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[54] **EGR WARNING SYSTEM**

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[73] Assignee: **Ford Motor Company,** Dearborn, Mich.

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[52] **U.S. Cl.** ..... **123/119 A,** 60/277, 60/278, 123/119 R, 123/198 D, 137/557

[51] **Int. Cl.** **F02m 25/06**

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

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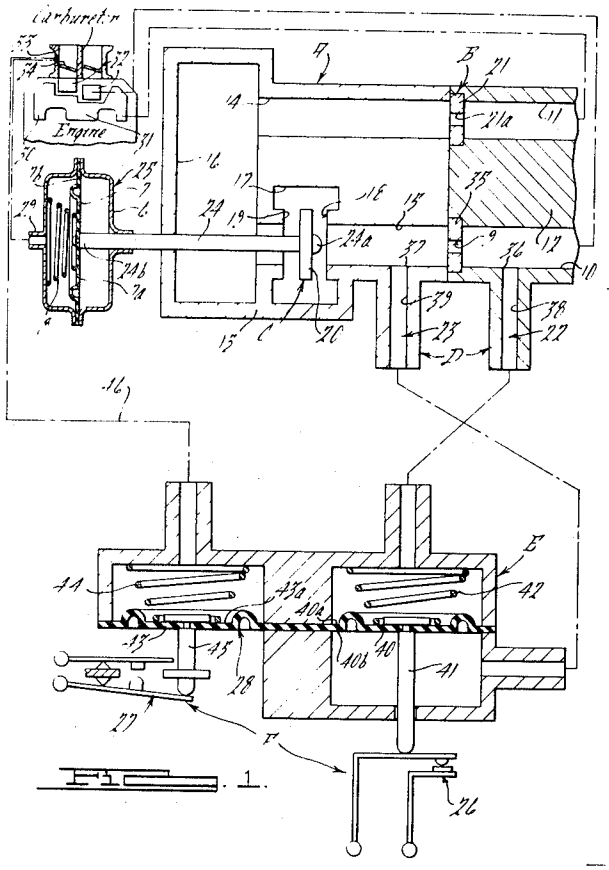
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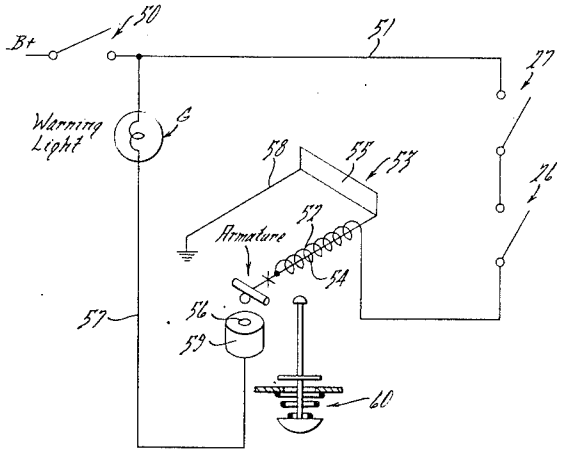
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[57] **ABSTRACT**

An exhaust gas recirculation system for an internal combustion engine is provided with a warning system for indicating to the driver of a vehicle a failure of recirculation. The warning system employs series switches to control an electrical circuit for energizing an indicator; one switch is subject to an engine vacuum signal serving also to control admission of exhaust gas recirculation. Another switch is subject to differential pressures on opposite sides of a restrictor in the recirculation flow to sense a failure of recirculation.

