

Jan. 24, 1961

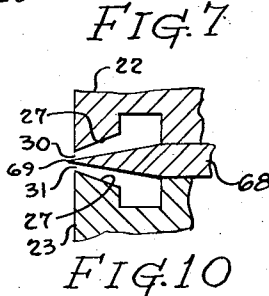
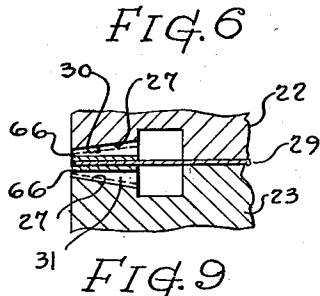
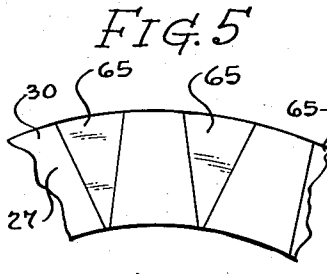
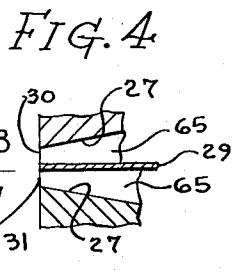
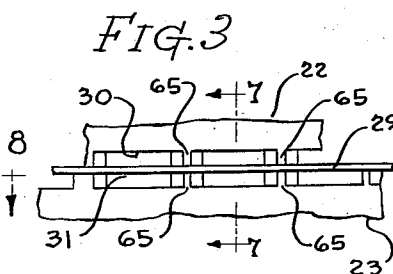
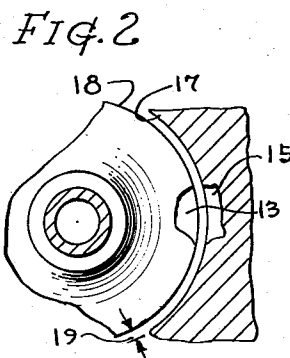
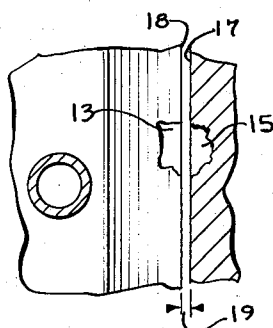
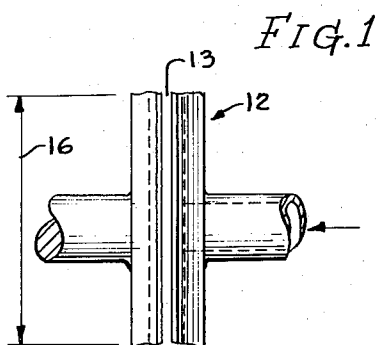
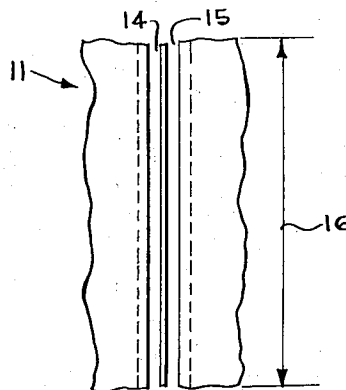
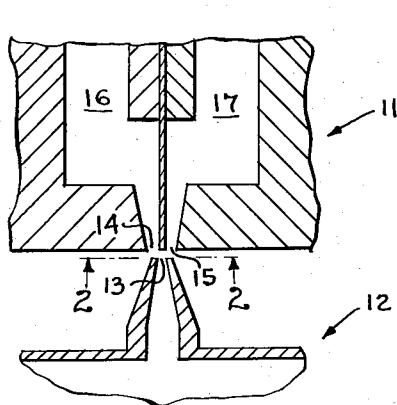
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2,969,079

HIGH CAPACITY HYDRAULIC RELAY

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2 Sheets-Sheet 1



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HIGH CAPACITY HYDRAULIC RELAY

