Dec. 5, 1961 R. G. REIP 3,011,505

EJECTOR FOR USE IN A JET-TYPE HYDRAULIC RELAY REGULATOR

Filed Feb. 8, 1957 2 Sheets-Sheet 1

FIG. 1

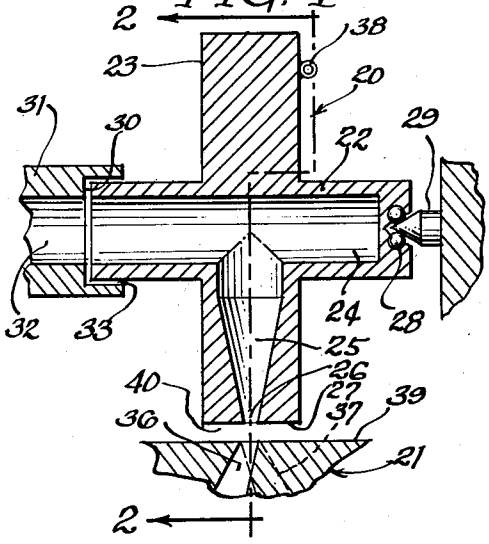


FIG. 2

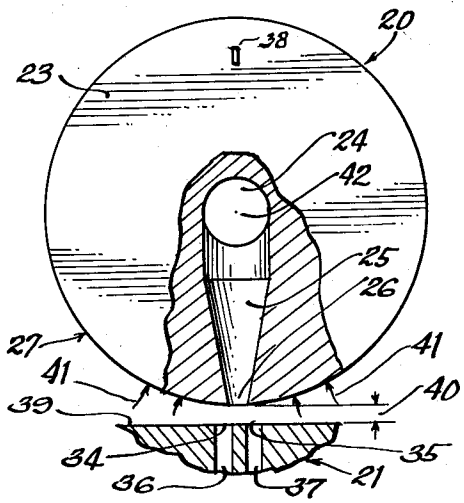


FIG. 3

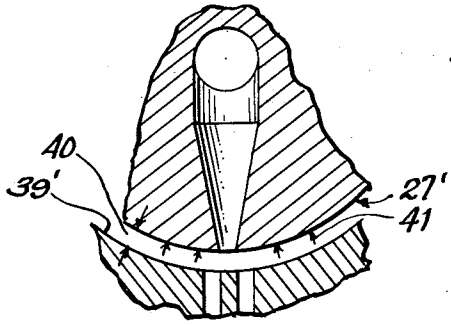


FIG. 4

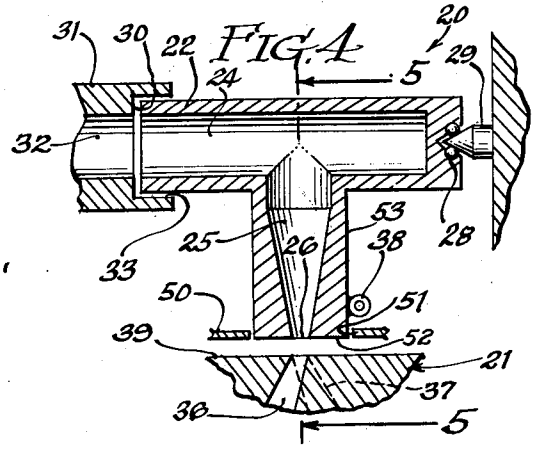


FIG. 5

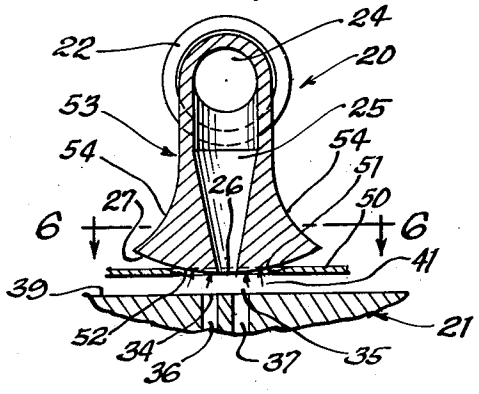
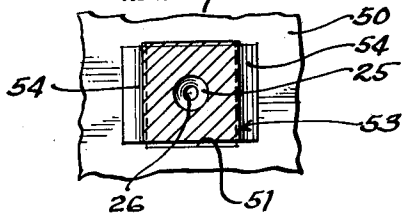