6 Claims, 5 Drawing Figures





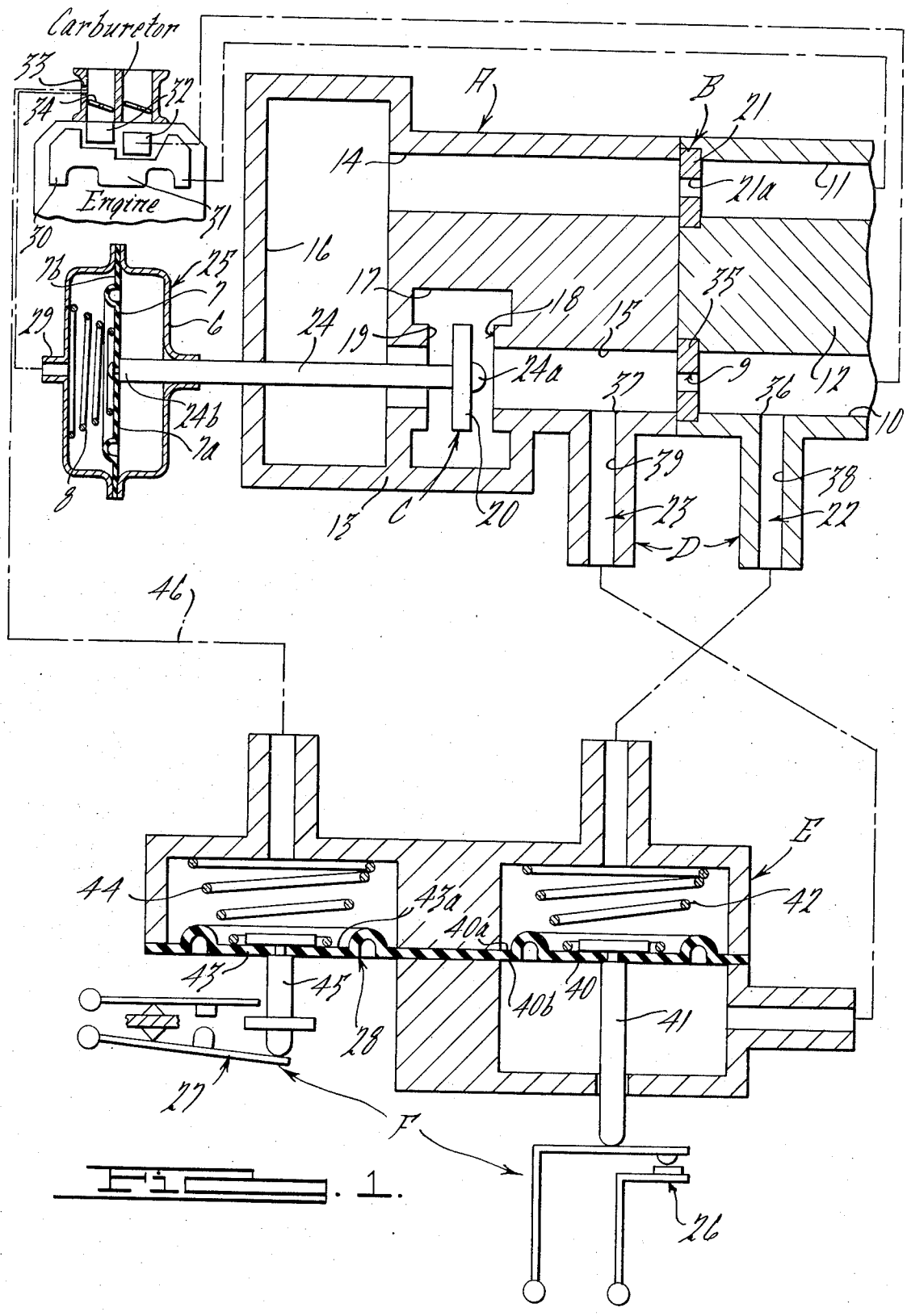

Carburetor
Engine
A
B
C
D
E
F
14
16
17
18
19
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21
21a
22
23
24
24a
24b
25
26
27
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32
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40a
40b
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42
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43a
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7a
7b
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11
12
15

Fig. 1.

FIG. 2.

