Dec. 10, 1968 N. D. TRBOVICH ET AL 3,415,283

TORQUE MOTOR

Filed Sept. 8, 1964

FIG. 1

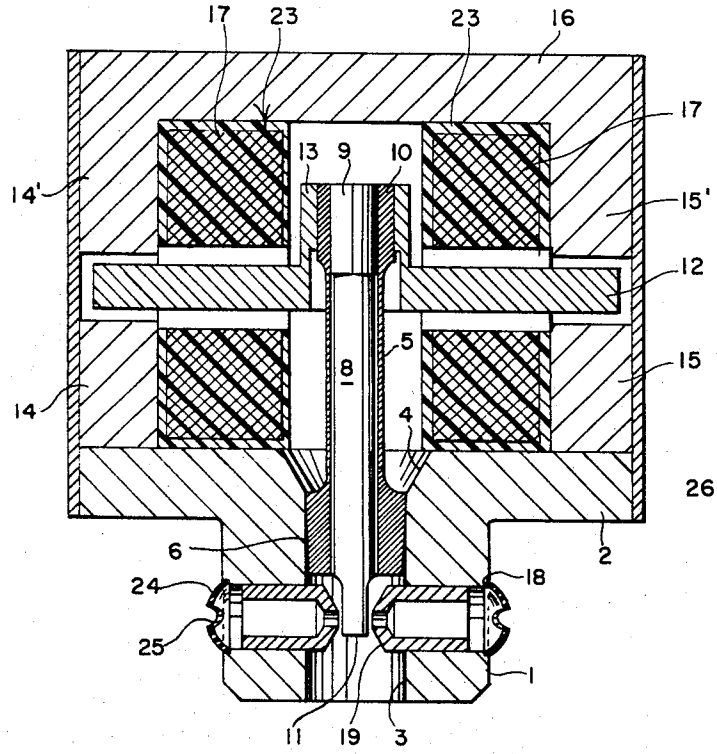



FIG. 2

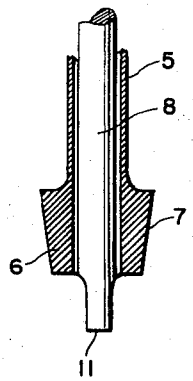



FIG. 3

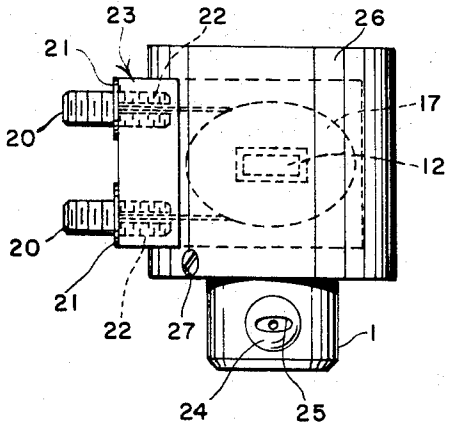
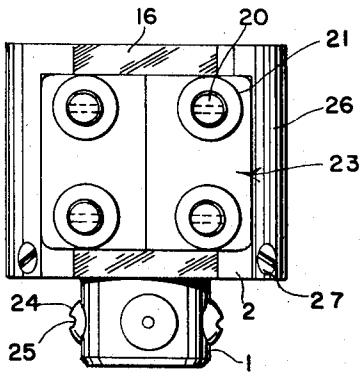



FIG. 4




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# TORQUE MOTOR

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## ABSTRACT OF THE DISCLOSURE

The nozzle block has a magnetic shunt integral therewith and a bore. A flexure tube is seated in the bore, and a flapper, carried by the flexure tube, extends beyond the tube into the bore. An armature is carried by the tube and magnetic control means are associated with the armature. Also, the magnetic control means includes an energizing coil and a terminal connected to the coil, the coil and the inner end of the terminal being encapsulated as a unit in electrically insulating material. In addition, the block has a lateral nozzle passage and a nozzle mounted in the passage and opening into the bore. A resiently yieldable dished sealing member is mounted in the block across the outer end of the passage, the block being of curvilinear side wall form and the sealing member normally projecting beyond the side wall of the block, the sealing member having a generally elliptical opening therethrough elongated circumferentially of the block.

This invention relates to a new and useful torque motor construction.

A primary object of our invention is to provide a torque motor flexure tube seating arrangement which is self-sealing, and which eliminates the need for a separate seal between the flexure tube and mounting plate.

