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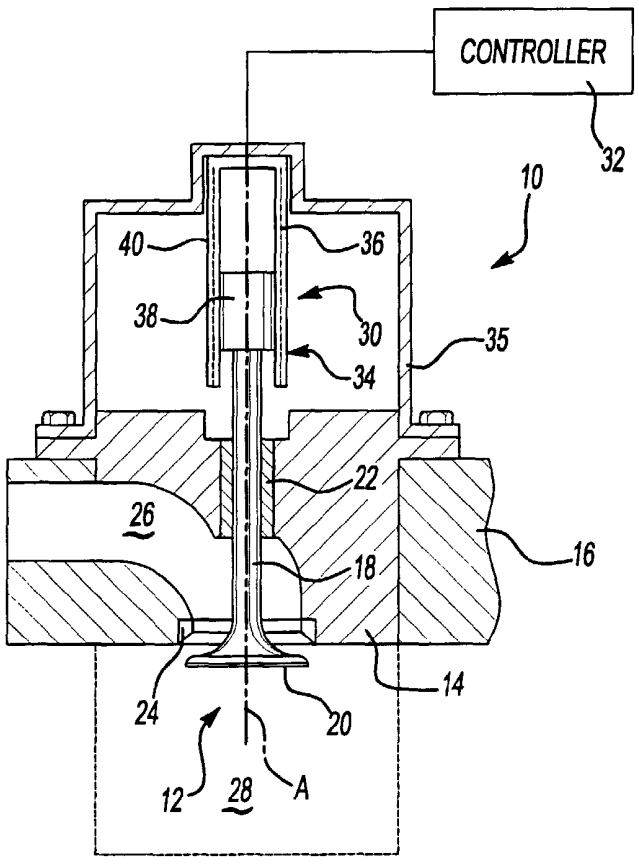
(54) Title: DIRECTLY ACTUATED ENGINE VALVE



(57) Abstract: An engine valve assembly includes an engine valve (12) connected to an electric motor (30). The electric motor may be a linear electric motor (34) which includes "rare earth" magnets to infinitely move the engine valve (12) between an open and closed position.Usage of "rare earth" magnets assures that the linear electric motor (34) generates enough force to properly and timely operate the engine valve (12.) The electric motor (30) may alternatively drive a threaded portion (42) of the valve stem (18.) Operation of the electric motor (30) threads the threaded valve stem (18) relative to a threaded support (40) to drive the engine valve (12') between an open and a closed position.

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DIRECTLY ACTUATED ENGINE VALVE

BACKGROUND OF THE INVENTION

The present invention relates to engine valves, and more particularly to actuation of engine valves.

Engine intake and/or exhaust valves are used to control the intake and exhaust in the cylinders of internal combustion engines. Camshafts that provide a valve motion profile as a fixed function of the crankshaft position commonly control the valves. While generally effective, ideal intake and exhaust valve timing and lift will vary under varying engine operating conditions. Variable valve timing and lift can account for such changing conditions and substantially improve overall engine performance.

Consequently, some attempts have been made to do away with camshafts altogether by individually actuating the engine valves by some type of electromechanical or electrohydraulic means. One known system employs a spring-biased valve with electromagnets as actuators. This may be inadequate as the magnets can not create enough force to properly and timely operate the valves without an inordinate amount of energy. Moreover, the release of the valve is generally too slow for use as an engine valve as the magnetic field takes some time to decrease to zero after the electromagnet is deactivated.

Accordingly, it is desirable to provide a reliable, fast, and energy efficient actuator for engine valves which provides the flexibility to vary both valve timing and lift to substantially improve engine performance.

SUMMARY OF THE INVENTION

The engine valve assembly according to the present invention provides an engine valve driven by an electric motor. As the engine valve is directly controlled by the electric motor, each engine valve is individually controllable. Moreover, variable valve timing and variable opening and closing profiles for each of a plurality valves is relatively straightforwardly achieved through a controller.

