

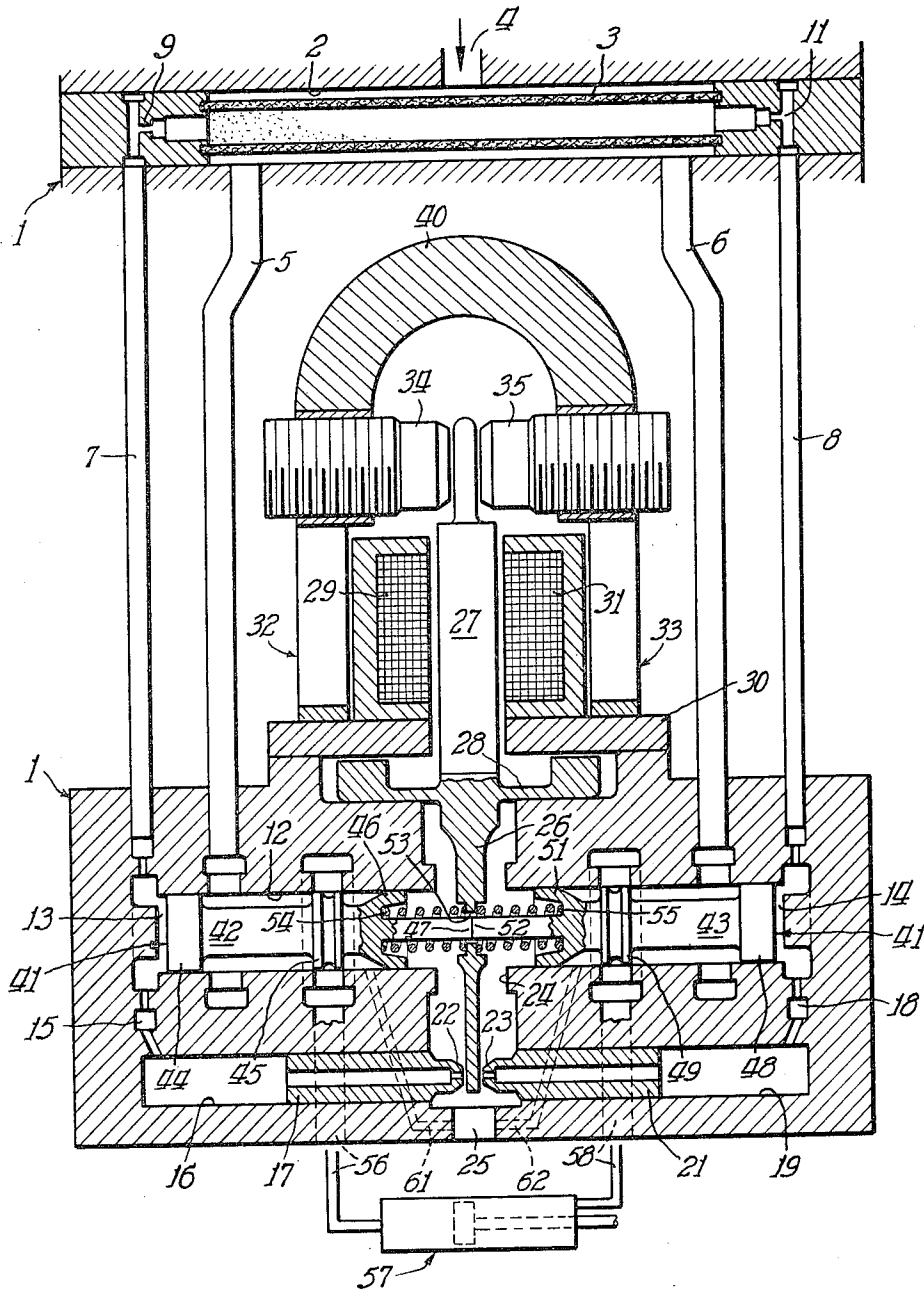
Dec. 14, 1965

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3,223,104

ELECTRO-HYDRAULIC SERVO VALVE

Original Filed Aug. 31, 1959



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3,223,104

ELECTRO-HYDRAULIC SERVO VALVE

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Continuation of application Ser. No. 836,967, Aug. 31,
1959. This application Oct. 26, 1962, Ser. No. 237,421
10 Claims. (Cl. 137-85)

This is a continuation of application Serial No. 836,967,
filed August 31, 1959, and now abandoned.

