March 18, 1958 D. V. HEALY 2,827,067

DAMPED ELECTROHYDRAULIC SERVO VALVE

Filed March 8, 1956

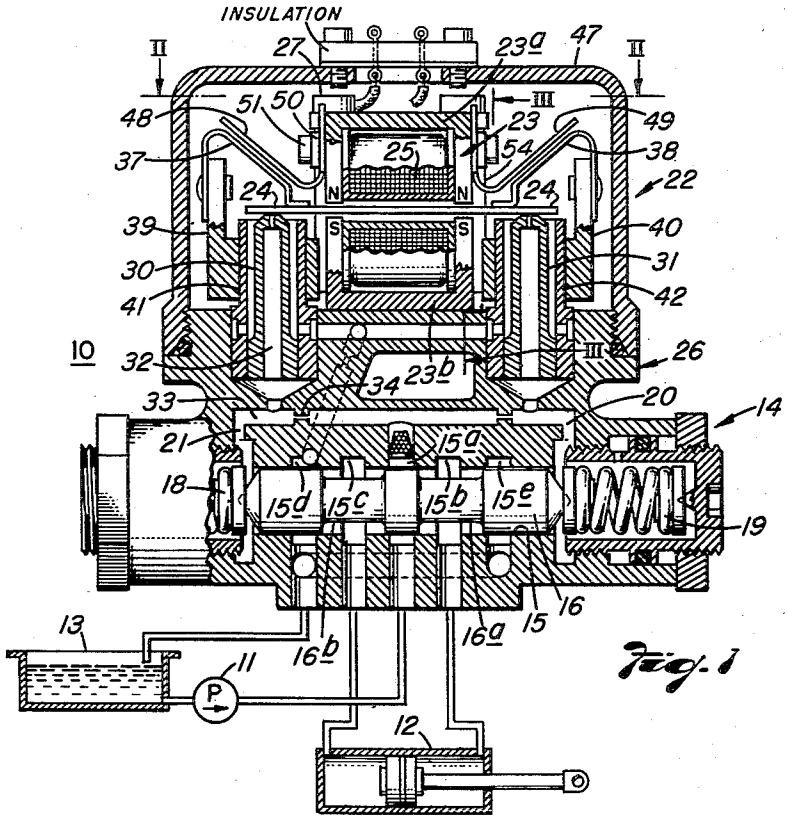
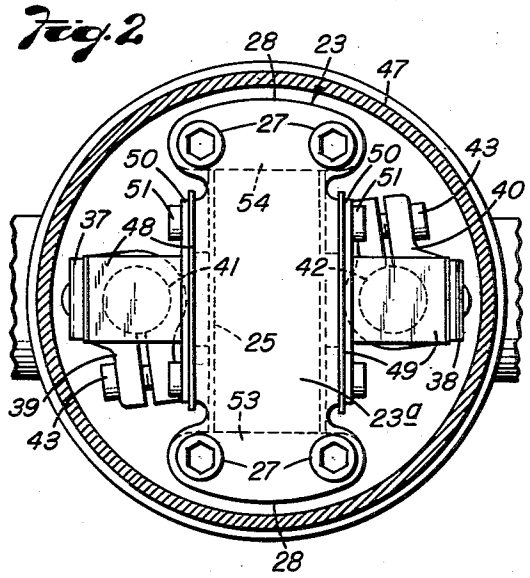



Fig. 1

Fig. 2



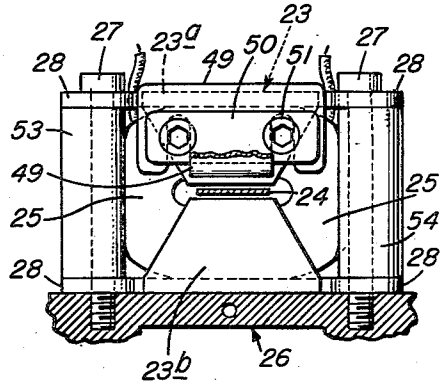




Fig. 3

INVENTOR.
D. V. HEALY
BY
ATTORNEY

United States Patent Office

2,827,067

Patented Mar. 18, 1958



2,827,067

# DAMPED ELECTROHYDRAULIC SERVO VALVE

Donald V. Healy, Northridge, Calif., assignor to Bendix Aviation Corporation, North Hollywood, Calif., a corporation of Delaware

Application March 8, 1956, Serial No. 570,356

7 Claims. (Cl. 137—82)

This invention relates to electrohydraulic servo valves of the type in which a light, movable armature of a sensitive electromagnetic motor or relay varies the position of a flow-impeding element with respect to a flow nozzle, to thereby produce pressure changes for hydraulic actuation of a valve controlling a hydraulic motor.

The function of a servo valve of this type is to control a relatively large amount of hydraulic power with a very weak electric signal that may change rapidly. It is found that when such servo valves are designed for extreme sensitivity and rapid response, they tend to become unstable and oscillate or sing spontaneously.

An object of the invention is to improve the stability of electrohydraulic servo valves.