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2 Sheets-Sheet 2

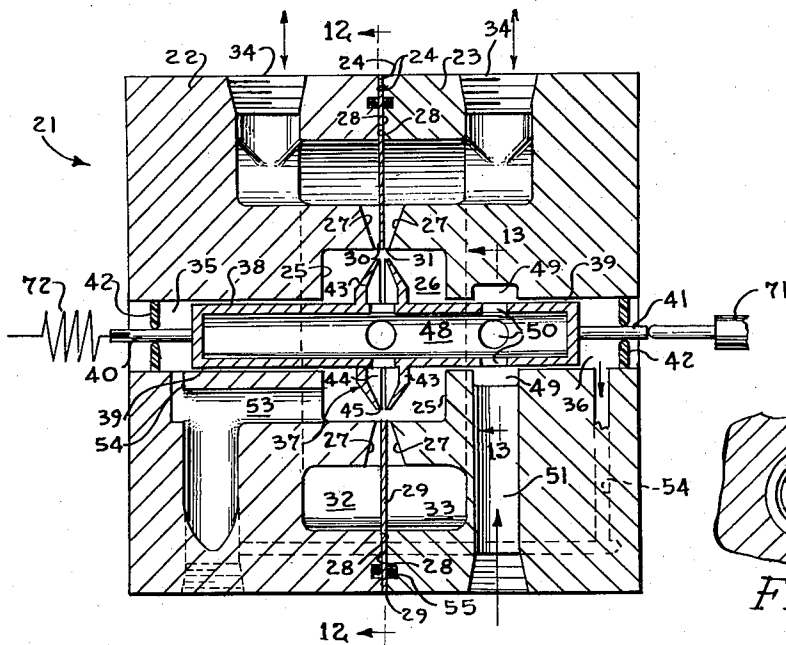


FIG. 11

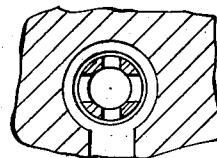


FIG. 13

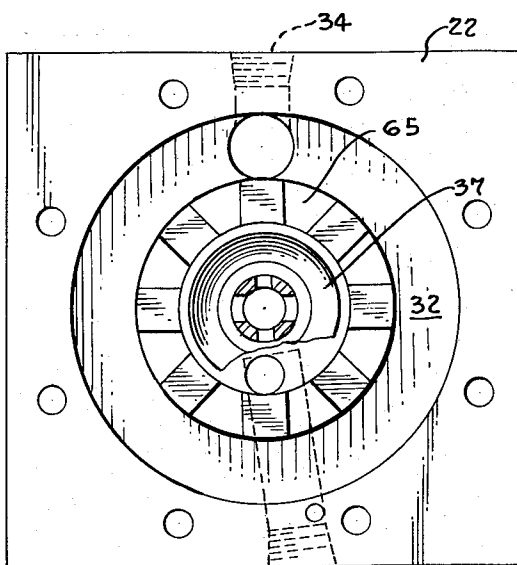


FIG. 12



FIG. 14

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2,969,079

HIGH CAPACITY HYDRAULIC RELAY

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6 Claims. (Cl. 137—83)

The present invention relates to hydraulic relay regulators of constant flow discharge type analogous to the well known jet pipe relay regulator of the type disclosed, for example, by U.S. Patents No. 1,550,410 and No. 1,558,530, to Wunsch. A jet pipe regulator comprises a pipe or nozzle with an end discharge orifice and an internal fluid supply passage, pivotally mounted in delicate suspension bearings to swing about an axis from which the nozzle projects radially to an angular position imposed by a control signal, which position determines degree of registration of the discharge orifice with a receiver port, or relative degrees of its registration with a pair of receiver ports narrowly spaced in the directions of orifice swing, whereby, magnitude of pressure developed in the single port, and transmitted to the power unit of a relay, or differential between magnitudes of pressures developed in the two receiver ports, and respectively transmitted to opposite sides of the movable wall of a dual expansible chamber power unit, such pressure or pressures being developed by kinetic energy of a stream of pressurized fluid discharged from the orifice, depends on the angular position of the jet pipe.

