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[11] **3,850,151**

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[54] **FAILURE WARNING DEVICE FOR EXHAUST GAS RECIRCULATION SYSTEM**

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[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.** ..... **123/119 A,** 60/278, 123/198 D, 123/198 R

[51] **Int. Cl.** ..... F 02m 25/06

[58] **Field of Search** ..... 123/119 A, 198 D, 198 R; 60/277, 278

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Primary Examiner—Wendell E. Burns

[57] **ABSTRACT**

A detector which actuates a relay to energize an alarm in response to a inoperability of an exhaust gas recirculation system metering valve.

10 Claims, 9 Drawing Figures

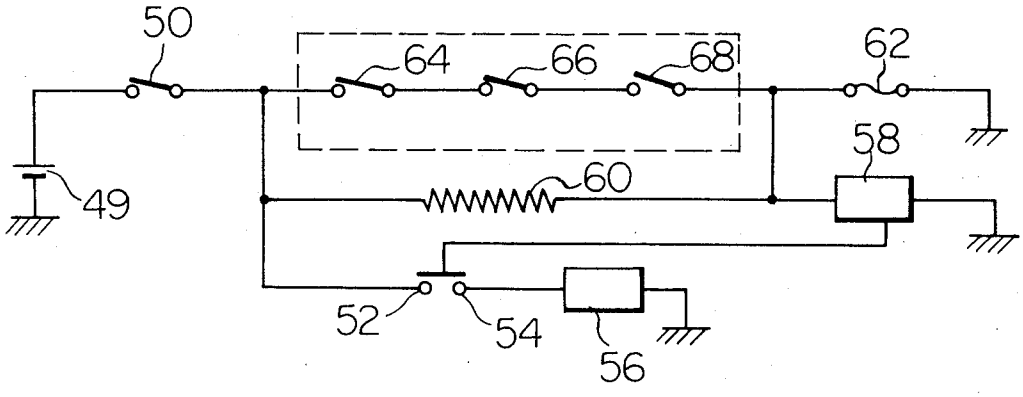


Fig. 1

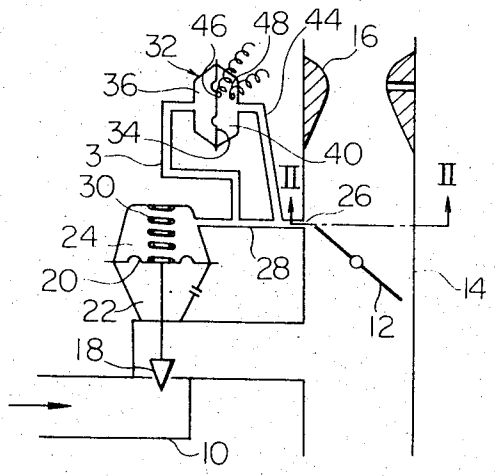


Fig. 2

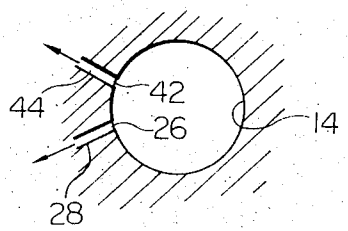


Fig. 3

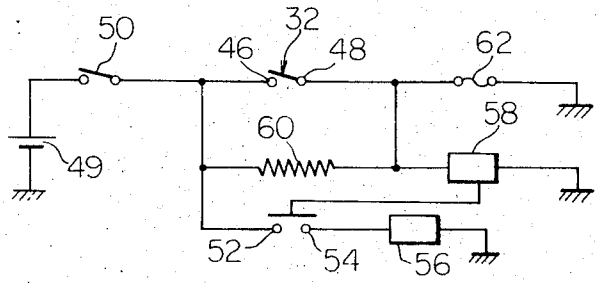


Fig. 4

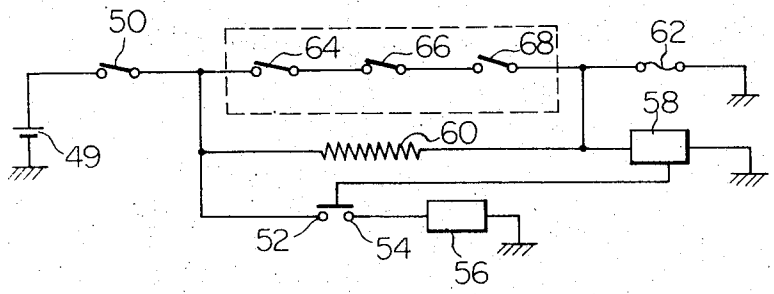


Fig. 5

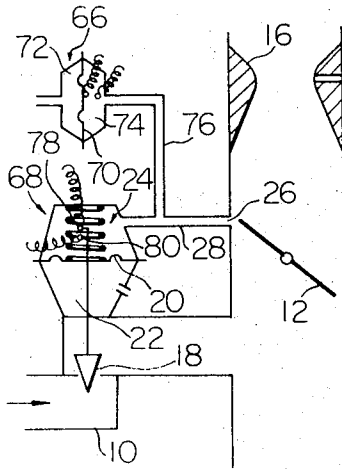


Fig. 6

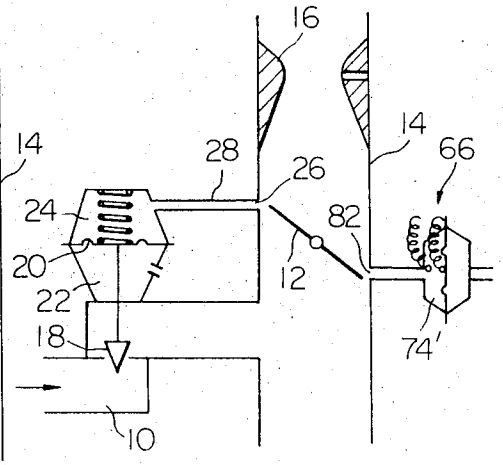


Fig. 7

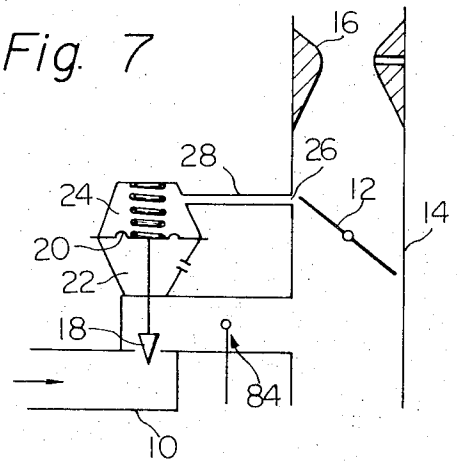


Fig. 8

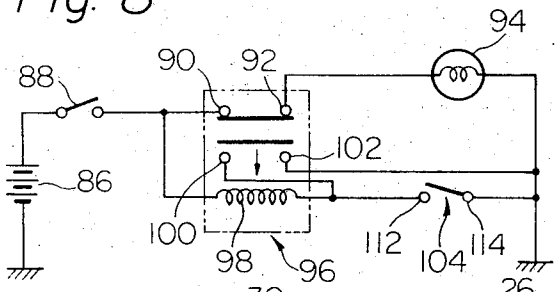
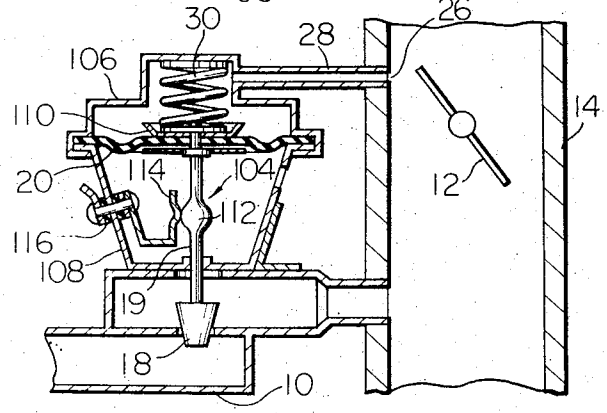


Fig. 9



FAILURE WARNING DEVICE FOR EXHAUST GAS RECIRCULATION SYSTEM

The present invention relates to an exhaust gas recirculation system fornan internal combustion engine, and more particularly to a failure warning device for an exhaust gas recirculation system.