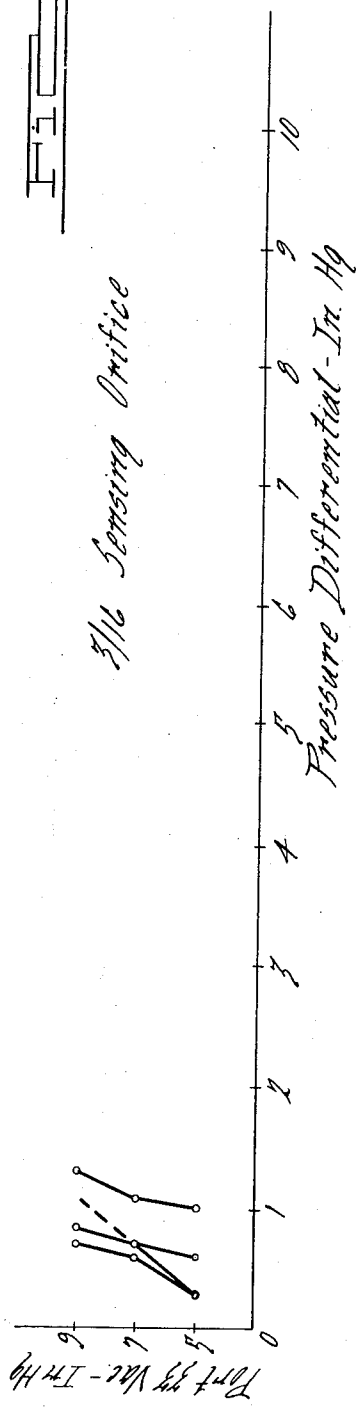


FIG. 3.

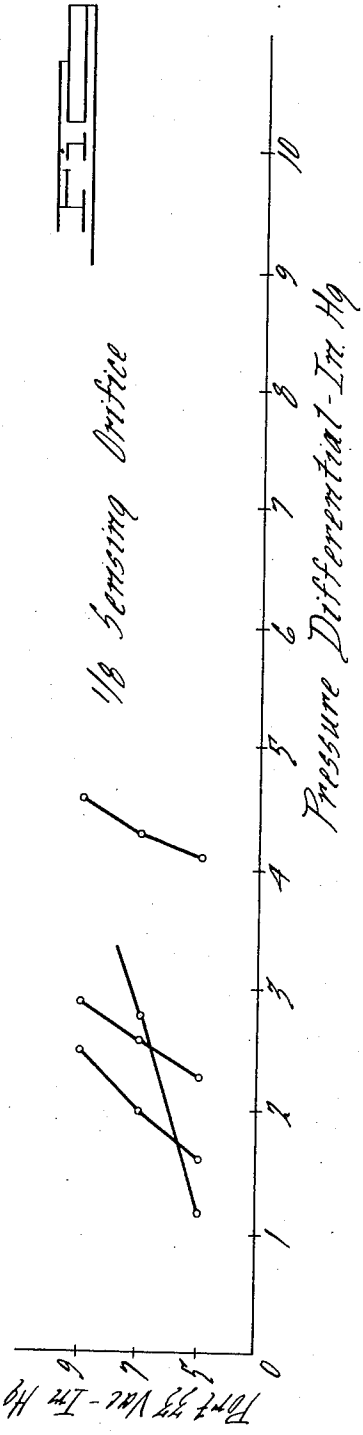
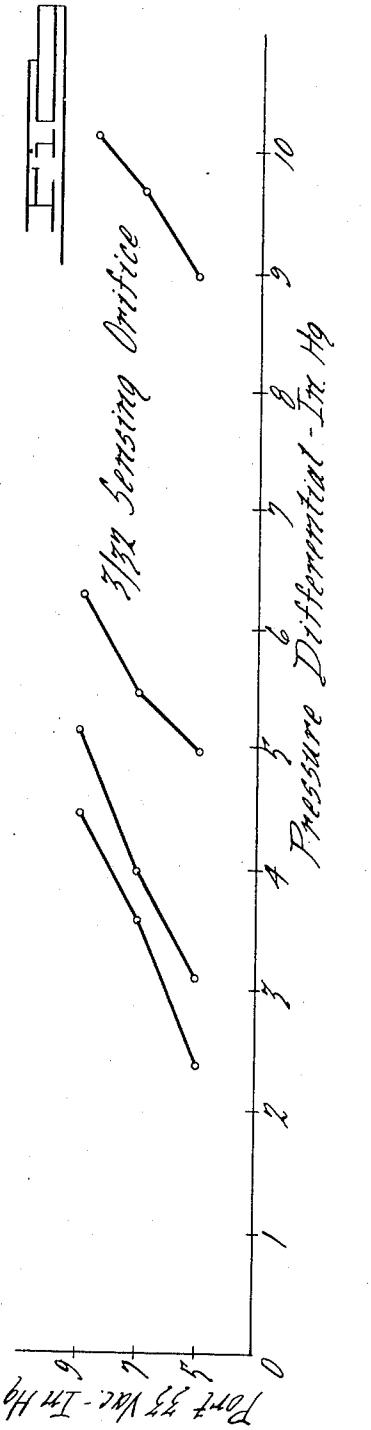