In one embodiment, the electric motor is a linear electric motor which may include "rare earth" magnets. A slidable rotor is fixed to a valve stem of the engine

valve such that as the slidable rotor is driven relative to a linear stator, the engine valve is infinitely movable between an open and closed position. Usage of "rare earth" magnets assures that the linear electric motor generates enough force to properly and timely operate the engine valve.

In another embodiment, the electric motor drives a threaded portion of the valve stem. Operation of the electric motor rotates the threaded stem relative to a threaded support. The engine valve is thereby screwed between an open and a closed position.

The present invention therefore provides a reliable, fast and efficient engine valve actuator which provides the flexibility to vary both valve timing and lift to substantially improve engine performance.

BRIEF DESCRIPTION OF THE DRAWINGS

The various features and advantages of this invention will become apparent to those skilled in the art from the following detailed description of the currently preferred embodiment. The drawings that accompany the detailed description can be briefly described as follows:

Figure 1 is a partial sectional view of an engine valve assembly according to the present invention;

Figure 2 is a partial sectional view of the engine valve assembly of Figure 1 in a closed position;

Figure 1A is an exploded view of another linearly actuated engine valve assembly according to the present invention;

Figure 3A is a partial sectional view of another engine valve assembly according to the present invention;

Figure 3B is an exploded view of another rotational engine valve assembly according to the present invention;

Figure 4 is a partial sectional view of the engine valve assembly of Figure 3 in a closed position;

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Figure 1 illustrates a general partial sectional view of an engine valve assembly 10. An engine valve 12 such as an intake or exhaust valve, is movably mounted within a cylinder head 14 of an internal combustion engine 16. The engine valve 12 includes a valve stem 18 and a valve head 20. The valve stem 18 defines an axis A.

The engine valve 12 is movably mounted within a support 22 such that the valve head 20 is movable along axis A. The support 22 provides for assembly of components into the cylinder head 14, and later servicing as a module, but may alternatively be integral with the head. The valve head 20 seats against a valve seat 24 to control flow through a port 26 into or out of a combustion chamber 28 within the engine 16.

The valve stem 18 is connected to an electric motor 30. The electric motor 30 communicates with a controller (illustrated schematically at 32) to drive the engine valve between an open and a closed position (Figure 2). As the engine valve is directly controlled by the electric motor, each engine valve 12 is individually controllable. Moreover, variable valve timing and variable opening and closing profiles for each of a plurality valves is relatively straightforwardly achieved through controller 32.

Preferably, the electric motor 30 is a linear electric motor 34 mounted along axis A. The linear electric motor 34 includes a linear stator 36 and a slidable rotor 38 which is drivable relative to the linear stator 34. Some rotational motion between the engine valve 12 and the slidable rotor 38 such as through a sleeve type mount is preferably provided to allow rotation of the valve during opening and closing to thereby equalize wear upon the valve head 20 and valve seat 24. The linear stator 36 preferably includes "rare earth" magnets 40 such as Neodymium and Samarium Cobalt magnets.

Detailed operation of a linear electric motor is well known and will only be generally described herein. Generally, the slidable rotor 38 is fixed to the valve stem 18 such that as the slidable rotor 38 is driven relative to the linear stator 34, the engine valve is infinitely movable between the open and closed position. Usage of "rare earth" magnets 40 assures that the linear electric motor 34 generates enough force to properly and timely operate the engine valve 12. In addition, as the linear electric motor 34 is sequentially actuated, an extremely large inductance is avoided. Avoidance of a large

inductance further increases the responsiveness of the linear electric motor 34 and thus the engine valve 12.

A housing 35 or the like is mounted to the cylinder head 14 to protect and provide maintenance access to the electric motor 34. It should be understood that other arrangements will also benefit from the present invention.