An exhaust gas recirculation system is known to be one of the most effective methods of reducing the level of nitrogen oxides (NOx) in exhaust gas. To ensure the operation of an exhaust gas recirculation system, it is desirable to check that exhaust gas is actually being recirculated through the system when needed. However, it is quite difficult to do so becuase the exhaust gas recirculation installation is generally inaccesible.

It is known that exhaust gas will not recirculate if an exhaust gas flow metering valve in the recirculation conduit malfunctions due to rupture of the diaphragm and/or sticking of the valve head to the valve seat caused by corrosion or deposition of fuel additives.

It is therefore a main object of the present invention to provide a device which warns a driver if an exhaust gas recirculation system fails.

It is a further object of the present invention to provide a simple failure warning device for an exhaust gas recirculation system.

It is another object of the present invention to provide a failure warning device which can instantly check whether an exhaust gas recirculation system is operable.

These and other objects and features of the present invention will be more apparent from the following description taken together with the accompanying drawings, in which:

FIG. **1** is a schematic partial sectional view of an exhaust gas recirculation system incorporating the present invention;

FIG. **2** is a view taken along a line II—II of FIG. **1**;

FIG. **3** is a wiring diagram of one form of a first preferred embodiment of a failure warning device according to the present invention;

FIG. **4** is a wiring diagram of another form of the embodiment of FIG. **1** .

FIG. **5** is a view similar to FIG. **1** and shows detector switches used in the embodiment of FIG. **4**;

FIG. **6** is a view showing a modified switch arrangement of the FIG. **4** embodiment;

FIG. **7** is a view showing another switch arrangement for the FIG. **4** embodiment;

FIG. **8** is a wiring diagram of a second preferred embodiment of a failure warning device according to the present invention; and

FIG. **9** is a view similar to FIG. **1** and shows a switch used in the FIG. **8** embodiment.

Referring to the accompanying drawings and particularly to FIGS. **1** to **3**, there is shown a first embodiment of the present invention.

In FIG. **1** there is shown a conventional exhaust gas recirculation system having an exhaust gas recirculation conduit **10** leading from an exhaust system of an engine (not shown) to a downstream side of a throttle valve **12** of a carburetor **14** which is provided with a venturi **16.** The exhaust gas recirculation conduit **10** incorporates a metering valve **18** by which the flow of exhaust gas through the recirculation conduit **10** is metered in dependence on the vacuum in the intake system such as at the throttle valve **12.** The metering valve **18** is fastened at its upper end to the center of a diaphragm **20.** An atmospheric chamber **22** below the diaphragm **20** is open to the ambient air and a vacuum chamber **24** above the diaphragm **20** is connected to a portion of the intake system such as to a throttle vacuum port **26** (see FIG. **2**) by means of a conduit **28.** A compression spring **30** biases the diaphragm **20** downward to urge the metering valve **18** toward a closed position. The above described configuration is well known in the art, and further explanation is unnecessary.

In order to detect in operability or a mulfunction of the metering valve **18,** a valve opening detector such as a diaphragm switch **32** is proposed. A diaphragm **34** divides the interior of the diaphragm switch **32** into chambers **36** and **40.** The chamber **36** communicates with the conduit **28** through a conduit **38,** and the chamber **40** communicates with another throttle vacuum port **42** through a conduit **44** (see FIG. **2**). The diaphragm switch **32** has a contact **46** mounted on the diaphragm **34,** and another contact **48** mounted on a casing (no numeral) of the diaphragm switch **32** as shown in FIG. **1.** The casing and the diaphragm **34** of the diaphragm switch **32** are electrically insulated from each other in a suitable manner. The contacts **46** and **48** are disposed in the diaphragm switch **32** such that they disengage when the pressures in the chambers **36** and **40** are equal, and engage when the diaphragm **34** moves beyond a predetermined position when the pressure in the chamber **36** is higher than the pressure in the chamber **40.** Thus, the switch **32** is able to detect a condition in which the diaphragm **20** is ruptured, since in this case the pressure in the chamber **24** will approach atmospheric pressure.

