VARIABLE GAIN JET PIPE SERVO VALVE
5 Claims, 5 Drawing Figs.

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Primary Examiner—Lloyd L. King
Attorneys—Derek P. Lawrence, Lee H. Sachs, Frank L.
Neuhauser, Oscar B. Waddell, Thomas J. Bird, Jr. and
Joseph B. Forman

ABSTRACT: A variable gain jet pipe device is disclosed which
comprises a nozzle, receiver means downstream of the nozzle,
and pressure recovery varying means interposed between the
nozzle and receiver means. The pressure recovery varying
means comprises movable means for deflecting the jetstream
relative to the receiver, which means is adapted to pass a portion
of the jetstream toward the receiver, and a diverter which is
adapted to divert part of the passed stream from the
receivers during a portion only of the stroke of the pressure
recovery varying means.
VARIABLE GAIN JET PIPE SERVO VALVE

The invention described and claimed in the U.S. patent application herein resulted from work done under U.S. Government contract FA-SS-66-6. The U.S. Government has an irrevocable, nonexclusive license under said application to practice, and has practiced the invention claimed herein, including the unlimited right to sublicense others to practice and have practiced the claimed invention for any purpose whatsoever.

BACKGROUND OF THE INVENTION

This invention relates to jet pipe servo valves and more particularly to servo valves having a variable gain characteristic. A jet pipe servo valve comprising a jet nozzle for generating a relatively high velocity liquid jetstream, receiver means for converting the kinetic energy of the jetstream into a recoverable pressure, and means for deflecting the jet stream relative to the receiver means are common to the control arts. As described, these jet pipe devices have a gain characteristic, i.e., pressure recovery versus jetstream deflection curve, which is nearly linear over the operating range of the jetstream deflection means. In many applications for these devices, however, it is preferable that a servo valve have a gain characteristic in which the slope of the recovered pressure versus input signal curve varies with the relative magnitude of the input signal. For example, in some applications it is desirable that the servo valve gain be relatively high near null and somewhat lower than the null gain when the valve operates near saturation. In other applications for the device, it may be desirable to provide a converse variable gain characteristic. It is further desirable in the interest of structural simplicity that the means for providing this variable gain characteristic be included in the jetstream deflection means. Prior art methods for providing a variable gain characteristic usually incorporated a second stage servo valve which may be driven by a jet pipe device and comprises a piston slideable in a cylinder wherein the cylinder piston combination provides a flow path which includes variable gain porting. This typical prior art device can, however, be simplified and the need for a second stage to provide variable gain can be eliminated if the jetstream deflecting means includes means for providing the desired variable gain characteristic.

OBJECTS OF THE INVENTION

It is therefore an object of this invention to provide a jet pipe servo valve in which the jetstream deflecting means includes means for varying servo valve gain as a function of relative input signal magnitude.

A further object of this invention is to provide such a jet pipe device which will have a relatively high gain near null and a relatively low gain near saturation.

A still further object of this invention is to provide such a jet pipe device which will have a relatively low gain about null and a relatively high gain near and about saturation.

SUMMARY OF THE INVENTION

Briefly stated, the invention is a variable gain jet pipe device comprising a nozzle for converting pressurized fluid into a relatively high velocity jetstream, receiver means for converting kinetic energy of the jetstream to pressure energy, and pressure recovery varying means interposed between the nozzle and the receiver means, the varying means comprising movable means for directing the jetstream relative to the receiver means and adapted to pass at least a portion of the jetstream toward the receiver means, and a diverter for diverting part of the passed portion of the jet stream from the receiver means during a portion only of the stroke of the movable directing means.