FIG. 6



INVENTOR.
Raymond G. Reip
BY
Attorneys

Dec. 5, 1961 R. G. REIP 3,011,505

EJECTOR FOR USE IN A JET-TYPE HYDRAULIC RELAY REGULATOR

Filed Feb. 8, 1957 2 Sheets-Sheet 2

FIG. 7

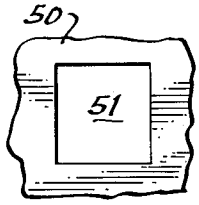


FIG. 8

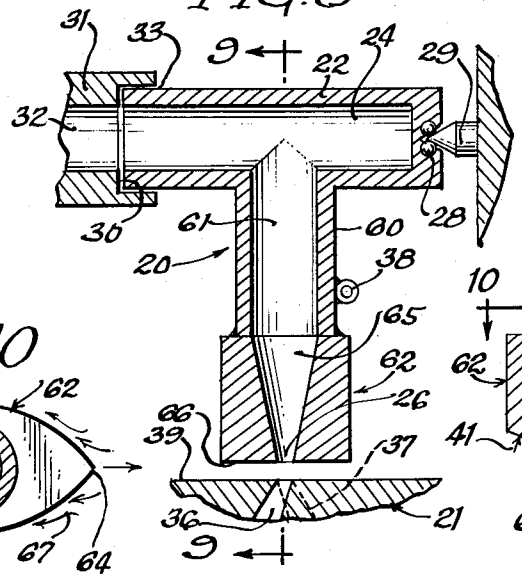


FIG. 9

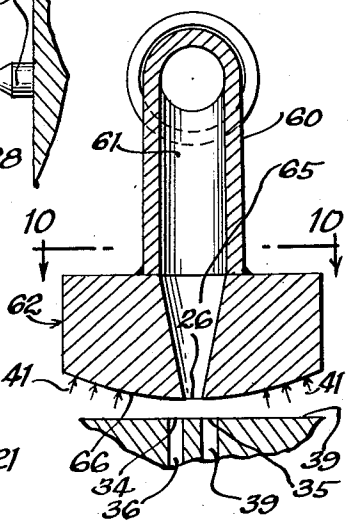


FIG. 10

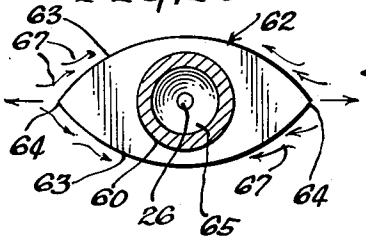
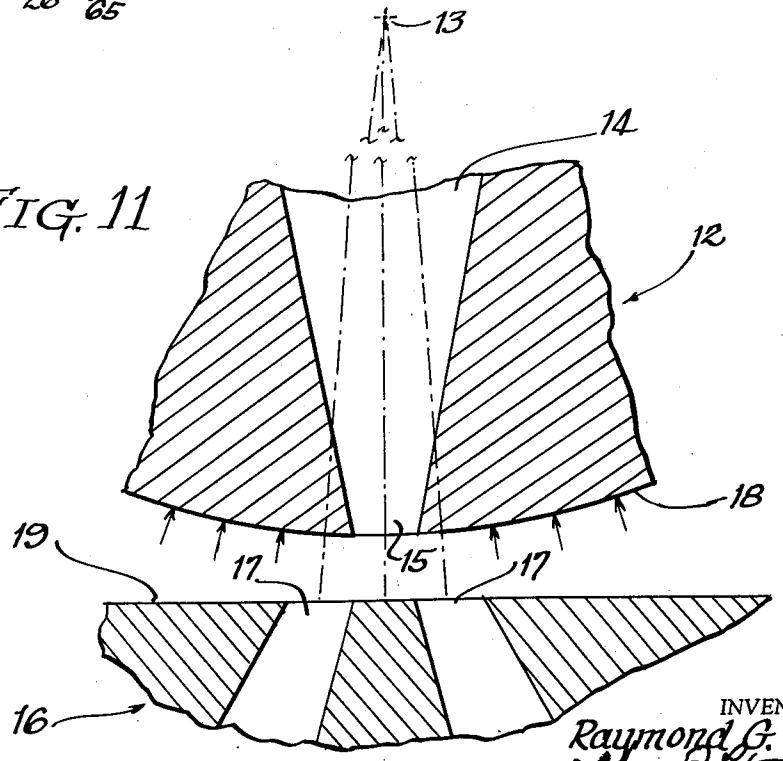