FIG. 4.



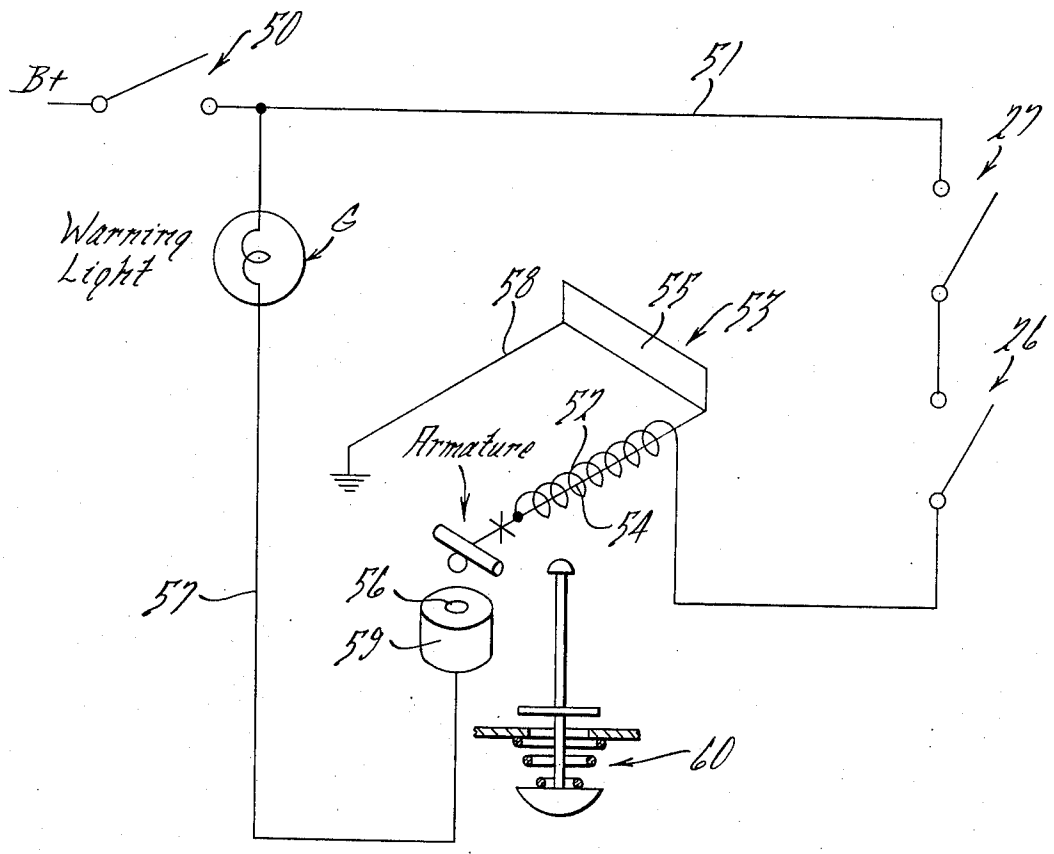


Fig. 5

EGR WARNING SYSTEM

BACKGROUND OF THE INVENTION

With the advent of stricter standards for controlling emissions from internal combustion engines, automotive engineers have found exhaust gas recirculation (EGR) to be a practical assist in lowering the ultimate content of the exhaust gas in such constituents as oxides of nitrogen. With EGR, it is typical to take a portion of the exhaust gas from the exhaust gas cross-over manifold and immediately recirculate the gases to the intake manifold by way of an EGR port. After exiting from the EGR port, the exhaust gases mix with the conventional air/fuel mixture delivered by the carburetor and together the diluted mixture proceeds to the combustion chamber of the engine. Since fuel is drawn in by flow vacuum in the carburetor, any additional flow introduced downstream from the carburetor, as by EGR, will automatically reduce the amount of flow passable through the carburetor venturi and, in turn, reduces the air/fuel ratio. As a result, the mixture which ultimately accompanies exhaust gas recirculation to the combustion chamber is more lean. A leaner mixture would normally allow for a slightly hotter combustion, but due to the mass absorption of the recirculated gases, cooler combustion and lower NO_x results.

Recirculation flow must be a predetermined fraction of the flow leaving the engine to be desirable for emission control. To this end, at least one restrictor is typically utilized. Since exhaust gases contain solid particulate matter, portions of the recirculating system will become blocked or substantially clogged preventing satisfactory recirculation to take place.

It is difficult to known when such blockage occurs, since the conditions under which EGR is operative varies. For example, exhaust gas recirculation is typically controlled by an admitting means which responds to a variation in vacuum pressure of one location of the carburetor so that at low as well as at high throttle positions, there will be no EGR. Therefore, a driver of the vehicle needs to know first, is the EGR system operative at any specific moment, and secondly is there a blockage of the EGR system contrary to a demand for such recirculation.

SUMMARY OF THE INVENTION

It is a primary object of this invention to provide a warning system for an automotive vehicle equipped with exhaust gas recirculation, said system being cumulative in responding to failures in both the control of EGR and the actual functioning of EGR. It is a further object of this invention that such system be provided which is inexpensive and reliable without responding to extraneous conditions.

