Aug. 29, 1967 C. P. FOWLER ET AL 3,338,682

MUFFLER SECONDARY AIR SILENCER

Original Filed Sept. 15, 1961 3 Sheets-Sheet 1

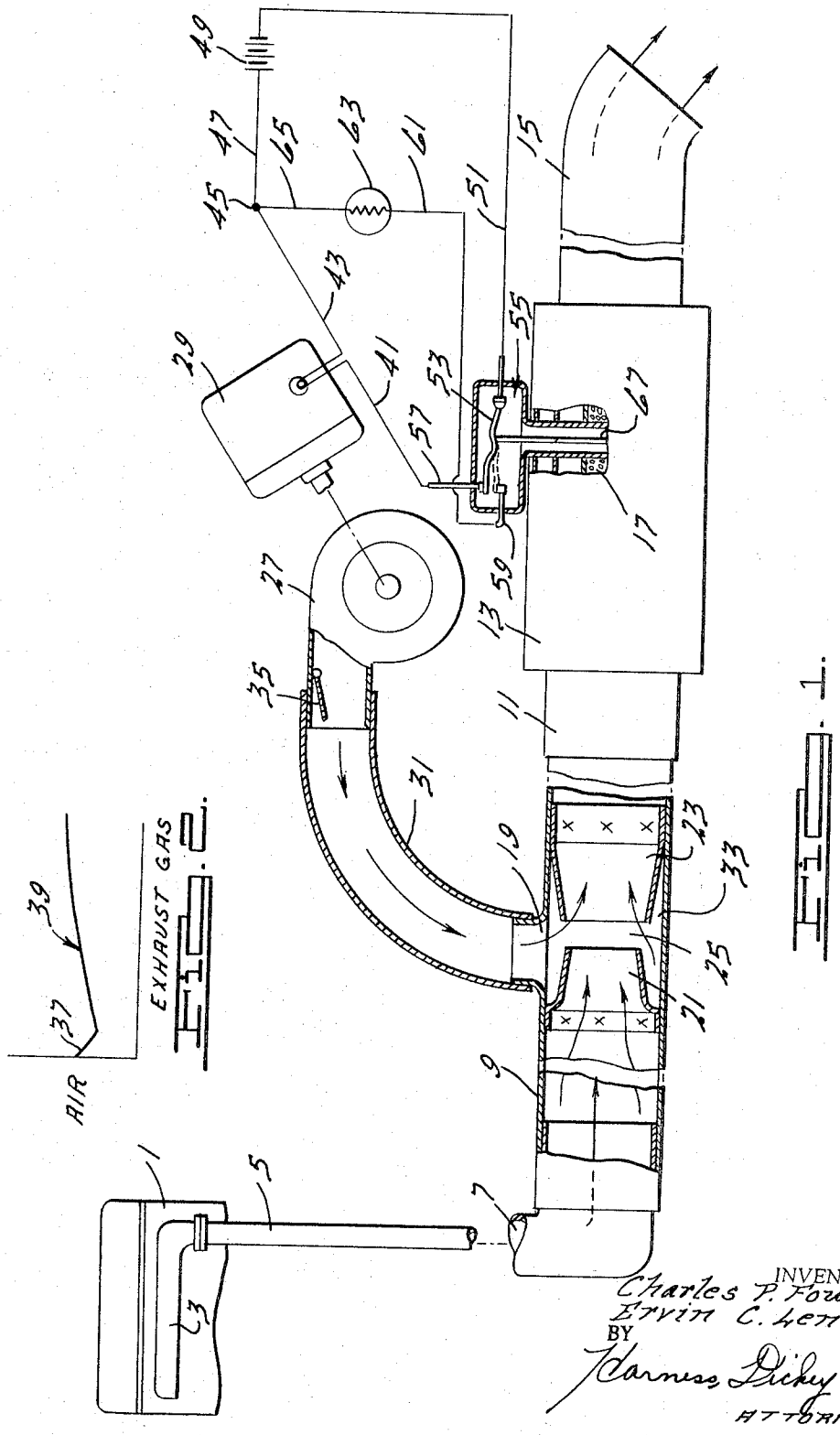


FIG. 1.

