United States Patent

Kaufmann, Jr.

[15] **3,657,878**

[45] **Apr. 25, 1972**

[54] **EXHAUST CONVERSION SYSTEMS**

[72] Inventor: **John Kaufmann, Jr.,** 3716 Woodrow Avenue, Pittsburgh, Pa. 15227

[22] Filed: **Apr. 14, 1970**

[21] Appl. No.: **28,406**

Related U.S. Application Data

[62] Division of Ser. No. 767,602, Aug. 30, 1968, Pat. No. 3,543,510.

[52] **U.S. Cl.** ....**60/319,** 23/277 C, 417/159

[51] **Int. Cl.** **F01n 3/10**

[58] **Field of Search** ....60/30; 23/2 C, 277 C, 288.3 F; 417/151, 155, 158, 159, 198

[56] **References Cited**

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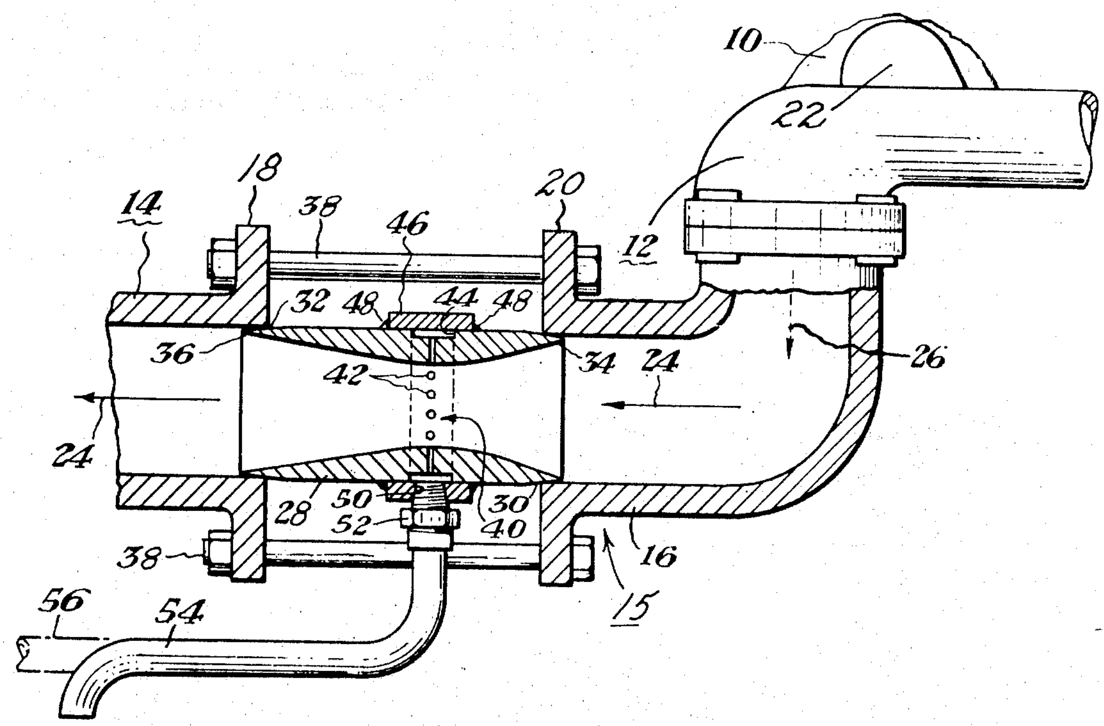
Primary Examiner—Douglas Hart
Attorney—Dan J. Smith

[57] **ABSTRACT**

I disclose a conversion system for an exhaust duct or the like through which partially reacted gases are circulated, said system comprising a venturi induction member mounted in the exhaust duct and having a circumferential array of radially extending apertures for inducting a reactant fluid into said duct upon passage of said gases therethrough said venturi member having inlet and outlet openings each having substantially the same cross-sectional area as that of the adjacent interior of said duct, said apertures being located in a thickened portion of said venturi member and having a length-to-diameter ratio capable of imposing a jetting action upon the reactant fluid passing therethrough so that thorough mixing of said reactant fluid and said gases is attained within said venturi member. Also disclosed are unique venturi configurations involving a throat ridge and induction apertures adjacent thereto for improved induction and mixing.

6 Claims, 8 Drawing Figures



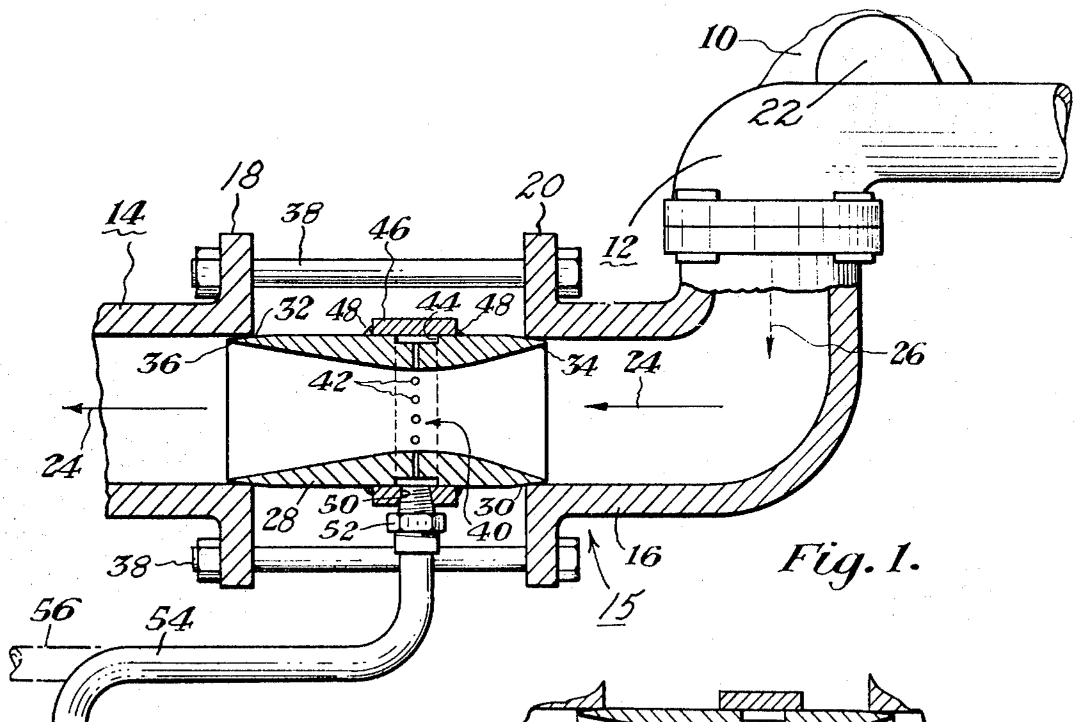


Fig. 1.