This invention relates to electrically controlled, hy-
draulic valves of the type generally referred to as
"transfer valves," or electrohydraulic servo valves.

One object of the present invention is the provision of
new and improved valves of the above type which have
an electrically actuated torque motor, a movable vane
or flapper controlled thereby, a pair of nozzles at op-
posite sides of the flapper and near one end thereof,
and shuttle means, having a mechanical communication
with the flapper, disposed between the torque motor and
the nozzles.

Another object of the present invention is the pro-
vision of a device in accordance with the preceding object
in which a single filter mechanism is employed.

Another object is the provision of a transfer valve of
the type having an electrically controlled flapper and in
which means are provided which isolate the flapper from
the impact of fluid returning to the valve from a con-
trolled device.

Other objects and features of the invention will be
readily apparent to those skilled in the art from the
specification and appended drawing illustrating a certain
preferred embodiment in which:

The figure is a schematic representation of a transfer
valve embodying the principles of the present invention.

Referring now to the figure, there is disclosed a body
indicated in general by the numeral 1; in the schematic
figure this is shown in two spaced parts, but it will be
readily apparent to those skilled in the art that in the
actual construction there is no separation. In the upper
portion of the figure the body 1 is illustrated as having
an elongated opening 2 in which there is disposed an elon-
gated filter assembly 3. This filter assembly is formed
of sintered metal wire and serves to trap any foreign
particles entering the valve hydraulic amplifier circuit in
the hydraulic fluid.

Communicating with the opening 2 is a pressure port
4. In normal system operation, the pressure of the
hydraulic fluid supplied to this port may be of the order
of 3,000 p.s.i. Hydraulic fluid at substantially this
pressure is, therefore, supplied to the passages 5 and 6,
which communicate with spaced points of the opening
2. The opposite ends of the opening 2 communicate with
fluid passages 7 and 8, through pressure restrictors 9 and
11 respectively, whereby fluid of the order of 300 to 700
p.s.i. is supplied to these passages.

Passages 5, 6, 7, and 8 communicate with an elongated
cylindrical opening 12 in the body 1; the passages 7
and 8 communicate with the opposite end portions 13
and 14, respectively, of the opening 12 while the passages
5 and 6 communicate with spaced points intermediate the
ends of the opening 12. End portion 13 of opening 12
is in fluid communication, through passage 15, with an
opening 16 in the body 1 in which there is disposed
a nozzle 17. Similarly, end portion 14 of opening 12 is
in communication, through a passage 18 with an opening
19 in the body 1 in which there is disposed a nozzle 21.
The nozzles 17 and 21 have ends 22 and 23, respectively,
which project into a central opening 24 extending verti-
cally, in the view of the figure, through the body 1. A

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port 25 is provided in the body 1 communicating the open-
ing 24 with the sump for the hydraulic fluid, port 25
therefore serving as the "return" port.

Disposed within the opening 24 is an elongated flapper
26. Flapper 26 has one end portion disposed between
the nozzles 17 and 21 and closely adjacent the ends 22
and 23 thereof, the spacing being such that when the
flapper is moved toward one of these ends the flow of
fluid therethrough is progressively restricted while the
flow of fluid through the opposite nozzle is progressively
increased. The opposite end of flapper 26 is integrally
connected to an armature 27 of an electro magnetic
material. Integral with the flapper 26—armature 27 unit
is a flexible diaphragm seal 28 of beryllium copper or
spring steel. The seal is generally circular in configura-
tion and is fixedly and sealably connected to the body 1
in such a manner that the armature 27 is isolated from
any fluid in the opening 24.

