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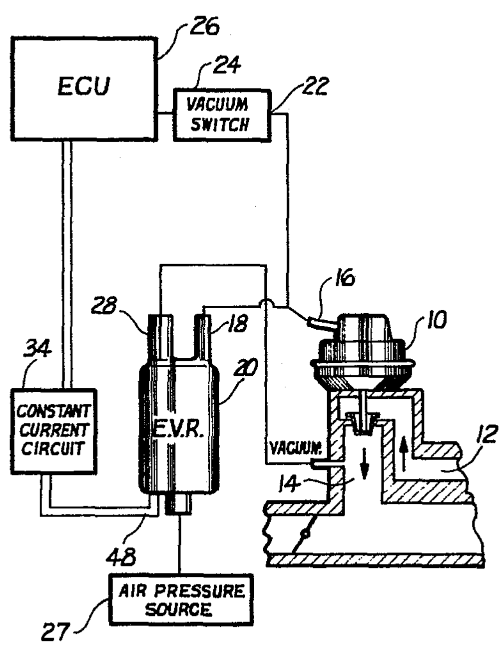
(54) Electric vacuum regulator.

(57) An electric vacuum regulator (EVR) (20) in response to a pulsed electric signal regulates its output vacuum value. The pulsed electric signal, which is generally generated in an electronic control unit (26), is typically duty cycled so as to mix input vacuum with some other source of air pressure, such as atmospheric, to achieve the desired level of output vacuum.



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ELECTRIC VACUUM REGULATOR

This invention relates to vacuum regulators in general and in particular to electric or electronic vacuum regulators for use with internal combustion engines.

In the engine systems of motor vehicles, vacuum regulators are used to control the vacuum which is created in the engine and used to operate many of the various pollution control devices. As with any control source, and vacuum sources are no different, it is a requirement that the control value of the source be either regulated or always known. If the source is to be regulated or maintained at a single fixed value, then the conventional mechanically constructed vacuum regulator comprising springs, diaphragms and orifices perform adequately.

In the modern internal combustion engine control system, computers having one or more microprocessors and read-only-memories (ROM) are being programed to generate electrical signals of various values. As certain engine operating parameters or conditions change, the computer through digital mapping techniques can generate unique control signals representing the present state of the engine. One such control signal may represent a vacuum level for controlling a vacuum utilization device.

Combining such control signal as generated by a computer with a prior art vacuum regulator, the single fixed value of vacuum can be maintained. Such prior art vacuum regulators have a rubber diaphragm for separating the vacuum and atmospheric chambers. An armature is attached to the diaphragm, and to form the regulating part of the valve, a seal is placed between the armature and the rubber diaphragm. As the armature moves reciprocally, the seal wears causing the regulator calibration to drift. To further complicate matters, in order to complete the magnetic circuit a steel member must be added thereby increasing the number of elements making up the regulator.

In order to avoid the subsequent wear and drift of regulator and to maintain accurate vacuum regulation, the present electric vacuum regulator was developed. One element, a steel disk or armature separates and provides a seal between the vacuum and atmospheric chambers and completes the magnetic circuit for the solenoid actuator. Because it seals on a brass seat, wear of the internal members of the regulator is virtually eliminated.

There is disclosed and claimed herein an electric vacuum regulator having an input port for connection to a vacuum source such as manifold vacuum in an internal combustion engine. A vacuum operated device such as an exhaust gas recirculation valve is connected to an output port of the regulator. Within the regulator, a mixing chamber interconnects the two ports and positioned within the chamber is an orifice which is connected to a source of air pressure such as atmosphere. A steel disk is adapted to seal the orifice from the chamber and since this is an electrically operated regulator, a coil surrounds a stator for generating magnetic flux causing the disk to be attracted towards the seat. The coil is energized by a unique duty cycle control signal generated in the computer in response to the operating conditions of the engine. As is conventional in vacuum operated devices, a bias spring is placed to maintain the disk in a position closing the orifice when there is no electrical signal and no vacuum.

