Feb. 17, 1970 D. L. LENANE 3,495,401

EXHAUST SYSTEM

Filed Oct. 23, 1967 2 Sheets-Sheet 1

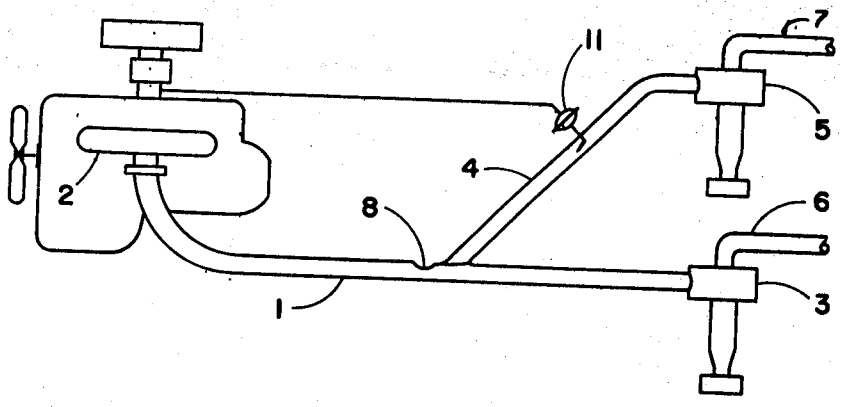


Fig. 1

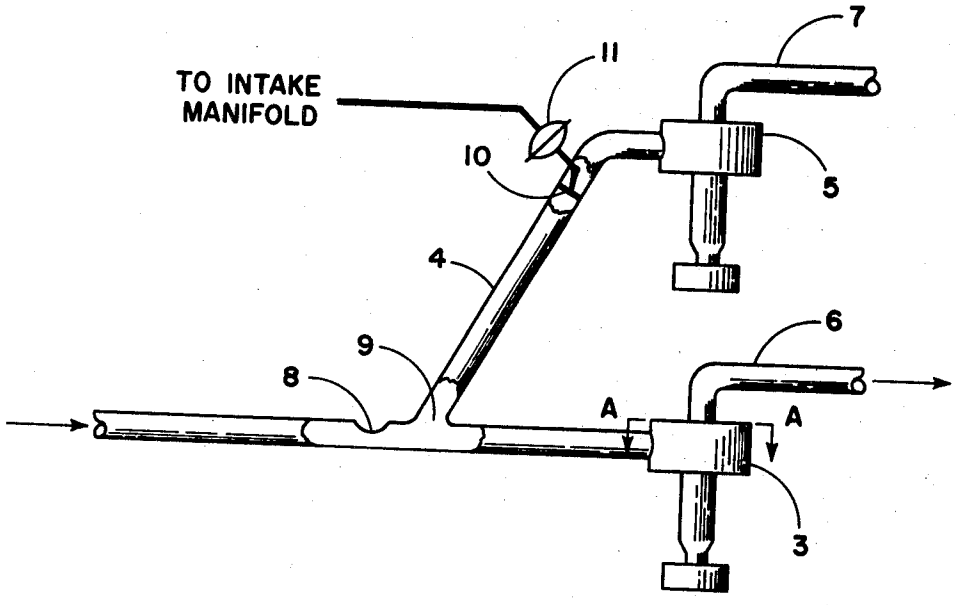


Fig. 2

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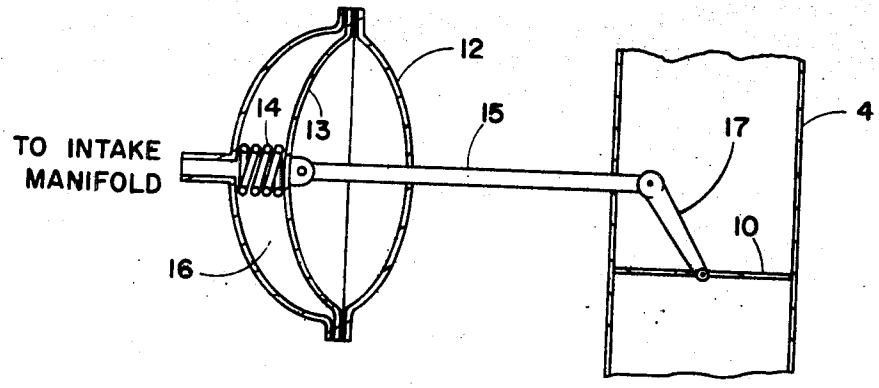