FIG. 11



INVENTOR.
Raymond G. Reip
BY
Attorneys

United States Patent Office 3,011,505 Patented Dec. 5, 1961

3,011,505

EJECTOR FOR USE IN A JET-TYPE HYDRAULIC RELAY REGULATOR

Raymond G. Reip, Chicago, Ill., assignor to Askania Regulator Company, Chicago, Ill., a corporation of Illinois

Filed Feb. 8, 1957, Ser. No. 639,170
2 Claims. (Cl. 137—83)

The present invention relates to hydraulic relay regulators of the type wherein a fluid jet is directed from one to the other of two relatively movable members to vary its registration and force delivery to a port in the member toward which it is directed, such as in the jet pipe regulator. The invention is directed more particularly to reduction of "noise," that is, vibration of the movable one of the two members of the regulator, namely the ejector member and the receiver member, the undesirable noise resulting from turbulent fluid irregularly striking against and tending to move the movable member. Turbulence arises from discharge of pressurized fluid from one member to the other.

A conventional jet pipe regulator comprises an elongated pipe or nozzle having a discharge orifice at one end and extended radial from a spindle that is mounted for rotative movement about its axis, whereby fluid supplied through the spindle is discharged from the orifice of the jet pipe. In the usual arrangement, a control signal is applied to the jet pipe for determining its angular position relative to the spindle axis, which position determines the relative degree of registration of the discharge orifice with one, or relative degrees of registration with the different ones of a pair of receiver ports formed in a receiver unit and closely spaced in the direction of the jet pipe swing.

By this arrangement, the angular position of the jet pipe as determined by the control signal applied thereto, determines the magnitude of pressure developed in each receiver port, the pressure being developed by kinetic energy of the stream of pressurized fluid discharged from the orifice and entering and impinging on fluid within each port, the pressure being transmitted from each port to a utilization device, as from the ports of a dual port receiver to opposite sides of the movable wall of a dual expansible chamber power unit whereby a differential of the pressures results in a movement of the chamber wall at a speed that is proportional to the angular position of the jet pipe and to the magnitude of the control signal input.

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, determined by such factors as limits of orifice travel, necessity of avoiding interference with the jet by fluid being returned from the power unit, and mass of the movable assembly are kept. In a conventional jet pipe, driven by a diaphragm device a discharge orifice diameter of the order of three millimeters is conventional. The receiver ports are slightly larger in diameter than the discharge orifice.

Another factor which contributes to the aforementioned desirable characteristics is the highly balanced suspension system wherein a hollow spindle, to which the jet pipe is attached, has one end mounted in a high precision bearing while the other end is mounted for rotation to a tubular stud through which fluid is delivered to the interior of the spindle. 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 factors contributing to the desirable characteristics for which the jet pipe relay regulator is known also tend to impose limits upon the magnitudes of pressure and volume rate of delivery of the fluid delivered to the regulator which in turn determines the rate of energy delivery to the utilization device.

There are numerous applications of hydraulic relay regulation where the maximum fluid delivery capacity of the practical conventional jet pipe of the prior art is not sufficient to provide the required operating speed, as in situations requiring high speed and high power utilization devices. For these applications, it has been found necessary to supplement the conventional jet pipe with a second power amplifying stage comprising a four-way service valve, the arrangement being one well known to those skilled in the art. There are, however, attendant disadvantages with that addition into the conventional jet pipe relay arrangement; primarily, increase of cost of equipment and numerical increase of highly precisioned parts, thereby increasing possibilities of service or failure problems.

It is a primary object of the invention to provide a novel jet type of relay regulator capable of delivering fluid at pressures and volume rates materially in excess of those that have been satisfactorily usable in conventional regulators, and that retains all of the advantages of the conventional jet pipe regulator.

It has been discovered, with all other factors being at their highest effectiveness, that one of the principal limitations on the maximum pressure, and thus the maximum flow delivered which can be utilized by the standard jet pipe, is that of noise, particularly that created by conditions of turbulence of fluid in the region of the jet pipe discharge orifice and which turbulence increases with increasing delivery pressure and volume rate. Even the liquid catcher as presented in Patent No. 2,228,015, issued Janauary 7, 1941, to Neukirch, whereby means were provided to reduce turbulence of liquid in the region of the jet pipe discharge and which has been effective in jet pipes supplied at the limited pressures of the order of one hundred pounds per square inch, is ineffective at increased pressures of the order of approximately four hundred pounds per square inch, and at such pressures the noise or vibration of the jet pipe due to random forces acting against it from the turbulence of the fluid rebounding from the surface of receiver unit and returning from the passages thereof prevents satisfactory jet pipe operation.

