Nov. 22, 1949 J. M. SILLS 2,488,563

EXHAUST PURIFYING SYSTEM AND METHOD

Filed Jan. 10, 1945 2 Sheets-Sheet 1

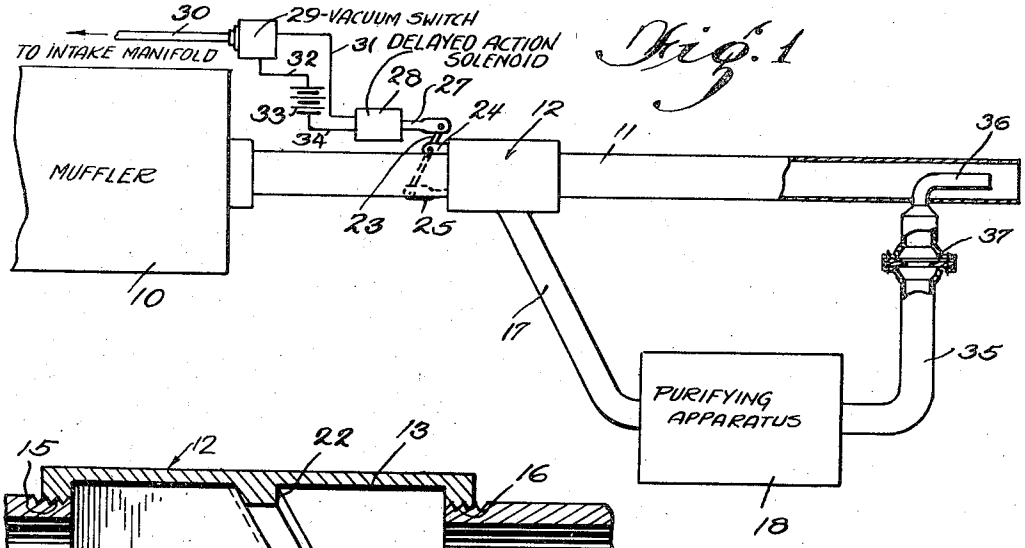


Fig. 1

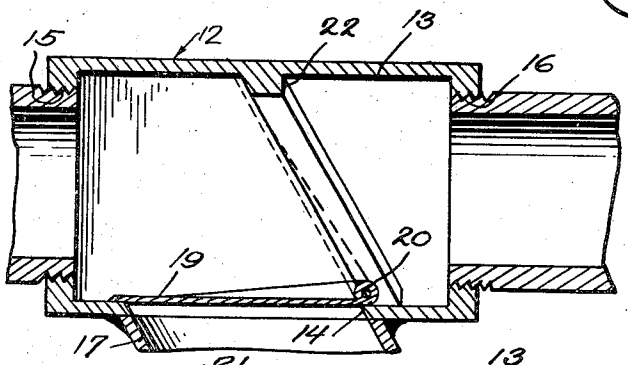


Fig. 2

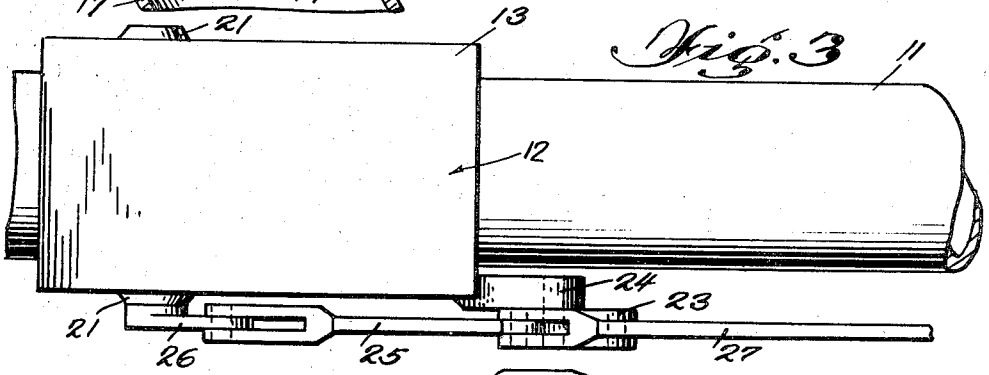