Referring to Figure 1A, other linear motor arrangements in which the engine valve 12a is not directly coupled to the slidable rotor 38a will also benefit from the present invention. A "force multiplier" such as a rack and pinion arrangement may alternatively or additionally be located between the valve stem 18a and the linear electric motor 34a. That is, the slidable rotor 38a includes a rack gear 39 which rotates a gear reduction arrangement 41 which correspondingly drives a stem rack gear 43 formed on the valve stem 18a. The force of the linear motor is thereby multiplied to further assure that the linear electric motor 34a generates enough force to properly and timely operate the engine valve 12.

Referring to Figure 3, another engine valve assembly 10' according to the present invention is illustrated. The engine valve assembly 10' is generally as described above and common items are defined by the same numerals as above. The engine valve assembly 10' includes a threaded support 40 to receive a threaded portion 42 of the valve stem 18. Preferably, one-quarter turn of the valve stem 18 drives the engine valve 12 between an open and a closed (Figure 4).

To drive the threaded valve stem 18, the electric motor 44 is mounted substantially perpendicular to the valve stem 18 such that a screw gear 46 attached to the electric motor rotor 48 engages the threaded portion 42. Operation of the electric motor 44 drives the engine valve 12 between an open and a closed (Figure 4). Preferably, the electric motor 44 includes a low-inertial permanent magnet or "squirrel cage" armature motor (illustrated schematically at 50) to properly and timely operate the engine valve 12. The electric motor 44 additionally or alternatively includes "rare earth" magnets as described above. It should be understood that other actuators such as a rotary solenoid will also benefit from the present invention.

Referring to Figure 3A, other rotational motor arrangements in which the engine valve 12b is directly coupled to a rotor 52 which rotates within a fixed stator 54. The

engine valve 12b includes a threaded portion 56 which meshes with a corresponding rotor thread 58 on the rotor 52. A guide 60 such as a key and slot arrangement prevents rotation of the engine valve 12b. Rotation of the rotor 52 thereby causes the rotor thread 56 to act upon the threaded portion 58 of the engine valve and drive the engine valve 12 between an open and a closed position. That is as the engine valve can not rotate interaction of the threads 56, 58 result in linear motion of the engine valve 12b.

The foregoing description is exemplary rather than defined by the limitations within. Many modifications and variations of the present invention are possible in light of the above teachings. The preferred embodiments of this invention have been disclosed, however, one of ordinary skill in the art would recognize that certain modifications would come within the scope of this invention. It is, therefore, to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described. For that reason the following claims should be studied to determine the true scope and content of this invention.

CLAIMS

1. An engine valve assembly for an engine cylinder comprising:

an engine valve having a stem portion and a head portion, said valve stem defining an axis and; and

an electric motor mounted to said valve stem to drive said engine valve along said axis to move said engine valve between an open and a closed position.

2. The engine valve assembly as recited in claim 1, wherein said electric motor includes a rare earth magnet.

3. The engine valve assembly as recited in claim 1, wherein said electric motor is a linear electric motor to slide said vale along said axis.

4. The engine valve assembly as recited in claim 3, wherein said linear electric motor includes a linear stator and a slidable rotor which is drivable relative to said linear stator, and a force multiplier between said slidable rotor and said valve stem.

5. The engine valve assembly as recited in claim 4, wherein said force multiplier includes a rack and pinion gear arrangement.

6. The engine valve assembly as recited in claim 1, wherein said valve stem includes a threaded stem portion.

7. The engine valve assembly as recited in claim 6, wherein said threaded stem portion is screwed into a threaded support.

8. The engine valve assembly as recited in claim 7, wherein said electric motor rotates said valve stem to screw said engine valve relative to said support and move said engine valve between said open position and said closed position.

9. The engine valve assembly as recited in claim 1, wherein said valve stem includes a threaded stem portion and a rotor of said electric motor includes a corresponding threaded portion.