A feature of the invention is an electrohydraulic servo valve of the type having a magnetically actuated armature controlling a flow nozzle, in which the armature is movably supported by leaf spring elements of such area that rapid movement thereof is damped by the resistance of the ambient fluid.

Other more specific objects and features of the invention will appear from the description to follow with reference to the drawing, in which:

Fig. 1 is a schematic diagram of a system incorporating a valve in accordance with the invention.

Fig. 2 is a view taken in the plane II—II of Fig. 1.

Fig. 3 is a view taken in the plane III—III of Fig. 1.

The present invention is shown applied to an electrohydraulic servo valve of the type disclosed in my application Serial No. 437,778, filed June 18, 1954, to which reference is made for details not specifically relating to the present invention.

The system shown in Fig. 1 consists of an electrohydraulic servo valve **10** incorporating the invention, for selectively controlling flow of pressure fluid from a pump **11** to either end of a load cylinder **12** and returning fluid from the other end of the load cylinder to a reservoir **13** which supplies the pump.

The lower portion **14** of the valve **10** comprises a conventional spool or shuttle-type four-way valve consisting of a valve cylinder **15** containing a pressure-actuated valve piston **16** movable from a central neutral position into either of two end positions. In the left end position of the piston **16**, an annular groove **16***a* therein connects an annular pressure port **15***a* in the cylinder to one annular motor port **15***b*, and an annular groove **16***b* in the piston connects another annular motor port **15***c* to a return port **15***d*, so that the piston of the load cylinder **12** is driven to the left. In the right end position of the valve piston **16**, the groove **16***b* thereof connects the pressure port **15***a* to the motor port **15***c*, and the piston groove **16***a* connects the motor port **15***b* to a return port **15***e*, so that the piston of the load cylinder **12** is driven to the right. In the neutral position of the valve piston **16**, as shown in Fig. 1, the grooves **16***a* and **16***b* of the piston are isolated from both the pressure port **15***a* and the motor ports **15***d* atnd **15***e*, so that the piston of the load cylinder **12** is locked in position.



The valve piston **16** is normally held in neutral position by helical compression springs **18** and **19** slightly compressed between the opposite ends of the piston and the adjacent ends of the cylinder. The piston is movable in either direction out of neutral position against the restraining force of the springs **18** and **19** by admitting fluid of different pressures to the opposite ends of the cylinder **15** through passages **20** and **21**, the relative pressures in which are controlled by an electromagnetic valve mechanism in the upper portion **22** of the valve **10**.

This upper portion **22** contains an electromagnetic motor or relay having a stationary field structure **23** and a movable armature element **24**, and a driving coil **25** surrounding the armature element **24**, the latter being of soft iron or similar material such that it is readily magnetized and demagnetized in response to changes in the current in the winding **25**. The field structure **23** comprises a pair of iron pole pieces **23***a* and **23***b* of general U-shape so associated with a pair of permanent magnets **53** and **54** that the upper pole piece **23***a* has a north pole at each end adjacent the armature, as indicated by the reference letters N, N, and the pole piece **23***b* has a south pole at each end adjacent the armature and juxtaposed to the north poles of the pole piece **23***a*. It will be apparent that a current in the winding **25** will oppositely magnetize the opposite ends of the armature element **24**, producing a force tending to rotate the armature about its midpoint in direction depending upon the direction of the current in the winding **25** and with a force proportional to the amplitude of the current.

As shown in Fig. 3, the pole pieces **23***a* and **23***b* are rigidly mounted with respect to the permanent magnets **53** and **54** and the frame **26** of the mechanism by four screws **27** extending through apertures in extensions **28** of the bight portions of the pole pieces **23***a* and **23***b*, the two pole pieces being maintained in accurately spaced relation to each other by the permanent magnets **53** and **54** interposed between the extensions **28** of the respective pole pieces.

Rotative movement of the armature element **24**, as previously described, varies the pressure delivered to the passages **20** and **21** in the following manner: The opposite ends of the armature **24** are juxtaposed to and in closely spaced relation to nozzles **30** and **31**, respectively. The nozzle **30** has a passage **32** connecting to a chamber **33** which in turn is connected by a restricted orifice **34** to the pressure port **15***a* and to the passage **21** leading to the left end of the valve cylinder **15**. The passage of the nozzle **31** is similarly connected by a restricted passage to the pressure port **15***a*, and to the passage **20** leading to the right end of the valve cylinder **15**.

When the armature element **24** is in neutral position, it equally impedes flow of fluid from the nozzles **30** and **31**, respectively, and the pressures in the motor passages **20** and **21** are equal so that the piston **16** remains in neutral position. If the armature **24** is rotated counterclockwise in response to energization of the coil **25** to move closer to the nozzle **30** and farther away from the nozzle **31**, then the flow through the nozzle **30** will be impeded to a greater extent than the flow through the nozzle **31**. This causes the pressure to rise in the chamber **33** and in the left end of the valve cylinder **15**, whereas the freer release of fluid from the nozzle **31** reduces the pressure in the right end of the valve cylinder, thereby producing movement of the valve piston **16** to the right. If the armature element **24** is rotated clockwise, the pressures are reversed, to move piston **16** to the left.