Jet pipe relay regulators are characterized by extreme sensitivity, highly accurate and repeatable response, enormous power amplification, and high efficiency, so long as certain empirically ascertained practical limits of discharge orifice and receiver port diameters, distance of orifice swing, and mass of the movable assembly are kept. For practical purposes a jet pipe orifice of diameter of the order of six or eight millimeters, and an orifice movement path of the order of one eighth inch are regarded as the limits that are productive of satisfactorily linear and repeatable response of variation in output pressure magnitude to degree of jet pipe discharge orifice movement.

As set forth in the preliminary portion of United States Patent No. 2,633,385, to Ziebolz, it has become conventional to suspend the jet pipe by means of a hollow spindle, one end of which is mounted in a high precision bearing, while the other is mounted, for rotation, to a tubular stud, through which fluid is delivered to the spindle interior. To minimize frictional resistance to rotative movement of the spindle, the stud and spindle are telescoped, and a narrow clearance is provided between their opposed surfaces.

A film of fluid escaping through this clearance serves to maintain the relatively movable surfaces in non-contacting relation, thereby minimizing frictional resistance to such movement. The clearance does introduce a certain amount of lateral play at the end of the spindle that is so mounted. The effect of that upon jet pipe movement response to control signal change has been minimized by spacing the point of signal application to the jet pipe at a substantial distance from the spindle axis, which in turn has imposed certain minimum jet pipe length requirements. Increase of the diameter of a jet pipe, which projects eccentrically from the spindle,

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has resulted in such increase of jet pipe weight, as to upset the floating character of the fluid supply spindle bearing, and introduce friction and resultant irregularity of jet pipe position change response to control signal variation. In some situations wherein extremely small magnitudes of force are available as control signals, or high sensitivity to small magnitudes of force variation is required, such frictional resistance, and inertia of larger jet pipes prove troublesome.

The present invention is directed to solution of the problem of increased fluid delivery capacity as compared to that of a jet pipe of maximum practical size, in a relay regulator of the kinetic stream energy type, and in an arrangement that provides the advantageous characteristics of sensitivity, large power and amplifications, repeatability and linearity that are typical of the jet pipe within the indicated limits. It may be noted that, while apparently capacity of a practical and conventional jet pipe might be increased by increase of rate of its fluid discharge, as a practical matter the receiver port diameter must be about twenty percent greater than the diameter of the jet pipe discharge orifice.

The basic concept of the present invention is delivery of the fluid in an uninterrupted sheet form.

This sheet-form fluid jet is delivered through a narrow, slot-like discharge orifice in an ejector structure and is directed toward a receiver port, or a pair of receiver ports of size and shape corresponding to those of the discharge orifice, in other words slot-like and oriented in correspondence to orientation of the discharge orifice, such port or ports being arranged in a receiver structure, and provision being made for relative rectilinear movement of the ejector and receiver structures in directions extended transverse to the slot-like ports and orifice, so that degrees of their registration may be varied.

In accordance with a refinement, the invention embraces, for purposes of providing maximum capacity with minimum mass of the movable one of the structures, an arrangement wherein one surrounds the other, with opposed and facing outer and inner peripheral surfaces narrowly spaced apart, with the discharge orifice opening through one, and the receiver port or ports opening through the other. Most conveniently, since it requires only one fluid flow passage, the ejector is the movable structure, and to minimize its mass and inertia, is the inner and therefore the smaller structure.

A primary object of the invention is provision of a novel high capacity hydraulic relay regulator of the type wherein a jet of fluid is discharged at constant volume rate or constant pressure in the direction of a receiver port or ports, to develop a pressure of pressures the magnitude or magnitudes of which are functionally related to degree of registration of the jet discharge orifice and port or ports, and which magnitude or magnitudes are variable by changing such degree of registration.

Another important object is the provision of a novel regulator of the general type in question, wherein one of a receiver and an ejector structure surrounds the other, with provision for discharge of a sheet form jet between them and continuously surrounding the inner one of such structures.