10. An engine valve assembly for an engine cylinder comprising:

an engine valve having a threaded stem portion and a head portion, said threaded valve stem portion defining an axis;

a threaded support to receive said threaded valve stem portion; and

an electric motor operably connected to said threaded valve stem, said electric motor operable to rotate said engine valve relative to said threaded support to drive said engine valve along said axis between an open and a closed position.

11. The engine valve assembly as recited in claim 10, wherein said electric motor includes a rare earth magnet.

12. The engine valve assembly as recited in claim 10, wherein said electric motor is mounted substantially perpendicular to said axis.

13. The engine valve assembly as recited in claim 10, wherein said threaded support includes a rotor rotatably mounted to a fixed stator.

14. The engine valve assembly as recited in claim 13, further comprising a guide which prevents rotation of said engine valve.

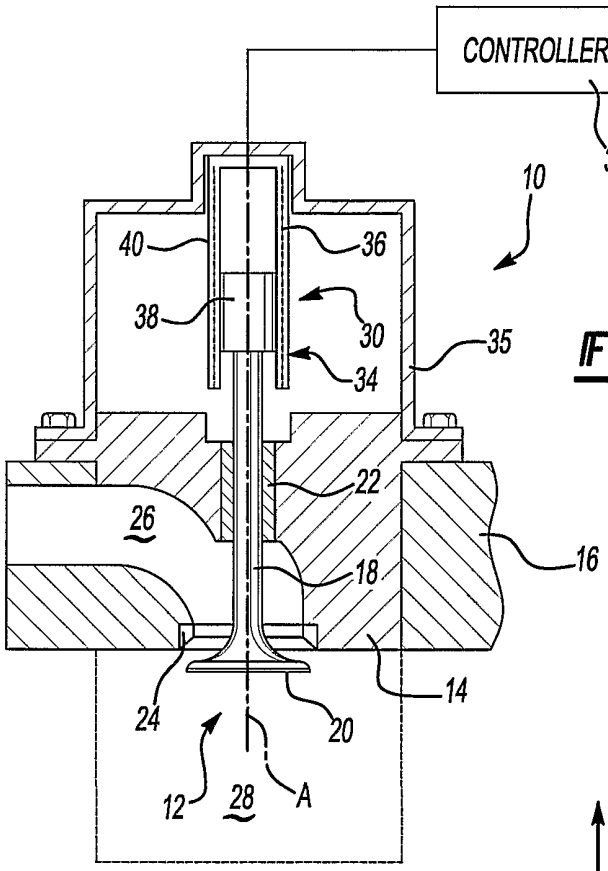
CONTROLLER
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Fig-1