These and other advantages of the electric vacuum regulator will become apparent from the following detached description and drawings in which:

Fig. 1 is a schematic block diagram of control system utilizing the positive gain electric vacuum regulator of the present invention;

Fig. 2 is a longitudinal sectional view taken along an axis of a positive gain electric vacuum regulator as may be used in the system of Fig. 1;

Fig. 3 is a longitudinal sectional view taken along an axis of a negative gain electric vacuum regulator;

Fig. 4 is a graph of the operation of the positive gain electric vacuum regulator of Fig. 2; and

Fig. 5 is a graph of the operation of the negative gain electric vacuum regulator of Fig. 3.

Referring to the Figs. by the reference numerals, a system is illustrated in Fig. 1 as may be found on an internal combustion engine of a motor vehicle. The vacuum utilization device is an exhaust gas recirculation (EGR) valve 10 which operates under certain engine operating conditions to recirculate, from the exhaust manifold 12 to the intake manifold 14, exhaust gas into the air-fuel mixture. Connected to the vacuum input 16 of the EGR valve 10 is the output port 18 of the electric vacuum regulator (EVR) 20 and an input port 22 of a vacuum switch 24.

The vacuum switch 24 functions to determine the presence of vacuum in the vacuum line to the EGR valve 10. If a vacuum hose is off or if the diaphragm is bad or if the EVR 20 is defective or if there is any other condition which adversely affects the vacuum level, the vacuum switch 24 generates a signal to the electronic control unit (ECU) or onboard computer 26.

The function of the ECU 26, as far as the present invention is concerned, is to map the curve of the output vacuum value from the electric vacuum regulator 20 against the voltage duty cycle of the electric vacuum regulator. Thus, for any desired output vacuum, the ECU

26 interprets the map in a ROM and develops the appropriate voltage duty cycle signal for the electric vacuum regulator 20 to regulate the output vacuum.

The electric vacuum regulator 20 receives the duty cycle signal and controls the output vacuum from its output port 18 according to the duty cycle of the signal. This is accomplished by mixing atmospheric pressure taken from an air pressure source 27 and the vacuum pressure taken from a vacuum source such as the intake manifold 14 of the engine. This is schematically represented by the line from the intake manifold 14 to the input port 28 of the electric vacuum regulator 20. The atmospheric pressure is provided through an orifice 30 in the regulator to the mixing chamber 32.

Thus, with the system of Fig. 1, the EGR valve 10 during normal engine operation is supplied with a variable vacuum signal which causes the EGR valve 10 to open a known amount and allow a calculated amount of exhaust gas to mix with the air-fuel mixture. The constant current circuit 34 maintains the current level to the electric vacuum regulator 20 regardless of resistance changes in the coil due to temperature or aging or due to fluctuations or changes in the battery voltage.

The system of Fig. 1 utilizes a positive gain electric vacuum regulator 20 which is defined as having the vacuum output therefrom increase as the duty cycle increases to 100%. The positive gain electric vacuum regulator 20 is illustrated in Fig. 2 and the graph of Fig. 4 illustrates its output characteristics for various adjustments of the stator means 36.

If the system of Fig. 1 utilized a negative gain electric vacuum regulator 21, which is illustrated in Fig. 3, the vacuum switch 24 would be omitted as any failure of the electric vacuum regulator 21 would affect the operability of the engine enough to make the engine operator notice that there is a failure. The negative gain electric vacuum regulator 21 is defined as having the vacuum output therefrom decreasing as the duty cycle increases to 100%. The graph of Fig. 5 illustrates the output characteristics of the negative gain electric vacuum regulator 21 for various stator adjustments.

The failure of an EGR valve 10, independently of the characteristic of the electric vacuum regulator 20, will in all probability not be noticed by the engine operator because exhaust gas will not be mixed with the air-fuel mixture, but such failure will cause emissions from the engine to be changed which may or may not pass environmental testing.

The electric vacuum regulator 20 as illustrated in Fig. 2 has a cap 38 having at least a pair of ports 18 and 28 at one end, one being the input port 28 and the other the output port 18. The interior of the cap 38 forms a portion of the mixing chamber 32 interconnecting the two ports. Each port 18 and 28 is adapted to receive a vacuum hose, which is not shown, for connecting the input port 28 to a source of the vacuum 14, and for connecting the output port 18 to the utilization device 16. In the embodiment of Fig. 2 at the opposite end of the cap 38, there is at least one aperture 40 open to a source of air pressure 27 or atmospheric pressure.

