Nov. 2, 1965 F. LISSAU 3,215,045

HYDRAULIC POSITIONING SERVO SYSTEM

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Fig. 1.

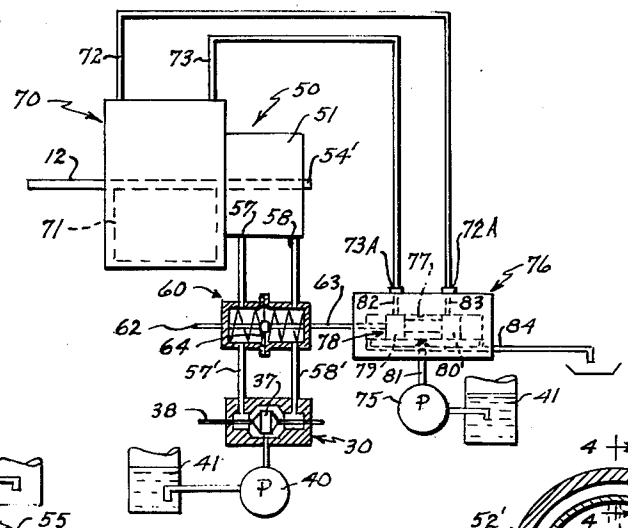


Fig. 2.

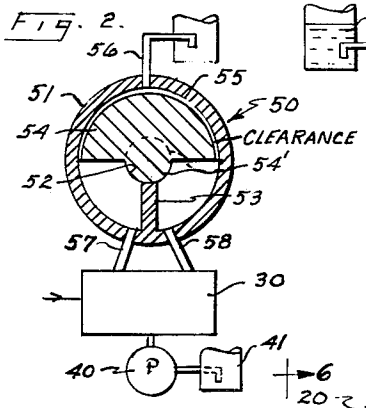


Fig. 4.

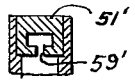


Fig. 3.

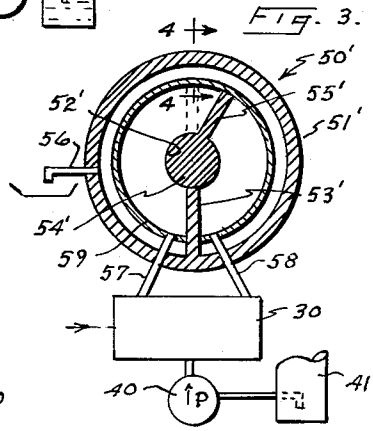


Fig. 5.

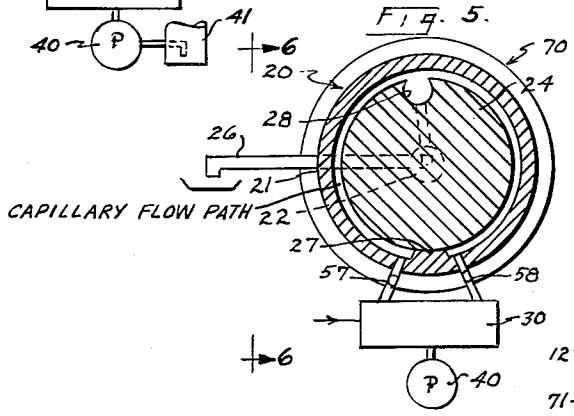


Fig. 6.

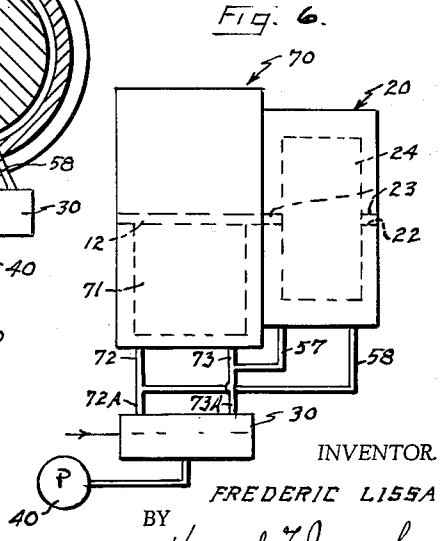
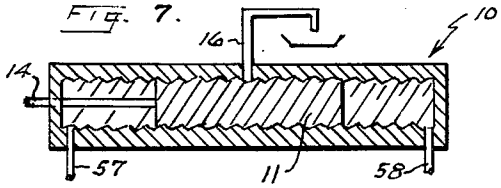


Fig. 7.



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FIG. 8.

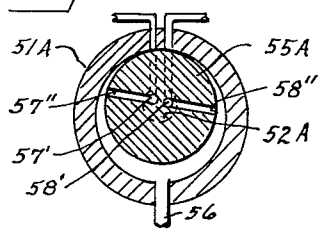


FIG. 9.

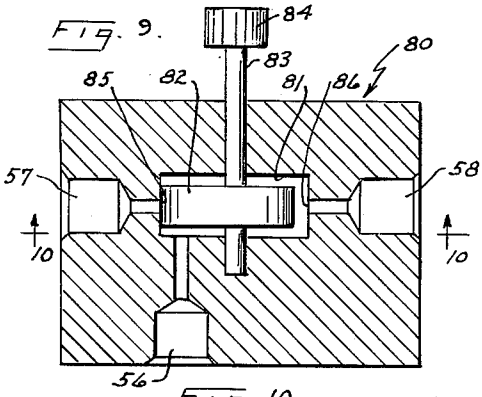


FIG. 11.

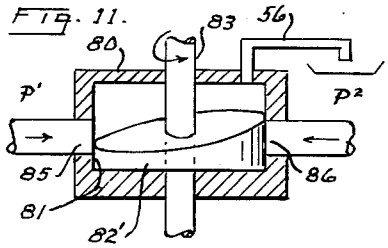


FIG. 10.