The armature 27 is part of an electro magnetic torque
motor comprising electrical coils 29 and 31—which are
preferably bifilar wound to reduce inductance to a mini-
mum—and pole pieces indicated in general by the numer-
als 30, 32 and 33 of electro magnetic material. In addi-
tion, there is provided a pair of top pole pieces of electro
magnetic material 34 and 35 which are adjustably mount-
ed and which are closely spaced from the extreme end
of the armature 27. Also there is a permanent magnet
40, preferably of Alnico 5 material, of generally horse-
shoe shape, the ends of which are in intimate contact
with pole pieces 32 and 33.

Referring once again to the elongated opening 12 in
the body 1, disposed therein is a shuttle assembly, which
is indicated in general by the numeral 41. The shuttle
assembly comprises two identical cylinder shuttles
42 and 43 which are oppositely directed. Shuttle 42 has
spaced lands 44 and 45, a flow shield 46 (to be discussed
more fully hereinafter) and an elongated nose 47. Simi-
larly, shuttle 43 has lands 48 and 49, a flow shield 51 and
a nose 52. When the device is in operation, fluid in the
end portions 13 and 14 of the opening 12 force the
shuttles 42 and 43 inwardly so that the noses 47 and 52
thereof are in engagement, as illustrated in the figure.
In this position the noses 47 and 52 extend into and
meet within an aperture 53 which extends through the
flapper 26, the dimension of aperture 53 being such that
the flapper 26 does not engage either of the shuttles re-
gardless of the flapper position. Disposed between the
flapper 26 and the flow shield 46 on the shuttle 42 is a
spring 54; similarly, disposed between the flapper 26
and the flow shield 51 is a spring 55, springs 54 and 55
surrounding the nose portions of their associated shuttles
as illustrated in the figure. In the illustrated position of
the shuttles 42 and 43, the land 45 on the shuttle 42 pre-
vents fluid flow between the opening 12 and a fluid pas-
sage 56 which serves as a utilization port for connection
to one side of a device controlled by the valve, and which
is schematically illustrated as a double acting piston 57.
Similarly, the land 49 on the shuttle 43 in the illus-
trated position prevents fluid flow between the opening 12
and a fluid passage 58 which serves as a utilization port
connecting the valve with the opposite side of the piston
57.

It should also be noted that within the body 1 there
is provided a fluid passage 61 which connects the return
port 25 with that portion of the opening 12 which is be-
tween the land 45 and the flow shield 46 on the shuttle
42. Similarly, there is provided a fluid passage 62 in the
body 1 connecting the return port 25 with that portion
of the opening 12 between the land 49 and the flow shield
51 on the shuttle 43.