Specific features pursuant to the above objects include the provision of an apparatus which comprises importantly a second restrictor or orifice in the recirculation path accompanied by pressure sensors on opposite sides of said orifice to determine a normal differential operating pressure. The absence of said differential pressure is indicative of a blockage of said recirculation to actuate a first control element of electrical apparatus for energizing a warning signal. The electrical apparatus is also actuated in series by another control element responsive to normal vacuum pressure controlling an admitting device for starting and stopping EGR in conformity with the needs of the engine. The second control element employs a switch which is actuated by a diaphragm assembly, one side of the diaphragm being exposed to vacuum within the carburetor just immediately in advance of the throttle, the diaphragm being balanced by an opposing resilient means. The presence or absence of appropriate vacuum against one side of said diaphragm determines the on or off condition of said switch and also the on or off condition of the admitting device.

SUMMARY OF THE DRAWINGS

FIG. **1** is a sectional plan view of certain components of one type of exhaust gas recirculation system including certain control elements for energizing a warning signal (the latter not shown);

FIGS. **2–4** are graphical illustrations of operating data for the apparatus of FIG. **1**;

FIG. **5** is a schematic illustration of a wiring diagram representing one embodiment of the electrical apparatus for presenting a warning signal responsive to the apparatus of FIG. **1**.

TECHNICAL DESCRIPTION

In outline, the warning system of this invention is embodied within an apparatus that comprises an exhaust gas recirculation flow means A preferably defined by passage in a spacer plate interposed between the carburetor and engine manifold. Interposed within the flow means A, at spaced locations, is firstly a means B defining a maximum limiting orifice for the exhaust gas recirculation flow; secondly, there is disposed an admitting means C controlled by an actuator **25** to allow or disallow exhaust recirculation flow as in conformity with conditions of said engine; thirdly, there is interposed a sensing orifice **9** forming part of a flow responsive means D. The flow responsive means D also has pressure sensing probes **22** and **23** respectively communicating with opposite sides of an actuator or diaphragm assembly E. The flow responsive means D is thereby capable of sensing a normal differential pressure between intake manifold pressure (through probe **23**) and a reduced pressure influenced by intake manifold vacuum pressure (through probe **22**). The position of actuator E determines the operation of a first control element **26** which forms part of a control means F effective to energize a signal means G (see FIG. **5**). A second control element **27** is operably controlled by an actuator **28** which commonly receives a vacuum signal from the carburetor with an actuator **25** controlling the operation of the admitting means C. Control element **27** forms part of the control means F and functions in series according to the preferred electrical system.