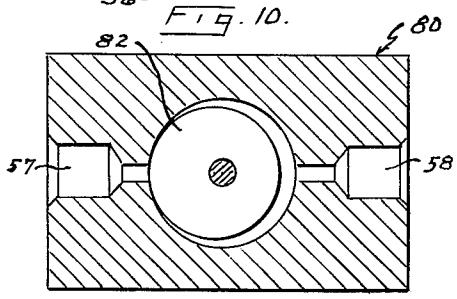


FIG. 13.

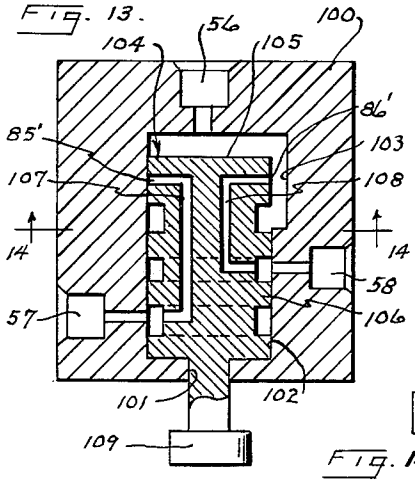


FIG. 12.

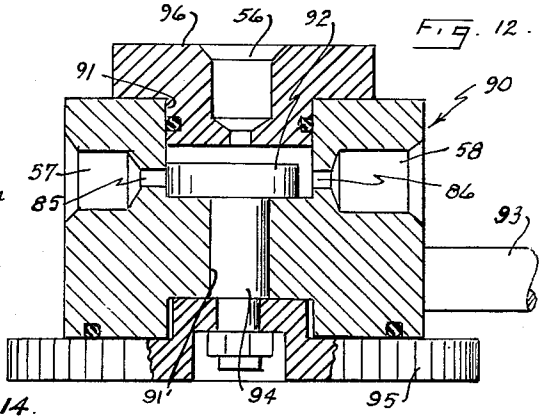
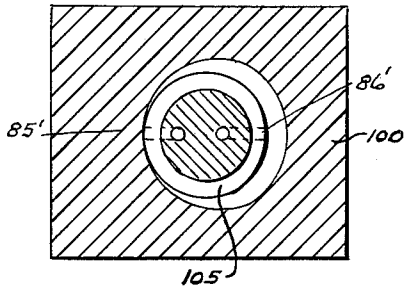


FIG. 14.



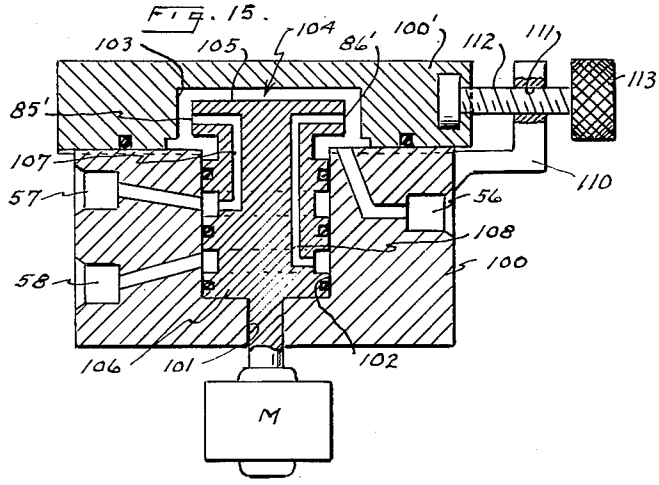
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FIG. 15.



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HYDRAULIC POSITIONING SERVO SYSTEM

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Filed Oct. 15, 1962, Ser. No. 230,642
10 Claims. (Cl. 91—388)

This is an continuation-in-part of my previous Patent No. 3,058,450 and application Serial No. 212,069 filed July 24, 1962, for Hydraulic Positioning Servo System.

The prior applications disclose, illustrate and define a servo system in which a hydristor is used. The hydristor is a mechanical assembly such as a hydraulic cylinder with two linear resistances mounted therein, two fluid inlet pressure ports and a fluid return port. The linear resistances are fitted within the cylinder with enough clearance to allow a linear flow. The linear resistances are displaced as a function of output position. There are two complementary resistances created, R1 and R2. The hydristor in the first application is a hydraulic cylinder with a linear piston therein whereas in the second application the hydristor is a hydraulic chamber having a metering element to form two resistances. The metering pin is movable laterally in either direction to change the ratio of these resistances in relation to its position. Thus when the metering pin is moved in either direction to change ratio of resistances in a complementary manner, it will increase one resistance while decreasing the other when moved in one direction and vice versa when moved in the other direction. In the first application, the hydristor is in the form of a hydraulic cylinder which is necessarily longer than the power cylinder to which it is connected and in the second application the hydristor is a cylinder, reservoir or a valve in which a metering pin is mounted and the cylinder reservoir or metering pin may be of the same length as the power cylinder. In the first application the hydraulic flow is a capillary flow over the surface of the piston whereas in the second application there is an orifice type of flow (mostly turbulent flow). The hydraulic cylinder in which the metering pin is mounted is only cylindrical in form because it contains and coacts with the metering pin and the stroke of the metering pin. Whereas in reality, the cylinder can take any shape as it is simply a reservoir for the return flow of the hydraulic fluid passing through the two variable orifices. The hydristor is in fact a valve which may take other shapes. In this invention the hydristor is rotary in form and may provide a piston and cylinder having a capillary flow over the surface of the piston or it may retain a rotary form with a metering pin. The rotary form cylinder is simply a reservoir and the metering pin has a stroke that controls two variable orifices to provide an orifice type or turbulent flow.