DESCRIPTION OF THE DRAWINGS

While the invention is particularly pointed out and distinctly claimed in the claims appended hereto, it is believed that the invention will be better understood by reference to the discussion below and the accompanying drawings in which:

FIG. 1 is a partially diagrammatic, partially fragmented section view of one embodiment of this invention illustrating the invention operating at a null position;

FIG. 2 is a sectional perspective view of the pressure recovery varying means incorporated in the jet pipe device of FIG. 1;

FIG. 3 is a partially fragmented section view of the jet pipe device shown in FIG. 1 operating in a low gain region;

FIG. 4 is a partially fragmented section view of the jet pipe device shown in FIG. 1 operating in a high gain region;

FIG. 5 is a partially fragmented section view of a further embodiment of this invention and illustrates a jet pipe device in a null position;

FIG. 6 is a partially fragmented section view of the jet pipe device shown in FIG. 5 operating in its high gain region;

FIG. 7 is a partially fragmented section view of the jet pipe device shown in FIG. 5 operating in its low gain region; and

FIG. 8 is a composite graph showing a typical gain characteristic of the devices of FIG. 1 and FIG. 5.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring first to FIG. 1, a jet pipe device 10 is shown which comprises a jet pipe 12, a nozzle 14 on the end of jet pipe 12 for generating a high velocity jetstream, receiver means 16 disposed downstream of the nozzle 14 and including receivers 18 disposed to be impinged upon by at least a portion of the jetstream, and a pressure recovery varying means 20 which includes means (not shown) for effecting motion thereof in response to a control input. Also shown is a source of pressurized fluid 22 connected to the jet pipe 12 by suitable conduit 24 and a load device 26 which comprises a cylinder 28, a piston 30 slideable in cylinder 28, and a piston rod 32 extending through one end of cylinder 28 and being adapted to drive a suitable load. Conduits 34 are provided to pass fluid from receiver 18 to opposite sides of the piston 30, the pressure differential across the piston 30, when held immobile, being dependent upon the proportionate areas of the receivers 18 upon which the jetstream impinges and system limitations such as fluid source pressure, and distance between the nozzle 14 and the receivers 18.

Referring now to FIGS. 1 and 2, pressure recovery varying means 20 includes a cavity 36 defined by divider plate 40, top plate 38, and walls 42 and 46 and being vented by vent passageway 44. Means 20 can be formed by machining a solid piece of material into a unitary structure consisting of divider plate 40 and walls 42 and 46 and securing a separate top plate 38 to walls 42 by bonding, welding, threaded fasteners, or other suitable means. Alternatively, means 20 can be a three piece structure consisting of a separately machined piece which includes walls 42 and separate top plate 38 and divider plate 40, both of which are secured to walls 42 as described above. Other means of fabrication will occur to those skilled in the mechanical design arts.

Top plate 38 serves as a means for directing the jetstream 48 from the nozzle 14 to the receivers 18. For this purpose, the top plate 38 includes an opening 46 whose dimension parallel to the direction of motion of means 20 exceeds the diameter of jetstream 48. Opening 46 may be circular as indicated in FIG. 2, however, this is not necessary as long as the above-mentioned dimensional relationship is maintained. Additionally, opening 46 is formed with a smoothly curved entrance profile 50, which appears continuously along the edge thereof.

A hole 52 having a dimension parallel to the direction of motion of means 20 which is approximately equal to the diameter of jetstream 48 (in the case of a circular hole as indicated in FIG. 2, hole 52 would have a diameter equal to the
jet stream 48 diameter) is provided in bottom plate 40. Means 20 will operate as desired if hole 52 has a dimension smaller than that of jetstream 48, however, a portion of the jetstream 48 which is dependent upon the actual dimensional relationship would be diverted through vent 44 and thus not be available for useful work. If, on the other hand, hole 52 were significantly larger than jetstream 48, device 10 would have a dead band wherein motion of means 20 would result in no corresponding difference in the proportions of jetstream 48 directed into the respective receivers 18. The saturation of 52 includes means comprising a sharply defined lip 54 angularly oriented toward a direction opposite the flow of jetstream 48, lip 54 being continuous around the periphery of hole 52.