Referring particularly to FIG. **3,** there is shown a wiring diaphragm of a failure warning device embodying the invention incorporating the detector or diaphragm switch **32.** One side of an electric power source **49** is connected to around and the other side to an ignition switch **50** which is closed when the engine is running. The other side of the switch **50** is connected to ground through relay contacts **52** and **54** in series with an alarm **56** such as a buzzer which produces a warning signal when a circuit is completed therethrough with the power source **49.** Connected in series to ground from the junction between the switch **50** and contact **52** are a load **60** such as a resistor and a relay **58** which operates to connect the contacts **52** and **54** when a current above a predetermined value flows through the relay **58.** A fuse **62** is connected to ground from the junction between the load **60** and relay **58.** The contacts **46** and **48** are connected in parallel with the load **60.** The failure warning device illustrated in FIG. **3** is designed such that if the diaphragm **20** is intact, the contacts **46** and **48** will be disconnected and the alarm **56** will be de-energized. However, if the diaphragm **20** ruptures, the contacts **46** and **48** will engage, and current will flow through the switch **50,** the contacts **46** and **48,** and the fuse **62.** This will cause the fuse **62** to blow. In this case, a high value of current will flow through the relay **58** which will energize it to connect the contacts **52** and **54** and energize the alarm **56.** The alarm **56** will continue to indicate the warning condition as long as the switch **50** is closed. The device is reset by replacing the fuse **62** after repairing the diaphragm **20.** If desired, the fuse **62** may be a resettable circuit breaker. The load **60** is selected so that when

the contacts **46** and **48** are disconnected, the current flow through the switch **50,** load **60** and fuse **62** is insufficient to blow the fuse **62.** However, when the contacts **46** and **48** are connected, the fuse **62** is connected to the source **49** through a low resistance path, the current increases, and the fuse **62** blows. As long as the fuse **62** is intact, the relay **58** is de-energized because it is effectively shunted to around through the fuse **62.** However, when the fuse **62** blows, the shunt is removed and the relay **58** is energized. It will be noticed that the relay **58** will remain energized even if the contacts **46** and **48** are disconnected due to the parallel connection of the load **60** and contacts **46** and **48** because sufficient current will flow through the load **60** to energize the relay **58.**

Referring to FIG. **4,** there is shown a modified form of a failure warning device embodying the invention. This failure warning device is similar to that of FIG. **3** except that three switches **64, 66** and **68** connected in series are employed instead of the single switch **32.** Thus the same reference numerals are used for like elements.

Referring now to FIGS. **4** and **5** inclusive, the switch **64** is a conventional engine temperature sensing switch which closes when the engine temperature is above a first predetermined value and opens when the engine temperature is below the first predetermined value. The switch **66** is an intake vacuum sensing switch which has a diaphragm **70,** an atmospheric chamber **72,** a vacuum chamber **74** connected to the conduit **28** by a conduit **76,** and a set of contacts (no numeral) which are disengaged when the vacuum in the chamber **74** is lower than a second predetermined valvett and are engaged when the vacuum is higher than the second predetermined value. The second predetermined vacuum value is preferably −50 mmHg for the vacuum switch **66** although any vacuum value between −50 mmHg and −400 mmHg may be selected.

The switch **68** is a valve opening sensing switch which is closed when the metering valve **18** is not open to a third predetermined value and opened when the valve opening exceeds the third predetermined value. Preferably, this third predetermined value is selected so that contacts **78** and **80** of the switch **68** are disengaged when the vacuum is higher than −45 mmHg and engaged when the vacuum is lower than −45 mmHg. The third predetermined value is expressed in terms of intake vacuum producing the corresponding valve opening degree under normal system operating conditions.

It is to be noted that the engine temperature sensing switch **64** and the intake vacuum sensing switch **66** are open under conditions in which recirculation of exhaust gas is not required, such as when the engine is cold and/or when the intake vacuum is low, and closed when recirculation of exhaust gas is required.