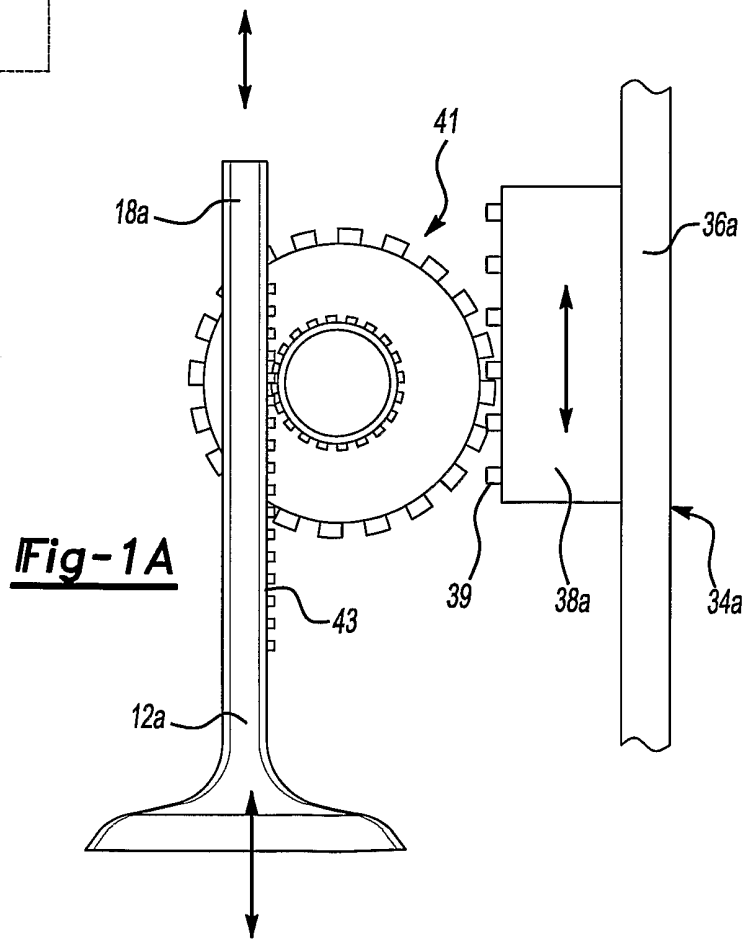
41
18a
36a
43
39
38a
34a
12a

Fig-1A

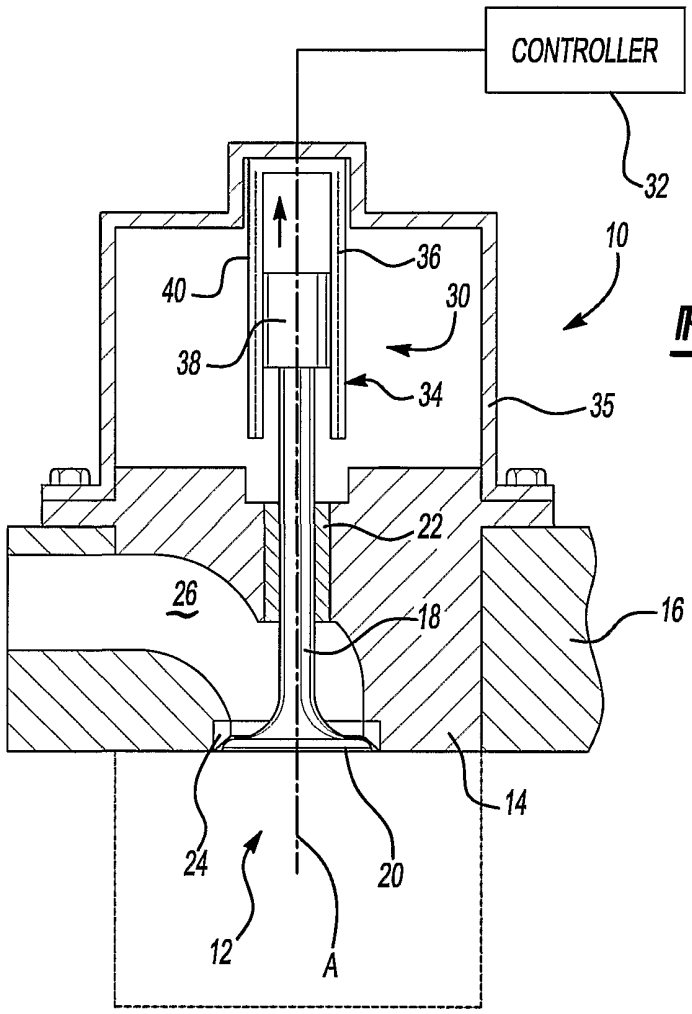
CONTROLLER
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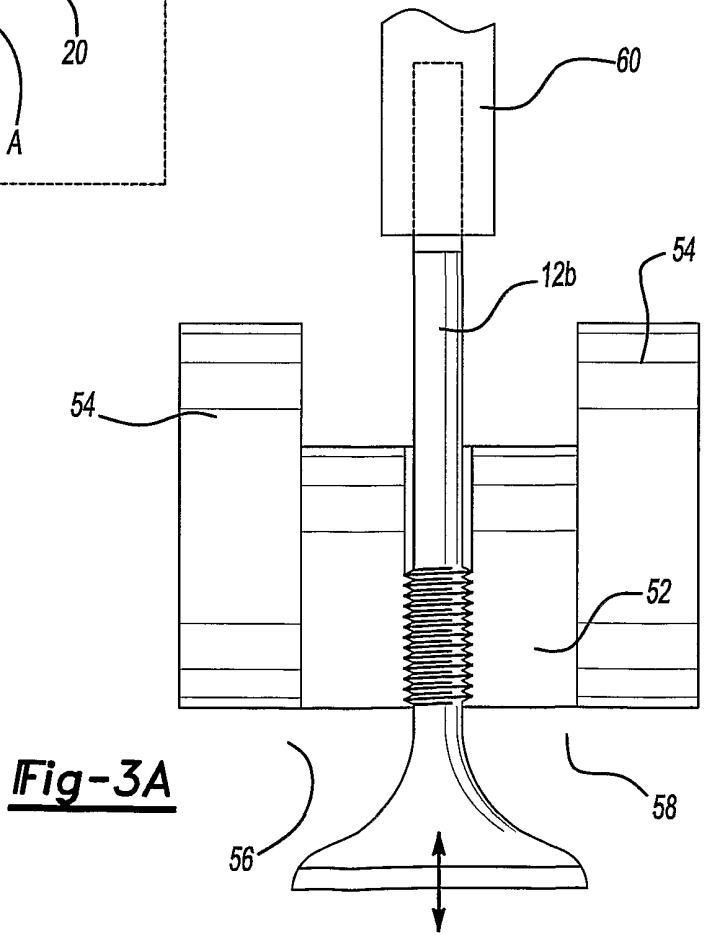
Fig-2