Still another object is the provision of a novel structural arrangement of a regulator unit of the sheet-form jet type described.

In the accompanying drawings:

Fig. 1 is a somewhat schematic longitudinal section of one form of regulator embodying the invention in a broad aspect.

Fig. 2 is a fragmentary elevation of a receiver structure of the type shown in Fig. 1.

Fig. 3 is a fragmentary elevation of an ejector of the type shown in Fig. 1.

Figs. 4 and 5 are transverse sections through regulators respectively of different form, each embodying the invention.

Fig. 6 is a fragmentary elevation of a preferred arrangement of a distributor type of receiver provided with a pair of receiver port systems.

Fig. 7 is a section on line 7—7 of Fig. 6.

Fig. 8 is a section on line 8—8 of Fig. 6.

Figs. 9 and 10 are cross sections of modified distributor receiver arrangements.

Fig. 11 is a median longitudinal section of a preferred form of relay regulator unit structure arranged according to the invention.

Fig. 12 is a section on line 12—12 of Fig. 11.

Fig. 13 is a section on line 13—13 of Fig. 11.

Fig. 14 is a fragmentary end view of the arrangement shown in Fig. 9.

First describing Figs. 1 to 5 a regulator arranged according to the invention comprises a pair of structures 11, 12, one of which is the ejector and the other the receiver. Structure 12 is provided with an elongate, narrow and slot-like aperture 13, and structure 11 with a similarly shaped aperture 14. Structures 11, 12 are mounted for selective rectilinear movement in directions extended transverse to apertures 13, 14 so that degree of registration between them is variable by such relative motion, and magnitude of pressure developed within one of the apertures by kinetic energy of a sheet-form jet of fluid forcibly discharged from the other, is a function of degree of registration of apertures 13, 14, and of the relative positions of structures 11, 12.

Since it is most common in the practical field to employ regulators of the dual receiver port, or distributor arrangement mentioned in the preceding description of jet pipe relay regulators, such form is illustrated in the drawings, and for that reason structure 11 is shown as the receiver or distributor structure, with aperture 14 serving as one receiver port, and provided with a second receiver port 15 and structure 12 is shown as the ejector with aperture 13 serving as the delivery orifice. Structure 11 is arranged with internal passage means providing a pair of delivery passages 16, 17 respectively communicating with receiver ports 14, 15 for delivery to a pair of service lines, such as may be connected to opposite ends of the cylinder of a power unit.

The elongate slot-like nature of the receiver ports 14, 15 and delivery orifice 13 is best shown in Figs. 2 and 3. As in jet pipe regulators, to provide for escape of fluid from the receiver ports 14, 15 after it has delivered its kinetic energy by impingement upon fluid lying inwardly of the port mouths, the receiver ports 14, 15 are slightly wider than is the delivery orifice 13. However the width by which such ports exceed discharge orifice width, again as in jet pipe regulators is limited by necessity of avoiding pressure loss by uncontrolled escape of fluid from within the ports, past the impinging jet. Discharge orifice width of the order of six millimeters, and width of each receiver port of the order of seven and one-half millimeters, while not critical, exemplify a satisfactory ratio of discharge orifice and receiver port widths, in a structure providing satisfactory characteristic of response of output pressure magnitude change to degree of change of relative positions, and change of degrees of registration of discharge orifice with dual receiver ports, and in a satisfactory range of distance of relative movement of a control member, for example an axially movable transmission rod, in a practical hydraulic relay regulator such as is used for many automatic control purposes.

Obviously, use of elongate ports and orifices permits substantial selective variation of the fluid delivery capacity of the regulator, with fluid delivered at a selected rate or pressure, by the simple but novel expedient of selecting the length of the ports and orifice, that is, the

dimension 16 in Figs. 2 and 3. As suggested by Figs. 4 and 5, selection may be exercised as to the peripheral profile of the surfaces 17, 18 through which the receiver ports and discharge orifice open respectively. The profiles of the surfaces should match. In a regulator of the port and orifice sizes suggested above, a spacing, indicated by dimension 19 in Figs. 4 and 5 in a range of the order of three-sixteenths to seven-thirty-seconds inch is satisfactory, this range also being non-critical and selected from considerations of efficiency of transfer of the energy content of the fluid jet as it leaves discharge orifice 13 to the fluid lying within the receiver ports, provision of escape clearance for spent fluid and exhaust fluid and so on.