Fig. 3

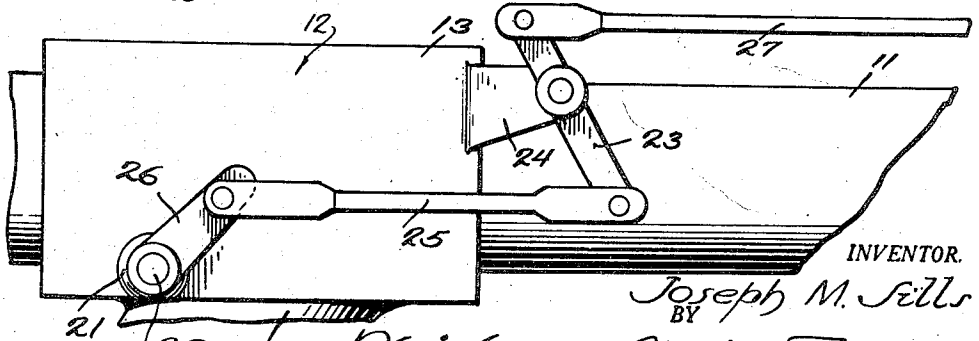


Fig. 4

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EXHAUST PURIFYING SYSTEM AND METHOD

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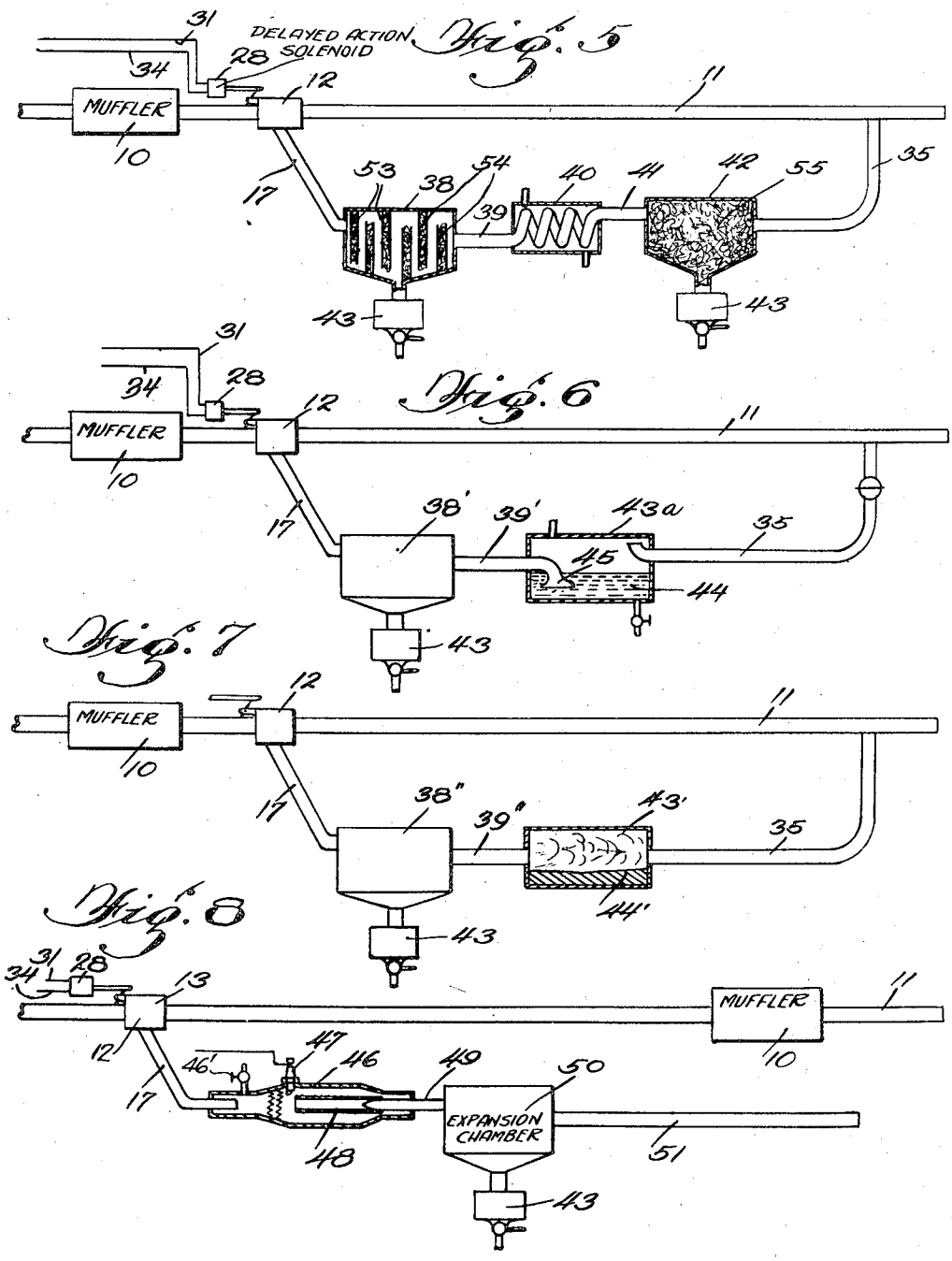