For this reason, a further object of the present invention is to provide an improved regulator of the general type indicated herein, wherein the jet position-disturbing effects of fluid turbulence forces occurring due to fluid discharging against and rebounding from the surface of the receiver unit and forcibly ejected from the passages and ports thereof is largely eliminated even at pressures substantially higher than heretofore used successfully.

Another object of the present invention is to provide an improved regulator of the general type indicated herein wherein the forces acting on the movable ejector unit in the direction of movement thereof due to fluid turbulences caused by the transmission and return of the fluid between the ejector unit and the receiver unit are caused to act substantially normal to the axis of support of the ejector unit whereby they are dissipated by the suspension structure of the ejector unit rather than tending to deflect the delivery unit from its signal-responsive position.

Yet another object of the present invention is to provide a novel regulator of the general type indicated wherein the surface of the ejector unit extending in the

direction of movement of the discharge orifice and adjacent the discharge orifice of the unit has a profile that curves in the direction of orifice movement, the points along the curved-surface being equidistant from the axis of swinging of the ejector unit, whereby fluid forces due to turbulence, necessarily acting in directions extended normal to the curved surface of the ejector unit, act perpendicular to the axis of rotation of the ejector unit and are taken up by the bearings in which the unit rotates.

These and other objects may be readily comprehended by reference to the following description and accompanying drawings wherein:

FIG. 1 is a median section of a suspended ejector unit and showing the adjacent receiver ports in section, the arrangement being in accordance with the present invention.

FIG. 2 is an elevation partly broken as indicated by the line 2—2 of FIG. 1.

FIG. 3 is a fragmentary section showing a modified form of the profile of the surface of the ejector unit and receiver unit adjacent the discharge orifice and receiver ports.

FIG. 4 is a median section similar to FIG. 1 and disclosing a modified form of the invention.

FIG. 5 is a section on line 5—5 of FIG. 4.

FIG. 6 is a view, partly in section, on line 6—6 in FIG. 5.

FIG. 7 is a fragmentary plan view of the baffle plate of FIGS. 5 and 6.

FIG. 8 is a median section similar to FIG. 1 and showing another modification of the present invention.

FIG. 9 is a section on line 9—9 of FIG. 8.

FIG. 10 is a view, partly in section, on line 10—10 of FIG. 9.

FIG. 11 is a fragmentary section showing the basic feature of the invention.

Although the invention is embodied herein in several different forms, it is to be understood that the invention is not to be so limited thereby; on the contrary, numerous modifications and alternate constructions may be conceived without departing from the true spirit and scope of the invention as defined in the appended claims.

Referring now to the drawings, FIG. 11 shows in profile the parts and the fluid passages in the area immediately surrounding the location of a stream of fluid passing between the two relatively movable structures of a regulator that embodies the invention.

The upper structure **12** is the movable structure and, as is conventional in jet pipe practice, is considered to be the delivery or ejector member. It may be delicately suspended so as to rotate about an axis **13** in a direction parallel to the plane of the paper in a variety of known ways, including that described. It has a radial passage **14** through which fluid under pressure may be delivered and ejected from a discharge orifice **15** in the edge of the structure, the supply stream formed thereby being discharged in a direction radial to the axis of rotation **13** of the unit **12**.

The lower structure **16** is considered to be the stationary unit, and may have a pair of closely spaced receiving ports **17** formed therein in opposition to the swing path of discharge orifice **15**. The ports **17** are connected to service passages which can be connected to a utilization system of such nature, a piston and cylinder power unit, for example, that in the case that more of the fluid ejected from discharge orifice **15** enters one of the ports **17** than enters the other, by reason of unequal registration of orifice **15** with the different ports, fluid would necessarily be forcibly ejected from the other port.

Ejector unit **12** may be required to be highly responsive to the application of a very minute signal force, by rotating slightly in either direction away from a neutral position wherein the discharge orifice is in equal registration with both receiver ports **17**. By this arrangement, wherein the portion of the supply stream of fluid received at each port depends on the degree of registration of that port with the discharge orifice, the sense and magnitude of difference in pressures between the fluids in the two ports and service lines connected to them is proportioned to the sense and magnitude of the variance of signal force from a neutral or zero value, as translated by the position of the movable ejector unit. It will be apparent that for accuracy of response, the angular position of the ejector unit should be, so far as possible, free from position affecting influences other than that of the signal force.