OPERATION

As previously indicated, when high pressure fluid is supplied to the pressure port 4, filtered high pressure flows through the passages 5 and 6 to the opening 12, filling the space between lands 44 and 45 on the shuttle 42 and the space between land 48 and 49 on the shuttle 43. Filtered, lower pressure fluid is supplied to the passages 7 and 8; this fluid enters the end portions 14 and 13 of the opening 12 forcing the shuttles 42 and 43 into engagement, as previously indicated, against the bias of springs 54 and 55. This lower pressure fluid also flows through passages 15 and 18 and through nozzles 17 and 21 where it impinges upon the end portion of flapper 26, then flowing through the return port 25. If a differential control current flow occurs in the coils 29 and 31, the differential flux produced thereby, in combination with the D.C. flux provided by the magnet 40 will cause the armature 27 to move either clockwise or counterclockwise. Assuming armature 27 is moved in a counterclockwise direction, the flexible seal 28 will permit the flapper 26 to be moved in such a direction that the end portion thereof approaches the end 23 of the nozzle 21. As the flapper 26 approaches the nozzle 21, fluid flow therethrough is progressively inhibited; simultaneously, fluid flow through nozzle 17 becomes progressively less inhibited. As a result, the fluid pressure in end portion 13 of opening 12 will decrease while fluid flow pressure in end portion 14 will increase. The shuttle means 41, comprising the shuttles 42 and 43, will therefore be moved toward the left in the view of the figure. The springs 54 and 55, as explained in the copending application of Harvey F. Gerwig et al., S.N. 649,862, now U.S. Patent 2,933,106 entitled Electro-Hydraulic Valve, issued April 19, 1960, filed April 1, 1957, are of the constant tension type so that movement of the shuttle means 41 toward the left effects a linearly increasing force on the flapper 26 tending to return it toward its neutral position indicated in the figure. In other words, a mechanical feedback opposes the deflection of the flapper caused by the torque motor. The movement of the shuttle means 41 increases the feedback force on the flapper 26 until the flapper is returned to nearly its neutral position; the flapper will remain off-set only enough to hold sufficient differential pressure across the shuttle means 41 to compress the feedback spring 55. As the shuttle means 41 are displaced toward the left, the high pressure fluid in passage 6 will be supplied through the fluid passage 58 to the right end, in the view of the figure, of the double acting piston 57. Fluid to the left of the piston will be expelled through the fluid passage 56 and into the opening 12.

As may be readily visualized from the figure when the shuttle means are displaced to the left of the position illustrated, fluid entering the opening 12 from the fluid passage 56 will be between the land 45 and the flow shield 46. The flow shield 46 is, in effect, a land which engages the walls forming the opening 12 with only the sliding fit so that fluid cannot pass therebetween. The interior facing surface of the fluid shield 46 is generally cup-shaped so as to provide a seat for the spring 54. (The flow shield 51 is identical with the flow shield 46.) The fluid, therefore, between the land 45 and flow shield 46 will pass through the fluid passage 61 to the return port 25. It is important to notice that the land 45 will completely uncover its associated port, connecting the fluid passage 56 with the opening 12, before the flow shield 46 will block fluid flow through fluid passage 61. It is also important to note that the fluid ejected from the double acting piston 57 will flow through passage 56 and passage 61 to the return port 25 without in any way impinging upon the flapper 26, in view of the shielding effect of flow shield 46.

The shuttle means 41 will be displaced to the degree required by the torque motor. The fluid pressures in end portions 13 and 14 are substantially equalized when the flapper 26 is returned to its "almost neutral" position,

described before. The shuttle means 41 will remain in this displaced position until the differential current supplied to the electrical coils 29 and 31 will effect the opposite movement of the flapper 26, at which time the shuttle means 41 will be returned to the position illustrated, or some other position as desired. It may be readily apparent that the shuttle means 41 may be positioned within the opening 12 as desired. The operation of the device when the armature 27 is moved in a clockwise direction, as distinguished from the counterclockwise direction as discussed above, will be readily apparent to those skilled in the art.

As described in the aforementioned copending application, should a pressure failure occur with the device as described, the springs 54 and 55 force the shuttles 42 and 43 outwardly; in this condition, both ends of the double acting piston 57 are freely communicated with the return port 25. It should also be observed that, while the schematic figure does not disclose all of the constructional details, the body 1 is preferably provided with a pair of concentric sleeves within which the shuttle assembly 41 operates, as also described in the aforementioned copending application.

It should be noted that the device of the present invention is bilaterally identical which precludes null shifts which might be caused by temperature variations or temperature fluctuations. The single large ten micron filter used for both halves of the hydraulic amplifier assures long service life, low pressure drop and valve balance. The use of the armature, diaphragm and flapper assembly for a summation bridge for input and feedback forces assures linear valve operation, and by mechanically closing the feedback loop will cause the valve to maintain good amplitude characteristics even at high frequency operation. The placement of the nozzles at the bottom of the valve and near the extremity of the flapper 26 gives high amplifier gain at reasonable nozzle clearances and utilizes optimum acceleration damping characteristics and pressure feedback. In addition, the flow shields provided on the shuttles isolate the flapper from impact forces which might otherwise be derived from fluid flow through the valve.