It is an object of this invention to provide a hydraulic servo system in which there is provided a rotary hydristor with a metering pin therein, and in which a fluid pump is connected through a ratio flow divider to the two complementary resistances in the rotary hydristor in a position seeking servo system.

A still further object of this invention is to provide a hydraulic servo system in which there is provided a rotary hydristor with a metering pin therein, and in which a fluid supply is connected through a ratio flow divider and the ratio flow divider in turn to a sensing null unit and in turn to two variable orifices in said rotary hydristor, and in which said metering pin is in turn connected to a power cylinder that is either in alignment, concentric, or in parallel relation or is connected by a mechanical means to the said power cylinder, and a second fluid supply is connected through an amplifier valve to opposite ends of said power cylinder, and said amplifier valve controlled in its movement by the sensing element of the null unit.

A still further object of this invention is to provide a hydraulic servo system in which there is provided a hydraulic rotary hydristor with a rotary metering pin therein and within the hydristor there is provided means to produce two complementary flows, and in which a fluid supply is connected through a ratio flow divider to the means to produce the two complementary flows.

A still further object of this invention is to provide a hydraulic servo system in which there is provided a reservoir or valve with a rotary metering element therein and in which a fluid supply is connected through a ratio flow divider and the ratio flow divider in turn to a sensing null unit and in turn to two variable orifices in said reservoir and in which said metering pin is in turn connected to a piston in a power cylinder that is mechanically linked with said metering pin and a second fluid supply is connected through an amplifier valve to opposite ends of said power cylinder and said amplifier valve is controlled in its movement by the sensing element of the null unit.

It is a still further object of this invention to provide a hydraulic servo system, in which there is provided a circular hydristor with a position seeking rotor therein, and in which a fluid pump is connected through a ratio flow divider to opposite sides of said rotor in said hydristor.

A still further object of this invention is to provide a hydraulic servo system, in which there is provided a circular hydristor with a non-position seeking rotor therein, and in which a fluid pump is connected through a ratio flow divider to opposite sides of said rotor in said hydristor and in which a power cylinder is mechanically linked to the rotor of said hydristor and said power cylinder is hydraulically connected to the signal input valve.

It is a further object of this invention to provide a hydraulic fluid servo system in which there is provided a fluid flow divider and in which a hydristor with a rotary positioned piston therein is connected from either side of said hydristor to either end of said flow divider and in which a fluid pump is connected to a central inlet on said hydristor to produce a capillary flow over said piston to either end of said hydristor and in turn to either side of said flow divider and to be discharged from the single outlet of said flow divider.

Other objects of this invention shall be apparent by reference to the accompanying detailed description and the drawings in which

FIG. 1 is a schematic of a servo system with a rotary hydristor,

FIG. 2 is a schematic partially in cross section of a simplified rotary position seeking hydristor system,

FIG. 3 is a cross sectional view of a further embodiment of FIG. 2,

FIG. 4 is a cross sectional view taken on line 4—4 of FIG. 3,

FIG. 5 is a cross sectional view of a further embodiment of a non-position seeking hydristor used in a simplified position seeking system,

FIG. 6 is an elevational view taken on line 6—6 of FIG. 5,

FIG. 7 is a cross sectional view of a further embodiment of a non-position seeking hydristor,

FIG. 8 is a cross sectional view of a further embodiment of a further non-position seeking hydristor,

FIG. 9 is a cross sectional view of an eccentric mounted non-position seeking hydristor,

FIG. 10 is a cross sectional view taken on line 10—10 of FIG. 9.

FIG. 11 is a cross sectional view of a further embodiment of FIGS. 9 and 10,

FIG. 12 is a still further embodiment of FIGS. 9 and 10,

FIG. 13 is a still further embodiment of FIGS. 9 and 10,

FIG. 14 is a cross sectional view of a still further embodiment taken on line **14—14** of FIG. 13, and

FIG. 15 is a cross sectional view showing a further embodiment of FIG. 13.

Referring to FIG. 1 there is shown a servo system as applied to power control of position and this system is load compensated whereas FIGS. 2, 3, 5 and 6 show a simplified system used for relatively lower power application. The hydristors shown herein are of two types, position seeking and non-position seeking. A non-position seeking hydristor as shown in FIGS. 5–15 when coupled with an actuator as shown in FIG. 6 will provide a simplified position seeking system. A position seeking hydristor as shown in FIGS. 2 and 3 will provide a simplified system. Either a position seeking or non-position seeking hydristor may be utilized as shown in FIG. 1.