There are, however, conditions present in the region between the confronting surfaces **18** and **19** of the ejector and receiver units **12** and **16** respectively that tend to create ejector position disturbing forces that in the conventional jet pipe systems of the prior art have imposed certain limits of practically usable volume rates and pressures of fluid supply. One such condition is set up by a portion of the supply stream striking the surface of the receiver unit **16** in the region of ports **17** and rebounding therefrom against the surface **18** of the movable ejector unit **12**. Another arises whenever a difference of fluid pressure exists between the respective ports and a stream of fluid is emitted forcibly from the low pressure port, which stream strikes the surface **18** of the ejector unit. Additionally, the fluid in the region of ports **17** tends to be extremely turbulent. Forces resulting from these conditions in the region of the discharge orifice and receiver ports are exerted upon the movable ejector structure.

It is easily comprehensible that should ejector unit **12** have surface portions the profiles of which are not circumferentially concentric to the axis of rotation **13** of the unit and which are positioned to have the described forces exerted on them, those forces would tend to rotate the unit in a manner to disturb and to affect adversely the position response of the unit to the magnitude of the signal force whereby the angular position of the discharge orifice **15** would not be a true reflection of the sense of the applied signal. The heretofore conventionally employed jet pipe, a radial delivery pipe projecting from a supporting spindle has been so provided with such surfaces so positioned that pressures and volume rates of fluid supply have had to be strictly limited to limit magnitudes of the described forces and their ejector position-disturbing effects to tolerable levels. The present invention provides a structural arrangement that inherently is insensitive to disturbing effects of such forces, whereby volume rate and pressure of fluid supply can be very materially increased as compared to the jet pipe limits heretofore conventionally maintained. The basis of the present invention is an arcuate configuration of surface **18** about axis **13** and extended at least throughout the region wherein the described disturbing conditions prevail. By this arrangement, forces developed by the turbulent and forcible stream conditions are exerted on structure **12** in directions extended normal to the curved surface **18**, minimizing their rotation producing effect on structure **12**.

Referring to FIGS. 1 through 3, a hydraulic relay regulator arranged according to the invention comprises a pair of structures or units **20** and **21**, one of which **20** is considered as the ejector unit and the other of which is considered to be the receiver unit. The ejector unit **20** is disclosed as including two elements, shown here as integral, an elongated, hollow spindle **22** and a circular fluid discharge element **23** surrounding and coaxial with the spindle. A fluid passage **24** is formed within the spindle **22** and, to minimize mass and inertia of the movable assembly, may be extended through substantially the entire spindle length. A radial flow passage **25** is formed within the discharge element **23** and connects at its inner end with the passage **24**, tapering to a discharge orifice **26** at the circular periphery **27** of the element **23**.

The ejector unit **20** is mounted for rotative movement about the longitudinal axis of spindle **22**, relative to the

stationary receiver unit 21, by a highly precisioned suspension system arranged to minimize frictional resistance to the regular movement of the unit 20. One end of the spindle 22 has a high precision bearing 28 secured therein for rotating about a fixed journal 29 and the other end is adapted for rotation within the recessed end 30 of a stud 31. A small portion of the pressure fluid delivered from a supply passage 32 within the stud 31 to the spindle passage 24, for discharge through the orifice 26, escapes through a narrow clearance 33 between the opposing surfaces of the spindle and the stud. This flowing film of escaping fluid serves to maintain the relatively movable surfaces in non-contacting relation, thereby minimizing frictional resistance to rotative movement of the spindle.

Unit 21, of which only a portion is shown, is provided with a pair of apertures 34 and 35 directly opposite the orifice 26 and aligned and closely spaced in direction of movement, the apertures serving as receiver ports, and has formed therein a pair of passages 36 and 37 communicating with the ports for connection of the latter to a pair of service lines, such as may be connected to opposite ends of the cylinder of a power unit.

By the arrangement thus far described, it may well be understood that as the units 20, 21 are mounted for selective movement in directions whereby the relative degrees of registration of the discharge orifice 26 with the two receiver ports 34, 35 is variable by such relative motion, the magnitude of pressure developed within each of the ports by kinetic energy of the stream of fluid discharged from the orifice is a function of the relative position of the units as determined by the magnitude and sense of a control signal input applied to the ejector unit at 38.