FIG. 3 illustrates operation of jet pipe device 10 when pressure recovery varying means 20 is in a position near or about its null position. With means 20 in the position shown in FIG. 3, jetstream 48 is undeflected as it passes through opening 46; however, lip 54 is located so that it is impinging upon jetstream 48 thereby diverting a portion of the jetstream into cavity 36 and ultimately to the discharge vent 44. At the same time, the edge of hole 52 has moved closer to the point of intersection of receivers 18, the net result being that a greater portion of jetstream 48 is directed into the left receiver 18 than is directed into the right receiver 18. This results in a higher pressure in left receiver 18 than in the right receiver 18 which, by reference to FIG. 1, can be seen to impart a pressure differential across piston 30 and thus cause motion thereof. An opposite direction of the described pressure differential would, of course, result if means 20 were moved to its corresponding position on the right of center.

FIG. 4 illustrates the operation of jet pipe device 10 when means 20 is in a position near saturation of device 10. In the near saturation or high gain position, jetstream 48 is deflected by entrance profile 50 so that substantially all of jetstream 48 is directed through hole 52. Some of jetstream 48 will be diverted by lip 54 into cavity 36 and thus outwardly through vent 44; however, the proportion which will be so diverted is small compared to the amount which is diverted during operation in the low gain region as shown by FIG. 3. Inasmuch as the majority of the jetstream 48 is directed into one of the receivers 18 when means 20 operates within a range near saturation, the ratio of pressure recovered by receiver means 16 to incremental motion of means 20 is relatively high compared to the same ratio resulting when means 20 is operated near its null position.

As indicated by the illustrations of FIGS. 3 and 4, the point at which gain of the device 10 begins to increase is that point in the motion of means 20 where entrance profile 50 contacts the outer boundary of jetstream 48. Thus the point of gain change can be designed into means 20 by specifying the dimensional relationship between opening 46 and jetstream 48. For example, if opening 46 is only slightly larger than jetstream 48, the low gain region of device 10 would encompass a relatively small band of travel of means 20 about null, and the high gain region would encompass two relatively wide bands of motion of means 20 near saturation. Conversely, if opening 46 is made considerably larger than jetstream 48, yet is maintained small enough to effect a gain change at some point between the saturation limits of device 10, the low gain region would encompass a relatively large portion of the stroke of means 20 about null and the high gain region would encompass two relatively small bands of the means 20 stroke near the high gain to low gain relationship. This relationship will, of course, depend upon the particular characteristics required of a jet pipe device by the control system into which it is to be incorporated.

FIGS. 5 through 7 illustrate an alternate embodiment of the invention which has a high gain when operated about null and a relatively low gain when operated near saturation. This embodiment is a jet pipe device 10 which comprises the jet pipe 12, nozzle 14, and receiver 16 of the device shown in FIG. 1 and includes an alternate pressure recovery varying means 51.

Means 51 comprises a movable deflecting plate 56 (which includes means—not shown—for effecting motion thereof in response to a control input) having an opening 58 therethrough and a diverter 60 having a structure to be described below. Opening 58 has a dimension parallel to the direction of motion of plate 56 which is somewhat smaller than the corresponding dimension of jetstream 48 so that plate 56 will allow only a portion of jetstream 48 to pass to receivers 18. Thus, by moving plate 56 in either direction away from the axis of jetstream 48, the relatively constant portion of jetstream 48 passed can be variably directed to provide a greater quantity of fluid to one of receivers 18 than to the other thereof. Plate 56 additionally includes lips 57 to aid in disposal of that portion of jetstream 48 which is not permitted to pass through opening 58; however, lips 57 are not necessary to the practice of the invention. Opening 58 may have a periphery which is circular, rectangular, or of any other configuration which can be provided within the limits of practicality, and lip 57 may extend continuously around the periphery thereof.

Diverter 60 is a fixed structure comprising a top plate 62 having a hole 64 formed therein and secured in spaced relation to the intersection of the interior walls of receivers 18. Hole 64 can have the same shape as opening 58 and similarly includes a sharply defined turning means comprising lip 66 continuously formed around its periphery. Hole 64 is larger than opening 58, the ratio between their sizes being dependent upon the desired ratio between the bandwidth of high gain operation and the bandwidth of low gain operation.