Referring to FIG. 2 there is illustrated a rotary position seeking hydristor **50**. The hydraulic cylinder or circular housing **51** is closed at either end thereof with a circular aperture **52** at either end. A stationary partition **53** is provided that is affixed to body **51** and bears against the edge of a rotor **54**. Rotor **54** is pivotally mounted in the circular apertures **52** at either end of body **51** and extends through these apertures to provide a rotary piston rod or drive shaft **54'** on either side of the body **51**. Rotor **54** is also provided with a semi-circular body **55** of a diameter slightly less than the internal diameter of body or housing **51**. The clearance between the outer periphery of this body and the inner periphery of body or housing **51** provides the necessary clearance or space for the capillary flow of fluid from the area on either side of the partition **53** to an outlet port **56**. A pair of inlet ports **57** and **58** are provided adjacent either side of partition **53**. This rotary cylinder as described shall be referred to hereinafter as the hydristor, hydristor being a coined word may be defined as applied to a capillary flow or as applied to an orifice flow. As applied to a capillary flow the hydristor is a mechanical assembly such as a rotary cylinder with a rotor piston mounted therein, a fluid inlet port at each side of the rotary piston and a fluid return port. The rotary piston is fitted within the cylinder with enough clearance to allow a capillary flow or leakage past the piston. The piston is displaced as a function of output position. There are two complementary resistances created **R1** and **R2**. As applied to an orifice flow the hydristor is a mechanical assembly such as a rotary cylinder or valve with a metering pin mounted therein to form two complementary resistances, two fluid inlet orifices and a fluid return port. The metering pin may be provided with slots, grooves, conical surfaces or flats to allow a flow from the orifices to flow past the metering pin. The metering pin is displaced as a function of output position either direct or through intermediate mechanical means. There are two complementary resistances created, **R1** and **R2**; their ratio $R1/R2$ is therefore a function of output position. Each of the resistances is connected in series, that is, through the legs or pipes to opposite ends of a ratio flow divider with similar resistances $r1$ and $r2$, which are created in the same order in the ratio flow divider as a function of input position, so that the pressure $p1$ and $p2$ in the legs or pipe connections equal each other if $R1/R2=r1/r2$. Thus, it is the purpose of the hydristor to utilize the pressure differential $p1$ and $p2$ as a remote input signal or error signal. Since the pressures $p1$ and $p2$ are created by the input setting of $r1/r2$, it would be equally correct to state that the ratio $r1/r2$ is used as the input signal, and the pressure differential $p1$ and $p2$. The theory of operation relating to the hydraulic resistances may be summed up in the following:

A hydraulic resistance could be defined as follows:

R ---------- Hydraulic resistance.
P ---------- Pressure differential.
Q ---------- Flow in gallons per minute.

d=Diameter of orifice
A=Area of orifice

(1) $$R=\sqrt{\frac{\Delta P}{Q}}$$ Definition

Flow through an orifice is

(2) $$Q=K_1 d^2\sqrt{\Delta P}$$

Whereby K_1 is a constant containing specific gravity and orifice coefficient

(3) $$R=\frac{\sqrt{\Delta P}}{K_1 d^2\sqrt{\Delta K}}=\frac{1}{K_1 d^2}$$

$$\text{if } \frac{1}{K_1}=K$$

(4) $$R=\frac{K}{d^2}=\frac{\frac{K}{4}}{A}$$

The hydraulic resistance is inversely proportional to the second power of the orifice diameter or to the first power of the orifice area.

A ratio of 2 resistances

$$\frac{R_1}{R_2}$$

would equal

(5) $$\frac{R_1}{R_2}=\frac{\frac{K}{d_1^2}}{\frac{K}{d_2^2}}=\frac{d_2^2}{d_1^2}=\frac{A_2}{A_1}$$

that is a ratio of resistances that is independent of K, which contains specific gravity and orifice coefficient. It is this resistance ratio which is being compared in the hydristor circuit. It is apparent that as the pressure drop across one orifice increases the pressure drop across the other orifice decreases and the servo valve is displaced to meter the fluid to a cylinder and the piston is moved to a new position.

Referring to FIG. 1 there is illustrated a schematic of a servo system using either a non-position seeking or a position seeking rotary hydristor. For example, using the position seeking rotary hydristor **50** of FIG. 2 as a feed back element, by means of the drive shaft **54'**, the hydristor may be connected to a rotary actuator **70**, the rotary actuator **70** being a rotary power cylinder with a central vane or piston **71** mounted therein and affixed to rotate with a shaft **12** extending through the power cylinder, shaft **12** being connected to the drive shaft **54'** of the hydristor. The power cylinder **70** is also connected by means of its ports **72** and **73** to a power hydraulic pump **75**, that is, hydraulic fluid under high pressure and proper volume is supplied by this pump **75** through an amplifier valve **76**. Valve **76** is a four ported valve with a closed cylindrical bore **77** and a double piston **78** mounted therein. Piston **78** is actually two lands **79** and **80** fitted to the cylindrical bore but connected by a central core of less diameter. The fluid from said pump **75** passes through an inlet **81** at the center of said valve to surround the lesser diameter of the piston. With the piston or spool **78** in its central position, the outlet ports **82** and **83** are closed. Piston **78** is also connected by the rod **63** extending through the body and attached to rod **62** of the null unit **60**. Thus, with movement of piston rod **62** of the null unit **60**, the double piston or spool **78** of valve **76** may be moved in either direction, for example, if moved to the left, it will open port **82** to permit a flow of fluid from pump **75** through valve **76**, through port

82, to inlet port 73 of the power cylinder. The opposite side of the power cylinder will expel fluid through port 72, through the opposite line to the opposite port 83 of valve 76, which is in turn connected to return port 84. Similarly, if piston 78 had been moved in the opposite direction, fluid would be expelled through the return port 82. In FIG. 1 the hydristor 50 with its cylinder 51 is connected by its inlet ports 57 and 58 through a null unit 60 to a ratio flow divider 30. The null unit 60 is in the form of a single enclosed cylinder with a spring centered diaphragm, the lines 57 and 58 being intercepted to pass into and out of either side of the diaphragm of cylinder 60. A single diaphragm 64 is mounted in the center of cylinder 60 to divide this fluid flow. Diaphragm 64 is also provided with a pair of piston rods 62 and 63 which extend through and out of either end of cylinder 60. It is apparent that diaphragm 64 becomes a sensing element that is moved in either direction depending upon the pressures on either side of said diaphragm and such movement is reproduced by the piston rods 62 and 63. It is to be noted that piston rod 63 is connected directly to the servo valve 76. The opposite side of the null unit 60 is connected by lines 57′ and 58′ to a ratio flow divider 30. Ratio flow divider 30 is provided with an actuator signal input rod 38 which is connected to the central dividing element or valve 37. This becomes the control element for the complete system. In this instance pump 40 will provide fluid under pressure from a fluid source 41 to the ratio flow divider 30 and depending upon the balanced or unbalanced position of the signal input rod 38, the fluid pressure will pass through lines 57′ and 58′ through either side of the null unit 60 and through lines 57 and 58 to the hydristor 50. The ratio flow divider may be of an unbalanced design so that the operator may actually feel any transfer of position. The unbalance is due to the design without balancing pistons. The movement of rod 38 can create a hydraulic balance at a point at which no load is felt. However if a load is applied on the piston, immediately the balance will be changed and the operator may feel the load on the signal input rod 38.