Fig. 3

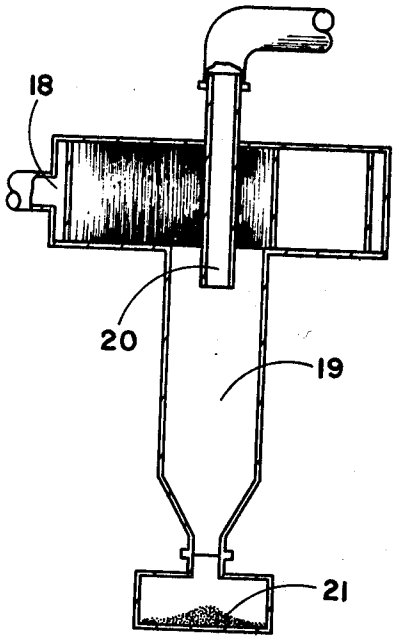


Fig. 4

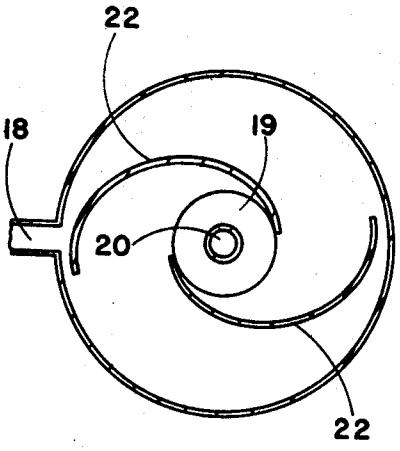


Fig. 5

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EXHAUST SYSTEM

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6 Claims

ABSTRACT OF THE DISCLOSURE

Particulates are removed from the exhaust gas of internal combustion engines by an exhaust system comprising a primary cyclone separator which operates at low exhaust levels in combination with a secondary cyclone separator which operates when the amount of exhaust gas exceeds that level efficiently handled by the primary separator.

BACKGROUND

The exhaust gas of internal combustion engines normally contains small amounts of particulate material. These particles are either carbonaceous or derived from the combustion of additives normally present in fuels such as tetraethyllead in gasoline or calcium and barium sulfonate in diesel fuels. Although these materials generally present no problem because they rapidly settle to the ground, it sometimes is desirable to remove them. In the past, various filters have been used for this purpose, but these generally result in excess back pressure and rapidly become plugged. Another means tried is the use of cyclone separators which have long been used to perform a similar function in removing dust from industrial gas streams. However, removing particles from the exhaust stream of an internal combustion engine presents special problems not encountered in industrial dust removal. The major problem is that the rate of exhaust gas effluent varies widely as the engine operates under different conditions. For example, at idle and low power steady state operation the exhaust volume is fairly low. However, during high output operation such as encountered during rapid acceleration or high speed operation the volume of exhaust gas increases greatly. In normal use engine operation frequently shifts from one set of conditions to another.

In order to function efficiently, a given cyclone separator requires that the gas volume handled be within a certain range. The rules which govern the selection of cyclone separators for maximum efficiency are well known and are discussed in such texts as Louis McCabe, "Air Pollution," p. 341, McGraw Hill (1952). If an engine exhaust system is equipped with a cyclone separator designed to function well under one set of conditions it will not function efficiently under different operating conditions. This is the problem that is solved by the present invention.

SUMMARY

In view of the foregoing factors, it is an object of this invention to provide an exhaust system suitable for the removal of particulates from exhaust gas under a variety of operating conditions.

According to the present invention, an exhaust system is provided comprising a primary exhaust conduit and cyclone separator in combination with a secondary exhaust conduit diverging from the primary conduit and forming a secondary exhaust path leading to a secondary cyclone separator.