Turning now in some particularity to the components above identified, the flow means A is defined by passages in a spacer plate **12** and an end plate **13**, the spacer being inserted between the carburetor and engine manifold (seen best in elevation in the schematic portion in FIG. **1**. The exhaust manifold is part of the engine cylinder head and is indicated partially at **30**. It includes an exhaust gas crossover passage **31**. The exhaust gases pass from the exhaust manifold, not shown, on one side of the engine to the opposite side beneath the manifold trunks **32** to provide the usual "hot spot" beneath the carburetor to better vaporize the air/fuel mixture.

As shown in section in FIG. 1, the spacer is provided with a passage 11 that is connected directly with the crossover passage (not shown). Passage 10 of the spacer plate communicates with the air barrel of the carburetor immediately below the throttle and just above the trunks 32 for communication with the intake valves of the engine.

The end plate 13 has a passage 14 in line with passage 11 and also has a passage 15 in line with passage 10 of the spacer plate 12; cross passage 16 communicates passages 14 and 15. An annular recess 17 is defined in the wall of channel 15 and has annular lips 18 and 19 operative as seats for a valve element 20 of admitting means C. A flow restrictor 21 is positioned in passage 11 adjacent to passage 14; restrictor 21 has an internal opening 21*a* calibrated for a predetermined maximum flow, here it is typically 0.15 inches in diameter. The opening 21*a* can be varied in size to meet specific engine requirements. Although, there may be opportunities for clogging other regions of the EGR system, the restrictor 21 is not an importantly critical part more likely to be blocked by particulate matter, but rather low flow rate regions will allow build up of contamination.

The admitting means C particularly comprises a reciprocally operated valve stem 24 carrying valve element 20 at one end 24a; the stem passes through an end wall of plate 13 and into passage 16 and passage 15 for movement of element 20 between valve seats 18 and 19.

It is necessary and desirable to provide some sort of control to prevent the recirculation of exhaust gases at undesirable times. For this purpose, the admitting means C is controlled by a servo mechanism or diaphragm assembly 25 which includes a chamber 6 containing an annular flexible diaphragm 7 separating the interior thereof. One side 7*a* of the diaphragm is vented to atmospheric pressure and the other side 7*b* is subjected to both a positive acting spring 8 and the negative force of a vacuum signal received through line 29 communicating with a port 33 slightly upstream from the edge of the throttle 34. Vacuum sensed by port 33 is generally nonexistent or very low at substantially closed throttle conditions when EGR is not needed due to low NO_x formation. End 24*b* of the stem is fixed to a central portion of diaphragm 7 for being moved in concert therewith. Spring 8 normally biases the diaphragm to the right as viewed in FIG. 1 and thereby valve element 20 is urged to a closed position against seat 18, preventing exhaust gas recirculation. However, under the influence of a suitable vacuum during mid-range throttle conditions, valve element 20 will be moved to a middle position as that shown in FIG. 1. Under low speed conditions (such as idling) the vacuum is sufficiently high to fully overcome the biasing force to cause valve element 20 to engage seat 19 and again close off EGR. Ambient temperature conditions for line 29 will range between −40° to +250°F and the vacuum from port 33 will typically range between 4–9 inches of mercury.