Referring to FIG. 3 there is illustrated a further modification of FIG. 2. In this figure, there is provided a rotary type hydristor and since the degree of movement of the rotor in FIG. 2 is limited to slightly less than 180°, FIG. 3 provides a rotor that will permit the movement of slightly less than 360°. In this embodiment a hydristor 50′ is comprised of a circular housing or body 51′ with a circular aperture 52′ at either end thereof, a stationary partition 53′ that is affixed to the body 51′ and extends laterally the length of the body and bears against the edge of a rotor 54′. Rotor 54′ is pivotally mounted in circular apertures 52′ at either end of body 51′, and extends through these apertures to provide a rotary piston rod or drive shaft on either side of the body 51′. Rotor 54′ is also provided with a blade 55′. The blade 55′ does not extend to the internal surface of housing or body 51′. Instead there is provided a circular partition 59 which extends from either end of said body 51′ and is provided with a slot 59′ (FIG. 4) at the lineal center of said body. It is also to be noted that the ports 57 and 58 must extend through housing 51′ and through the circular partition 59 on either side of the stationary partition 53′. Thus, in operation with an equal flow on either side of partition 53′, the rotor 54′ will be moved so that blade 55′ is in an upright position as shown in dotted lines, FIG. 3 and of course the fluid flow will be through the slot 59′ and out the outlet 56. A change in the proportionate flow may move the rotor to a position as illustrated and of course the control of the rotor will be to a degree of slightly less than 360°.

Referring to FIG. 5 there is illustrated a non-position seeking hydristor 20 that may be utilized in place of the hydristor 50 shown in FIG. 1. The hydristor 20 is a hydraulic cylinder or circular housing 21 that is closed at either end thereof with a circular aperture 22 at either end. A rotor 24 is pivotally supported in the circular apertures 22 by means of a shaft 23 on either side of body 21. The rotor 24 is a circular body of a diameter slightly less than the internal diameter of the body or housing 21. The clearance between the outer periphery of this body and the inner periphery of the housing 21 provides the necessary clearance for the capillary flow of fluid for port 57 and port 58 around the periphery of body 24 to an exhaust port 26. To divide the flow from ports 57 and 58 there is provided a sealing lip 27 between these ports and the housing 21 and the rotor 24. Ports 57 and 58 are connected to a ratio flow divider 30. The rotor 24 is provided with a circular cutout portion 28 which is a return collector and although this rotor 24 rotates moving the cutout portion 28 in a circular movement, portion 28 is connected to the exhaust port 26 at all times. This may be accomplished in various ways such as providing an opening through the rotor to the center of the rotor and providing the exhaust port directly through the center of the rotor as illustrated. In this particular form the rotor is limited to a movement of slightly less than 360°.

Referring to FIG. 6 there is illustrated an elevational view taken on line 6—6 of FIG. 5 showing a schematic of a simplified power system using either the non-position seeking hydristor as shown in FIG. 5 or a position seeking hydristor as shown in FIGS. 2 or 3. For example, using the non-piston seeking hydristor 20, FIG. 5, the ratio flow divider 30 and the pump 40 in the same sequence, we may add a power cylinder 70 with a rotary piston 71 mounted therein, in which the piston 71 is provided with a connecting rod 12 and in which rod 12 extends through sealed bearings at either end of the cylinder 70 and in which rod 12 is either connected to or is the same rod 23 extending from hydristor 20. Cylinder 70 is provided with two ports 72 and 73 at either end thereof. Ports 72 and 73 are in turn connected to the ports 72A, 73A of the ratio flow divider 30. Thus with the operation of pump 40, when the ratio flow divider is in a central position to divide the flow equally, the fluid flow to the hydristor and similarly to the power cylinder 70 will produce a movement of piston 71 which in turn produces a movement of the rotor of the hydristor to a central position. It is obvious that any input signal on the ratio flow divider that shall change the ratio flow produces the same change of flow to both the hydristor and the power cylinder so that they will work simultaneously to correct their position. It is obvious that the effective areas of the hydristor, if position seeking, will simply be added to the effective area of the actuator (piston) of the power cylinder. In this system, the position error is sensed because P1–P2 exists but is not compensated.

Referring to FIG. 7 there is illustrated a still further embodiment of a non-position seeking hydristor which comprises an elongated cylinder 10 with a piston 11. Piston 11 is normally centered for a balanced flow and piston 11 is movable in either direction depending upon an unbalance created on either side of said piston. Piston 11 is provided with a piston rod 14 that extends through cylinder 10 at one end thereof. This embodiment is similar to FIG. 5 except that the piston 11 is provided with a threaded external periphery and the internal surface of the cylinder 10 is similarly threaded to permit a rotary movement of piston 11. Thus even though this construction provides effective areas for the fluid pressure that will be produced on either side of the piston, the loads or pressures would be absorbed by the threads and, although this embodiment illustrates a threaded element, it is to be understood that there will be sufficient clearance at the crests and roots of the threads to permit a fluid flow therethrough. Thus, with inlet ports 57 and 58, the fluid flow to either side of piston 11 will permit a seepage or leakage past the threads to the outlet port 16. In FIG. 7, if the helix of the external thread of the piston is made big enough, the unit will become a position seeking hydristor.