As mentioned hereinbefore, the proximity of the discharge orifice of the ejector unit 20 to the surface 39 of the receiver unit in the area adjacent the orifice and the ports is of importance relative to obtaining the high efficiency of recovery of pressure. In a regulator of the port and orifice sizes suggested in the introductory portion hereof, a spacing, indicated by dimension 40 in FIGS. 2 and 3, of the order of three-sixteenths inch is satisfactory, this distance being non-critical, however.

As noted before, however, the close proximity of the surfaces of the two units in the particular area mentioned, that is, about the discharge orifice 26 and the receiver ports 34, 35 results in the presence in the immediate vicinity of the ejector structure of a body of turbulent fluid having considerable energy and force. With respect to the conventional jet pipe arrangement mentioned hereinbefore, the forces exerted by the turbulent fluid can at certain pressures act upon the jet pipe in such a manner as to effect the efficiency of the jet pipe relay. By visualizing the action of the turbulent and irregularly varying forces against all sides of the usually narrow, elongated jet pipe, it may be readily seen that the forces, particularly those acting against the jet pipe in the directions of travel, may rise to such a magnitude as to actually cause vibration and lower frequency displacement of the pipe from its correct position. As such displacement tendencies may be in aiding or opposing relation to the force exerted on the jet pipe by the control signal, an error is introduced into the system. Magnitudes of such disturbing forces are a function of magnitude of pressure of fluid discharge by the jet pipe, and an inverse function of spacing of the discharge orifice from the receiver surface.

In order to minimize the undesirable jet pipe-displacing effect of random fluid forces while retaining the desirable close proximity of the involved surface areas, so that higher pressures resulting in increased fluid flows may be successfully utilized in the system, the jet pipe is formed to present a curved surface 27 to these forces, which forces are suggested by arrows 41 in FIG. 2. The center of the curved surface 27, whether an arc of particular dimension or whether a closed circle as shown in FIG. 2, is located at the axis of rotation 42 of the ejector unit 20.

The effects of the forces 41, acting normal to the curved surface 27 of the unit 20, are transmitted in directions extended radially of, and toward, the axis of rotation of the unit 20 where they, the forces, are absorbed by the bearing structures at each end of the unit. By this arrangement, the ordinarily disadvantageous effect of the turbulent forces represented at 41, which effect up to the present time has prevented the jet pipe relay from utilizing the higher fluid pressures of which it is capable and which are desirable in many instances, is substantially eliminated; this improvement being the basis of the present invention.

As disclosed in FIGS. 1 and 2, the surface 39 of the receiver unit 21 may be plane, or, as shown in FIG. 3 at 39', it may be arcuately profiled and concentric with the ejector surface 27.

The relay unit of FIGS. 1 and 2 may be immersed in fluid enclosed in a fluid-tight compartment and turbulent forces throughout the fluid body may be free to act against all portions of the circular surface 27, thus the circular periphery of the discharge element 27 is shown as comprising a complete circle to obtain the optimum benefits of the improvement.

By placing a baffle plate 50 (FIG. 4), having an opening 51 therein through which a segment of the discharge element symmetrical about orifice 26 may extend into adjacency with surface 39 of the receiver unit, spaced therefrom a sufficient distance so as to allow for the proper transfer of the fluid jet and so as not to interfere with the escape of the excess and the returning fluid from the area of transmission, the turbulent forces represented at 41 may be confined to acting against only that portion 52 of the curved surface 27 of the element 53 exposed by the opening 51.

Thus by restricting the peripheral extent of the area of the element 23 against which the turbulent forces 41 are permitted to act, the element 23 may be modified to the form of segment 53, as in FIGS. 4 and 5, the lateral sides 54 of which may be curved inwardly to minimize the mass of the segment, and those sides 54 being shielded by plate 50 from forces exerted by turbulent fluid. The radial flow passage 25 is formed centrally of the segment, communicating at its inner end with the spindle passage 24 and tapering at its outer end to the discharge orifice 26 at the periphery 52 of the segment. The opening 51 of plate 50 should be of dimensions sufficiently close to those of the segment 53 to prevent the turbulent forces from escaping the enclosed area and acting on surfaces 54 but should allow the segment 53 freedom of movement necessary for its operation.