The flow responsive means D comprises sensing orifice 9 defined by a disc 35 having said opening, the disc being disposed as indicated in passage 10 adjacent to passage 15. It is preferred that the opening of the sensing orifice be comparable in size and not smaller than that of the first restrictor opening 21*a* so as to retain the latter as the maximum limitation of flow. Orifice 9 is here typically about 0.15 inches in diameter. The sensing orifice produces a pressure differential during normal exhaust recirculation whereby the positive pressure of exhaust gas is lower on the downstream side of orifice 9 and is potentially subject to intake manifold vacuum. As an important alternative, the sensing orifice may be provided by the restriction constituting the seats 18 and 19 for the admitting means (this usually is practical only for high rate recirculation systems). Appropriate openings 36 and 37, and passages 38 and 39 constitute respectively said probes 22 and 23 and are provided on opposite sides of the orifice 9 to communicate any pressure differential to different sides 40*a* and 40*b* of a diaphragm 40 of the actuator E. A movable member 41 is connected to the diaphragm, the latter being biased in a downward direction as viewed in FIG. 1 by resilient spring 42. Positive pressure, conveyed by probe 23 during the "on" condition of EGR, is placed against side 40*b* to counter spring 42. Lower positive pressure conveyed by probe 22 during normal EGR assists spring 42. However, when EGR is blocked, there will be no positive pressure to overcome spring 42 and element 41 will be moved to its lowermost position. Thus, the differential pressure during normal EGR operation is effective to overcome the spring pressure to maintain switch or control element 26 in an open condition.

To operate control element or switch 27, a servomechanism or diaphragm assembly 28 is placed in parallel with assembly 25, both utilizing a vacuum signal received from port 33 to act against a diaphragm. In assembly 28, the diaphragm 43 has spring 44 normally biasing diaphragm 43 and thereby element 45 in a downward direction to normally open switch 27; vacuum is conveyed by line 46 to side 43*a* of the diaphragm to counter spring 44 when and only when EGR is permitted to flow, thereby closing switch 27.

The amount of testing that is necessary to achieve the appropriate size for orifice 9 is best illustrated by referring to FIGS. 2, 3 and 4. Shown in FIG. 2, a relatively large opening has been chosen for the orifice (three-sixteenths inch) and test data indicates that a very narrow differential is achieved between the upstream and downstream probes during operable conditions of exhaust gas recirculation. This would require that the spring biased diaphragm 40 be extremely sensitive to a narrow pressure differential to be accurate in providing a warning signal; this would be impractical. The narrow pressure differential does not shift substantially in accordance with various speed levels. The differential ranging between approximately one-half inch of mercury to as much as 1.6 inches of mercury.

As the orifice size is increased to four-thirty-seconds of an inch, the pressure differential increases and ranges from about 1 inch of mercury to as much as 4.7 inches of mercury in accordance with various speed levels. For design of the orifice, the lowest point of vacuum and differential is significant. Since this point may be at about a differential of 1.2 at 5 inches of vacuum, it would require too sensitive a diaphragm assembly.

At a control orifice size of three-thirty-seconds of an inch, the pressure differential ranges well above 2 inches of Hg. for the pressure differential at the lowest level of operating vacuum. This appears to be within practical limits of a durable and reliable actuator E.

Since certain conditions of providing a pressure differential may be erratic and momentary, a preferred

electrical circuit system for energizing the warning signal is shown in FIG. 5. Tracing through the circuit, starting at the power source B+, the ignition switch **50** must be closed by turning on the ignition key permitting current to flow along the path **51** which must pass through switches **27** and **26** corresponding to the control elements of FIG. **1.** Assuming the switches are closed due to faulty interruption in EGR as well as the on position of the EGR control valve, current will pass through the winding **52** of a bimetal time delay device **53** so as to heat one leg **54** of juncture **55** causing the leg **54** to move downwardly and engage a terminal **56** completing a circuit through portion **57** to the warning light or signal G. Before contact is made with terminal **56,** the circuit is completed by a ground connection to the other leg **58** of juncture **55.**

Once the terminal **56** is engaged, there is a magnet lock-in device **59** which holds contact with leg **54** (which constitutes an armature), even after switches **26** or **27** is opened. When the vehicle is returned to a repair shop for servicing of the EGR system, the mechanic may use a manual reset assembly **60** to return the leg or armature to its initial non-contacting condition. The use of a bimetal device is needed to give a time delay which will integrate contact vibrations and not show a false failure.