The rotary portion of the motion provides feed back for more than 360°. In this embodiment the inlet lines **57** and **58** may be similarly connected as shown and described in the previous embodiments.

Referring to FIG. 8 there is illustrated a still further embodiment of a non-position seeking rotary hydristor which is related to the rotary hydristor of FIG. 3 but differs in its construction in that the body **51A** is provided with a single outlet port **56** at the bottom of the body. There is an internal rotating body **55A** eccentrically mounted with respect to body **51A** on a shaft **52A**. The internal body **55A** will rotate concentrically about its axis. The internal body **55A** is provided with two inlet bores **57'** and **58'** through shaft **52A**. The inlet bores are in turn connected to a pair of radial bores **57''** and **58''**, the radial bores extending to the periphery of the internal body **55A** which provide a pair of orifices at the surface of rotor **55A**. The inlet bores **57'** and **58'** are connected to a ratio flow divider (not shown). Thus in operation, if there is an equal flow to each inlet port, the internal body **55A** will assume a balanced position with the radial bores **57''** and **58''** in a horizontal position showing equal clearance between the internal body and external body on either side. However when FIG. 8 is connected in a simplified system as shown in FIG. 6 when the flow through inlet port **58'** is more than the flow through the inlet port **57'**, the internal rotor **55A** will be moved to a position as illustrated in FIG. 8 and thus produce a rotary motion indicating the unbalance. Thus complementary openings or resistances are formed by the two orifices. The rotary movement is limited to a maximum displacement of 180°. In this particular embodiment there is provided an orifice flow rather than a capillary flow.

Referring to FIGS. 9 and 10 in which there is illustrated a further embodiment of this invention in the form of an eccentrically mounted non-position seeking hydristor, that is, the rotor is eccentrically mounted with respect to the rotor or piston chamber. More particularly FIG. 9 illustrates a housing **80** provided with a rotor or piston chamber **81**. Within chamber **81** there is provided an eccentric rotor **82** mounted on and affixed to a shaft **83**, shaft **83** being rotatably supported in housing **80**. Shaft **83** is provided with means such as a gear **84** to permit rotation of shaft **83** and the eccentric rotor **82**. There are provided a pair of opposed ports **57** and **58** in housing **80** that are connected to chamber **81** in opposed relation thus providing a pair of opposed orifices **85** and **86**. Also connected to chamber **81** is a return port **56**. Thus it is apparent in use that with the inlet ports **57** and **58** connected to a fluid supply as in the previous embodiments, there will be an orifice flow through the orifices **85** and **86**. The degree of orifice flow is controlled by the eccentric rotor **82**. As illustrated in FIGS. 9 and 10 rotor **82** is in a position at which there will be a minimum flow from orifice **85** and a maximum flow from orifice **86**. Rotor **82** may be turned to vary and change the orifice flow from this position to an equal flow from either orifice or to an opposite position where the flow will be a minimum at orifice **86** and a maximum at orifice **85**. Rotor **82** is not necessarily round, it is simply a cam providing a minimum and maximum orifice.

Referring to FIG. 11 there is illustrated a cross-sectional view of a hydristor similar to FIGS. 9 and 10 in which the housing **80** is provided with a rotor or piston chamber **81**. Within chamber **81** there is provided a concentric rotor **82'** mounted on and affixed to a shaft **83**, shaft **83** being rotatably supported in housing **80**. Shaft **83** is provided with means (not shown) to permit rotation of shaft **83** and the concentric rotor **82'**. Although rotor **82'** is concentric for rotation, the upper and lower faces of rotor **82'** are not parallel. Thus the periphery of rotor **82'** will vary from a minimum periphery to a maximum periphery as illustrated in FIG. 11. Rotor **82'** is positioned on the axis of the opposed orifices **85** and **86** so that the maximum periphery of the rotor will completely cover either orifice as illustrated at orifice **86** or will completely uncover either orifice as illustrated at orifice **85**. Orifices **85** and **86** are in reality ports **P1** and **P2** and may be connected to lines **57** and **58** as in the previous embodiments. A return port **56** is also connected to the chamber **81**. Thus in this embodiment as in the previous embodiment the rotation of shaft **83** will regulate the orifice flow from orifices **85** and **86**.

Referring to FIG. 12 there is illustrated a cross-sectional view of a hydristor similar to FIGS. 9 and 10 in which there is a body portion **90** with two concentric bores **91** and **92** and a pair of ports **57** and **58** that are connected to bore **91**. The body **90** is supported and connected to a shaft **93**. An eccentric rotor **92** is positioned in bore **91**. Rotor **92** is formed as an integral part of shaft **94** which is rigidly connected to a base plate **95**. Bore **91** is closed at its upper end by element **96** that is fitted into bore **91**. Element **96** may be provided with seals and thus be rotatable with respect to body **90**. Element **96** is provided with a return port **56** which is connected to the chamber formed by bore **91** in which rotor **92** is mounted. Thus with this arrangement there are two variations in use, one in which base plate **95** is stationary and body **90** may be rotated by shaft **93** to vary the orifice flow through orifices **85** and **86** and even though body **90** is rotated, port **56** will remain in a stationary position depending upon the seals to retain the fluid flow in the chamber formed by bore **91**. In the other variation of FIG. 12, shaft **93** and body **90** may be stationary and the base plate **95** may be rotated to thus rotate the eccentric rotor **92** and in turn control the flow through orifices **85** and **86**.