FIG. 2.

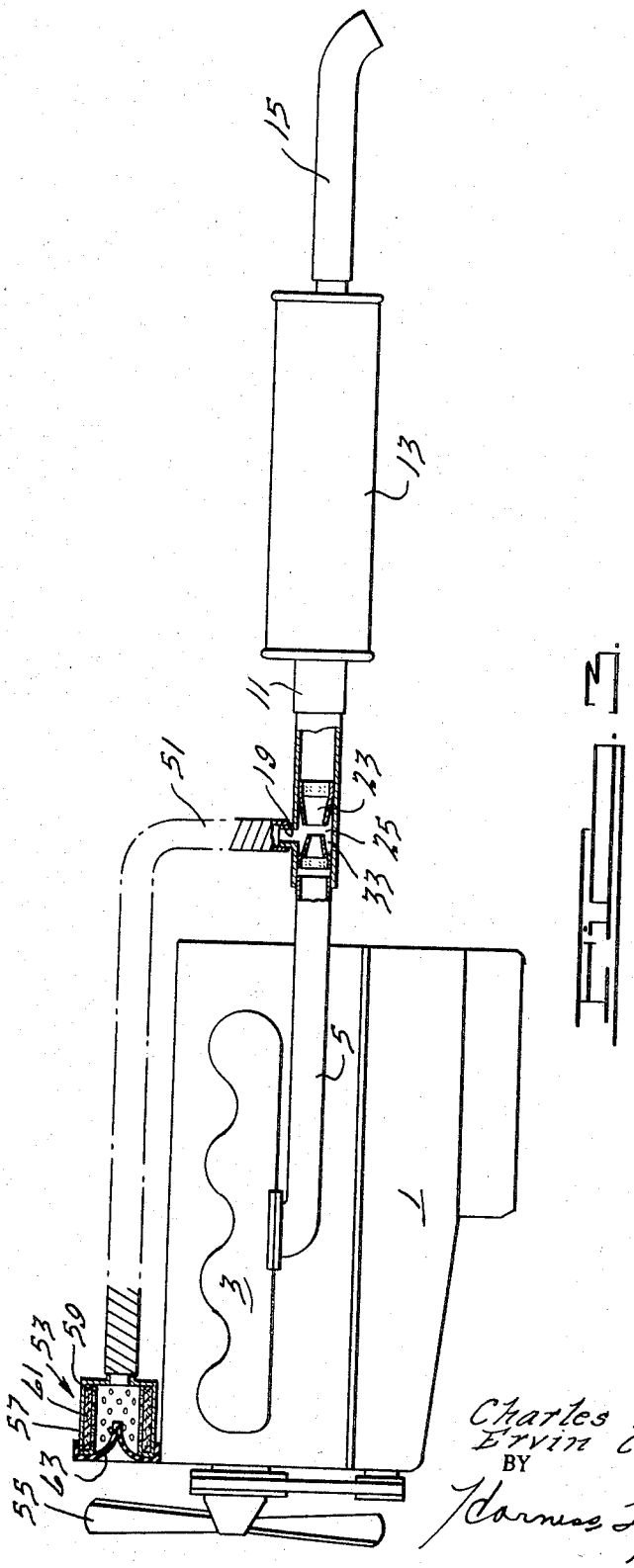
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3 Sheets-Sheet 2