Another object of our invention is to provide a flexure tube seating arrangement reducing the size of the torque motor as a whole, for greater compactness, while increasing the length of the flexure tube, for better stress distribution and increased life.

Still another object of our invention is to provide a nozzle block sealing arrangement of improved efficacy in sealing the nozzle passages when the block is inserted in the member to be controlled.

An additional object of our invention is to provide a torque motor incorporating coil terminals ready for connection to a circuit board or the like.

It is also an object of our invention to provide a high performance torque motor of simplified, relatively inexpensive design which is durable and dependable in operation.

In one aspect thereof, a torque motor constructed in accordance with our invention is characterized by the provision of a nozzle block having a bore, a flexure tube seated in the bore, a flapper carried by the flexure tube and extending therethrough into the bore, and an armature carried by the flexure tube.

In another aspect thereof, a torque motor constructed in accordance with our invention is characterized by the provision of a flexure tube, an armature connected to the flexure tube, an energizing coil associated with the armature, and a terminal connected to the coil, the coil and the inner end of the terminal being encapsulated as a unit in electrically insulating material.

In still another aspect thereof, a torque motor constructed in accordance with our invention is characterized by the provision of a nozzle block having a bore, a lateral nozzle passage through the block from the bore, a nozzle mounted in the passage and opening into the bore, and a resiliently yieldable disk shaped sealing member carried by said block at the outer end of the passage, the block



being of curvilinear side wall form, and the sealing member normally projecting beyond the side wall of the block, and having a generally elliptical opening therethrough elongated circumferentially of the block.

The foregoing and other objects, advantages and characterizing features of a torque tube constructed in accordance with our invention will become clearly apparent from the ensuing detailed description of an illustrative embodiment thereof, having reference to the accompanying drawing depicting the same wherein like reference numerals denote like parts throughout and wherein:

FIG. 1 is a vertical sectional view of a torque motor constructed in accordance with our invention;

FIG. 2 is an enlarged fragmentary longitudinal sectional view of the seat end of the flexure tube thereof;

FIG. 3 is a side elevational view thereof, on a reduced scale; and

FIG. 4 is end elevational view thereof.

Referring now to the accompanying drawing, the illustrative embodiment of our invention depicted therein has a nozzle block **1** of circular cross sectional configuration. Whereas such torque motors ordinarily have separate bottom shunt and mounting plates, it is a feature of our invention that the bottom shunt and mounting plates are combined into a single shunt mounting plate **2** of magnetic material. Plate **2** is integral with nozzle block **1**, whereby the block **1** and shunt **2** comprise a one-piece fabrication. A bore **3** is provided through block **1**, opening through plate **2** and provided thereat with a flared or tapered end **4**.

Also, whereas the flexure tube customarily is seated on the mounting plate, it is a feature of our invention that flexure tube **5** extends through plate **2** and is seated in the nozzle block bore **3**. To this end, flexure tube **5** is formed with an enlarged end **6** which is seated in bore **3**, having a force fit therein. The tube end **6** is guided into bore **3** by its flared end **4**, and is provided with a tapered side wall **7** force fitted in the bore so as to be self-sealing.

A flapper **8** extends through tube **5**, having an enlarged head **9** mounted in the opposite end **10** of flexure tube **5**. Flapper **8** extends through tube **5**, beyond the seat end **6** thereof, and terminates in an output end **11** projecting into bore **3** of nozzle block **1**.

A magnetic armature **12** is carried by flexure tube **5** in spaced relation to shunt plate **2**. Armature **12** is mounted on the end **10** of tube **5**, by a circular connecting ring member **13** which spaces armature **12** inwardly from the end **10** of tube **5**. This causes the armature to rotate about an axis through the natural pivot or bending point of the flexure tube, as more fully described in our pending application Ser. No. 224,305, filed Sept. 18, 1962 for Torque Motor, now Patent 3,238,398 dated Mar. 1, 1966.