By this modified arrangement, as with the structure of FIGS. 1 and 2, the effect of the turbulent forces arising from that portion of the pressure fluid discharged from the orifice 26 and not entering the receiving ports 34, 35 but striking the surface 39 of the receiving structure, and arising also from the pressure fluid forcibly returning from one of the receiver ports, is substantially eliminated as the forces act perpendicular to the axis of rotation of the integral segment 53 and spindle 22 and are absorbed by the bearing units at each end of the spindle.

Referring to FIGS. 8 through 10, another modified version of the invention is disclosed. Here, the discharge element 20 is disclosed as comprising an elongated tubular pipe 60 integral with the spindle and extending radially therefrom at an angular position determined by the magnitude of a control input signal impulse applied at 38.

The pipe 60 has a passage 61 formed therein communicating at its inner end with the passage 24 in the spindle 22 whereby pressure fluid entering the passage 24 from the supply passage 32 in the stud 31 is delivered radially outward. At the end of the pipe 60 and secured thereto is a body 62, the external configuration designed to minimize the jet pipe displacing effect of turbulent fluid in the region of discharge orifice 26. To this end

surfaces 63 are streamlined in the directions of jet pipe swing and at each end of body 62 merge in a point 64. The width of the structure 62 at its middle is slightly more than the diameter of the pipe 60 so as to provide for a passage 65 formed centrally therein, the passage registering at its inner end with the pipe passage 61 and tapering to the discharge orifice 26 at the surface 66 of the base of the nozzle structure 62.

The profile of the surface 66 of body 62 comprises a segment of a cylinder extending in the direction of movement of the ejector unit 20, the center of which is located at the axis of rotation of the unit 20. As in FIGS. 1 and 2, the receiver unit 21 includes a closely spaced pair of receiver ports 34 and 35, the ports being aligned in the path of movement of the discharge orifice 26.

By the modified arrangement, a conventional jet pipe is altered to the extent of providing the nozzle structure 62 described, whereby the majority of forces caused as hereinbefore described are rendered ineffective to displace the jet pipe, due to their acting normal to surface 66 of the nozzle and perpendicular to the axis of rotation of the unit 20, and being absorbed by the bearings at each end of the ejector unit spindle rather than being exerted to swing the jet pipe 60. Those forces 67 which escape around the ends of structure 62 are also rendered partially ineffective as regards their action against the nozzle structure 62 in the directions of movement thereof, due to the pointed ends 64 and the curving sides 63 of the structure 62.

From the foregoing, it will be seen that the employment of a surface the periphery of which is arcuate and centered upon the axis of swing of the movable unit, and whether the unit be the ejector as herein, or the receiver which latter is practicable also, of the hydraulic relay regulator, will substantially minimize the effect of the fluid forces that develop in the space between the units, and particularly it will minimize the effect of those forces acting against the movable unit in the directions of movement thereof. By this arrangement, and without changing or affecting the factors that are important to the attainment of the advantageous characteristics of the jet type relay regulators, fluid pressures and volume rates of delivery materially higher than those heretofore usable in jet pipe assemblies may be employed, thus enabling capacities of this type of relay regulator to be very greatly increased.

I claim:

1. In a fluid jet-type hydraulic relay regulator means, a stationary wall member having an aperture opening through a surface portion thereof confronting a continuously unobstructed space; a cylindrical ejector having a port opening through a portion of the cylindrical peripheral surface thereof; a passage through the ejector for delivering fluid under pressure to said port to pass outwardly therefrom to said space; and means mounting said ejector for oscillative pivotal movement about its axis with said portion of the ejector movable in an arc closely adjacent said portion of the stationary wall member to direct the fluid through said space and into said aperture.

2. The regulator means of claim 1 wherein said ejector comprises a tubular axial portion and a radially enlarged mid-portion substantially midway between the ends of the tubular portion and provided with a radially outwardly narrowing passage communicating with said port.

References Cited in the file of this patent

UNITED STATES PATENTS

825,998	Wilkinson	July 17, 1906
2,724,397	Zieboiz	Nov. 22, 1955
2,742,919	Ray	Apr. 24, 1956
2,848,041	Hollings et al.	Aug. 19, 1958
2,904,057	Callender et al.	Sept. 15, 1959

FOREIGN PATENTS

410,244	Italy	Sept. 28, 1942
638,380	Great Britain	Aug. 8, 1947