60
12b
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54
52
56
58

Fig-3A

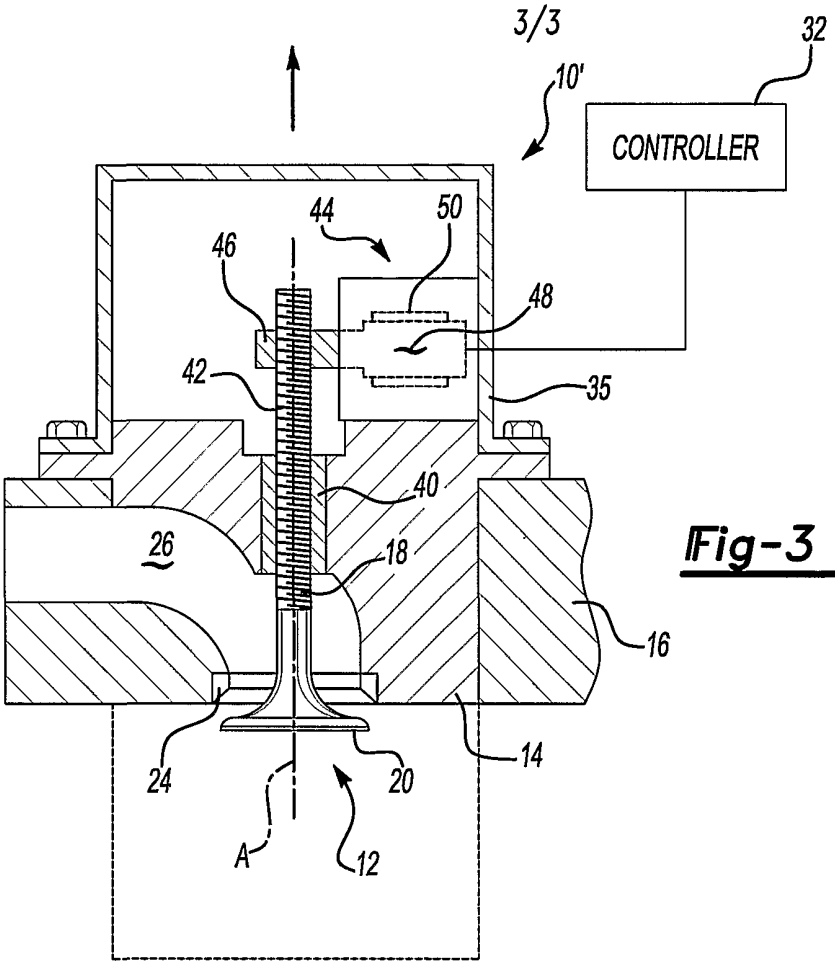
32
10'
CONTROLLER
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Fig-3