Fig. 5

Fig. 6

Fig. 7

Fig. 8

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2,488,563

## EXHAUST PURIFYING SYSTEM AND METHOD

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15 Claims. (Cl. 60—29)

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The invention described herein, if patented, may be manufactured and used by or for the Government for governmental purposes, without the payment to me of any royalty thereon.

My invention relates to a purifying system for removing the noxious and harmful components from the exhaust gases of internal combustion engines, and more particularly to a system that is automatically operated intermittently to effect treatment only at those times when the percentage of noxious and harmful components in the exhaust gases is high enough to be harmful due to conditions of the engine operation.

The existence of certain noxious and harmful components in the exhaust gases expelled from internal combustion engines of automotive or other vehicles, such as carbon monoxide, numerous aldehydes and gasoline or oil vapors, and their deleterious effect on the health of drivers or others subject to such vapors is well known as evidenced by the many attempts that have been made in the past to devise a satisfactory method and apparatus for removing such components from the exhaust gas, but prior to this time, and in spite of these attempts by many individuals, a successful solution has not been found. In all of these systems an attempt is made to run the entire volume of exhaust gas expelled from the engine through the purifying apparatus even though, during most periods of engine operation, the content of noxious and harmful components in the exhaust gas is too small to result in any harmful effects on pedestrians or other drivers. As a result the purifying system soon fails because a system large enough to handle this volume of gas cannot conveniently be used in conjunction with an internal combustion engine, particularly in connection with automotive vehicles, trucks and other conveyances.

It is known that the content of noxious and harmful components in exhaust gases is dangerously high only when combustion is incomplete, and this occurs at those times when the engine is being decelerated or when it is being run at idling speeds with a partially or fully closed throttle whether or not the vehicle is in motion, and for a few moments thereafter, because as the throttle is opened and the engine speeds up, the increased flow of exhaust gases tends to scavenge from the exhaust line of the engine those exhaust gases which have accumulated therein during deceleration or idling operation so that there will be a sudden blast of extremely

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noxious gas from the exhaust line immediately upon acceleration.

It is an object of the present invention, therefore, to provide a simple and inexpensive construction by which the exhaust gases are automatically directed through a purifying apparatus during deceleration or when the engine is running at idling speeds or partially or fully closed throttle, and at other times follow the usual course through the exhaust pipe.

It is a further object of the invention to provide an exhaust purifying system in which the automatic valve operator includes a delayed action device so as to momentarily delay the shifting of the valve as the engine is speeded up, thereby providing for the purification of the large volume of exhaust gases ejected from the exhaust system at such times.

For the purpose of carrying out my invention, I have disclosed in the drawing and described in the specification a preferred embodiment thereof as applied to the internal combustion engine of an automotive vehicle, but it will be obvious as the description proceeds that my new purifying system may be applied advantageously to internal combustion engines used on other types of conveyances or in other installations such as stationary engines.

In the drawings:

Figure 1 is a diagrammatic side elevational view showing my exhaust gas purifying system as it might be installed in the exhaust line of an automotive vehicle.

Figure 2 is a vertical section through the flow control valve.