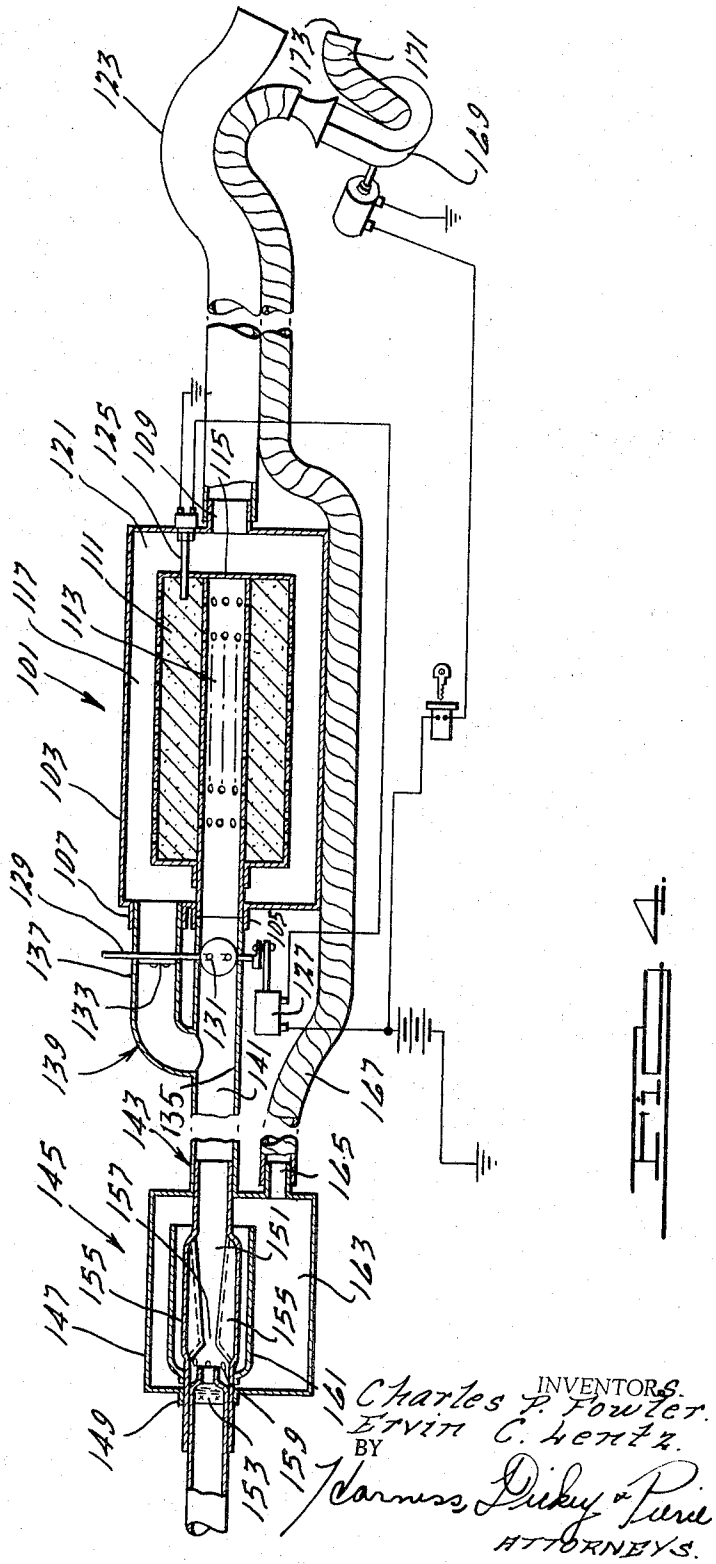


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MUFFLER SECONDARY AIR SILENCER

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Continuation of application Ser. No. 138,521, Sept. 15, 1961, now Patent No. 3,220,805, dated Nov. 30, 1965. This application Dec. 14, 1964, Ser. No. 417,972
2 Claims. (Cl. 23—288)

This invention relates to the treatment of exhaust gases to remove unburned constituents and, in particular, concerns improvements relating to the supply of secondary air and this application is continuation of our copending patent application of the same title, Ser. No. 138,521, filed Sept. 15, 1961, now U.S. Patent 3,220,805, issued Nov. 30, 1965.