Pole pieces **14**, **14'** and **15**, **15'** are provided on opposite sides of armature **12**, adjacent the opposite ends thereof. Pole pieces **14** and **15** are mounted on shunt plate **2**, in magnetic flux conducting relation thereto. Pole pieces **14'** and **15'** are connected to an upper shunt plate **16** in magnetic flux conducting relation thereto, being formed integrally therewithin in the illustrated embodiment. Permanent magnets (not shown) are provided on opposite sides of the paired pole pieces **14**, **14'** and **15**, **15'**, and energizing coils **17** encircle the opposite halves of armature **12**, for controlling pivoting of the armature and movement of the flapper end **11** in a manner known in the art (see, for example, the article "Small Displacement Electromechanical Actuators" by Nicholas D. Trbovich, one of the inventors herein, appearing in Military Systems Design for January-February, 1960, published by Instruments Publishing Company, Pittsburgh 12, Pennsylvania; and the article "The Torque Motor As a Separate

Servovalve Component," also by Nicholas D. Trbovich, appearing in Hydraulics & Pneumatics for May, 1964). Nozzle block **1** is provided with lateral nozzle passages **18** therethrough, and nozzle assemblies **19** are fitted in the passages **18**, projecting into bore **3** and opening therein on opposite sides of the flapper output end **11**. Opening and closing movement of flapper end **11** relative to the nozzle openings regulates fluid flow therethrough and thereby controls the fluid pressure in the nozzle.

Thus, it is seen that the torque motor of our invention is greatly simplified. There is provided only a single shunt-mounting plate **2**, instead of separate plates, thereby making the unit more compact. At the same time, the seating of tube **5** in the nozzle block bore lengthens the tube, for longer life. In addition, the tube is self-sealing in the nozzle block bore, whereby no separate seals are required, and no separate fastenings are necessary. This is particularly important when controlling hot gases.

Conventionally, the ends of coils **17** project from the motor, and must be separately attached to terminals which must be connected in the control circuit. However, it is another feature of our invention that the torque motor is provided with pre-set, built in terminals. This is accomplished as follows. Each end of each coil **17** is connected to a terminal **20** having a contact head **21**. The inner ends **22** of the terminals **20** connected to a particular coil, and the entire associated coil **17** are encapsulated in an electrically insulating material. Any suitable potting compound can be used, such as an epoxy resin. The insulating material is rigid when it sets, whereby each coil **17** and its terminals **20** are arranged in a self-sustaining, rigid, insulated sub-assembly unit **23**. When assembled in the torque motor the coil units **23** present terminals ready to be mounted on a circuit board. This greatly facilitates mounting and connection of the torque motor during installation.

Nozzle block **1** is adapted to be inserted into the control block, in the manner of a probe, and it is important that the outer ends of nozzle passages **18** be sealed against the escape of fluid along the side of the block. This poses a problem, particularly because of the curvilinear nature of nozzle block **1** which seats in a correspondingly curved structure (not shown).

Accordingly, it is a further feature of our invention that the nozzle passage ends are effectively sealed, by the provision of outwardly dished, resiliently yieldable sealing members **24**. These members are mounted in block **1**, across the outer ends of passages **18**, and normally project laterally outwardly beyond block **1**. When the block is inserted in place, sealing members **24** resiliently yield, somewhat in the manner of a Bellville spring, for sealing contact with block **1** and with the adjacent structure. To effectively seal around the passages **18**, while permitting the flow of fluid into the passages, the sealing members **24** are provided with generally elliptical openings **25** therethrough, which openings are elongated circumferentially of block **1**. This construction provides an effective sealing surface completely around the openings **25**.

The torque motor is completed by a shell-like housing **26** fastened to plates **2** and **16**, as by screws **27**, and holding the various parts in place as shown. Shunt plate **2**, armature **12**, pole pieces **14**, **14'** **15**, **15'** and upper shunt plate **16** can be of any suitable magnetic material of high permeability and low retentivity. Flexure tube **5** can be of any suitable non-magnetic spring material.

Accordingly, it is seen that our invention fully accomplishes its intended objects. While we have disclosed and described in detail only one embodiment of our invention, that has been done by way of illustration only, it being intended to include within the scope of the appended claims such modifications thereof and variations therein as will naturally occur to those skilled in the art.

Having fully disclosed and completely described our



invention, together with its mode of operation, what we claim as new is:

**1.** A torque motor comprising a nozzle block having a magnetic shunt integral therewith and having a bore, a flexure tube seated in said bore, a flapper carried by said flexure tube and extending therebeyond into said bore, an armature carried by said tube, and magnetic control means associated with said armature.

**2.** A torque motor comprising a one piece magnetic shunt and nozzle block, said nozzle block having a bore opening through said shunt, a flexure tube seated in said bore and extending through said shunt, a flapper carried by said flexure tube and extending therethrough into said bore, an armature carried by said flexure tube in spaced relation to said shunt, pole pieces on opposite sides of said armature adjacent the opposite ends thereof, the pole pieces on one side of said armature being mounted on said shunt in magnetic flux conductive relation thereto, another magnetic shunt connected to the pole pieces on the other side of said armature in magnetic flux conductive relation thereto, and electromagnetic control coils associated with said armature.