In a modified embodiment, the primary conduit has an exhaust deflector immediately upstream from where the secondary exhaust conduit diverges from the primary conduit. This deflector functions to divert the exhaust gas stream from the secondary exhaust gas conduit so that the bulk of the exhaust gas flows to the primary cyclone separator until the back pressure in the primary conduit rises enough to cause some of the exhaust gas to follow the secondary conduit to the secondary cyclone separator.

In another embodiment, a valve is provided in the secondary conduit which is closed when the volume of exhaust is low and efficiently removed of particulates by the primary cyclone. The valve opens when the volume of gas exceeds that which can be efficiently handled by the primary system. The secondary conduit valve may be used with or without the exhaust deflector in the primary conduit. The secondary conduit valve is readily operated by an actuator responsive to either primary conduit back pressure or intake manifold vacuum. The secondary conduit valve remains closed at either low primary conduit back pressure or high intake manifold vacuum which are generally encountered at the same time. The secondary conduit valve opens when primary conduit pressure rises above an acceptable level of about 3–5 p.s.i.g. or alternatively opens when intake manifold vacuum drops below a specified level. Both of these conditions occur during rapid acceleration or high speed substantially full throttle operation of the engine. In practice, the best results are obtained when the valve is closed when the intake manifold vacuum exceeds about 7 inches of mercury and opens when the manifold vacuum drops below about 7 inches.

The present invention is best understood by reference to the attached drawings.

FIGURE 1 is a diagrammatic view of the exhaust system connected to the exhaust manifold of an internal combustion engine showing the primary exhaust conduit and cyclone, the diverging secondary exhaust conduit and cyclone, and an intake manifold vacuum responsive actuator connected to the control level of a butterfly valve in the secondary exhaust conduit.

FIGURE 2 is a drawing of a part of the exhaust system with portions cut away to show the exhaust deflector in the primary conduit and the butterfly control valve assembly in the secondary exhaust conduit.

FIGURE 3 is a cross-sectional enlargement of a vacuum actuator connected to the secondary conduit butterfly valve.

FIGURE 4 is a longitudinal cross-section of the primary cyclone separator.

FIGURE 5 is a cross-section of the primary cyclone separator at AA in FIGURE 2.

DESCRIPTION OF THE PREFERED EMBODIMENTS

Referring first to FIGURE 1, it is seen that the installed system comprises a primary conduit **1** forming an exhaust path from the exhaust manifold **2** of the internal combustion engine to the inlet of the primary cyclone separator **3**. A secondary exhaust gas conduit **4** diverges from the primary exhaust gas conduit and forms an exhaust path to the entry port of the secondary cyclone separator **5**. The exit ports of the primary and secondary cyclone separators are connected to exhaust pipes **6** and **7**.

In operation under low to moderate exhaust volume conditions the exhaust gas from the engine is conducted through primary exhaust conduit **1** to the entry port of primary cyclone separator **3**. In passing, the exhaust gas is deflected by indented surface **8** so that the major portion of the exhaust gas by-passes entry port **9** of diverging secondary exhaust conduit **4**. In the preferred embodiment shown, the exhaust gas is forced to pass to primary cyclone separator **3** under low exhaust volume conditions by butterfly valve **10**, which remains closed under low exhaust conditions. Valve **10** is actuated by any means which respond to the exhaust volume such as the back pressure in the primary exhaust conduit. By this arrangement, valve **10** opens when the back pressure in the primary conduit reaches a maximum pressure for effective

operation of the engine and primary cyclone separator.

A very suitable means for actuating the butterfly valve shown in the drawing is through intake manifold vacuum operated diaphragm actuator **11**. Intake manifold vacuum is generally high under conditions when exhaust volume is low to moderate. These conditions include idle, moderate acceleration and steady state part throttle operation. Intake manifold drops under wide open throttle acceleration or high speed operation.