In order to minimize mass of the movable one of the ejector and receiver structures, and provide as great capacity as practical, it is preferable that one such structure surround the other, with the fluid jet delivered as a sheet continuously surrounding the inner one. Additionally, it is regarded as preferable that the matching peripheral surfaces through which the discharge orifice and receiver ports open be circular in profile, so that the fluid jet is in the form of an annular sheet. Still further, since the ejector requires only a single fluid flow path, whereas most frequently the receiver has two receiver ports and consequently requires two fluid delivery passages, and for consequent reasons of minimizing mass of the movable structure and providing for fluid-transmitting bearings presenting minimum and regular frictional resistance to movement, it is regarded as preferable to make the ejector structures the inner and movable structure of a relay regulator embodying the invention.

Figs. 11 to 13 disclose a unitary regulator assembly having these preferred arrangements and also an arrangement that is convenient and practical to manufacture, install and use in practical relay installations, including those intended for automatic condition control.

In this arrangement the receiver structure designated generally 21 is in the form of a casing comprising a pair of matching bodies 22, 23 having meeting end surfaces 24. Internally surfaces 24 have inner surface portions 25 that are spaced apart to define the ends of a regulator chamber 26, intermediate, annular surface portions 27 that define opposite sides of a receiver port-providing aperture that encircles chamber 26 and opens radially into it, and outer surface portions 28 between which is engaged an annular, thin divider plate 29 that projects into the port-providing aperture, dividing it centrally into a pair of receiver ports 30, 31 each of which encircles chamber 26. Between surface portions 27 and 28 the facing ends of bodies 22, 23 are provided with annular channels 32, 33 that in the assembly are isolated by plate 29, and that provide a pair of delivery passages that respectively communicate with the different receiver ports 30, 31 and each of which is provided with a coupling tap opening 34 for connection of a service line. Bodies 22, 23 also are provided with bores 35, 36 that enter chamber 26 and that preferably are coaxial with that chamber and with ports 30, 31, it also being regarded as preferable that chamber 26 be cylindrical, so that ports 30, 31 are circular in peripheral profile.

The ejector structure, designated 37 generally, includes a support member 38 having portions extended into bores 35, 36 with member 38 extended across chamber 26. To minimize frictional interference with movement of ejector 37, the portions of member 38 that lie within bores 35, 36 are sufficiently smaller than those bores to provide free clearance, shown exaggerated at 39, between opposed bore and member surfaces, and bearing pins 40 projecting from the ends of member 38 are slidable in suitable slide bearing elements 42 mounted in the outer bore portions.

Within chamber 26 member 38 supports an ejector body comprising a pair of flanges 43 that define between them an annular passage 44 for radial, outward flow of fluid.

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The facing marginal portions of flanges 43 adjacent their peripheries define between them a discharge orifice 45 that faces and is encircled by the receiver ports 30, 31, the flanges 43 being circular in peripheral profile and coaxial with the receiver ports and chamber 26.

To provide for fluid supply to discharge orifice 45, member 38 is provided with a passage 48 that communicates with the radial flow passage 44 between flanges 43 and that is extended into one bore, here 36, which is provided with an enlargement providing a chamber 49 through which that member portion is extended and wherein it is provided with one or more fluid entry openings 50 providing for fluid flow to passage 48 from chamber 49 to which it is delivered by a supply passage 51. To minimize pressure and fluid loss from chamber 49 to chamber 26, clearance at 39 between the surface defining bore 36 and the facing outer surface of member 38 is sufficiently narrow to present substantial resistance to flow of the fluid to be used in the regulator, a clearance of the order of three-one-thousandths inch being entirely satisfactory for regulators using oil or similar liquids as power fluid.