While a certain preferred embodiment of the invention has been specifically disclosed, it is understood that the invention is not limited thereto, as many variations will be readily apparent to those skilled in the art and the invention is to be given its broadest possible interpretation within the terms of the following claims.

We claim:

1. In a transfer valve, an electro responsive torque motor, an elongated flapper operated by said torque motor, a body, means defining an elongated opening in said body, shuttle means in said elongated opening adapted for reciprocable movement therein, a flexible seal sealably connected to said flapper and said body and disposed between said torque motor and said shuttle means effective to isolate said torque motor from fluid, mechanical means operated by movement of said shuttle means to exert a feedback force on said flapper at a point intermediate the ends thereof, a pair of nozzles adapted for fluid flow therethrough respectively positioned at opposite sides of that extremity of said elongated flapper which is spaced from said torque motor and positioned immediately adjacent said flapper whereby movement of said flapper by said torque motor simultaneously and inversely varies the flow of fluid through said nozzles; and fluid passage means in said body including passages adapted to supply high pressure fluid to spaced portions of said elongated opening, including passages adapted to supply lower pressure fluid to opposite end portions of said elongated opening and to said nozzles, and including passages adapted to supply high pressure fluid from said elongated opening to a controlled device external of the transfer valve and vice versa upon movement of said shuttle means in said elongated opening.

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2. In a transfer valve, an electro responsive torque motor, an elongated flapper operated by said torque motor, a body, means defining an elongated opening in said body, shuttle means comprising a pair of shuttles in said elongated opening adapted for reciprocable movement therein, a flexible seal sealably connected to said flapper and said body and disposed between said torque motor and said shuttle means effective to isolate said torque motor from fluid, mechanical means operated by movement of said shuttle means to exert a feedback force on said flapper intermediate the ends thereof, a pair of nozzles adapted for fluid flow therethrough respectively positioned at opposite sides of that extremity of said elongated flapper which is spaced from said torque motor and positioned immediately adjacent said flapper whereby movement of said flapper by said torque motor simultaneously and inversely varies the flow of fluid through said nozzles; and fluid passage means in said body including passages adapted to supply high pressure fluid to spaced portions of said elongated opening, including passages adapted to supply lower pressure fluid to opposite end portions of said elongated opening and to said nozzles, and including passages adapted to supply high pressure fluid from said elongated opening to a controlled device external of the transfer valve and vice versa upon movement of said shuttle means in said elongated opening.

3. In a transfer valve, an electro responsive torque motor, an elongated flapper operated by said torque motor, a body, means defining an elongated opening in said body, shuttle means comprising a pair of shuttles in said elongated opening adapted for reciprocable movement therein, a flexible seal sealably connected to said flapper and said body and disposed between said torque motor and said shuttle means effective to isolate said torque motor from fluid, resilient means operated by movement of either of said pair of shuttles to exert a feedback force on said flapper means intermediate the ends thereof, a pair of nozzles adapted for fluid flow therethrough respectively positioned at opposite sides of that extremity of said elongated flapper which is spaced from said torque motor and positioned immediately adjacent said flapper whereby movement of said flapper by said torque motor simultaneously and inversely varies the flow of fluid through said nozzles; and fluid passage means in said body including passages adapted to supply high pressure fluid to spaced portions of said elongated opening and to said nozzles, and including passages adapted to supply high pressure fluid from said elongated opening to a controlled device external of the transfer valve and vice versa upon movement of said shuttle means in said elongated opening.