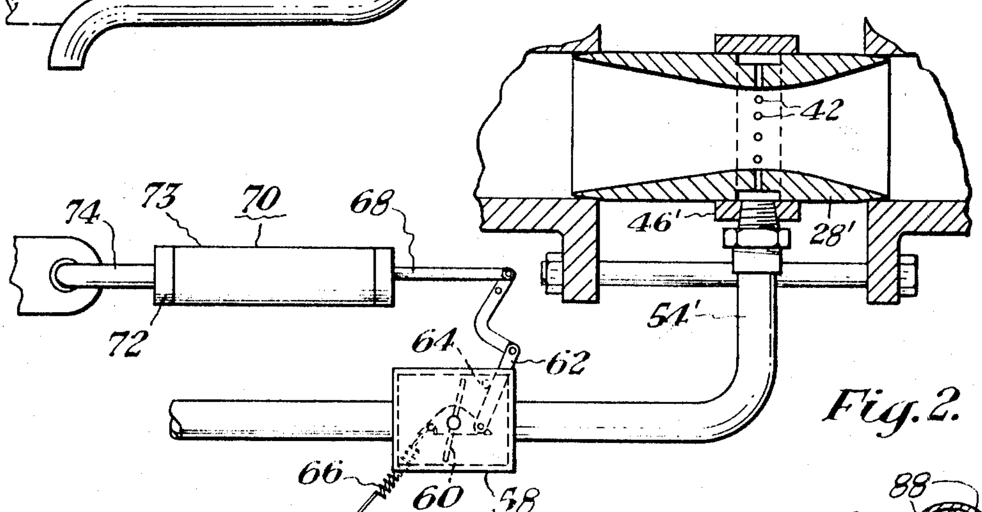


Fig. 2.

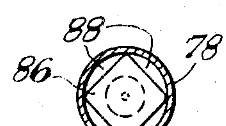
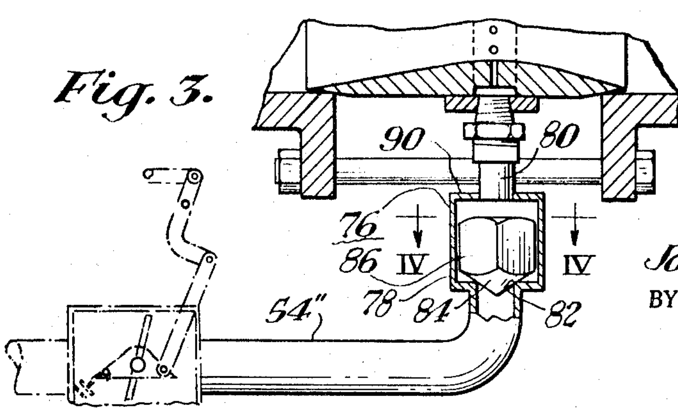


Fig. 4.

Fig. 3.



INVENTOR.
John Kaufmann Jr.
BY
HIS ATTORNEYS

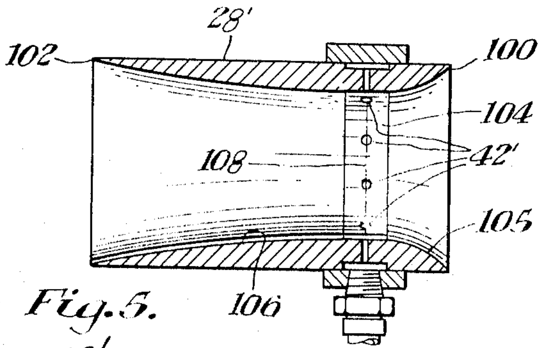


Fig. 5.

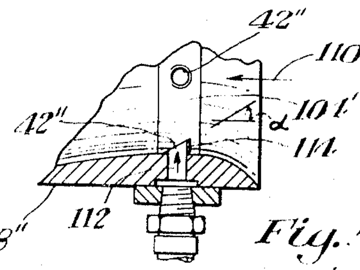


Fig. 5A.

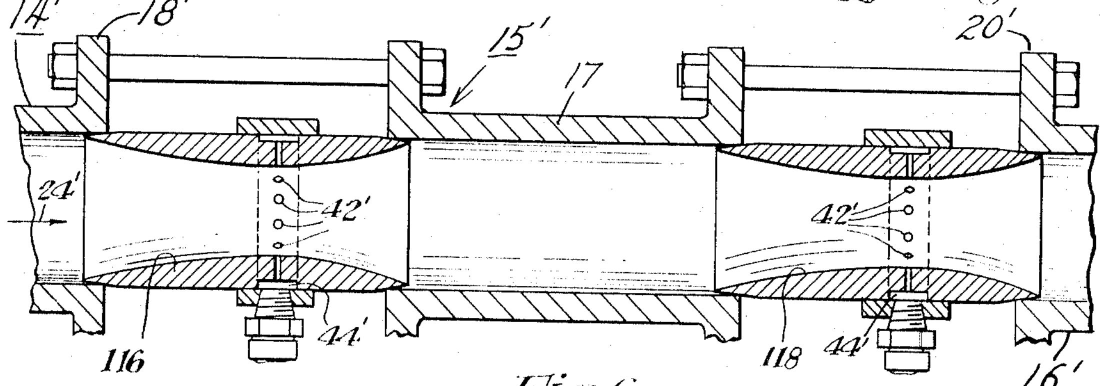


Fig. 6.