It will thus be understood that if the metering valve **18** fails to operate under conditions in which recirculation of exhaust gas is required, all the switches **64, 66** and **68** will close and a warning signal will be produced by the alarm **56.**

FIG. **6** illustrates a modified form of the vacuum sensing switch **66** of FIG. **5.** A modified intake vacuum sensing switch **66'** differs from that of FIG. **5** in that a vacuum chamber **74'** is connected to a spark advance vacuum port **82** of the carburetor **14.** The intake vacuum sensing switch **66'** is advantageous over the switch **66** of FIG. **5** in that the former is operable should the vacuum chamber **24** open to the atmosphere due to rupture of the diaphragm **20.** In this case, the valve **18** will be closed by the spring **30,** the switches **64, 66'** and **68** will be closed, and the alarm **56** will be energized. This will be readily understood from the fact that the vacuum chamber **74** of the throttle vacuum sensing switch **66** communicates with the vacuum chamber **24.**

With the valve opening switch **68,** it can not be detected if the valve seat of the metering valve **18** is clogged and no recirculation of exhaust gas is provided because the valve **18** may be open. If the valve seat of the metering valve **18** is clogged, exhaust gas does not flow through the conduit **10** and the temperature therein downstream of the valve **18** will be low. To detect this condition, a temperature sensing switch **84** having a bimetallic element, thermistor or thermocouple may be employed in the conduit **10** downstream of the valve **18** as shown in FIG. **7** instead of the valve opening sensing switch **68.** The temperature sensing switch **84** is designed to close when the temperature downstream of the valve **18** in the recirculation conduit **10** is below a fourth predetermined value, such as below 100°C or 200°C, and open when the temperature is above the fourth predetermined value.

Referring next to FIGS. **8** and **9** inclusive, there is shown another preferred embodiment of a failure warning device according to the present invention. In this embodiment, an alarm is energized when the ignition switch is closed and remains energized until the exhaust gas recirculation system (metering valve) begins to operate. The failure warning device illustrated in FIG. **8** has an electric power source **86,** an ignition switch **88,** a set of normally closed contacts **90** and **92** of a latching type relay **96,** and an alarm **94** such as a lamp. The electric power source **86,** the ignition switch **88,** the set of normally closed contacts **90** and **92** and the alarm **94** are connected in series as shown. The relay **96** of the failure warning device may be an electromagnetic re relay or an electronic relay employing switching transistors. An electromagnetic relay **96** as shown has a solenoid coil **98** and a set of normally open contacts **100** and **102.** The coil **98** and the normally open contacts **100** and **102** are connected in seies with the ignition switch **88** as shown. The failure warning device further has a detector such as a valve opening sensing switch **104** connected in parallel with the normally open contacts **100** and **102** of the relay **96** as shown. If the siwtch **104** is closed due to failure of the valve **18,** the relay **96** will energize and latch to energize the alarm **94.** The alarm **94** will remain energized even if the switch **104** is subsequently opened as long as the ignition switch **88** is closed.

Referring particularly to FIG. **9** there is shown a detailed configuration of the metering valve **18** and diaphragm **20** incorporating the valve opening switch **104.** As shown, the diaphragm **20** is clamped between an upper casing **106** and a lower casing **108,** and the compression spring **30** biases the diaphragm **20** downward through a washer **110.**

The valve opening switch **104** is different from the valve opening switch **68** illustrated in FIG. **5** in that the former is closed when the metering valve **18** is open above a fifth predetermined value. One contact **112** is in the form of a ball section of a valve stem **19** of the metering valve **18,** and another contact **114** is a metal

leaf connected through a suitable insulator **116** to the lower casing **108.** The contact **112** is grounded to the body of vehicle (not shown) through the valve stem **19,** washer **110,** compression spring **30** and upper and lower casing **106** and **108.** The contacts **112** and **114** engage when the metering valve **18** is open (the position of FIG. **9**) and disengage when the metering valve **18** is closed.