At the present time, considerable effort is being devoted in the automotive industry to the development of a satisfactory device for burning the unburned constituents in the exhaust gases of automotive type vehicles, as it is believed that they are one of the major causes of smog and are generally undesirable in the huge quantities emitted in metropolitan areas. One of the many problems encountered in the development of a device of this type concerns the admission of secondary air in the exhaust stream, such air being needed to supply the oxygen for the complete combustion of the unburned constituents. The use of a venturi to inspirate or aspirate the air is a relatively inexpensive device but it is not capable of inducting the required amount of air over the entire range of operating conditions without a large increase in back pressure. On the other hand, compressors have been proposed as a means for supplying secondary air but such units are costly and would bring the overall cost of an exhaust treatment system to a prohibitive level for widespread usage.

The present invention provides an inexpensive way to furnish secondary air to an exhaust system. In its elementary form, it comprises a venturi, a plenum chamber around the venturi, and a forced air supply for the venturi such as the radiator fan or an extra, inexpensive, small propeller or centrifugal fan of the type used in automotive heaters. The invention also provides a control responsive to the temperature within the burner unit for regulating operation of the fan or forced air supply.

The invention is illustrated in the accompanying drawings in which:

FIGURE 1 is a more or less schematic illustration of one form of exhaust treatment system in accordance with the invention and is partly in section and partly broken away and shows the engine and exhaust manifold on a scale that is reduced from the remainder of the system for the sake of clarity;

FIG. 2 is a curve showing the volume relationship between secondary air and exhaust gas for systems such as described herein;

FIG. 3 is a schematic view of another form of the invention in which the engine fan is used as a forced air supply; and

FIG. 4 is a schematic view of another form of the invention in which a by-pass is provided for over temperature control.

Referring to FIG. 1, the piston type internal combustion engine **1** has an exhaust manifold **3** which delivers gases exhausted from the cylinders of the engine into the exhaust conduit **5**. Merely for the purpose of illustration, the conduit **5** is shown as connected to an elbow **7** and this fits within a conduit **9**. The conduit **9** fits within the inlet bushing **11** of a catalytic type exhaust gas burner **13**. The catalyst container **13** delivers gases to the outlet pipe or tail pipe **15** from which it exhausts to atmosphere.

The catalytic unit **13** contains a catalyst **17** and the internal structure of the unit **13** is such as to bring the exhaust gases into contact with the catalytic material and thereby effect combustion of those unburned constituents in the exhaust gases. It is apparent that the catalytic system of this invention corresponds to the conventional exhaust system used on automobiles, trucks, etc. It will act to silence the gases as well as remove the unburned constituents.

The gases exhausted from the engine **1** do not contain sufficient oxygen to support complete combustion of all the unburned constituents. Consequently, secondary air is introduced into the exhaust line ahead of the catalyst container **13**. For this purpose, the conduit **9** has a flanged opening **19** for the air and spot-welded within the conduit **9** on the upstream side of the opening is a bushing forming a tapered nozzle **21** and spotwelded downstream from the nozzle **21** is a bushing forming a divergent diffuser **23**. The nozzle **21** and the diffuser **23** form a venturi and the two are spaced from each other at their minimum diameters by a gap as seen at **25** which forms the throat of the venturi. The minimum diameter of the diffuser **23** is preferably slightly larger than the minimum diameter of the convergent nozzle **21** to give a desirable relationship between the amount of inflow of supplemental air and the exhaust gas flow. The gap **25** constitutes an inlet for air entering through the hole **19** into the diffuser **23** and thus into the exhaust gas passage.

A small centrifugal fan **27** is driven by a motor **29** has its outlet connected to the flanged opening **19** by a tube **31** so that the output of the fan **27** is delivered to the annular plenum chamber **33** formed around the outside of the nozzle **21** and the diffuser **23**, the gap **25** constituting the outlet to plenum chamber **33**. Functionally, the duct **31** is convenient but not essential and the outlet of the fan could be coupled directly to the opening **19**. The fan and motor unit **27** and **29** is an inexpensive low pressure centrifugal fan that is readily available on the open market for use in automobile heaters. A check valve **35** in the outlet end of the blower **27** will prevent backflow of gases from the conduit **9**. Air can be drawn in by the venturi through pipe **31** even if the fan **27** is not operating.