As previously indicated, valves of this type can be made extremely sensitive and capable of very rapid response, but when so constructed, they are apt to be unstable and oscillate or sing. In accordance with the present inventions, such undesired oscillations are reduced or

prevented by providing a damping action on the armature element 24.

Armature element 24 is supported for limited, restrained movement by a pair of leaf spring elements 37 and 38, respectively, rigidly connected to the armature element adjacent opposite ends thereof and extending from the armature at an angle of approximately 45° for an appreciable distance beyond which the ends are turned down and secured to supporting clamps 39 and 40, respectively, which are adjustably mounted on housings 41 and 42 which surround the nozzles 30 and 31, respectively. Each of the clamps 39 and 40, as shown in Fig. 2, is split and is adapted to be tightened about its supporting housing by a screw 43. By loosening the screw 43 of either clamp, the clamp can be adjusted axially with respect to the axis of the associated nozzle to center the related end of the armature element 24 in a desired position with respect to the magnet structure and the nozzle structure.

In normal operation, the entire mechanism 22 is enclosed in a hermetically sealed housing or cap 47 and is filled with oil. By virtue of the fact that the intermediate portions of the leaf springs 37 and 38 are relatively wide and have a substantial area, their movement is inherently damped to a certain extent by the ambient liquid in which they are immersed.

However, I find it desirable to further increase this damping effect by providing adjacent the intermediate flat portion of each leaf spring a stationary damping vane 48 or 49, respectively. Each damping vane 48 or 49, in addition to its rather large flat surface juxtaposed to the associated leaf spring 37 or 38, has a supporting or base portion bent at an angle and clamped to the upper pole piece 23*a* by a clamp strip 50 and screws 51. By loosening the screws 51, each damping vane 48 can be accurately adjusted to a desired closely spaced relation to the associated leaf spring 37 or 38.

It has been found by test that the damping structure described, including the stationary damping vanes 48 in closely spaced relation to the flat portions of the springs 37 and 38, effectively prevents undesired oscillation or singing of a valve without materially impairing its sensitivity or rapidity of response.

Although for the purpose of explaining the invention a particular embodiment thereof has been shown and described, obvious modifications will occur to a person skilled in the art, and I do not desire to be limited to the details shown and described.

I claim:

1. An electrohydraulic valve comprising: an electric motor having an element movable within a fixed short path and means responsive to an electric current for urging said movable element into a position within said path dependent upon the strength and polarity of said current; valve means controlled by said movable element and including a stationary nozzle and a flow-impeding element on said movable element movable with respect to said nozzle in response to said movement of the movable element in said path; a damping vane secured to said movable element for movement therewith to damp movement of said movable element by the frictional resistance to movement of said vane presented by the ambient fluid; and a stationary vane juxtaposed to said damping vane in close proximity thereto.

2. Apparatus according to claim 1 in which said vanes are substantially flat.

3. Apparatus according to claim 2 in which said vanes are so positioned relative to said path of movement of said movable element that movement varies the spacing between said vanes.

4. An electrohydraulic valve comprising: an electric motor having an element movable within a fixed short path and means responsive to an electric current for urging said movable element into a position within said path depending upon the strength and polarity of said current; valve means controlled by said movable element and including a stationary nozzle and a flow-impeding element on said movable element movable with respect to said nozzle in response to said movement of the movable element in said path; a damping vane secured to said movable element for movement therewith to damp movement of said movable element by the frictional resistance to movement of said vane presented by the ambient fluid; and stationary supporting means in spaced relation to said movable element; said damping vane comprising a leaf spring attached at one end to said movable element and at the other end to said supporting means.

5. Apparatus according to claim 4 in which said leaf spring has an intermediate flat portion, and a stationary vane juxtaposed to said flat portion in close proximity thereto.

6. Apparatus according to claim 4 in which said stationary supporting means comprises a cylindrical supporting member in fixed concentric relation to said nozzle; and a clamp on said cylindrical supporting member rotatably and axially adjustable thereon, said other end of said leaf spring being attached to said clamp for adjusting movement therewith.

7. Apparatus according to claim 1 in which said movable element and current responsive means are symmetrical about an axis of movement and said flow-impeding element and nozzle are on one side of said axis; a second stationary nozzle and second flow-impeding element on said movable element symmetrically disposed on the opposite side of said axis with respect to the first nozzle and flow-impeding element, so that movement of the movable element about said axis moves one flow-impeding element toward and the other away from its associated nozzle; said one damping vane being connected to said movable element on one side of said axis; another damping vane on said movable element symmetrically disposed on the opposite side of said axis with respect to said one vane; and another stationary means juxtaposed to said other damping vane in close proximity thereto.

**References Cited** in the file of this patent

UNITED STATES PATENTS

| | | |
|---|---|---|
| 2,625,136 | Moog | Jan. 13, 1953 |
| 2,773,660 | Rasmussen | Dec. 11, 1956 |

FOREIGN PATENTS

| | | |
|---|---|---|
| 562,645 | Great Britain | July 11, 1944 |