Figure 3 is a top plan view of the flow control valve.

Figure 4 is a side elevational view of the valve.

Figure 5 is a diagrammatic side elevational view of a purifying system using expansion chambers and a heat exchanger as the purifying means for removing the noxious components from exhaust gases.

Figure 6 is a diagrammatic side elevational view of a purifying system in which an expansion chamber and a liquid absorbent are used to purify exhaust gases.

Figure 7 is a diagrammatic side elevational view of a purifying system having an expansion chamber and non-liquid absorbent for purifying exhaust gas.

Figure 8 is a diagrammatic side elevational view of a purifying system in which a combustion chamber and an expansion chamber are used to

remove the noxious components from exhaust gases.

Referring to the drawings, there is shown in Figure 1 a portion of the exhaust disposal line of an internal combustion engine including a muffler 10 of conventional construction for deadening the sound of the discharging exhaust and a tail pipe 11 for conducting the exhaust gas from the muffler to the atmosphere at a point adjacent the rear end of the vehicle. Mounted in the tail pipe adjacent the muffler is an exhaust flow control valve 12, the details of which are shown in Figures 2 to 4. This valve includes a housing 13 generally rectangular in cross-section and provided with a by-pass outlet 14 in its bottom side and threaded openings 15 and 16 in the front and back sides respectively in which are received the threaded ends of the conduits which make up the tail pipe so that the housing 13 forms a part of the path of flow of exhaust gases from the muffler to the atmosphere. A conduit 17 is secured by suitable means in the by-pass outlet 14 and leads to the purifying apparatus 18 which is shown diagrammatically in Figure 1 and will be described hereinafter in more detail.

The valve proper comprises a plate 19 of rectangular shape rigidly secured upon a pin 20 which is pivotally mounted in bosses 21 located along the lower edge on each side of the housing 13. The interior of the housing is provided with a ridge 22 which extends angularly upwardly on the sides of the housing from the bottom and across the top and forms a valve seat for the valve 19 to limit movement thereof and prevent leaking of gases past the valve when the latter is in raised position as shown in dotted lines in Figure 2.

The mechanism for actuating the valve 19 shown diagrammatically in Figure 1 and in more detail in Figures 3 and 4 comprises a bellcrank lever 23 pivotally mounted on an arm 24 extending horizontally from the back edge of the housing 13 and a tie rod 25 pivotally secured to the lower end of the bellcrank lever 23 and to the upper end of an arm 26 rigidly secured on the outwardly projecting end of the hinge pin 20. The upper end of the bellcrank 23 is connected by a tie rod 27 to the plunger of a delayed action solenoid 28 of the general type shown in A. T. Marshall Patent No. 1,278,189. When the solenoid is energized and the plunger is drawn inwardly it rotates the hinge pin 20 and causes the valve to be raised to the position shown in dotted lines in Figure 2 through the tie rods and bellcrank. In this position of the valve the exhaust gas is directed through the by-pass conduit 17 to the purifying apparatus 18.

Normally, the noxious content of exhaust gases will be great enough to require purification only at those times when combustion is incomplete, that is, when the engine is being decelerated, or is idling at partially or fully closed throttle at a speed of from 150 to 700 R. P. M. and it is necessary to run exhaust gases through the purifying apparatus only at those times. To accomplish this, the operation of the valve 19 must be synchronized with the operation of the engine and this can be done in several ways. It is known that the intake manifold vacuum of an internal combustion engine varies under different conditions of engine operation, but is highest at those times when the engine is being decelerated or is idling at partially or fully closed throttle which is also the time at which combustion is incomplete and the noxious content of the exhaust gases highest so that a device responsive to variations in intake manifold vacuum offers one means for actuating the by-pass valve 19. Such a device may consist of a vacuum contactor switch 29 of conventional construction which is connected by a conduit 30 to the intake manifold of the engine. One of the contacts of this switch is connected by a lead 31 to one of the contacts of the solenoid and the other contact is connected by a lead 32 to a source of current 33. The circuit to the solenoid is completed by a third lead 34 connecting the solenoid and the source of current.