With the arrangement described, the total air supplied to the system is a combination of forced air from the fan **27** and inspired air from the venturi and neither the fan nor the venturi alone would supply sufficient air. It is the concept of the invention to use the low pressure forced air supply to give a slight assist or push to the air as the venturi tries to inspirate it between pressure pulses of the exhaust gas. The fan **27** or forced air supply will help to overcome the resistance or impedance of the system to the initiation of air flow into the venturi throat so that the venturi can more easily inspirate the air. It is also the concept of the invention to use the low and negative pressure at the throat of the venturi and the negative pressure in the pulsating flow of the exhaust gases as a means to reduce the load on the forced air supply, thus enabling an inexpensive forced air source such as described herein to be used.

In carrying out this concept of combining a venturi and low pressure air source we have discovered that the plenum chamber **33** plays an important role. It, of course, serves as a low pressure space to which the fan outlet can be connected. Additionally, it serves as an accumulator or reservoir for exhaust gases that flow out of the throat of the venturi on the pressure pluses, such outflow occurring because the forced air source operates at pressures only a little above atmospheric and therefore considerably lower than the peak exhaust gas pressures or even the mean of the pressure pulses. The plenum cham-

ber should be large enough, therefore, so that such exhaust gas outflow will be confined in it (and, possibly, in pipe **31** which may be regarded as an extension of the plenum chamber) and not reach atmosphere or preferably even the check valve **35**. In so confining the exhaust gas, the pressure in the plenum chamber may increase slightly and between pressure pulses (during the negative "pulse") of exhaust gas this pressure in the chamber **33** may act with the fan **27** to help overcome resistance and initiate air flow into the throat of the venturi. In doing this it may help lower the load on the fan. Furthermore, at least when used with the type of venturi shown herein (wherein there is a gap between the nozzle and diffuser and the latter is slightly larger than the nozzle) the plenum chamber **33** increases the quantity of air inducted by the venturi during both operation and inoperation of the fan and it also helps to optimize the pattern of air flow in that it increases the proportion of air to exhaust gas flow at the very low gas flows, such as at idle, when an air boost for the venturi is most needed. FIG. 2 shows the general relationship between the volume of secondary air and volume of exhaust gas in the present system and the venturi boost at low flows as indicated by the portion **37** of the curve **39**.

A control circuit of cutting off the motor **29** and thus the fan **27** when the temperature of the burner **13** is too high is schematically illustrated. By cutting off the supply of forced air to the catalyst bed the exothermic reaction in the bed is limited and therefore the temperature of the bed is controlled. The circuit includes the electrical leads **41** and **43** to the motor **29**. The lead **43** is connected at a junction **45** with a lead **47** going to the battery **49** or other sources of current such as a generator. The other side of the battery **49** is connected by a lead **51** to a switch element **53** forming a part of the switch device **55**. The lead **41** is connected through a connector **57** to the switch element **53** also. The other switch element **59** is connected by a lead **61** to one side of an indicator light **63**, which would be mounted on the dashboard of the automobile, and the other side of the light **63** is connected by a lead **65** to the junction **45**. The switch elements **59** and **53** have contacts that will close to permit current flow from the battery to the light **63** bypassing the lead **41** and the motor **29** so that when the light is on the motor **29** is off. The switch is operated by a suitable type of temperature sensitive member that has an element **67** in the catalyst bed **17** which upon a predetermined bed temperature will function to cause the switch element **53** to contact the switch element **59** and close the indicator light circuit and stop the fan **29**. When the temperature of the container **13** has dropped below the predetermined maximum, the switch **53** will automatically open and the light **63** will be turned off and the motor **29** will resume operation.

Since thte circuit just described controls operation of the fan it will also control the admission of that part of the secondary air developed by the fan. At idle and deceleration, the two worst conditions from the standpoint of the quantity of unburned constituents, the fan is especially important in furnishing the secondary air since the low exhaust gas flow will make it difficult for the venturi to aspirate much air. Hence, at these conditions control of the fan will prevent overheating. At high speeds where the venturi can aspirate enough air without the fan, sufficient air is inducted to actually cool the bed so this condition is not critical from the temperature standpoint.