4. In a transfer valve, an electro responsive torque motor, an elongated flapper operated by said torque motor, a body, means defining an elongated opening in said body, shuttle means comprising a pair of shuttles in said elongated opening adapted for reciprocable movement therein, a flexible seal sealably connected to said flapper and said body and disposed between said torque motor and said shuttle means effective to isolate said torque motor from fluid, aperture defining means in an intermediate portion of said elongated flapper, means on said shuttles adapted to extend through said aperture defining means, a pair of spring means respectively disposed between said shuttles and flapper operated by relative movement therebetween to exert a feedback force on said flapper intermediate the ends thereof, a pair of nozzles adapted for fluid flow therethrough respectively positioned at opposite sides of that extremity of said elongated flapper which is spaced from said torque motor and positioned immediately adjacent said flapper whereby movement of said flapper by said torque motor simultaneously and inversely varies the flow of fluid through said nozzles; and fluid passage means in said body including passages adapted to supply high pressure fluid to spaced portions of said elongated opening, including passages

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adapted to supply lower pressure fluid to opposite end portions of said elongated opening and to said nozzles, and including passages adapted to supply high pressure fluid from said elongated opening to a controlled device external of the transfer valve and vice versa upon movement of said shuttle means in said elongated opening.

5. In a transfer valve, an electro responsive torque motor, an elongated flapper operated by said torque motor, a body, means defining an elongated opening in said body, shuttle means in said elongated opening adapted for reciprocable movement therein, a fluid pressure supply port and a return port in said body, a flexible seal sealably connected to said flapper and said body and disposed between said torque motor and said shuttle means effective to isolate said torque motor from fluid, mechanical means operated by movement of said shuttle means to exert a feedback force on said flapper intermediate the ends thereof, a pair of nozzles adapted for fluid flow therethrough respectively positioned at opposite sides of that extremity of said elongated flapper which is spaced from said torque motor and positioned immediately adjacent said flapper whereby movement of said flapper by said torque motor simultaneously and inversely varies the flow of fluid through said nozzles; fluid passage means in said body including passages adapted to supply high pressure fluid to spaced portions of said elongated opening, including passages adapted to supply lower pressure fluid to opposite end portions of said elongated opening and to said nozzles, and including passages adapted to supply high pressure fluid from said elongated opening to a controlled device external of the transfer valve and vice versa upon movement of said shuttle means in said elongated opening; an elongated filter opening in said body, a single elongated filter in said filter opening, and means communicating said filter opening with said pressure port and said passages adapted to supply lower pressure fluid.

6. In a transfer valve, a body having an opening therein, a pressure port and a return port in said body, fluid passage means in said body adapted to communicate said opening with a controlled device, shuttle means having a first position within said opening and movable within said opening, first means on said shuttle means adapted to prevent fluid flow through said fluid passage means when said shuttle means occupy said first position thereof, a flapper, means for moving said flapper, nozzle means adapted for fluid flow therethrough and variably restrictable by movement of said flapper, other fluid passage means in said body communicating said nozzle means with spaced portions of said shuttle means whereby variations in restriction of said nozzle means effect movement of said shuttle means within said opening, shield means disposed between said first means and said flapper adapted to prevent fluid flow to said flapper from said fluid passage means when said shuttle means are displaced from said first position thereof, means communicating said opening at a position adjacent said shield means with said return port, and resilient means interposed between said shield means and said flapper whereby upon movement of said shuttle means from said first position, said resilient means is effective to apply a feed-back force against said flapper.

7. In a transfer valve, a body having an opening therein, a pressure port and a return port in said body, fluid passage means in said body adapted to communicate said opening with a controlled device, shuttle means having a first position within said opening and movable within said opening, first means on said shuttle means adapted to prevent fluid flow through said fluid passage means when said shuttle means occupy said first position thereof, a flapper, means for moving said flapper, nozzle means adapted for fluid flow therethrough and variably restrictable by movement of said flapper, other fluid passage means in said body communicating said nozzle means with spaced portions of said shuttle means whereby variations in restriction of said nozzle means effect movement of said shuttle means within said opening, shield means

carried by said shuttle means disposed between said first means and said flapper adapted to prevent fluid flow to said flapper from said fluid passage means when said shuttle means are displaced from said first position thereof, means communicating said opening at a position adjacent said shield means with said return port, and resilient means interposed between said shield means and said flapper whereby upon movement of said shuttle means from said first position, said resilient means is effective to apply a feed-back force against said flapper.