Switch 29 is adjusted to be actuated when the vacuum in the intake manifold exceeds a predetermined amount, for example, when it exceeds 10 inches of mercury and when actuated it closes the circuit to the solenoid 28 which through the tie rod 27, bellcrank 23 and tie rod 25 operates the valve 19 to close the passageway to the tail pipe 11 and open the by-pass 14 leading to the purifying system. The solenoid 28 is of the delayed action type so that the valve 19 is not immediately operated upon acceleration of the engine after it has been decelerated or run at idling speeds but is delayed for an interval of time long enough to cause the first scavenging blast of exhaust gases upon acceleration to pass into the purifying apparatus.

To facilitate operation of the system I have provided means for evacuating the purifying apparatus at those times when the exhaust gases are being discharged through the conventional exhaust disposal line comprising a conduit 35 connecting the outlet side of the purifying apparatus 18 with the tail pipe 11 at a point beyond the by-pass valve 12. Conduit 35 is provided with an eductor or aspirator 36 positioned in the tail pipe so that it will be acted upon by the exhaust gases flowing through the tail pipe under normal engine operation and will cause the purifying apparatus to be evacuated at such times thereby drawing out of the apparatus the purified exhaust gases and reducing the pressure to sub-atmospheric. A check valve 37 is also provided in the conduit 35 to prevent back flow from the tail pipe through the conduit and to the purifying apparatus when the valve 19 is open to the dotted line position shown in Figure 2. This valve also causes the exhaust gases passing into the purifying apparatus to be momentarily trapped therein until the pressure in the purifying system builds up to atmospheric pressure. In some instances the eductor 36 will be unnecessary and the purified gases may be discharged directly to the atmosphere through a discharge pipe 52 shown in Figures 5, 6, and 7 by dotted lines.

Although I have described a means for actuating the flow control valve 19 which operates in response to changes in the engine intake vacuum it will be obvious that other means for actuating the valve may be used.

In Figures 5 to 8 inclusive are shown various types of purifying systems that may advantageously be used for purifying exhaust gases. In the system shown in Figure 5 the conduit 17 leading from the by-pass valve 12 is connected to an expansion chamber 38 in which the gases expand and as a result are cooled, the cooling being sufficient to condense out some of the noxious aldehydes along with other components such as water vapor. A series of spaced baffles 53 are disposed within the expansion chamber 38 arranged in staggered relation to define a tortuous path for the gas flowing through the expansion chamber so that the flow is restricted but not sufficiently to

create an objectionable back pressure. These baffles are loosely packed with metallic wool 54 upon which the condensate collects and from which it drips to the bottom of the expansion chamber.

The outlet side of the expansion chamber is connected by a conduit 39 to heat exchanger 40 where the gases are further reduced in temperature, the reduction required varying under different circumstances, but in most cases a reduction to 100° F. will be sufficient. However, there may be cases where a reduction to about 126° F. will be sufficient to condense out all of the toxic, malodorous and harmful aldehydes, and in other instances depending on the type of engine, type of fuel and conditions of engine operation, it may be necessary to reduce the temperature to a point below 100° F. and even to as low as 50° F. From the heat exchanger 40 the gases flow through a conduit 41 to a second expansion chamber 42, which also acts as a collector for gas and a trap for any other liquids which may condense out. Expansion chamber 42 may be of the same construction as expansion chamber 38 or it may be of the simplified construction shown in Figure 5 in which the chamber 42 is merely loosely packed with metallic wool 55 so that the flow of the gas through the chamber is restricted to a limited extent. Condensate collects on the wool and drops to the bottom of the chamber. From the chamber 42 the purified gases flow through the conduit 35 to the tail pipe 11, when the pressure rises above atmospheric or the engine resumes normal operation.

Each of the expansion chambers 38 and 42 is provided with a bottom declined toward the center point and a drain connected to a small reservoir 43 for collecting condensate. This reservoir may be periodically drained through a petcock or by other suitable means.