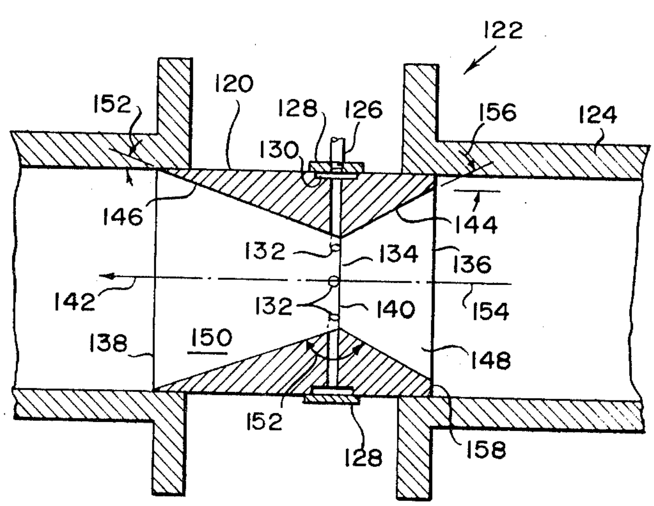


Fig. 7.

INVENTOR
John Kaufmann, Jr.
BY
Buell, Blenko & Ziesenheim
HIS ATTORNEYS

EXHAUST CONVERSION SYSTEMS

This application is a division-in-part of my copending application entitled EXHAUST CONVERSION SYSTEMS, filed Aug. 30, 1968, Ser. No. 767,602, now U.S. Pat. No. 3,543,510.

The present invention relates to novel venturi constructions and to means for reducing or eliminating altogether the noxious gases emitted from the exhaust systems of combustion operations, in particular internal combustion engines, in order to reduce the air pollution resulting from operation thereof. More particularly, the invention relates to means of the character described for completing the combustion of internal combustion engine exhaust gases, irrespective of engine speed, in order to convert them to innoccuous fluids.

Although my invention is described with primary reference to the exhaust system of internal combustion engines, it will become apparent as this description proceeds that the invention is not limited to this application. My exhaust conversion system is of general utility, and can be installed in a variety of exhaust systems handling products of incomplete combustion to oxidize potential air contaminants or in similar systems handling high temperature oxidizable or combustible gases. For example, it is contemplated that my conversion system or antipollution means can be installed in the exhausts of various types of reaction motors, industrial furnaces and the like. The invention is capable of analogous applications, as in the induction of various types of reactant fluids other than combustion air. It is also contemplated that my novel venturi system can be used in conjunction with other exhaust and/or inductional systems, such as vacuum or jet pumps.

It is well known that the various hydrocarbon fuels employed in those engines generally classed as internal combustion engines are not completely combusted therein. This unavoidable, incomplete combustion of the fuels thus employed results in the generation of substantial quantities of unburned or partially burned hydrocarbons, carbon monoxide, and other noxious waste gases which are usually vented to the atmosphere through the exhaust system. It is also well known that these noxious gases constitute a health hazard owing to their pollutional effects in the atmosphere. In recent years the health hazard has grown to dangerous proportions as a result of the rapidly increasing numbers of automobiles and other vehicles powered by internal combustion engines.

Many proposals have been advanced previously for combatting this health menace, most of which have attempted to burn or oxidize the exhaust gases either by thermal or catalytic conversional techniques. In the catalytic method, the exhaust gases leaving the engine are passed through a conversion unit in which the catalyst is suspended. Such units are rather bulky in construction and are therefore difficult to accommodate in most types of vehicles, where space is at a premium. Moreover, it is necessary to provide a carefully balanced supply of oxygen or the like and to maintain a particular heat balance. Catalytic converters therefore are difficult to maintain in proper adjustment even under ideal conditions and are virtually useless in the wide range of driving conditions encountered by the average vehicle.

In many of the thermal converting systems, an additional combustion chamber is required in the exhaust system of the engine. The combustion chamber is equally difficult to accommodate in the vehicle for the same reasons mentioned above in connection with the catalytic chamber. Many of these exhaust combustion chambers are provided in the form of afterburners which require additional fuel and an auxiliary ignition system, in addition to auxiliary combustion air, to accomplish the conversion of the exhaust fumes. The use of secondary fuel, of course, decreases the efficiency of the vehicle considerably, and in the event of failure of the ignition system or other malfunctioning in the afterburner, the noxious fumes from the engine exhaust are greatly increased by addition of the secondary fuel. Moreover, if either the catalytic converter or the thermal converter are placed under the hood of a conventionally constructed automobile, the danger to the vehicles' occupants is considerably increased in the event of malfunctioning of these converters.

It has also been proposed to conduct auxiliary combustion air from a blower or from a source of compressed air directly into the inlet ports of the exhaust manifold of an internal combustion engine. Such an arrangement, as typified by the U.S. Pat. to Dworak No. 3,091,078, would utilize the exhaust manifold or manifolds as exhaust combustion chambers. However, as the incoming exhaust streams through each of the exhaust manifold inlet ports is pulsating, as dictated by the engine's operating pattern, it is difficult, if not impossible, to maintain any sort of uniformity and continuity of combustion within the exhaust manifold. Whatever combustion does occur in the exhaust manifold is initiated at points very close to the exhaust valves of the engine with the result that these valves are rapidly burned. The resulting turbulence of these gates which are thus combusted, within the manifold moreover interferes with the proper flow of exhaust gases therethrough. As a result, it has been found necessary to employ some sort of catalytic or thermal conversion unit downstream of the exhaust manifold.

In general, none of the prior proposals for combusting or converting noxious exhaust fumes into innoccuous substances have been successful. In those known systems wherein a substantial conversion has been effected, the physical size of the equipment required to make the conversion has precluded their use with internal combustion engines employed in most automobiles and other vehicles where space is at a premium.

In many of the previously proposed exhaust conversion systems, auxiliary combustion air has been inducted into the exhaust stream by jet aspirators or by improperly shaped and improperly located venturi aspirators or the like. These devices provide an uncertain supply of auxiliary combustion air at best, and under certain conditions for example when the engine is idling or nearly so, the flow through the jet or venturi aspirator is reversed so that noxious exhaust fumes are emitted prematurely from the exhaust system, i.e. at a location where the fumes can enter the cab or passenger compartment of the vehicle resulting in a hazard to the occupants thereof. Examples of such prior proposals are the U.S. Pats. to Knopp No. 3,300,964 and Barnes No. 3,032,969. In particular, the induction apertures of these proposals are not located for optimum mixing or shaped for a jetting action to promote mixing of exhaust with the inducted combustion air or other reactant.