Although other equivalent valve actuating devices will be apparent, the device shown in FIGURE 3 comprises diaphragm body **12**, flexible diaphragm **13**, compression spring **14**, and push rod **15**. Vacuum from the intake manifold reduces the pressure on the vacuum side **16** of the diaphragm tending to compress spring **14** and withdraw push rod **15**. Push rod **15** is flexibly connected to valve lever **17**, which actuates pivotably-mounted butterfly valve **10** disposed within secondary exhaust conduit **4**. In the drawing, the valve is shown in the closed position which occurs under low exhaust volume operating conditions. Under these conditions, intake manifold vacuum is high. Good results are obtained when compression spring **14** is selected so that the push rod **15** withdraws at a vacuum of about 7 inches of mercury or more, causing valve **10** to close at an intake manifold vacuum greater than 7 inches. Below 7 inches of vacuum, compression spring **14** pushes push rod **15** outward and through lever **17** opens valve **10**.

The particulate-containing exhaust gas enters the primary cyclone separator through entry port **18** and swirls down cyclone chamber **19**, reverses direction and spirals out exit tube **20**. Particulates drop into collection chamber **21**. At high exhaust levels, excess exhaust flows through secondary conduit **4** and enters secondary cyclone **5**, which removes particulates from the excess exhaust.

The cyclone separator shown in FIGURES 4 and 5 has a center entry port **18** and vanes **22** to insure cyclonic flow. Other equivalent cyclone separators are well known. Some employ a tangential entry port to induce cyclonic flow. Some have an inverted cone-shaped cyclone chamber with a tangential entry port in the base of the cone, a particle collection chamber at the apex and an exit tube extending axially through the base into the cyclone chamber. The particular type cyclone selected is not critical as long as they are sized according to well-established principles to handle the exhaust volume. The primary cyclone separator should be of a size that most efficiently removes the particles of the particular internal combustion engine with which it is used under steady state approximately half-throttle operation. The secondary cyclone separator should be sized so that when used in combination with the primary cyclone the two effectively remove particles from the internal combustion engine under conditions of full throttle operation. For example, with a 327 cubic engine, 10.5:1 compression ratio, modern V-8 engine, excellent particulate removal efficiency is obtained when standard two-inch cyclones are used as primary and secondary cyclone separators.

In the embodiment described, only two cyclones were employed. It will be apparent that this system may be modified to employ a greater plurality of cyclone chambers, each coming into play when the exhaust volume exceeds a given level by following the principles taught in the foregoing disclosure. These systems are fully equivalent to that described herein and claimed as follows.

What is claimed is:

1. An exhaust system for an internal combustion engine especially suitable for removing particulates from the exhaust gas, said system comprising a primary exhaust conduit having a straight section, a primary cyclone particulate separator, a secondary exhaust conduit and a secondary cyclone particulate separator, said primary exhaust conduit forming an exhaust flow path from the exhaust manifold of said internal combustion engine to the entry port of said primary cyclone particulate separator, said secondary exhaust conduit forming a diverging exhaust flow path from said straight section of said primary exhaust conduit to the entry port of said secondary cyclone particulate separator, further characterized by having a fixed exhaust deflector in said straight section of said primary exhaust conduit located immediately upstream from where said secondary exhaust conduit diverges from said straight section of said primary exhaust conduit and functioning to deflect the exhaust gas from the secondary exhaust conduit.

2. The exhaust system of claim **1** further characterized by having an exhaust cut-off valve in said secondary exhaust conduit, said valve being operated by actuation means whereby said valve is closed at low exhaust levels and is opened at high exhaust levels.

3. The exhaust system of claim **2** wherein said actuation means is a vacuum actuator operated by the vacuum in the intake manifold of said internal combustion engine such that said cut-off valve is closed at high intake manifold vacuum encountered during part throttle operation and is opened at low intake manifold vacuum encountered during substantial open throttle operation.

4. The exhaust system of claim **3** wherein said vacuum actuator closes said cut-off valve at an intake manifold vacuum above 7 inches of mercury and opens said cut-off valve when said intake manifold vacuum is less than 7 inches of mercury.

5. An exhaust system of claim **1** wherein said engine is a spark ignited internal combustion engine.

6. An exhaust system of claim **5** wherein said primary and secondary cyclone particulate separators are two-inch cyclone separators.

References Cited

UNITED STATES PATENTS

1,890,070	12/1932	Whiton	55—346
3,056,662	10/1962	Ridgway	60—30

FOREIGN PATENTS

165,966	12/1905	Germany.	

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U.S. Cl. X.R.

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