Connected to the cap 38 is a bobbin means 42 providing an area to wind an electromagetic coil 44 therearound and cooperates with the cap 38 to form the remaining portion of the mixing chamber 32. The bobbin means 42 is enclosed by a shell 46 fabricated from a magnetizable material. The leads or the ends of the coil are extended to a pair of terminals which are connected to wires 48 extending outward of the shell 46 for receiving the electrical control signals.

At the end of the bobbin means 42, opposite the terminals, a seating means 50 having a central orifice 30 is retained within the bobbin means 42 in Figure 2. The central orifice 30 is concentric with the central aperture of the bobbin means 42 which receives the stator means 36. The stator means 36 is an elongated shaft threaded at one end to provide an adjustment for positioning the stator means 36 in alignment with the central orifice 30 of the seating means 50. This adjustment, which may be made by means of a small hexagonal wrench or similar tool applied to a receptacle 52 in the end of the stator means 36, affects the operation of electromagnetic circuit as will hereinafter be described.

There is positioned across the seating means 50, which is typically cylindrical in shape, a flat steel disk 54 which is free to move and is constrained only by the walls of the mixing chamber 32. The mixing chamber 32 interconnects the input port 28 and the output port 18 providing for the transfer of vacuum therebetween. In a normal state with no current applied to the coil 44 and no vacuum, the disk 54 rests upon the seating means 50 encircling the orifice 30. A spring bias means 56 is positioned so as to bias the disk 54 against the seating means 50.

Located in the input port 28 upstream of the mixing chamber 32 is a bleed orifice or restrictor 58 which controls the amount of vacuum flow from the input port 28.

Adjacent a plurality of apertures 40 in one end of the shell 46 is a filter means 60 which prevents any particles in the air pressure source 27 from getting into the valve. As is customary in devices of this nature, the filter 60 operates to make sure that the air that flows within the valve is clean of any particles which would inhibit or hinder the operation of the valve.

In Figure 2, once the air from the air pressure source 27 flows through the filter 60, the clean air then flows up through the central aperture 62 of the bobbin means 42. The stator means 36 has a crosshole 64 inclined to its longitudinal axis to provide for the flow air therethrough. The crosshole 64 is then connected with the longitudinally extending bore 66 from the middle of the stator means 36 to the top of the stator means 36. At the end of the stator means 36, this bore 66 is the central orifice 30 for supplying the air pressure source 27 to the mixing chamber 32 of the vacuum regulator 20.

For the operation of the electric vacuum regulator 20 of Fig. 2, reference is made to Fig. 4 which shows a series of curves 68-71 illustrating the relationship of the output vacuum as a percent of the voltage duty cycle of the operation of the coil 44. The onboard computer 26 of Fig. 1 determines the voltage duty cycle desired for operation of the coil 44 so that the vacuum of the output port 18 is a previously calculated value. This value enhances the operation of the internal combustion engine which is controlled in part by the utilization device 10 from the output port 18 of the EVR 20. When the coil 44 is not energized the position of the steel disk 54 is determined by the pressure of the air from the air pressure source 27, the spring force from the spring bias means 56 and the amount of vacuum in the mixing chamber 32. As the onboard computer 26 determines what is necessary for the operation of the utilization device 10, the duty cycle signal will cause the vacuum regulator 20 to operate at some percent duty cycle. The curves 68-71 of Fig. 4 indicate that for different adjustments of the stator means 36 the output vacuum varies with the value of the duty cycle. The fourth curve 71 indicates that there is a point in the duty cycle with a particular stator means 36 adjustment when the magnetic force retains the steel disk 54 against its seating means 50 and the output 18 and input 28 ports are substantially connected together such that the input and output vacuums are equal.

With input vacuum applied to the input port 28 in the cap 38 and the output port 18 attached to a utilization device 10, a vacuum will start to build up inside the valve. This will create a force that will try to lift the disk 54 off the seating means 50. The spring force of the bias spring 56 will prevent this up to the point that the vacuum force will overcome it. Then the disk 54 will lift off from the seating means 50 and atmospheric air will enter through the filter 60. This will reduce the vacuum force and the spring 56 will push the disk 54 back on the seating means 50. The vacuum will build up again and the process will be repeated.