When the ignition switch **88** is closed to start the engine and the engine is idling, the contacts **112** and **114** are disengaged because the metering valve **18** is closed, and the alarm **94** is energized. When the metering valve **18** opens as the intake vacuum increases, the contacts **112** and **114** engage to energize the coil **98,** thereby causing the contacts **100** and **102** to engage while the contacts **90** and **92** disengage. Thus, the alarm **94** is de-energized. If the contacts **112** and **114** once engage, the coil **98** is energized and the relay **96** electrically latches the contacts **100** and **102** together. Thus, the alarm **94** will remain energized until the ignition switch **88** is opened. Therefore, even if the metering valve **18** closes when the intake vacuum is low (such as when the engine is idling or running at full throttle), the alarm **94** remains de-energized. When the ignition switch **88** is opened to stop the engine, the coil **98** is de-energized and the failure warning device will return to the condition shown in FIG. **8.**

Should the metering valve **18** fail to open, the contacts **112** and **114** will remained disengaged even if the intake vacuum increases, and the alarm **94** wil remained energized once the ignition switch **88** has been switched on. Thus, the driver will notice the failure of the exhuast gas recirculation system.

It will be appreciated that the failure warning device illustrated in FIGS. **8** and **9** inclusive can be used as a tester to determined whether or not the exhaust gas recirculation system is operable by depressing the gas pedal to increase the intake vacuum before running.

From the foregoing description with regard to the various embodiments of the present invention, it will be noted that the switch **32,** the combination of switches **64, 66** and **68** and the switch **104** serve as detectors for the failure warning devices of FIGS. **3, 4** and **8,** respectively.

It will now be appreciated that a failure warning device provided in accordance with the present invention is very simple in construction and very reliable in operation.

What is claimed is:

1. A failure warning device for an exhaust gas recirculation system for an internal combustion engine, the exhaust gas recirculation system having an exhaust gas recirculation conduit, an intake vacuum actuated metering valve to meter exhaust gas flow through the recirculation conduit, the metering valve having a diaphragm, one side of which communicates through a conduit with the engine intake system and the other side of which communicates with the atmosphere, said device comprising: an ignition switch which is closed when the internal combustion engine is operating; an alarm; a relay; and a detector to detect inoperability of said metering valve; said relay being actuated by said detector to energize said alarm in response to inoperability of said metering valve if said ignition switch is closed.

2. A device as claimed in claim **1,** wherein said relay once actuated by said detector maintains said alarm energized until said ignition switch is opened.

3. A device as claimed in claim **2,** wherein said detector is a valve opening sensing switch having a diaphragm, one side of which communicates with said conduit and the other side of which communicates with the intake system independently of said conduit, and a set of contacts which open and close in response to the position of said diaphragm of said valve opening sensing switch.

4. A device as claimed in claim **2,** wherein said detector comprises first, second and third switches connected in series with one another, said first switch being an engine temperature sensing switch which is closed when the engine temperature exceeds a first predetermined value, said second switch being an intake vacuum sensing switch which is closed when the sensed intake system vacuum exceeds a second predetermined level, said third switch being a valve opening sensing switch which is closed when the degree of opening of said metering valve is below a third predetermined level.

5. A device as claimed in claim **4,** wherein said intake vacuum sensing switch has a diaphragm, one side of which communicates with the conduit and the other side of which communicates with the atmosphere, and a set of contacts which open and close in response to the position of said diaphragm of said intake vacuum sensing switch.

6. A device as claimed in claim **4,** wherein said intake vacuum sensing switch has a diaphragm, one side of which communicates with a spark advance vacuum port of the intake system and the other side of which communicates with the atmosphere, and a set of contacts which open and close in response to the position of said diaphragm of said throttle vacuum sensing switch.

7. A device as claimed in claim **2,** wherein said detector has first, second and third switches connected in series with one another, said first switch being an engine temperature sensing switch which is closed when the engine temperature exceeds a first predetermined value, said second switch being an intake vacuum sensing switch which is closed when the sensed intake system vacuum exceeds a second predetermined value, said third switch being a temperature sensing switch which is closed when the temperature in the recirculation conduit downstream of the metering valve is below a fourth predetermined value.

8. A device as claimed in claim **1,** wherein the detector actuates said relay to de-energize said alarm once said metering valve operates.

9. A device as claimed in claim **8,** wherein the detector is a switch which closes when the opening degree of said metering valve is above a fifth predetermined value.

10. A device as claimed in claim **9,** wherein the relay is a latching type relay which maintains said alarm de-energized once said metering valve operates.

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