Other electrical circuit systems are envisioned within the scope of this invention. For example, it may not be desirable to have an armature lock in the on-signal condition and the only time it can be unlocked is by a repairman. To this end, the circuit may be arranged so that the current flows through the winding and through the switches **26** and **27** in series to ground, to heat one leg of a bimetal time delay which will simply engage a terminal to energize all the signal through a current path independent of switches **26** and **27.** Then, only when the ignition switch is turned off, will the signal light be de-energized; the entire sequence must be traversed once the ignition switch is turned on again creating a time delay prior to again energizing the warning light.

Yet another electrical circuit embodiment may involve the concept of providing a check of the EGR system once during a driving trip or cycle and if defective to lock in the failed warning light mode; this prevents battery drain. To this end, electrical energy passes from the power source B+ first through a first path having a first bimetal time-delay device which is in series with the control elements or switches **26** and **27** and with a ground. Current flow, if permitted, will heat and move one leg of the delay device to close across terminals completing an independent circuit path which contains the warning light and will stay in this condition until the ignition is turned off. There will be no continuous monitoring of the EGR system. In the event the EGR system is operative but that there is no failure in the system, switch **27** will be closed, not switch **26,** thereby unable to affect the first time delay device. A second bimetal time delay device is provided so that current through switch **27** can activate the second device to complete a lock-off circuit path assuming no energization of the warning light. The lock-off condition is deactivated when the ignition is turned off.

I claim:

1. A warning system for indicating malfunction of exhaust gas recirculation which is adapted to return exhaust gases from an exhaust manifold to the intake manifold of an internal combustion engine, the combination comprising:

a. means defining a limiting orifice through which said exhaust gas recirculation must flow;

b. means responsive to predetermined conditions of said engine to admit recirculation flow;

c. flow responsive means having an actuator normally biased in one direction and urged in an opposite direction by the combination of both exhaust manifold pressure and intake manifold vacuum pressure during substantial exhaust gas recirculation;

d. a signal means to indicate failure of said recirculation;

e. control means operably interconnecting said flow responsive means and admitting means with said signal means, said control means having a first control element responsive to movement of said actuator in said opposite direction idicative of the absence of exhaust gas recirculation for permitting energization of said signal means, and a second control element in series with said first control element permitting energization of said signal means only when said flow admitting means is operative to permit recirculation of exhaust gases.

2. The warning system as in claim **1,** in which said actuator comprises a diaphragm normally biased in one direction and having one side of the diaphragm subject to the pressure of said recirculation flow immediately upstream from said orifice and the other side of said diaphragm subject to the pressure of said recirculation flow immediately downstream of said orifice, whereby during recirculation the differential between said pressures is effective to overcome said bias and during a failure of said recirculation the differential between said pressures is effective to operate said first control element for energizing said signal means.

3. A warning system as in claim **1,** in which said admitting means comprises a valve movable between positions to permit or prevent exhaust gas recirculation, a first diaphragm assembly having a diaphragm normally biased in one direction and subject to a vacuum signal from said engine for urging said diaphragm in an opposite direction, said second control element being responsive to the operative positioning of said diaphragm for determining an open or closed position thereof.

4. The combination as in claim **3,** in which said engine has a carburetor with a port arranged to communicate a vacuum signal which is non-existent at closed or wide-open throttle conditions of said carburetor, means connecting said port with said diaphragm assembly to subject said diaphragm to said vacuum signal.

5. The combination as in claim **3,** in which a second diaphragm assembly is employed in parallel with said first diaphragm assembly, said first assembly operating to directly effect the positioning of said valve and said second assembly operating to directly effect positioning of said second control element.

6. The warning system as in claim **1,** in which said signal means comprises a visual indicator normally energized by an electrical circuit with said control elements comprising electrical switches in said circuit, said signal means further comprising a time delay means in said circuit effective to energize said indicator only after a predetermined time has elapsed from when both said switches are closed.

* * * * *