My researches in this field indicate that these devices would not function properly at all engine speeds owing to the shapes of their venturi structures and the location of the air intake apertures. As described more fully below, to complete the combustion of the exhaust gases requires a careful addition and distribution of combustion air into the exhaust duct. Under certain conditions, it is necessary to introduce a particular type of glow ignition device to maintain ignition of the exhaust gases.

Crank case scavenging arrangements utilizing the venturi principle are shown in Phillips U.S. Pat. No. 2,585,495 and Griswold U.S. Pat. No. 1,766,900. The Phillips device would appear to add to atmospheric pollution, as apparently there is no attempt to oxidize the exhaust and crank case gases.

Other exhaust handling systems are shown in the U.S. Pats. to Cornelius No. 2,677,231 and No. 2,851,852 and in Bowen III et al. U.S. Pat. No. 2,772,147. In the Cornelius patents the several illustrated venturi structures provide minimal flow area and considerable obstruction to the passage of the exhaust gases therethrough. Rather large and complicated structures are entailed for this reason. The Bowen venturi arrangement does not provide adequate induction and mixing of combustion air to solve the problems confronted by the present invention. The Bowen structure further incorporates a catalytic conversion unit downstream of the mixing venturi.

I am also aware of a number of venturi pump and mixer structures as exemplified by the U.S. Pats. to Phillips No. 2,711,284 and Campbell No. 2,493,387, and French Pat. No. 233,502 to Mr. Laguilharre. These structures likewise fail to provide the requisite induction and mixing action, and attendant jetting action of my novel venturi structures.

I have solved these difficulties of the prior art by providing a simple yet reliable conversion or anti-pollution system for exhaust gases, which requires little or no additional space in the vehicle exhaust system or other exhaust system when my conversion means is mounted in the exhaust duct forming part thereof. My conversion system includes means for inducting auxiliary combustion air directly into the vehicle exhaust system at a point where the heat of the exhaust system is sufficient to initiate and to drive the combustion of the exhaust fumes substantially to completion. I have determined that the most advantageous point of entry for the auxiliary combustion air is adjacent the outlet of the one or more exhaust manifolds of the vehicle engine. At this point the exhaust system is relatively steady, in contrast to the pulsating stream at the exhaust manifold inlet ports. Furthermore, the usual cast iron construction of the exhaust manifold does not permit a significant temperature drop in the hot exhaust gases between the exhaust ports of the individual cylinders and the exhaust manifold outlet. Accordingly, an adequate temperature level is available under all driving conditions of the vehicle to initiate and to sustain the combustion of the exhaust gases in conjunction with the auxiliary combustion air added by my conversion system. In certain applications, my conversion system also includes means for carefully metering the auxiliary combustion air supplied to the conversion system and for preventing reverse flow from the conversion system for example when the engine is idling.

In order to afford proper induction and/or mixture of combustion air or other reactant with the exhaust gases, in particular at widely variable exhaust flow rates, I have found particular shapes of the venturi structure to be most effective. For example, depending upon the application of the invention, I provide the inner surfaces of the venturi structure with a certain curvature (inclusive, of course, of rectilinear surfaces) in combination with particular angles and shapes of leading and trailing edges. The efficacy of my venturi structure is further enhanced by a particular location of the combustion air entrance apertures relative to the venturi throat and the use of a particular shape of surface surrounding or adjacent the apertures. For the same purpose, I provide a particular shape of venturi throat structure.

In other applications of my invention, I have found that combustion of the exhaust gases is made even more complete by the use of two or more venturi structures in series for superior mixing and/or induction purposes. With the use of multiple venturi structures, combustion air can be supplied independently to one or more of the venturi structures.

Most applications of my conversion system, in addition to requiring little or no additional space for the exhaust system, involve no moving parts with a result that the possibilities of malfunctioning of the system are almost mil. In other forms of my conversion system, those moving parts which are utilized are simple and rugged in construction so that maintenance of the system is minimized and its reliability is enhanced. Finally and most importantly, my novel conversion system requires little or no modification of existing exhaust ductwork so that my system can be installed on existing as well as newly manufactured vehicle exhausts or on other exhaust systems.

I accomplish these desirable results by providing a conversion system for an exhaust duct or the like through which partially reacted gases are circulated, said system comprising a venturi induction member mounted in the exhaust duct and having a circumferential array of radially extending apertures for inducting a reactant fluid into said duct upon passage of said gases therethrough, said venturi member having inlet and outlet openings each having substantially the same cross-sectional area as that of the adjacent interior of said duct, said apertures being located in a thickened portion of said venturi member and having a length-to-diameter ratio capable of imposing a jetting action upon the reactant fluid passing therethrough so that thorough mixing of said reactant fluid and said gases is attained within said venturi member.

I also desirably provide a similar conversion system wherein a check valve is coupled to said inlet port and is directed to prevent an outflow of said gases therethrough when the velocity of said gases through said duct is insufficient to generate a venturi effect.

I also desirably provide a similar conversion system wherein said length to diameter ratio varies between about 3:1 and about 5:1.

I also desirably provide a similar conversion system wherein said exhaust duct is coupled to an internal combustion engine, said venturi member being coupled between an outlet port of an engine exhaust manifold and an exhaust outlet pipe, said manifold and said pipe forming said exhaust duct sections.

I also desirably provide a similar conversion system wherein conduit means including a throttling valve are coupled to said venturi apertures, and means are provided for moving said valve toward opened and closed positions thereof in accordance with engine acceleration and deceleration respectively, said moving means including fluid motive means coupled to said throttling valve and to an intake manifold of said engine for energization thereby.

I also desirably provide a conversion system for an exhaust duct or the like through which partially reacted gases are circulated, said system comprising a venturi induction member mounted in the exhaust duct and having a circumferential array of radially extending apertures for inducting reactant fluid into said duct upon passage of said gases therethrough, said venturi member having a throat area defined by an inwardly extending peripheral ridge, said array of apertures being disposed adjacent said ridge. I also desirably provide a similar conversion system wherein said aperture array is positioned downstream of said ridge, and the inward opening of each of said apertures is substantially contingent with said ridge.