Referring to FIGS. 13 and 14 which are a detailed application of the schematic shown in FIG. 8 and are also a further embodiment of FIGS. 9 and 10 in which there is a housing **100** and the housing **100** is provided with bores **101**, **102** and **103** to form a chamber for a rotor assembly **104**. Chamber **103** is eccentric to the rotor axis. Rotor assembly **104** at its upper end is a concentric rotor **105** and at its lower end is a concentric rotatable valve body **106**. Rotor **104** is provided with two internal ducts **107** and **108**, duct **107** being connected between the orifice **85'** and the port **57** while duct **108** is connected between the orifice **86'** and the port **58**. The internal chamber is connected at the upper end of bore **103** to a return port **56**. The rotor assembly **104** extends through bore **101** and is provided with a means to rotate such as a gear **109**. Thus in use, by means of gear **109**, the rotor assembly **104** may be rotated while body **100** remains stationary. Thus the flow through orifices **85'** and **86'** may be varied from minimum to maximum. In this form of the invention, the rotor assembly **104** may be continually rotated to provide a regular pulse or flow variation for each cycle of rotation; this is also true with the hydristor in FIGS. 5 and 9. This lends itself to a particular use where a power stroke such as that illustrated in FIG. 1 is to be continually repeated. In this embodiment the rotor **105** has been shown as concentric with the bore **103** as eccentric to the center line of the valve.

Referring to FIG. 15 there is illustrated a further embodiment of FIG. 13 in which the body is split into an upper and lower portion **100** and **100'**. In this embodiment there are provided concentric bores **101** and **102** in portion **100** while the bore **103** is in the upper portion **100'**. In this embodiment the rotor assembly **104** is similar to the previous embodiment. As in the previous embodiment there are provided two ducts **107** and **108**, duct **107** connecting orifice **85'** with port **57** while duct **108** connects orifice **86'** with port **58** and the chamber formed by bore **103** is connected to a return port **56**. The portion **100** is provided with a bracket **110** that is provided with a threadable aperture **111**. The upper portion of the body **101** is provided with a rotatable threaded element **112** that is rotatable in body **100'** and the threaded element **112** that is rotatable in body **100'** and the threaded

portion mates with the threaded aperture **111** and the threaded element **112** is provided with a control head **113**. Body **100'** is securely mated and sealed with the upper face of body **100** such as by providing key slots (not shown) on either side of said body so that portion **100'** may be moved in a reciprocating manner to left or right with relation to lower portion **100**. Thus by means of element **113**, the upper portion **100'** may be moved to a very exact position to establish the eccentricity of the bore **103** that is eccentric to rotor **104** thus affecting the flow through orifices **85'** and **86'**. The adjustment may be from an equal flow with everything concentric as illustrated or portion **100'** may be moved to the left to decrease the orifice flow from **86'** and increase the orifice flow from **85'** or vice versa. In this embodiment as in the embodiment illustrated in FIG. 13 the rotor assembly **104** may be rotated by means of a motor M to provide a regular pulse pattern for each rotation of rotor **105** to be utilized in the same fashion as described in FIG. 13 or to be utilized for any particular purpose such as a mechanical vibrator wherein the degree of balance or unbalance of the pulse may be regulated to the desired vibration. If the hydristor shown in FIG. 15 is utilized in FIG. 1 as a flow divider then when element **113** is adjusted the displacement of the power cylinder may be changed in accordance with the adjustment to vary for a given angular signal input. The same result can also be obtained by using the device of FIG. 15 as a feedback device. This FIG. 15 in combination with FIG. 1 lends itself to a further use as an oscillator with adjustable amplitude. By varying the input speed of motor M the frequency of the oscillator may be variable.

Although applicant has shown the application of the hydristor to a servo system as illustrated in FIG. 1 and FIG. 6, the hydristor that shall be applied to the servo system may take different forms as disclosed herein and although the hydristor has been shown as part of a servo system, the servo system may be applied to many uses, for example, a mechanical vibrator or any form of device where a varying pulse for each cycle of rotation of the hydristor is to be utilized without departing from the spirit of this invention and this invention shall be limited only by the appended claims.

What is claimed is:

1. A hydraulically positioned servo system which includes a hydristor as a position feedback element, said hydristor comprising a casing with a cylindrical fluid chamber having a rotatable metering element mounted therein to modulate the fluid flow through said chamber into two complementary fluid flows resulting from two complementary hydraulic resistances, said hydristor provided with two fluid inlet ports to said chamber, said inlet ports being formed as orifices that are controlled by said metering element, a common outlet port connected to said chamber, said metering element being fitted and rotatably positioned within said fluid chamber and provided with movable surfaces to provide two complementary hydraulic resistances to allow two complementary flows over said metering element and to said common outlet, said two complementary hydraulic resistances are formed by the two orifices and the movable surfaces of the metering element, said servo system divided into a power stage and a feedback control stage, said power stage comprising a power cylinder and piston, a main pressure source and a four way valve, said four way valve connected by fluid lines to said power cylinder, said feedback control stage comprising said hydristor, an auxiliary pressure source, a ratio flow divider to provide two complementary resistances and two complementary flows, and a differential pressure sensing device which is mechanically connected to said four way valve and connected with fluid lines to said ratio flow divider and to said hydristor, said hydristor having its metering element mechanically connected to the rotatable piston of said power cylinder as a feedback element, said ratio flow divider comprising a closed casing with a fluid inlet port at its center and two fluid outlet ports, one at each end of said casing, a piston and rod mounted loosely and centrally within said closed casing to produce said two complementary hydraulic resistances and two complementary fluid flows, said rod providing the means for a mechanically produced input signal, said piston rod extending through said casing, said differential pressure sensing device comprising a closed cylindrical casing with two fluid inlet ports and two fluid outlet ports, one inlet and one outlet port connected to each end of said closed cylindrical casing to allow a fluid flow therethrough, a dividing piston with its piston rod extending through said closed cylindrical casing, and a resilient element positioned on each side of said piston to normally retain said piston centered when said fluid pressure on each side of said piston is equal, said piston of said differential pressure sensing device connected to said piston of said four way valve to control its movement and in turn control the fluid flow to said power cylinder, said differential pressure sensing device providing means to compare the ratio of the two complementary resistances of the hydristor with the ratio of the two complementary resistances of the signal input valve during fluid flow, said differential pressure sensing device which includes said resilient element also responding to pressure changes to move said four way valve and correcting an error signal when a pressure differential exists in said differential sensing device by moving said four way valve in the direction indicated by the error signal and in turn move said piston of said power cylinder and said metering element of said hydristor to reduce said error signal to zero.