Preferably support member 38 of the ejector structure is hollow throughout its length, as shown, to limit mass and inertia of the structure.

A drain or exhaust line 53 opens into chamber 26 for drainage of spent fluid and fluid exhausted from receiver ports 30, 31 and a utilization system to which they may be connected. Auxiliary drain lines 54 connect the outer ends of bores 35, 36 to drain line 53 to carry off fluid escaping past member 38, and to prevent buildup in the bore ends of pressure that would interfere with proper movement of ejector structure 37. Seal between outer surface portions 38 of the receiver bodies 22, 23 is shown at 55 as provided by O-rings compressed in channels and against surfaces of plate 29.

For high sensitivity and linearity of response of output effective pressure magnitude to degree of movement of ejector structure 37 it is essential that receiver ports, as 14, 15 of Figs. 1 to 5 and 30, 31 of Fig. 11 be very closely adjacent. Close spacing may be accomplished by making plate 29 very thin, say of the order of eight or ten one-thousandths inch in thickness.

Such thinness imparts to such a plate a certain flexibility that makes it necessary to support it against deflection from proper position under differential of pressures effective upon opposite surfaces, as in the receiver ports and passageways separated by the plate. Under the condition of maximum differential between these ports, wherein discharge orifice 45 is registered completely with one port, and completely out of registration with the other, the pressure differential across plate 29 is of the order of ninety to ninety-five percent of its static pressure at which fluid is delivered to orifice 45. At a conventional fluid delivery pressure of one hundred pounds per square inch, the maximum differential effective across plate 29 will be of the order of ninety to ninety-five pounds per square inch. To prevent deflection of such thin material used for plate 29 the arrangements of Figs. 6 to 8 may be employed. In this arrangement the port-defining surfaces of the receiver structure are provided with plural, projecting shoulders 65 that are spaced along the ports and that tightly clamp divider plate 29 between them at frequency intervals along the lengths of the port. Thereby lateral deflection of plate 29 within the ports proper is prevented and bulging deflection of the more inward portions of the plate that divides the delivery passages, as 32, 33 also is prevented by the radially spaced clamping of plate 29 between the shoulders 65 and between surfaces 28 of the receiver structure parts 22, 23, Fig. 11. Figs. 9 and 14 show a less desirable arrangement for clamping and supporting a thin divider plate 29, comprising a pair of annular thin metal plates 65 that are formed, in flat surfaced corrugations, to provide alternate

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offset portions respectively contacting plate 29 and the port-defining surfaces of the receiver structure.

As shown in Fig. 10 the divider plate, here designated 68, may be of metal sufficiently thick to resist distortion rigidly, and provided with a sharp bevel edge 69.

Application of a signal to ejector structure 37 to position discharge orifice 45 relative to receiver ports 30, 31 in correspondence with the magnitude of that signal may be made by a transmission rod 71 that contacts the end of a projecting member portion 41. The arrangement shown is in accordance with conventional force balance signal control of hydraulic relay regulators, a return spring 72 exerting a force tending to position ejector structure 37 in a neutral position wherein its discharge orifice is in equal degrees of registration with ports 30, 31, and equal pressures are developed in them, and application of a signal force through rod 71 tending to displace the ejector structure to produce a corresponding difference in the receiver port pressures as a consequence of movement of ejector structure 37 to a position corresponding to the signal force magnitude and resulting in a corresponding difference in degrees of registration of orifice 45 with ports 30 and 31.

From the foregoing, it will be seen that the employment of discharge orifice and receiver ports that are elongate and, for purposes of proper linearity of response, narrow, and relatively movable transversely, provides for tremendous increase of useful fluid delivery capacity as compared to a round jet delivering jet pipe the stream diameter of which is limited to the limit of the width of such ports and orifice and for similar reasons. It will further appear that employment of receiver and ejector structures one of which surrounds the other and arranged for peripheral jet discharge between them provides for maximum capacity per occupied space unit, and that arrangement of the ejector as the inner and movable structure permits minimizing of mass and inertia of the movable structure.