I also desirably provide a similar conversion system wherein the inward surfaces of said venturi member on either side of said ridge are defined by substantially frustoconical sections respectively.

During the foregoing discussion various objects, features and advantages of the invention have been alluded to. These and other objects, features and advantages of the invention together with structural details thereof will be elaborated upon during the forthcoming description of certain presently preferred embodiments of the invention together with presently preferred methods of practicing the same.

In the accompanying drawings I have shown certain presently preferred embodiments of the invention and have illustrated certain presently preferred methods of practicing the same in which:

FIG. 1 is an elevational view, partly in section of one form of exhaust system, including for example an internal combustion engine and its exhaust, for which my novel exhaust conversion or anti-pollutional system is suitable;

FIG. 2 is a partial longitudinally sectioned view of a modified form of my conversion system;

FIG. 3 is a longitudinally sectioned view of still another form of my conversion system;

FIG. 4 is a cross-sectional view of the apparatus as shown in FIG. 3 and taken along reference line IV—IV thereof;

FIG. 5 is a longitudinally sectioned view of an exemplary venturi construction arranged in accordance with my invention and useful in the embodiments of the exhaust systems depicted or described herein;

FIG. 5A is a partial view similar to FIG. 5 and showing a modified aperture entrance structure;

FIG. 6 is a partial longitudinally sectioned view of still another form of my conversion system wherein a pair of venturi structures are mounted in series within an exhaust duct or the like; and

FIG. 7 is a partial longitudinally sectioned view of still another venturi construction according to the invention and useful in the exhaust conversion systems described herein.

Referring now more particularly to the figures and initially to FIG. 1 of the drawings, the exemplary form of my exhaust conversion system or anti-pollution means shown therein is adapted for use with a conventional gasoline or diesel internal combustion engine 10 or the like, having a conventional exhaust manifold 12 and tailpipe 14, which normally is secured directly to the outlet port 16 of the exhaust manifold 12. The tailpipe 14 and manifold outlet 16 and associated components form an exhaust duct 15. In this arrangement, however, the tailpipe 14 which is provided with a conventional connecting flange 18 is spaced from the exhaust manifold outlet port 16 which is also provided with a conventional connecting flange 20. The exhaust manifold 12 is provided with the usual number of inlet ports 22 whereby the exhaust manifold is joined to the engine block in alignment with the individual cylinder exhaust ports. The direction of flow of exhaust fluids through the exhaust system thus far described is denoted by flow arrows 24. As mentioned previously, my exhaust conversion system can be employed in exhaust ducts coupled to apparatus other than that shown herein, for example in various types of furnace and oven ducts and in connection with other process equipment. It is contemplated further that the exhaust gases need not be partially combustible in the ordinary sense of the term. Rather, the exhaust gases can be partially reacted in the general sense, and a reactant fluid can be inducted as described below, which may be ambient air, oxygen, or some other fluid reactant capable of converting the gases into nontoxic or innocuous effluents.

In the region of the flow arrows 24 the pulsating inlet exhaust streams through the inlet ports 22, designated by dashed outline arrows 26, have been converted into a substantially steady flow of effluents. The usual cast iron structure of exhaust manifold 12 minimizes the temperature drop between the exhaust manifold inlet ports 22 and its outlet port 16. Accordingly, as noted previously, I have determined that the optimum induction point for auxiliary combustion air is adjacent the manifold outlet port 16. A venturi inductor section 28 is inserted between the manifold outlet 16 and the tailpipe 14. In this arrangement of the invention, the venturi section 28 is provided with an outside diameter similar to the inside diameter of the outlet port 16 and tailpipe 14. Specifically, the outside diameter of the venturi section 28 is made slightly larger than the aforementioned inner diameters with the exception of tapered portions 30 and 32 formed on the outer surface of the venturi section 28 at its leading and trailing edges 34, 36. These edges 34, 36 are substantially feathered or tapered to a relatively thin edge to minimize the fluid resistance of the venturi section 28. The tapered surfaces 30, 32 can be cast integrally with the venturi section 28 or alternatively, the tapered surfaces can be machined thereon with conventional equipment.

The tapered surfaces 30, 32 are preferably shaped so that portions of the venturi section 28 adjacent its leading and trailing edges 24, 26 can be inserted initially and closely within the associated openings of the exhaust outlet port 16 and the tailpipe 14. When such insertion is made, the venturi section 28 is securely mounted between the exhaust manifold 12 and the tailpipe 14 by a number of tie-bolts 38 inserted through suitably aligned apertures in the exhaust manifold and tailpipe flanges 18 and 20 respectively.

Communication between the exhaust manifold and the tailpipe 14 is thus established through throat 40 of the venturi section 28. It will be seen, then, that my conversion system as thus far described requires little or no additional space for the engine exhaust system, in the illustrated application. Moreover, my conversion system can be applied to existing vehicles simply by separating the exhaust manifold 12 and the tailpipe 14 a sufficient distance to permit insertion of the venturi section 28. For this purpose, the existing exhaust forepipe can be appropriately shortened at the inlet muffler clamp. Thus, my conversion system can also be applied to existing vehicles and need not be necessarily installed by the manufacturer.

In order to induct auxiliary combustion air into the vehicle exhaust system 12–14 in the area of the hottest portion of the nonpulsating effluent, the venturi section 28 is provided with a circumferential array of radial openings 42 which open into the venturi throat 40. In this arrangement, eight such openings are employed although it will be understood that the number can be varied depending upon the size and character of the internal combustion engine. As evident from FIG. 1 of the drawings, the length of the apertures 42 in comparison to their diameter is such that the apertures 42 impart a jetting action to the inducted auxiliary combustion air passing therethrough. A useful jetting action is obtained when the length to diameter ratio of the venturi apertures varies between about three to one and about five to one. In the illustrated case, the jetting and mixing action optimizes when the length to diameter ratio is in the neighborhood of 4 to 1. This jetting action together with the substantially normal disposition of the apertures 42 relative to the direction of exhaust gas flow 24 causes the inducted air to be thoroughly and uniformly mixed with the exhaust gases. When thus mixed and when thus provided with the proper amount of combustion air as determined by the venturi section 28, a substantially complete combustion of the engine exhaust gases results throughout a wide range of engine operating conditions.