**3.** A torque motor as set forth in claim **2**, together with terminals connected to said coils, each coil and the inner ends of its terminals being encapsulated in a rigid block of insulating material.

**4.** A torque motor comprising, a magnetic shunt mounting plate, a nozzle block integral with said plate and projecting from one face thereof, a bore in said block opening through said plate, a flexure tube seated at one end in said bore, a flapper carried by said flexure tube adjacent the opposite end thereof, said flapper extending through said tube beyond said one end thereof and terminating in on output end in said bore, a pair of nozzles carried by said block, said nozzles opening into said bore on oppoiste sides of said output end, an armature carried by said tube in spaced relation to said plate, paired pole pieces on opposite sides of said armature adjacent the opposite sides of said output end, an armature carried by armature being magnetically connected to said plate, another magnetic shunt magnetically connected to the others of said pole pieces, and energizing coils encircling the opposite end portions of said armature.

**5.** A torque motor having a pre-set built in terminal comprising a flexure tube seated adjacent one end thereof in said motor, an armature connected to said flexure tube adjacent the opposite end thereof, means including an energizing coil associated with said armature for controlling pivoting thereof, said terminal connected to said coil, said coil and the inner end of said terminal being encapsulated as a unit in a rigid block of electrically insulating material whereby said terminal and said coil and said block comprises a single self-sustaining unit.

**6.** A torque motor having a pair of pre-set built in terminals comprising a flexture tube seated adjacent one end thereof in said motor, a flapper carried by said flexure tube adjacent the opposite end thereof, an armature mounted on said flexure tube adjacent said opposite end thereof, means including an energizing coil encirling said armature for controlling pivoting thereof, said pair of terminals connected to the ends of said coil, and a rigid body of electrically insulating material encapsulating said coil, the inner ends of said terminals being embedded in said insulating body whereby said terminals and said coil and said body comprise a single self-sustaining unit.

**7.** A torque motor comprising a nozzle block having a bore, a lateral nozzle passage through said block from said bore, a nozzle mounted in said passage and opening into said bore, and a resiliently yieldable dished sealing member mounted in said block across the outer end of said passage, said block being of curvilinear side wall form, and said member normally projecting beyond the side wall of said block and having a generally elliptical opening therethrough elongated circumferentially of said block.

8. A torque motor comprising a generally cylindrical nozzle block having a bore, a flapper having an output end extending into said bore, a nozzle passage extending laterally through said block from said bore, a nozzle mounted in said passage and opening into said bore adjacent said flapper output end, and a sealing washer carried by said block around the outer end of said passage, said washer comprising an outwardly dished member of resiliently yieldable material normally projecting outwardly beyond said block and having a generally elliptical opening therethrough, said opening being elongated circumferentially of said block.

9. A torque motor as set forth in claim 1, said flexure tube having an enlarged end seated in said bore, and said armature being carried by said flexure tube in spaced relation to said nozzle block.

10. A torque motor as set forth in claim 9, said flexure tube end being of tapered side wall form and seated in said bore with a force fit.

11. A torque motor as set forth in claim 2, said flexure tube having an enlarged end of tapered side wall form seated in said bore with a force fit.

12. A torque motor comprising a magnetic shunt mounting plate, a nozzle block integral with said plate and projecting from one face thereof, a bore in said block opening through said plate, a flexure tube having an enlarged end of tapered side wall form seated in said bore with a force fit, a flapper carried by said flexure tube adjacent the opposite end thereof, said flapper extending through said tube beyond said one end thereof and terminating in an output end in said bore, a pair of nozzle passages extending laterally through said block from said bore, a pair of nozzles mounted in said passages and opening into said bore adjacent said flapper output end, sealing washers carried by said block around the outer ends of said passages, said washers comprising outwardly dished members of resiliently yieldable material normally projecting outwardly beyond said block and having a generally elliptical opening therethrough, said block being of curvilinear side wall form and said openings being elongated circumferentially of said block, an armature carried by said tube in spaced relation to said plate, paired pole pieces on opposite sides of said armature adjacent the opposite ends thereof, said pole pieces on one side of said armature being magnetically connected to said plate, another magnetic shunt magnetically connected to the others of said pole pieces, energizing coils encircling the opposite end portions of said armature, and terminals connected to said coils, the inner ends of said terminals being incapsulated as a unit with the associated one of said coils in electrically insulating material.



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