Accordingly, it will be understood that many changes in and modifications of the specific exemplary disclosures herein may be made while obtaining fully the advantages and benefits made possible by the invention, and that the limits of the invention are determined by and to be ascertained from only the appended claims.

I claim:

1. A hydraulic relay regulator device comprising a receiver structure comprising a pair of bodies having registered internal openings of corresponding peripheral profiles, meeting surfaces spaced outward from and surrounding said openings, and facing surface portions adjacent said openings and that are spaced apart and define between them a narrow, inward facing aperture that is extended about the periphery of said openings between said bodies, a thin plate having an internal opening of profile substantially matching said internal openings, said plate having a portion mounted between said meeting surfaces with all said internal openings registered, a portion of said plate being disposed in and dividing said aperture, said body surface portions being spaced at equal distances from facing surfaces of said plate, and said receiver structure having a pair of internal passages respectively communicating with portions of said aperture to opposite sides of said plate and arranged for connection to a pair of service lines, said device including an ejector structure comprising a support member, a pair of flanges surrounding and laterally projecting from said member, with facing surfaces spaced apart and defining an intervening flow passage, and with peripheral portions of said facing flange surfaces defining a discharge orifice of a width substantially matching the distance of spacing of said body surface portions from said plate surfaces, said member having an internal fluid delivery passage communicating with the flow passage defined between said flange surfaces, said device including means mounting said member with said internal openings, and being arranged to permit relative

movement of said structures in directions extended transverse to said discharge orifice and aperture, and spacer means inserted between said plate and said surface portions for maintaining constant the spacing between them.

2. A hydraulic relay regulator device comprising a receiver structure and an ejector structure, one of said structures including a pair of bodies having matching opposed end surfaces having inner portions that are spaced apart and define a regulator chamber between them, intermediate portions surrounding said inner portions that are spaced apart more narrowly than said inner portions and define between them a narrow aperture opening through the peripheral surface that extends between said surface portions and defines the periphery of said chamber, and outer portions surrounding said intermediate portions and disposed in sealing contact, said structure having internal fluid passage means communicating with said aperture for conducting fluid that flows therethrough, and a pair of bores that open through said inner surface portions into said chamber, the other said structure including a support member having spaced portions respectively slidable in said bores and having an internal fluid passage, a body structure disposed in said chamber and mounted on said member for movement in directions extended transverse to said aperture as said member portions slide in said bores, said body having a peripheral surface facing said peripheral surface that extends between said inner and intermediate surface portions of said one structure and a peripheral, outward facing narrow aperture adapted to be more or less registered with the first said aperture by movement of said body and communicating with said internal member passage.

3. A hydraulic relay regulator device according to claim 2, wherein the body of said other structure comprises a pair of flanges spaced narrowly in the directions of movement of said body and defining between them the second said aperture.

4. A hydraulic relay regulator device according to claim 2, wherein said one structure comprises the receiver structure and includes a thin plate engaged between said outer surface portions, extends into the first said aperture and divides it into two receiver ports of substantially equal widths, and has an internal opening corresponding to the cross section of and registered with said chamber, and the passage means of said receiver structure comprises a pair of flow passages communicating with the first said aperture respectively on opposite sides of said plate, and arranged for connection to a pair of service lines.

5. A hydraulic relay regulator device according to claim 2, wherein the internal passage of said member is extended from said body of the other structure to a location within one of said bores, and opens laterally through said member within that bore, and said one structure is provided with additional passage means opening into the region of the latter said bore wherein said member passage opens.

6. A hydraulic relay regulator in accordance with claim 2, wherein the internal passage of said member is extended from said body of the other structure to a location within one of said bores and opens laterally of said member within that bore, the portion of said member that extends into that bore being sufficiently smaller in cross section than said bore to provide clearance between said member and the surface defining said bore that is sufficiently narrow to present resistance to flow of the fluid to be used in said device, and said device including slide bearing means mounting said member for sliding movement in said bores and restraining it against lateral movement.

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