2. In a device according to claim **1** in which the metering element is formed as an eccentrically shaped disk.

3. In a device according to claim **1** in which the metering element of said hydristor is eccentrically mounted on a central axis and rotatable on said axis.

4. In a device according to claim **1** in which said rotary metering element is a circular disc and in which one of the sides of the disc is slanted to form a metering surface of a varying size periphery from a predetermined minimum to a predetermined maximum and in which the metering element may vary the orifice opening from a complete closure to a complete opening and in which the opening of one orifice is in exact proportion to the closing of the other and vice versa.

5. A hydraulicly positioned servo system which includes a hydristor as a position feedback element, said hydristor comprising a casing with a cylindrical fluid chamber having a metering element mounted therein to modulate the fluid flow through said chamber into two complementary fluid flows resulting from two complementary hydraulic resistances, said hydristor provided with two fluid inlet ports to said chamber, said inlet ports providing a flow that is controlled by said metering element, an outlet port open to the fluid flows past said metering element, said metering element being fitted and rotatably positioned within said fluid chamber and provided with movable surfaces to provide two variable openings which react in complementary relationship so that the ratio of hydraulic resistances created by the metering element is a function of output position, said two variable openings allowing two complementary flows over said metering element and to said common outlet, said two complementary hydraulic resistances are formed by the two orifices and the movable surfaces of the metering element, said servo system divided into a power stage and a feedback control stage, said power stage comprising a power cylinder and piston, a main pressure source and a four way valve, said four way valve connected by fluid lines to said power cylinder, said feedback control stage comprising said hydristor, an auxiliary pressure source, a ratio flow divider serving as a signal input valve to provide two complementary resistances and two complementary flows, a differential pressure sensing device which is mechanically connected to said four way valve

and connected by fluid lines to said ratio flow divider and to said hydristor, said hydristor having its metering element mechanically connected to the piston of said power cylinder as a feedback element, said metering element of said hydristor generating two complementary hydraulic resistances so that the ratio of hydraulic resistance created is a function of output position, said ratio flow divider comprising a closed casing with a fluid inlet port at its center and two fluid outlet ports, one at each end of said casing, a piston and rod mounted loosely and centrally within said closed casing to produce two complementary hydraulic resistances and two complementary fluid flows, said rod providing the means for a mechanically produced input signal, said piston rod extending through said casing, said differential pressure sensing device comprising a closed cylindrical casing wtih two fluid inlet ports and two fluid outlet ports, one inlet and one outlet port connected to each end of said closed cylindrical casing to allow a fluid flow therethrough, a dividing piston with its piston rod extending through said closed cylindrical casing, and a resilient element positioned on each side of said piston to normally retain said piston centered when said fluid pressure on each side of said piston is equal, said piston of said differential pressure sensing device connected to said piston of said four way valve to control its movement and in turn control the fluid flow to said power cylinder, said differential pressure sensing device providing means to compare the ratio of the two complementary resistances of the hydristor with the ratio of the two complementary resistances of the signal input valve during fluid flow, said differential pressure sensing device which includes said resilient elements providing means to respond to pressure changes to move said four way valve to correct an error signal when a pressure differential exists in said differential sensing device by moving said four way valve in the direction indicated by the error signal and in turn move said piston of said power cylinder and said metering element of said hydristor to reduce said error signal to zero.

6. In a device according to claim **1** in which said metering element is formed with a rotor portion and valve portion in which the valve portion is eccentric to said cylindrical fluid chamber and the rotor portion is concentric to said cylindrical fluid chamber and in which the inlet ports in said cylinder fluid chamber are directed to said valve portion.

7. In a device according to claim **1** in which said metering element is formed with a rotor portion and valve portion in which the chamber for the rotor portion is variable from concentric to eccentric to the axis of said metering element and said inlet ports are directed to said valve portion.

8. In a device according to claim **1** in which said rotary metering element is a cam that provides two complementary orifices which provide a minimum and a maximum orifice in one position.

9. In a device according to claim **5** in which said cylindrical chamber of said hydristor is provided with a smaller cylindrical partition that divides said cylindrical chamber into a first and second chamber and in which said smaller cylindrical partition is provided with a slot at its lineal center to connect said two chambers and in which there is a movable partition within said second chamber that is rotatable slightly less than 360° and in which said first and second chambers are divided by a stationary partition that also separates said two inlet ports and in which said inlet ports extend into said second chamber and said outlet port is connected to said first chamber.

10. In a device according to claim **5** in which the exterior surface of said hydristor piston and the interior surface of said chamber are provided with complementary male and female threads to form a helix from one end to the opposite end and in which the displacement of said piston is a rotary motion.

References Cited by the Examiner

UNITED STATES PATENTS

2,431,593	11/47	Strike	137—625.4 X
2,703,149	3/55	Nelson.	
2,924,199	2/60	Lawson et al.	

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