With current applied to the coil 44, a magnetic field will be created in the valve. This field will pass through the shell 46, the stator means 36 and the disk 54 creating a magnetic force between the stator means 36 and the disk 54. This force works in the same direction as the spring force, so increased current will give increased regulated output vacuum.

Referring to the negative gain embodiment of Fig. 3, wherein the same reference numerals are used to identify similar elements as the embodiment of Fig. 2. The difference in this embodiment is that the vacuum force and the magnetic force from the coil 44 aid each other and work against the force from the spring bias means 56, where in the embodiment of Fig. 2 the force from the spring bias means 56 and the magnetic force aid each other and work against the vacuum force.

In Fig. 3 when the vacuum regulator 21 has no power applied to the coil 44 and no vacuum, the central orifice 30 from the air pressure source is closed and the input

28 and output ports 18 are connected together. In this particular condition, the spring bias means 56 holds the disk 54 against the seating means 50 surrounding the central orifice 30 effectively closing the orifice 30. Inasmuch as the stator means 36 in this particular embodiment extends into the mixing chamber 32 which is typically at a vacuum level and not at atmospheric level, a sealing means 72 must be provided along the stator means 36 to prevent any leakage of air pressure or vacuum from the mixing chamber 32. As in Fig. 2, the stator means 36 is threadably adjusted, although in Fig. 3 the bobbin means 42 is tapped to provide the thread adjustment.

With input vacuum applied to the input port 28 in the cap 39 and the output port 18 attached to a utilization device 10, a vacuum will start to build up inside the valve 21. This will create a force that will try to lift the disk 54 off the seat means 50. The spring force of the bias spring 56 will prevent this up to the point that the vacuum force will overcome it. Then the disk 54 will lift off from the seating means 50 and atmospheric air will enter through the filter 60. This will reduce the vacuum force and the spring 56 will push the disk 54 back on the seating means 50. The vacuum will build up again and the process repeated.

With current applied to the coil 44, a magnetic field will be created in the valve. This field will pass through the shell 46, the stator means 36 and the disk 54 creating a magnetic force between the stator means 36 and the disk 54. This force works against the spring force, so increased current will give decreased regulated output vacuum.

In both embodiments, Figs. 2 and 3, the magnetic circuit comprises the shell 46, the disk 54 and the stator means 36. The coil 44, when supplied with a current, will generate the magnetic field for the magnetic circuit. It is to be understood in both the embodiments, that once an EVR is set up and the stator means 36 adjustment is made, only one of the curves of Fig. 4, or Fig. 5 as the case may be, is applicable as the stator means 36 is sealed in place.

As previously mentioned the electric vacuum regulator of the present invention, either the positive gain embodiment 20 or the negative gain embodiment 21, comprises a steel disk 54 which functions to separate and seal the vacuum side of the regulator from the atmospheric side and to complete the magnetic circuit. In each of the embodiments, the central orifice 30 is surrounded by a seating means 50 which in the preferred embodiment is brass and non-magnetic and also is virtually wear resistant in this application. The steel disk 54 seats on the brass seating means 50 sealing the central orifice 30 supplying air pressure into the mixing chamber 32 of the regulator 20 or 21.

There has thus been shown and described an electric vacuum regulator responding to duty cycle pulse electrical signals for regulating the vacuum utilization devices within predetermined limits. As previously indicated the main or a major application of such electric vacuum regulators may be found in internal combustion engines for motor vehicles.

Claims:

1. An electric vacuum regulator (20) comprising:

an input port (28) adapted to be connected to a vacuum source, said input port having restrictor (58) coupled thereto;

an output port (18) adapted to be connected to a vacuum utilization device (10);

a mixing chamber (32) interconnecting said input and said output ports;

an orifice (30) for communicating an air pressure source with said chamber;

a disk (54) adapted to seal said orifice for separating the air pressure source from the vacuum source;

spring means (56) biasing said disk in a closed position against said orifice;

stator means (36) located in alignment with said orifice and spaced from said disk;

a shell (46) enclosing said mixing chamber, orifice, disk, spring means and said stator means; and

coil means (44) magnetically coupled to said stator means, said shell and said disk and operative in response to an electrical signal for magnetically attracting said disk for controlling the mixing of the air from the air pressure source with the vacuum from said input port and thereby regulating the vacuum at said output port proportional to the vacuum at said input port.

