward movement of main piston **58**. Thus, readout rod **54** becomes torsionally loaded, and in the particular embodiment illustrated, this is approximately 90 in.-lbs. Helical keyways **86** and **66** are designed with sufficient clearance to eliminate completely any possibility of jamming, as in understood in the art. Hence, movement of main piston **58** in response to fluid pressure, upwardly for example, results in like movement of servo piston **78**. The ratio of motion between main piston **58** and servo piston **78** is approximately thirty-eight to one in the particular configuration illustrated so that a three inch motion of the servo piston **78** represents the full stroke of main piston **58**.

In order to control the movement and location of the control rod or other load (not illustrated) connected to piston rod **72**, motor **36** would be energized to turn pinion **28** and rotate the control sleeve drive gear **118** to move gimbal drive ring **104** and hence control sleeve **94** axially. With the control sleeve **94** moved axially to rod or load bottom, extreme right, position leakage control slots **96** will be fully opened and excessive leakage through these slots will result in insufficient system pressure to actuate main piston **58**. Axial upward movement of control sleeve **94** in response to rotation of piston control motor **36** will reduce the leakage area of control slots **96** as control sleeve **94** moves upwardly to cause servo piston key **82** to close off a portion of control slots **96**. This will result in an increased system pressure sufficient to move main piston **58** upward. If at some particular point, upward motion of control sleeve **94** is stopped by halting the rotation of motor **36**, motion of main piston **58** and that of coupled servo piston **78** will continue until the change in control slot area and leakage causes reduction of system pressure to a "holding" value. In a similar fashion, downward movement of control sleeve **94** will increase the leakage area of control slots **96** which will

result in a decrease in system pressure sufficient to cause downward movement in main piston **58**.

When downward motion of control sleeve **94** is stopped, main piston **58** and the coupled servo piston **78** motions will continue until the change in control slot area and leakage cause an increase in system pressure to a "holding" value. During downward motion of main piston **58** the mechanical linkage between main piston **58** and servo piston **78** applies a force on the latter to overcome the hydraulic force and thereby moves servo piston **78** downward.

By this arrangement, avoiding shaft seals altogether and without backlash, it is seen that simple, effective and close control is exercised over the control rod or other load connected to piston rod **72**.

Readout rod **54**, whose rotational position is indicative of the axial location of piston rod **72**, may be terminated within pressure vessel head **14** in any convenient fashion, provided, there are openings for the hydraulic fluid. A magnetic coupling (not shown) may be utilized to detect the orientation of readout rod **54** and hence the location of piston rod **72**. It should be noted that mechanism **10** may be oriented in other than a vertical position for the movement of piston rod **72** provided that other than gravitational means are used to insure proper movement of the load when system pressure drops. While not illustrated, a snubbing arrangement may conveniently be incorporated into piston rod **72** and cylinder **126**. Also, a gimbal driving means similar to the gimbal drive for control sleeve **94** except for size may be used between readout rod **54** and the servo piston keys **82**. It may be fitted into the annular opening above servo piston **78**. Another gimbal drive between main piston **58** and readout rod **54** for which a second helical keyway must be provided on readout rod **54** may also be incorporated. The mechanism is fail-safe and non-jamming and yet is compact. Being substantially all hydraulic there will be no performance deterioration due to mechanical wear.

It is thus seen that there has been provided a unique and almost completely hydraulic arrangement for obtaining the control and drive of a control rod or other load.

While only a preferred embodiment of this invention has been illustrated and described, it is understood that within the principles of this invention many variations may be made without departing from the scope thereof as set forth in the appended claims.

What is claimed is:

1. A hydraulic servo control mechanism comprising, in combination, a source of fluid pressure, main piston means slidable in axial directions, servo piston means spaced from said main piston means also slidable in axial directions, said servo and main piston means each exposed on one side to said fluid under pressure for being urged in one direction, means transferring a biasing force to said main piston means to urge the latter in a direction opposite to that urged by said fluid under pressure, mechanical means interconnecting said main and servo piston means (1) to restrain the latter to move simultaneously with the movement of the former in response to an excess of fluid pressure over said biasing force and (2) to drive said servo piston means back in response to movement of said main piston means when said biasing force exceeds fluid pressure on the latter, control means movable with respect to said servo piston means, control slots formed in said control means to discharge fluid acting on said servo and main piston means thereby effecting a decrease in fluid pressure, means attached to said servo piston means for adjustably blocking fluid flow through said control slots as a result of relative movement of said control means and servo piston means, and means for selectively adjusting the position of said control means to alter flow through said control slots and hence to change fluid pressure on said servo and main piston means to cause a change in force acting on said main piston means as a result of change in fluid pressure acting thereon.

2. The hydraulic servo control mechanism of claim 1 in which fluid pressure acting on said main and servo piston means urges said servo piston in the direction of uncovering said control slots thereby causing a decrease in fluid pressure and consequent lessened force acting on said servo and main piston means.

3. The hydraulic servo control mechanism of claim 2 in which means are provided to bias said control means in a direction tending to unblock said control slots thereby eliminating backlash between said servo and main piston means.

4. The hydraulic servo control mechanism of claim 3 in which said mechanical means includes a hollow rod extending through said servo and main piston means, said fluid under pressure being delivered to said servo and main piston means through said hollow rod.

5. The hydraulic servo control mechanism of claim 3 in which said mechanical means consists of a hollow rod extending through said servo and main piston means, the mechanical connection between each of said servo and main piston means and said hollow rod being formed by helical keyways on the outer surface of said rod and follower keys attached to both said servo and main piston means for converting slidable movement of said main piston means to rotary movement of said rod and converting rotary movement of said rod to slidable movement of said servo piston means.

6. The hydraulic servo control mechanism of claim 1 in which means are provided to override the operation of the control arrangement and dump all fluid within said mechanism and thereby bring said main piston means into unopposed movement in a direction opposite to that urged by said fluid under pressure.

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