It has been found that the various aldehydes form the greatest percentage of malodorous and toxic components in exhaust gas when an engine is being decelerated or run at idling speed and combustion is incomplete. The majority of these aldehydes which are harmful will condense out when the temperature of the gas is reduced to about 100° F. so that in the ordinary installation a reduction to this temperature will be sufficient. Under certain conditions, for example, during cold weather this reduction may be accomplished merely by using the expansion chambers 38 and 42 and simple air cooled heat exchanger 40, but under other conditions of operation, for example, in warm climates, or when it is necessary to condense a larger percentage of the noxious aldehydes, this will have to be done by reducing the temperature of the gases below atmospheric temperature.

In Figure 6 I have shown a different type of system in which purification is accomplished by absorption of the noxious components of the exhaust gases. In this system the conduit 17 is connected to an expansion chamber 38', similar to the chamber 38, and the outlet therefrom is connected to a conduit 39' which leads into a reservoir 43a for containing a liquid purifying agent indicated at 44. Conduit 39' is provided with an enlarged end 45 immersed in the chemical and an outlet for dispersing the exhaust gases through the chemical in a finely divided state to secure maximum contact between the gas and the purifying liquid. A gas outlet conduit 35 is provided with an end which projects into the upper end of the reservoir and connects with the tail



pipe 11 through a check valve similar to the check valve 37 for returning purified gas to the tail pipe. The purifying agent must be of such chemical characteristics that it reacts with the aldehydes in the exhaust gases so that they are absorbed and removed from the gas and the reservoir is preferably provided with a drain and an inlet for chemical so that the purifying agent may be periodically renewed by draining the reservoir and refilling it with a new charge.

The construction and operation of the system shown in Figure 7 is similar to that of the system just described, but a non-liquid absorbent chemical 44' is used in the reservoir 43' instead of a liquid absorbent and the conduit 39'' connecting the expansion chamber 38'' and the reservoir 43' has an outlet which directs the flow of exhaust gases over the non-liquid absorbent 44'.

The system shown in Figure 8 accomplishes purification of the exhaust gases by burning the noxious components which in most instances are combustible under proper conditions. In this system the by-pass valve housing 13 is located as close to the exhaust manifold as conveniently possible so that the exhaust gases passing into the conduit 17 will be at a relatively elevated temperature. The outlet of the conduit is in the forward end of a combustion chamber 46 which is provided with a spark plug 47 connected in the electric circuit of the engine for producing the flame necessary to ignite the exhaust gases that are directed into the combustion chamber. This chamber is of conventional construction and may be provided with an inlet 46' at the forward end for admitting auxiliary air for supporting combustion and a shutter or valve for the inlet. A baffle pipe 48 is included in the combustion chamber to insure complete combustion of the gases which after combustion pass through a conduit 49 to an expansion chamber 50 similar to the expansion chamber 38 in the embodiment shown in Figure 5. This chamber has a direct outlet to the atmosphere through a conduit 51.

While I have described various purifying apparatus to be used individually in rendering harmless the noxious and malodorous components of exhaust gases, it is to be understood that in some installations these different types of purifying systems can be advantageously used in combination or in sequence to accomplish the desired purification. Due to conditions of engine operation, the type of fuel used or the type of engine the harmful components of the exhaust gases may vary in composition or in the amount present so that it may be necessary to combine in one system the various types of treatment shown in Figures 5 to 8 in sequence to effect the desired purification. Other combinations of systems and other modifications and arrangements of parts may also be made without departing from the scope and spirit of the invention as set forth in the appended claims.

What I claim is:

1. An intermittently operable system for purifying the exhaust gases of an internal combustion engine having a conventional exhaust disposal line and an intake manifold comprising purifying means adapted to remove the noxious components from said exhaust gases, means for by-passing said exhaust gases from said conventional exhaust disposal line through said purifying means for purifying the same, a solenoid for actuating said by-pass means, a circuit for supplying current to said solenoid, a vacuum switch in said circuit operably connected to said intake

manifold for closing said circuit to energize said solenoid when the vacuum in said intake manifold exceeds a predetermined amount, said solenoid operating said by-pass to cause gases to flow to said purifying means.