The outward extremities of the induction openings 42 communicate with a circumferentially extending groove 44 formed in this example in the outer periphery of the venturi section 28. The groove 44 together with a closely fitting sleeve 46 form an inlet manifold for the induction apertures 42. The sleeve 46 can be applied to the outer surface of the venturi section 28 in a number of ways. For example, as shown in FIG. 1, the outer surfaces of the venturi section can be machined in the area of its groove 44 and the sleeve 46 having its inner surface similarly machined can be forced thereover as by tapping lightly with a hammer or mallet or other suitable tool. When thus positioned, the sleeve 46 can be secured by spot welds 48. Alternatively, the sleeve 46 can be shrunk-fit upon the venturi section 28, in which case the spot welds 48 will be omitted. In certain applications it may be desirable to seal the sleeve 46 to the adjacent outer surface of the venturi section 28 by seal-welding the lateral edges of the sleeve 46 to the adjacent outer surfaces of the venturi section 28. Obviously, the manifolding groove 44 can be omitted from the venturi section 28 and provided instead on the adjacent inner surface of the sleeve 46.

Air is supplied to the manifolding groove 44 by means of a tapped aperture 50 or the like extending through the sleeve 46 to which a suitable fitting 52 and conduit 54 are secured. The conduit 54 desirably is extended into the slip stream area of the vehicle to ensure the induction of fresh auxiliary combustion air into the venturi section 28 through the manifolding groove 44 and induction apertures 42. Such induction is effected by the reduced pressures in the venturi throat 40 caused by the flow of exhaust effluents therethrough. Owing to the elevated temperatures of the exhaust effluents, secondary combustion thereof is immediately initiated adjacent the induction apertures 42. Because of the normally constant streamline flow of the exhaust effluent in the area of the exhaust manifold outlet 16 and downstream thereof a relatively stable flame front is established adjacent the induction apertures 42. The stability of the flame front is further enhanced by the symmetrical array of the apertures 42 and the transverse dispositions thereof, all of which produce uniform and thorough mixing between the exhaust gases and the auxiliary combustion air. Most importantly, the flame front is particularly stabilized by the controlled turbulence and mixing of the inducted reactant and exhaust gases caused by the jetting action of the induction apertures. This jetting action coupled with location of the venturi member in that portion of the exhaust duct where the effluent gases would have exhibited a stream line flow, but for the presence of the venturi, further enhance the uniformity of the turbulence and attendant mixing action. If desired, the induction conduit 54 can be disposed as denoted by the chain outline thereof in FIG. 1, so that its inlet portion **56** is directed upstream of the vehicle slip stream, so that the slip stream aids the venturi effect in inducting air through the apertures **42** into the exhaust system, when the vehicle is in motion.

During vehicle cruising and acceleration conditions, the suctional effects of the exhaust stream **24** flowing through the venturi section **28** will regulate the amount of auxiliary combustion air required to complete the combustion of exhaust gases, in dependence upon the speed of the engine and the resultant quantity of exhaust gases produced thereby. Under conditions of relatively heavy engine acceleration, however, the proportion of combustible gases in the exhaust effluent increases so that the quantity of auxiliary combustion air provided by the induction effects of the flowing exhaust gases will be insufficient for complete combustion, if the combined flow area of the venturi apertures is undersized. On the other hand, during engine decelerations when the proportion of combustibles in the exhaust gases decreases, too much auxiliary combustion air may be inducted.

Accordingly, a modified form of my conversion system is shown in FIG. **2** of the drawings for providing additional control of auxiliary combustion to meet these situations. In the latter arrangement of my invention, the venturi section **28'** and sleeve **46'** are coupled to an air induction conduit **54'** in which is mounted a throttle valve **58**. The valve **58** can be provided in a variety of forms, a desirable form of which is a butterfly valve having vane **60** and operating lever **62**. A stop **64** desirably is provided within the casing for engagement by the lever **62** to prevent fully closing the valve. The vane **60** desirably is biased toward its partially closed position, as shown in FIG. 2 by means of spring **66**.

The lever **62** in this example is operated by a cable **68** or the like which in turn is moved by fluid motor **70**, comprising for example the piston **72** and cylinder **73**. The position of piston **72** is controlled by the depression in the intake manifold of the engine to which the piston and cylinder is coupled by conduit **74**. Accordingly, when the engine is at or near idling conditions the maximum manifold depression draws the lever **62** via cable **68** against stop **64** so that only a small amount of auxiliary combustion air can be drawn into the venturi apertures **42**. On the other hand, decreasing manifold depression with increasing acceleration permits the spring **66** to draw lever **62** in the opposite direction toward the full open position of the valve **58**. With this arrangement the maximum available air through the conduit **54'** is varied in proportion to the load upon the associated engine. Thus, the venturi section **28'** and associated components are designed to supply adequate auxiliary combustion air under maximum or near maximum engine load conditions. For decreasing load conditions the valve **58** will be increasingly moved toward its closed position by the fluid motor **70**, and this movement will vary with both the speed and accelerating conditions of the engine as reflected by the intake manifold depression. Thus, the amount of auxiliary combustion air inducted by the venturi section **28'** will be related both to the speed of the engine and to the engine acceleration and deceleration. It is to be understood, of course, that the valve lever **62** can be manually operated by suitable linkage extending to and mounted on the vehicle dash or it can be coupled to the throttle linkage of the engine carburetor (not shown) for simultaneous action therewith so that the carburetor throttle plate (not shown) and the valve member **60** will be moved simultaneously toward their opened and closed position.

The arrangements of my invention as shown in FIGS. **1** and **2** are satisfactory for almost all vehicle operating conditions. However, when the vehicle is stationary with the engine idling, the velocity of exhaust gases through the venturi section is usually not sufficient to induce the venturi effect. Accordingly, the exhaust gases may pass outwardly through the venturi apertures **42** rather than drawing auxiliary combustion air into the throat **40** of the venturi section **28** or **28'**. It is desirable therefore to elongate the induction conduit **54** such that its outer or intake end is positioned as far as practical from the cab or passenger compartment of the vehicle.