FIG. 3 shows an alternative and even less expensive means of supplying forced air to the plenum chamber **33**. In this form a flexible hose **51** has its outlet end connected to the inlet **19** of the plenum chamber **33**. The inlet end of the hose **51** is connected to the back or bottom of a cylindrical air collector **53** that is mounted on the engine **1** directly behind the radiator propeller fan **55** so that the fan will drive some air into it. The collector **53** has an outer, imperforate shell **57** and an inner perforate shell **59** and sound deadening material **61** preferably fills the space between the shells **57** and **59**. A rubber check valve **63** of a common type may be attached to the front or inlet end of the collector **53** to limit back flow on the pressure pulses of the exhaust gases. Though not shown, it is clear that a solenoid operated shut-off valve could be inserted in hose **51** and controlled by a temperature responsive circuit such as shown in FIG. 1 to cut off air flow through hose **51** and, if desired, connect the plenum to atmosphere, when the temperature is too high in container **13**.

In operation, the forced air supply of FIG. 3 will provide a relatively small amount of air, compared to a compressor, but it will act in the manner described above to supplement and boost the air inspirated by the venturi.

In FIG. 4 there is illustrated a system in which a bypass of gas around the catalyst is provided when the temperature of the catalyst exceeds a predetermined value. The modification of FIG. 4 also illustrates other important features in that it provides silencing, preheating of the secondary air, and elimination of the check valve. The venturi chamber, the catalyst converter, and the bypass are adapted to be manufactured by equipment and know-how used in the manufacture of modern automotive exhaust systems.

In FIG. 4, there is a catalyst container **101** (preferably of the type shown in the aforementioned Lentz application) which comprises an outer shell **103** having a pair of inlets **105** and **107** and an outlet **109**. An annular catalyst bed **111**, containing suitable catalyst material, is supported inside the casing **103**. It has an internal inlet passage **113** which is closed at its end **115** and there is an annular outlet passage **117** between it and the shell **103** which is in direct communication through space **121** with outlet **109**. Gas entering inlet **105** goes into passage **113** and must pass radially through the catalyst bed **111** to reach passage **117** from which it can flow to outlet **109** and into the tailpipe **123** and then to atmosphere. In passing through the bed **111** the unburned constituents are burned and heat is liberated. The temperature in the bed **111** is sensed by a temperature responsive switch or valve **125** which is mounted on casing **103** and which preferably has a probe extending into the downstream end of bed **111** as shown. Suitable units **125** are available on the open market.

The inlet **107** to container **103** permits gases to go directly into the passage **117** on the outlet side of the bed **111**. Such gas then must pass the length of the casing to go out through outlet **109**. In doing this the gas will be in contact with the entire annular outer surface of the catalyst bed which will act as a sound absorber to silence the gas. Secondary air is still admitted so some conversion will occur when the by-passed gases go through passage **117** since they will be in contact with the outside of bed **111**. However, there will be no heat liberated inside of the bed and it will gradually cool so long as the by-passing continues.

Whether or not by-passing occurs, and the length of time that it continues, are under the control of the temperature responsive unit **125** which controls a solenoid or vacuum motor **127** which in turn acts through a crank to rotate a shaft **129** that carries butterfly valves **131** and **133**. The valve **131** is in one leg **135** and the valve **133** is in the other leg **137** of the Y-joint coupling **139** having an inlet **141**. Leg **135** is attached to container inlet **105** (gases pass through the bed **111**) and leg **137** is connected to the by-pass inlet **107** of container **101**. The valves **131** and **133** are 90° out of phase so that when one leg is open the other is closed. The unit **125** is arranged to close leg **135** when the temperature of bed **111** exceeds a desired level, whereupon by-passing will occur. FIG. 4 illustrates suitable electric wiring to operate the controls if they are of the electrical type wherein unit **125** is a thermal switch, unit **127** is a solenoid, and the

leads joining these with the battery, ignition switch, and fan motor may be as illustrated.