2. An intermittently operable system for purifying the exhaust gases of an internal combustion engine having a conventional exhaust disposal line and an intake manifold comprising purifying means adapted to remove the noxious components from said exhaust gases, means for by-passing said exhaust gases from said conventional exhaust disposal line through said purifying means to purify the same, a delayed action solenoid, means connecting said solenoid and by-pass means for actuating the latter when said solenoid is energized, a circuit for supplying current to said solenoid, a vacuum switch in said circuit operably connected to said intake manifold for closing said circuit to energize said solenoid when the vacuum in said intake manifold exceeds a predetermined amount, said by-pass being operated by said solenoid to cause gases to flow to said purifying means.

3. An intermittently operable system for purifying the exhaust gases of an internal combustion engine having a conventional exhaust disposal line and an intake manifold comprising purifying means adapted to remove the noxious components from said exhaust gases, means for by-passing said exhaust gases from said conventional exhaust disposal line through said purifying means to purify the same, a delayed action solenoid, means connecting said solenoid and by pass means for actuating the latter when said solenoid is energized, a circuit for supplying current to said solenoid, a vacuum switch in said circuit operably connected to said intake manifold for closing said circuit to energize said solenoid when the vacuum in said intake manifold exceeds a predetermined amount, said by-pass means being operated by said solenoid to cause gases to flow to said purifying means, and means for returning said purified exhaust gases to the conventional exhaust disposal line.

4. A method of removing the noxious gas components from the exhaust gases formed during the operation of a variable speed internal combustion engine which comprises passing said exhaust gases through a confined passageway to the atmosphere, and during deceleration of said internal combustion engine, diverting all of said exhaust gases from said passageway to a treating zone to remove the noxious components of said exhaust gases and discharging the treated gases from the treating zone to the atmosphere substantially free of noxious components, and while passing the exhaust gases directly through said passageway to the atmosphere, maintaining a condition of partial vacuum in said treating zone.

5. A method of removing the noxious components from the exhaust gases formed during the operation of a variable speed internal combustion engine which comprises passing said exhaust gases through a confined passageway to the atmosphere, and during operation of said engine throughout the entire range of speed when the intake manifold vacuum is higher than 10 inches of mercury, diverting all of said exhaust gases from said passageway to a treating zone to remove the noxious components of said exhaust gases, and discharging the treated gases from the treating zone to the atmosphere substantially free of noxious components.



6. An intermittently operable system for purifying the exhaust gases of an internal combustion engine having the conventional exhaust disposal line, comprising purifying means adapted to remove the noxious components from said exhaust gases, means for by-passing said exhaust gases from said conventional exhaust disposal line through said purifying means to purify the same, and pressure-responsive means communicating with the intake manifold of the engine for automatically operating the by-pass means to cause exhaust gases to be by-passed through said purifying means when the vacuum in the intake manifold is relatively high.

7. An intermittently operable system for purifying the exhaust gases of an internal combustion engine having a conventional exhaust disposal line, comprising purifying means adapted to remove the noxious components from said exhaust gases, means for by-passing said exhaust gases from said conventional exhaust disposal line through said purifying means, and pressure-responsive means communicating with the intake manifold of the engine for automatically operating the by-pass means to cause exhaust gases to be by-passed through said purifying means when the vacuum in the intake manifold is relatively high, said operating means for the by-pass including a delayed-action solenoid to normally delay the operation of the by-pass means upon increase of the vacuum in the intake manifold.

8. An intermittently operable system for purifying the exhaust gases of an internal combustion engine having a conventional exhaust disposal line, comprising purifying means adapted to remove the noxious components from said exhaust gases, means for by-passing said exhaust gases from said conventional exhaust disposal line through said purifying means, pressure-responsive means communicating with the intake manifold of the engine for automatically operating the by-pass means to cause exhaust gases to be by-passed through said purifying means when the vacuum in the intake manifold is relatively high, said operating means for the by-pass including a delayed-action solenoid to normally delay the operation of the by-pass means upon increase of the vacuum in the intake manifold, and means for returning said purified exhaust gases to said conventional exhaust disposal lines.