FIG. 6 illustrates the jet pipe device 10 with plate 56 in an off-null position which is within the high gain operating region. With plate 56 in the position illustrated, that portion of jetstream 48 which is allowed to pass through plate 56 is directed into receivers 18 in proportions dependent upon the displacement of plate 56 from the line of intersection of the axes of receivers 18.

Referring now to FIG. 7, if plate 56 is displaced far enough, part of the passed portion of the jetstream 48 will be diverted by lip 66 away from receiver means 16 and will not be realized as recovered pressure in receivers 18. Thus, the ratio of pressure differential between receivers 18 to incremental motion of plate 56 will be lower than the same ratio when plate 56 is operating in the position shown in FIG. 6. The point at which this ratio (i.e., gain) changes is determined by the dimensional relationship between hole 64 and opening 58. For example, if hole 64 is only slightly larger than opening 58, high gain operation will encompass only a small band of movement of plate 56 about null. Conversely, if hole 64 is considerably larger than opening 58, but still within limits of a low gain region somewhere near saturation, the high gain region will encompass a relatively wide band of motion of plate 56 about null, and the low gain region will encompass two relatively small bands of translation of plate 56 near saturation.

FIG. 8 illustrates a typical operating characteristic of a jet pipe device incorporating the invention described herein. For simplicity of illustration, two jet pipe devices having the same characteristic about null have been assumed. Lines 70 represent the near saturation characteristic of the FIG. 1 embodiment, and lines 72 represent the near saturation characteristic of the FIG. 5 embodiment. Considering first the characteristic of the device shown in FIG. 1, the relationship between pressure differential across receivers 18 and the motion of pressure recovery varying means 20 about null is defined by line 68, the gain in this region being the slope of line 68. When means 20 is displaced an amount dependent upon the dimensional relationship described in conjunction therewith, the pressure difference-displacement relationship approaches that shown by line 70. The FIG. 5 embodiment has a differential pressure-input characteristic about null which is defined by line 68, the gain thereof being equivalent to the slope of line 68, and a characteristic near saturation which is defined by line 72, the gain near saturation being defined by the slope of line 72.

What I claim is:

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1. A variable gain jet pipe device comprising, a nozzle for converting pressurized fluid into a relatively high velocity jetstream; receiver means downstream of said nozzle for receiving said jetstream and for converting the kinetic energy of said jetstream into pressure energy, said receiver means comprising at least two fluid receivers; and movable pressure recovery varying means interposed between said nozzle and said receiver means, said varying means comprising:

   two spaced plates aligned substantially perpendicular to said jetstream, each of said plates having an opening adapted to pass at least a portion of said jetstream toward said receiver means;

   a first of said plates including means for modulating the amount of said jetstream which passes to said receiver means through said opening in the second of said plates, whereby the recovery pressure differential in said receivers varies in a nonlinear manner in response to increments of movement of said varying means.

2. A jet pipe device as recited in claim 1, wherein said modulating means comprise said opening in the first of said plates, said first plate opening having a dimension parallel to the direction of motion of said varying means larger than the cross section of said jetstream and further having a smoothly curved entrance profile upon which said jetstream impinges during a portion of the movement of said varying means.

3. A jet pipe device as recited in claim 2, further characterized in that said plates form portions of a movable structure having a top plate, a bottom plate, and a wall member forming a cavity between said top and bottom plates, wherein said top plate comprises said first plate and said bottom plate comprises said second plate.

4. A jet pipe device as recited in claim 3, further characterized in that said opening in said second plate has a dimension parallel to the direction of motion of said varying means smaller than the corresponding dimension of said opening in said first plate.

5. A jet pipe device as recited in claim 4, further characterized in that said opening in said second plate includes turning means extending from said second plate toward said first plate for diverting a portion of said jetstream into said cavity, and further including means for venting said cavity.