2. An electric vacuum regulator according to Claim 1 additionally including seating means (50) encircling said orifice (30) for cooperating with said disk (54) for closing said orifice.

3. An electric vacuum regulator according to Claim 2 wherein said seating means (50) is a non magnetic member and said stator means (36), said shell (46) and said disk (54) are magnetizable members.

4. An electric vacuum regulator according to Claim 2 wherein said stator means (36) is adjustable for changing the air gap between said stator means and said disk (54) thereby controlling the vacuum level at said output port (18).

5. An electric vacuum regulator according to Claim 1 additionally including filter means (60) between the air pressure source and said orifice (30) for filtering out particles from the air pressure source.

6. A vacuum operated system used on an internal combustion engine for controlling the operation of the engine, said system comprising:

a source of vacuum (14);

a vacuum utilization device (10) operable in response to a vacuum signal for controlling the operation of the engine, said device having an input vacuum port (16);

control means (26) for generating a plurality of electrical output vacuum value signals in response to various engine operating conditions and operable to generate one of said electrical output vacuum value signals having a duty cycle according to the present engine operating condition;

a source of pressure; and

an electric vacuum regulator valve (21) connected to said source of vacuum and said source of pressure and responsive to said electrical signal for generating said vacuum signal at a regulated vacuum level between said source of vacuum and said source of pressure according the duty cycle of said electrical signal.

7. A vacuum operated system used on an internal combustion engine for controlling the operation of the engine, said system comprising:

a source of vacuum (14);

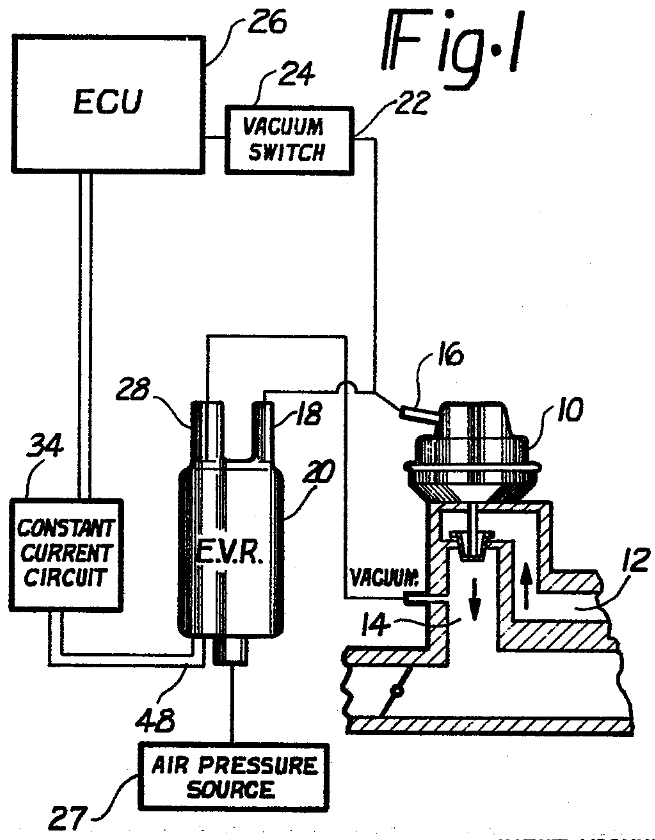
a vacuum utilization device (20) operable in response to a vacuum signal for controlling the operation of the engine, said device having an input vacuum port (16);

a vacuum switch (24) responding to the vacuum applied to said input port of said device for indicating the presence of a vacuum level sufficient to operate said device;

control means (26) for generating a plurality of electrical output vacuum value signals in response to various engine operating conditions and operable in response to said vacuum switch to generate one of said electrical output vacuum value signals having a duty cycle according to the present engine operating condition;