8. In a transfer valve, a body having an opening therein, a pressure port and a return port in said body, fluid passage means in said body adapted to communicate said opening with a controlled device, shuttle means having a first position within said opening and movable within said opening, first means on said shuttle means adapted to prevent fluid flow through said fluid passage means when said shuttle means occupy said first position thereof, a flapper, means for moving said flapper, nozzle means adapted for fluid flow therethrough and variably restrictable by movement of said flapper, other fluid passage means in said body communicating said nozzle means with spaced portions of said shuttle means whereby variations in restriction of said nozzle means effect movement of said shuttle means within said opening, shield means integral with said shuttle means disposed between said first means and said flapper adapted to prevent fluid flow to said flapper from said fluid passage means when said shuttle means are displaced from said first position thereof, means communicating said opening at a position adjacent said shield means with said return port, and resilient means interposed between said shield means and said flapper whereby upon movement of said shuttle means from said first position, said resilient means is effective to apply a feed-back force against said flapper.

9. In a transfer valve, a body having an opening therein, a pressure port and a return port in said body, fluid passage means in said body adapted to communicate said opening with a controlled device, shuttle means having a first position within said opening and movable within said opening, first means on said shuttle means adapted to prevent fluid flow through said fluid passage means when said shuttle means occupy said first position thereof, a flapper, an electro responsive torque motor for moving said flapper, nozzle means adapted for fluid flow therethrough and variably restrictable by movement of said flapper, other fluid passage means in said body communicating said nozzle means with spaced portions of said shuttle means whereby variations in restriction of said nozzle means effect movement of said shuttle means within said opening, resilient means disposed between said flapper and said shuttle means operated by movement of said shuttle means to exert a feedback force on said flapper intermediate the ends thereof, shield means adapted

to support said resilient means disposed between said first means and said flapper, said shield means being further adapted to prevent fluid flow to said flapper from said fluid passage means when said shield means are displaced from said first position thereof, and means communicating said opening at a position adjacent said shield means with said return port.

10. In a transfer valve, an electro responsive torque motor, an elongated flapper operated by said torque motor, a body having a fluid pressure port and a return port, means defining an elongated opening in said body, shuttle means comprising a pair of shuttles in said elongated opening adapted for reciprocable movement therein, a flexible seal sealably connected to said flapper and said body and disposed between said torque motor and said shuttle means effective to isolate said torque motor from fluid, mechanical means operated by movement of said shuttle means to exert a feedback force on said flapper intermediate the ends thereof, a pair of nozzles adapted for fluid flow therethrough respectively positioned at opposite sides of that extremity of said elongated flapper which is spaced from said torque motor and positioned immediately adjacent said flapper whereby movement of said flapper by said torque motor simultaneously and inversely varies the flow of fluid through said nozzles; fluid passage means in said body including passages adapted to supply high pressure fluid from said pressure port to spaced portions of said elongated opening, including passages adapted to supply lower pressure fluid to opposite end portions of said elongated opening and to said nozzles and return port, and including passages adapted to supply high pressure fluid from said elongated opening to a controlled device external of the transfer valve and vice versa upon movement of said shuttle means in said elongated opening, land means on said shuttle means normally adapted to prevent fluid flow through said passages adapted to supply high pressure fluid to spaced portions of said elongated opening, shield means disposed between said land means and said flapper adapted to prevent fluid flow to said flapper, and means communicating said elongated opening at a position adjacent said shield means with said return port.

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