However, elongation of the induction conduit **54** or **54'** can be avoided with the arrangement of my conversion system as shown in FIGS. **3** and **4** of the drawings. In the latter arrangement the induction conduit **54''** need be provided only with sufficient length to reach the nearest slip stream area of the vehicle. To prevent the outflow of exhaust gases therethrough, a check valve **76** of simple and rugged construction is positioned in the conduit **54''** and is directed so that the induction of auxiliary combustion air opens the check valve.

In this arrangement, the check valve **76** includes a generally circular valve casing **78** mounted desirably in a vertical section **80** of the induction conduit **54''**. An annular valve seat member **82** is mounted in the bottom of the casing **78** as viewed in FIG. **3** for cooperation with a conical seating surface **84** machined on the lower end portion of plunger **86**. The remainder of plunger **86**, as better shown in FIG. **4** is of regular polygonal configuration, for example square, to provide longitudinal passages **88** between the flat sides of the plunger **86** and the encircling wall of the valve casing **78**. Alternatively, the valve casing **78** can be of a regular polygonal configuration while the preponderant portion of plunger **86** can be of cylinder configuration, for example, to provide the aforementioned air passages. The related interior dimensions of the casing **78** in any event are made slightly larger than the diametric or diagonal dimension of the plunger to provide a guide therefor without binding.

Upward movement of the plunger **86** is limited by the annular top wall **90** of the casing **78**. Desirably, the plunger **86** is fabricated from a lightweight material so as not to interfere unduly with the inducted auxiliary combustion air through the conduit **54''**. On the other hand, the vertical mounting of the check valve **76** assures closing of the check valve during engine idle, inasmuch as both the weight of the plunger **86** and the pressure of any outflow of exhaust gases through the apertures **42** operate to close the check valve **76**. A throttling valve such as the valve **58'** and associated components, as indicated by the chain outline thereof in FIG. **3**, can optionally be provided in the induction conduit **54''**, depending upon the specific application of the invention.

With reference now to FIG. **5** of the drawings, I have discovered that an improved operation of the venturi structure such as that shown in FIGS. **1–3** of the drawings results from the use of particular surface configurations and/or of dimensions and relationships falling within certain critical ranges. Thus, I have found, for improved combustion air induction and maximum exhaust gas combustion (resulting apparently and additionally from an improved mixture of the reactants) over the widest variation in engine speeds that the entrance or leading angle **100** of the venturi member **28'** should vary between **45°–65°** with an angle of 60° being optimum within this range. Likewise, the angle of the trailing edges **102** of the venturi structure **28'** can vary between 3½° and 7°. The combustion air inlet apertures **42'** desirably are located within the throat area **104**, i.e., at the narrowest portion or throat area of the passage through the venturi. In the FIG. **5** arrangement, for improved results the throat area **104** desirably is cylindrical, in contrast to the remaining inner venturi surfaces **105**, **106** which are of convex curvatures. Desirably also the apertures **42'** are disposed adjacent the median or mid-point of the cylindrical throat area **104** as denoted by chain reference line **108** in FIG. **5**. Finally, I have determined that the operational characteristics of the venturi **28'** are further enhanced when the axial lengths of the convex inner surface sections **105**, **106** are in a ratio of about 1:4.5 to 1:6.

In the venturi structure **28''** of FIG. **5A**, additional means are provided for more thoroughly mixing the exhaust gases flowing through the venturi **28''** as denoted by arrow **110** with inducted combustion air flowing into the venturi throat area **104'** as denoted by flow arrow **112**. In this arrangement, some or all of the venturi apertures **42''** are provided with inwardly extending hood means **114** comprising, in this example, a relatively short, truncated section of cylindrical conduit. I have further found that the mixing induced by the use of the hoods **114** is optimized when the truncating angle ——, relative to the cylindrical throat surface 104′, is between 25°–35° and preferably about 30°.

In FIG. 6 of the drawings exhaust duct 15′ including in this example forepipe 14′, intermediate duct section 17, and manifold port 16′ is provided with a pair of series-mounted venturi sections 116, 118, each of which has a manifold structure 44′ and induction apertures 42′. The venturi sections 116, 118 are spaced along the length of the exhaust duct 15′ and in general are disposed at the same general location with reference to the exhaust manifold 12 (FIG. 1). With the exhaust gases flowing through the duct 15′ in the direction denoted by flow arrow 24′, the apertures 42′ of the first venturi section 116 are sized to induct a portion of the total requirement in combustion air. This results in a partial combustion and preheating of the exhaust gases and in consequence the combustion is carried more nearly to completion adjacent the second venturi section 118. Desirably, the venturi sections 116, 118 are spaced such that maximum temperature of the combusting gases is achieved. In the example shown, the venturi sections 116, 118 desirably are spaced a distance equivalent to about the length of one venturi member. Additional venturi members (not shown) can be so coupled in series, depending upon a specific utilization of the invention.

A venturi member 120 having a modified configuration is illustrated in FIG. 7 for the purpose of still further enhancing the operational characteristics of the exhaust conversion system 122. In the illustrated arrangement, the venturi member 120 is supported within exhaust duct denoted generally at 124 after the manner of the preceding figures. The venturi member 120 is provided with manifolding means 126 including in this example a circumferential ring or band 128 enclosing circumferential groove means, in this example a groove 130 formed on the outer periphery of the venturi member 120. Obviously the groove can be formed on the band 128 instead. Communicating with the groove 130 are a plurality of induction apertures 132 which extend radially from the groove 13 to throat area 134 of the venturi member 120.

The apertures 132 and throat area 134 desirably are located closer to leading edge 136 than to trailing edge 138 of the venturi member. In this arrangement, the throat area 134 of the venturi member is represented by a relatively blunt circumferential ridge or edge portion 140 extending inwardly and circumferentially relative to the inner wall surfaces of the venturi member 120. For improved induction and mixing characteristics the venturi apertures 132 preferably are disposed adjacent the venturi throat ridge 140 and desirably on the downstream side thereof (flow arrow 142). Such characteristics are enhanced still further by having the upstream edges of the inward openings of the venturi apertures 132 contingent or very nearly contingent to the downstream side of the venturi throat ridge 140. In the illustrated arrangement, eight such venturi apertures 132 are employed, although it will be apparent that a different number can be utilized depending upon the specific employment of the invention. If desired, each of the venturi apertures 132 can be provided with the length to diameter ratio discussed previously for jetting characteristics and for a further improvement in the mixing characteristics of the venturi member 120.