9. An intermittently operable system for purifying the exhaust gases of an internal combustion engine having a conventional exhaust disposal line, comprising purifying means adapted to remove the noxious components from said exhaust gases, means for by-passing said exhaust gases from said conventional exhaust disposal line through said purifying means, pressure-responsive means communicating with the intake manifold of the engine for automatically operating said by-pass means to cause exhaust gases to be by-passed through said purifying means when the vacuum in the intake manifold is relatively high, said operating means including a delayed-action solenoid to delay momentarily the operation of said by-pass means upon change in the condition of engine operation to produce high vacuum in the intake manifold, and means for causing said purifying means to be evacuated to sub-atmospheric pressure when exhaust gases are flowing through said conventional exhaust disposal line to facilitate the flow of gas into said purifying means when exhaust gases are by-passed thereto.

10. An intermittently operable system for purifying the exhaust gases of an internal combustion engine having a conventional exhaust disposal line, comprising purifying means adapted to remove the noxious components from said exhaust gases, means for by-passing said exhaust gases from said conventional exhaust disposal line through said purifying means, and pressure-responsive means communicating with the intake manifold of the engine for automatically operating said by-pass means to cause exhaust gases to be by-passed through said purifying means when a predetermined degree of vacuum in the intake manifold is exceeded, said operating means including a delayed-action solenoid to delay the operation of said by-pass means momentarily upon change in the degree of vacuum in the intake manifold.

11. An intermittently operable system for purifying the exhaust gases of an internal combustion engine having a conventional exhaust disposal line and an intake manifold, comprising purifying means adapted to remove the noxious components from said exhaust gases, means for by-passing said exhaust gases from said conventional exhaust disposal line through said purifying means, a solenoid for actuating said by-pass means, a circuit for supplying current to said solenoid, a switch in said circuit, pressure-responsive means communicating with the intake manifold for closing said switch to energize the solenoid when a relatively high degree of vacuum is created in the intake manifold and a relatively high percentage of noxious components is produced in the exhaust gases discharged from the engine.

12. An intermittently operable system for purifying the exhaust gases of an internal combustion engine having a conventional exhaust disposal line, comprising a by-pass valve in said exhaust disposal line and a by-pass passageway leading therefrom, pressure-responsive means communicating with the intake manifold of the engine for automatically operating said by-pass valve when a high degree of vacuum is produced in the intake manifold to cause the exhaust gases to flow through said by-pass passageway, an expansion chamber and heat exchanger connected to said by-pass passageway for expanding the exhaust gases passing therethrough and reducing the temperature thereof substantially to condense out the noxious components in said gases.

13. An intermittently operable system for purifying the exhaust gases of an internal combustion engine having a conventional exhaust disposal line, comprising a by-pass valve in said exhaust disposal line and a by-pass passageway leading therefrom, pressure-responsive means communicating with the intake manifold of the engine for automatically operating said by-pass valve when a high degree of vacuum is produced in the intake manifold to cause the exhaust gases to flow through said by-pass passageway, an expansion chamber connected to said by-pass passageway for expanding the exhaust gases therethrough to remove a portion of the noxious components therefrom by condensation, and an absorbent fluid for removing the balance of said noxious components by dissolving the same.

14. An intermittently operable system for purifying the exhaust gases of an internal combustion engine having a conventional exhaust disposal line comprising a by-pass valve in said exhaust disposal line and a by-pass passageway leading therefrom, pressure responsive means communicating with the intake manifold of the engine for automatically operating said by-pass valve when a high degree of vacuum is produced in the intake manifold to cause the exhaust gases to flow through said by-pass passageway, an expansion chamber connected to said by-pass passageway for expanding the exhaust gases passing therethrough to remove a portion of the noxious components therefrom by condensation, and a reactant chamber for removing the balance of said noxious components by chemical reaction.

15. An intermittently operable system for purifying the exhaust gases of an internal combustion engine having a conventional exhaust disposal line, comprising a by-pass valve in said exhaust disposal line and a by-pass passageway leading therefrom, pressure-responsive means communicating with the intake manifold of the engine for automatically operating said by-pass valve when a high degree of vacuum is produced in the intake manifold to cause the exhaust gases to flow through said by-pass passageway, a combustion chamber connected to said by-pass passageway for receiving the gases flowing therethrough, means for admitting auxiliary air to said chamber to support combustion therein, means for producing a flame in said chamber to cause the combustible and noxious components of said gases to burn and form harmless gases, and an expansion chamber for expanding and cooling said purified gases.

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