The inlet leg **141** of the coupling **139** is connected to the outlet **143** of an acoustically tuned aspirator **145**. The unit **145** is basically similar to the venturi-plenum chamber units described in the preceding modifications but includes means tuned to silence low and medium frequencies in the exhaust gases when they flow directly through the container **101** and especially when they bypass the bed **111**. It will also act to silence the secondary air passage.

The unit **145** has a shell **147** with an inlet **149** that receives gas from the exhaust manifold. A straight through passage **151** connects the inlet **149** and outlet **143**. The passage **151** is arranged to form a venturi. For this purpose a nozzle **153** may be spotwelded inside a piece of tubing and to the neck **149**. The tubing is reduced at **155** to provide a diffuser **157** spaced downstream from the nozzle which has a minimum diameter slightly larger than the minimum diameter of the nozzle as previously described in connection with FIG. 1. Holes **159** in the tubing provide an inlet for air to the throat of the venturi. These holes are large enough in area to act similarly to the gap **25** in FIG. 1. Surrounding the inlet holes **159** and extending downstream is a flow through tuning shell **161** which is open at its downstream end to provide an inlet for air to reach holes **159** from the plenum chamber **163**. The length and size of shell **161** and chamber **163** are selected in accordance with usual muffler design techniques to provide silencing of the secondary air passage and of the gas when it flows through either leg **135** or **137** of Y-joint **139**.

The plenum chamber **163** has an inlet **165** for secondary air to which a flexible hose **167** is attached. The other end of the hose is attached to outlet of the fan and motor unit **169** of an inexpensive type as described in connection with FIG. 1. The motor of this unit may be conveniently located in the trunk of a car and the fan located in the rear fender well or some other protected position at the rear of the car. The inlet to the fan **169** may receive air direct from atmosphere or, as shown, from a flexible hose **171** and it will be noted in particular that the inlet end **173** of the hose section **171** is at the rear of the automobile (rear of the exhaust system) and very close to the outlet end of the tailpipe **123**. The hose sections **171** and **167** are fastened to the tailpipe and other parts of the system carrying exhaust gas wherever possible so that the heat of the exhaust gases will preheat the secondary air. Such heat transfer is preferably downstream from the inlet end of the converter **101** so as not to abstract useful heat from the system.

In addition to the possibility of preheating the secondary air, two other important advantages are obtained by locating the inlet to the secondary air supply (inlet **173** to hose **171**) at the rear of the automobile. First, the need for a check valve in the secondary air system is eliminated. If there is excessive back flow of exhaust gases on the pressure pulses through the plenum chamber and secondary air conduits it will merely empty at the rear of the vehicle at substantially the same location as the gases leaving the tailpipe. Hence, no check valve is needed. Secondly, the noise associated with the secondary air system is concentrated at the inlet end **173** of the secondary air conduit and is similar to the noise coming out of the tailpipe. By putting the inlet end of the secondary air supply at the rear it is remote from the passengers and cannot be easily distinguished from tailpipe noise, and does not audibly add to it.

Modifications may be made in the specific structure described above without departing from the spirit and scope of the invention.

We claim:

1. In a motor vehicle having an internal combustion engine, an exhaust system for the engine including a venturi for aspirating secondary air, means defining a plenum chamber around the venturi, a tuning shell in the chamber extending around the venturi to silence the exhaust system, means defining a first air passage between said venturi and the volume between said tuning shell and said venturi, means defining a second air passage between said volume and said chamber for forming an acoustical silencing device comprising said volume and said chamber, and means defining an inlet in the chamber for the entry of secondary air.

2. In a motor vehicle having an internal combustion engine, an exhaust system for the engine including a venturi for aspirating secondary air, a plenum chamber around the venturi, a tuning shell in the chamber around the venturi to silence the exhaust system, an inlet in the chamber for the entry of secondary air, and an air conduit connected to said chamber inlet and having its inlet at the rear of the vehicle.

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