In the illustrated arrangement, the venturi throat ridge 140 desirably is formed and defined by the inner venturi surfaces 144, 146. The upstream venturi surface 144 defines an induction chamber 148 of the venturi member 120 while the downstream venturi surface 146 defines a mixing chamber 150. In the arrangement of FIG. 7, the venturi surfaces 144, 146 are disposed at a significant angle 152 to one another in the region of their convergence to define the venturi throat ridge 140. Although illustrated as frusto-conical sections, the venturi surfaces 144, 146 can be somewhat arcuate in either the convex or concave sense while still defining an appreciable throat angle 152.

For optimum results in the illustrated arrangement, the trailing edge 138 of the venturi member 120 exhibits an angle 152 of between about 15° to 25° with the venturi axis 154. Similarly, the leading edge 136 of the venturi exhibits an angle 156 of between about 20° and 30°. The leading edge 136 can be truncated, as denoted by reference numeral 158, in order to introduce a controllably uniform turbulence into the exhaust gases flowing through the exhaust duct 124 (arrow 142). Such turbulence improves the induction and mixing characteristics of the venturi 120, which is, of course, further enhanced by the particular disposition of the venturi surfaces 144, 146.

I have found, in the illustrated arrangement, that optimum induction and admixture are obtained when the diameter of the venturi throat 134 and the outer diameter of the venturi member 120 are in the ratio of about 2:3, respectively. Likewise, optimum results have been secured when the lengths of the induction chamber 148 and of the mixing chamber 150 are in the ratio of about 3:5, respectively. These optimum ratios will, of course, vary depending upon a specific utilization and configuration of the venturi member 120. In the illustrated arrangement a considerable improvement will still attain, although reasonable ratio ranges on either side of the aforementioned optimum ratios respectively are employed.

From the foregoing it will be apparent that novel and efficient exhaust conversion systems have been disclosed herein which can largely eliminate the pollutants which would otherwise be exhausted to the atmosphere. With my arrangement the carbon monoxide and other harmful, combustible substances such as hydrocarbons are substantially fully converted into relatively harmless carbon dioxide and water vapor. My conversion system is applicable to gasoline, diesel and other internal combustion engines. For example, a venturi section such as venturi section 28 can be mounted in or adjacent the thrust nozzle of a jet engine. Such arrangement not only will ensure the complete combustion of the jet fuel but also will provide additional thrust. As noted previously, the venturi arrangements disclosed herein likewise can be mounted in the exhaust ducts of domestic and industrial furnaces, ovens, heaters, and the like where partially combusted exhaust gases are apt to be encountered. My exhaust conversion system can be utilized with various types of reactional vessels and other process equipment for the purpose of inducting additional reactant fluid into an exhaust duct or the like associated therewith to ensure completion of the chemical reaction.

In my exemplary utilization, I have found, upon application of my conversion system to the exhaust system of a diesel-powered truck that the usually dense, smoky exhaust which is characteristic of an operating diesel engine is almost entirely eliminated. Even under conditions of maximum load, only a relatively thin brown smoke is emitted from the exhaust instead of the usual dense black smoke. In this same connection, a smoky orange flame has been observed emanating 6 to 8 inches from the diesel exhaust outlet before installation of my conversion system. After installation only a barely visible dull red glow is apparent.

While I have shown and described certain presently preferred embodiments of the invention and have illustrated presently preferred methods of practicing the same, it is to be distinctly understood that the invention is not limited thereto but may be otherwise variously embodied and practiced within the spirit and scope of the invention.

I claim:

1. A conversion system for an exhaust duct or the like through which partially reacted gases are circulated, said system comprising a venturi induction member mounted in the exhaust duct and having a circumferential array of radially extending apertures for inducting a reactant fluid into said duct upon passage of said gases therethrough, said venturi member having inlet and outlet openings each having substantially the same cross-sectional area as that of the adjacent interior of said duct, said apertures being located in a thickened portion of said venturi member and having a length-to-diameter ratio capable of imposing a jetting action upon the reactant fluid passing therethrough so that thorough mixing of said

reactant fluid and said gases is attained within said venturi member, said venturi member including end portions partially and closely inserted into a pair of duct sections respectively, and said venturi member being supported between said sections.

2. The combination according to claim **1** wherein said exhaust duct is coupled to an internal combustion engine, said venturi member being coupled between an outlet port of an engine exhaust manifold and an exhaust outlet pipe, said manifold and said pipe forming said exhaust duct sections.

3. A conversion system for an exhaust duct or the like through which partially reacted gases are circulated, said system comprising a venturi induction member mounted in the exhaust duct and having a circumferential array of radially extending apertures for inducting a reactant fluid into said duct upon passage of said gases therethrough, said venturi member having inlet and outlet openings each having substantially the same cross-sectional area as that of the adjacent interior of said duct, said apertures being located in a thickened portion of said venturi member and having a length-to-diameter ratio capable of imposing a jetting action upon the reactant fluid passing therethrough so that thorough mixing of said reactant fluid and said gases is attained within said venturi member, said venturi member being provided with a relatively shallow circumferentially extended groove communicating with said apertures, and a closely fitting sleeve having an inlet port secured to the outer surface of said venturi member in closing relationship with said groove, for delivering said reactant fluid to said apertures.

4. The combination according to claim **3** wherein a check valve is coupled to said inlet port and is directed to prevent an outflow of said gases therethrough when the velocity of said gases through said duct is insufficient to generate a venturi effect.

5. The combination according to claim **2** wherein conduit means including a throttling valve are coupled to said venturi apertures, and means are provided for moving said valve toward opened and closed positions thereof in accordance with engine acceleration and deceleration respectively, said moving means including fluid motive means coupled to said throttling valve and to an intake manifold of said engine for energization thereby.

6. The combination according to claim **4** wherein said check valve includes a casing and a plunger relatively closely fitted within said casing for guided movement therein, the cross-sectional configurations of said plunger and of said casing being of differing regular geometric shapes to afford longitudinal flow passages between said plunger and said casing.

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