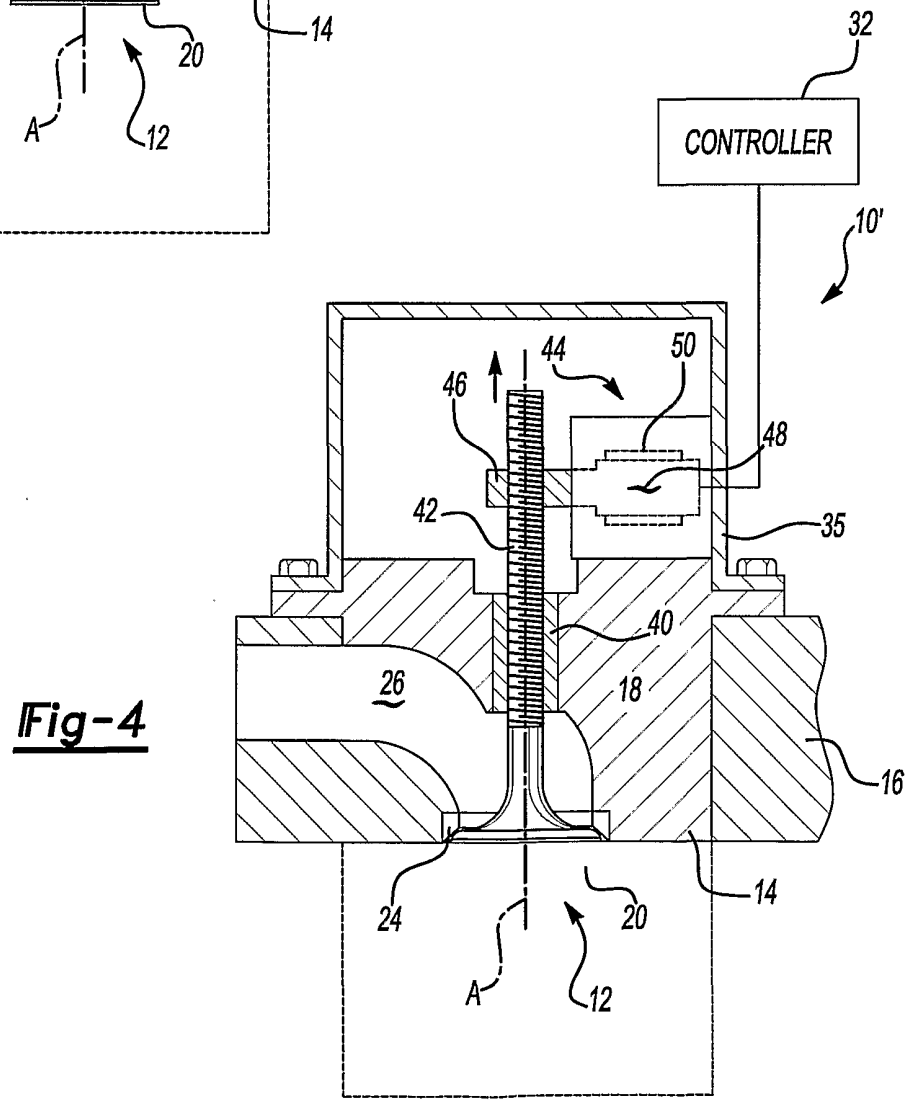
32
CONTROLLER
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Fig-4