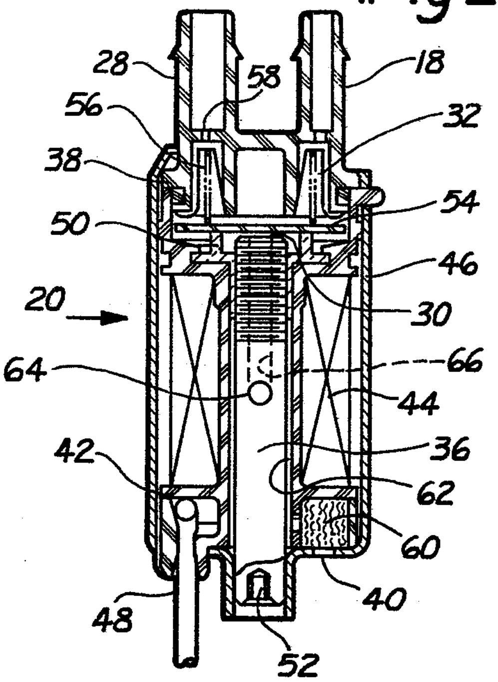
a source of pressure; and

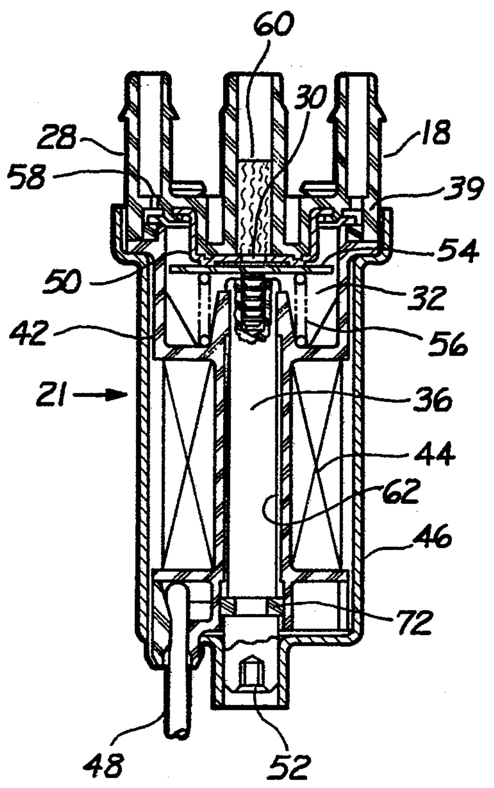
an electric vacuum regulator valve (20) connected to said source of vacuum and said source of pressure and responsive to said electrical signal for generating said vacuum signal at a regulated vacuum level between said source of vacuum and said source of pressure according the duty cycle of said electrical signal.



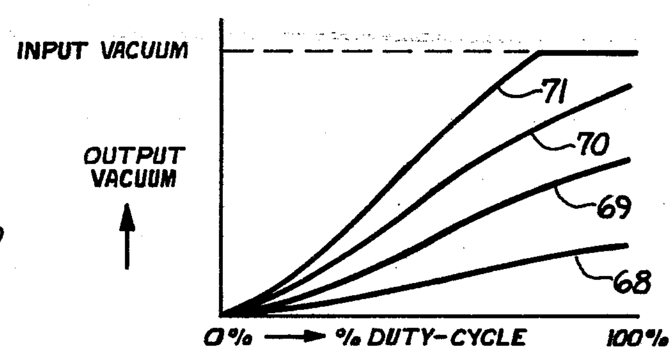
Fig·1

Fig·2

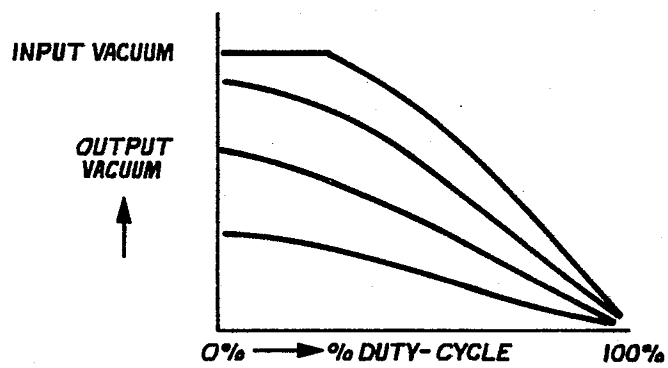




Fig·3



Fig·4



Fig·5