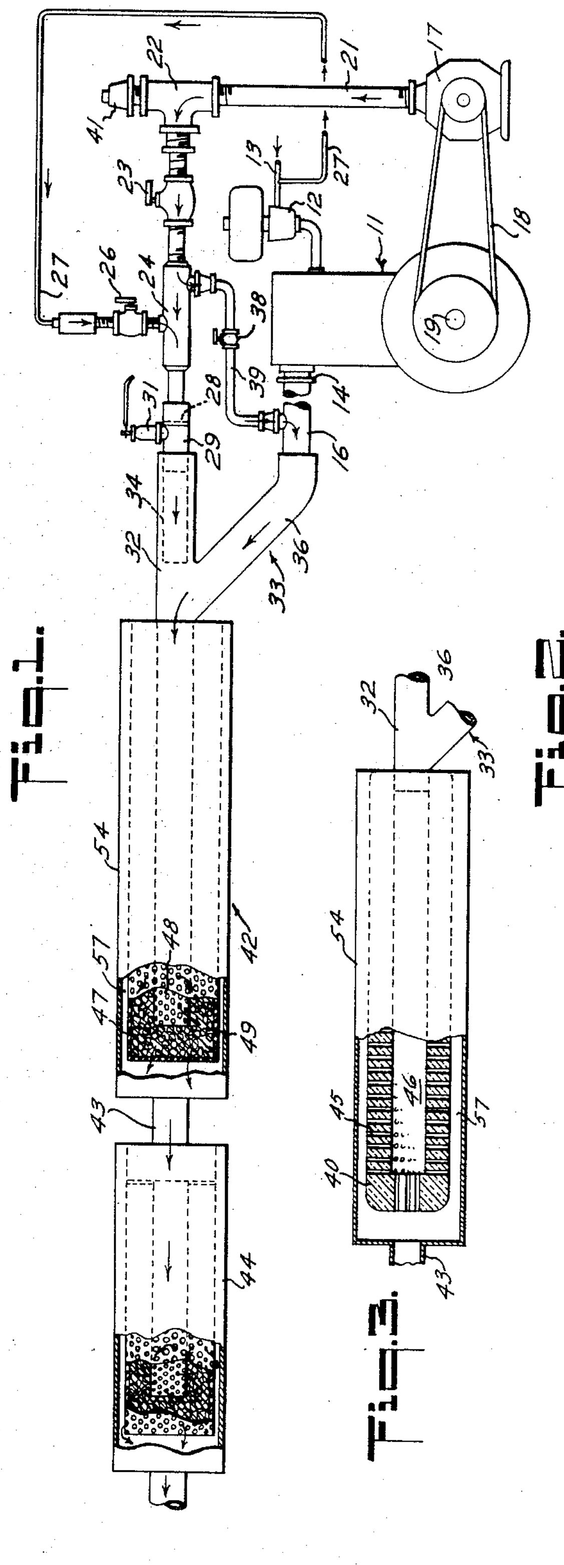
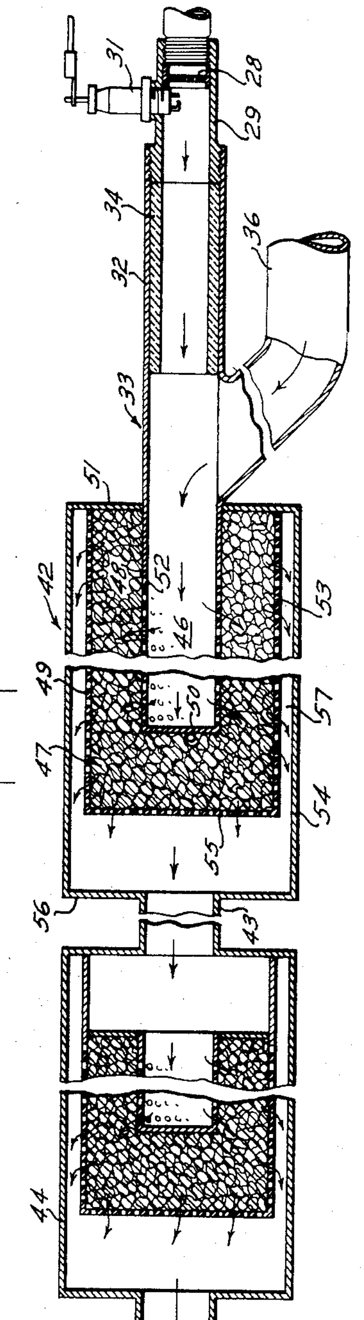
Oct. 18, 1960 D. P. WILLIAMS, SR 2,956,865

EXHAUST GAS PURIFIER

Filed Feb. 3, 1958





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United States Patent Office

2,956,865

Patented Oct. 18, 1960

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2,956,865

EXHAUST GAS PURIFIER

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Filed Feb. 3, 1958, Ser. No. 712,962

8 Claims. (Cl. 23—284)

The present invention relates to apparatus for purifying gas and particularly exhaust gases from combustion engines such as, for example, automotive engines.

Although innumerable devices and systems have been developed to the end of purifying exhaust gases from engines, the complete purification of exhaust from hydrocarbon fuels is yet to be attained. The satisfactory control of exhaust gases broadly includes the muffling of noise, the minimization of smoke and the elimination of noxious gas. The first two of the foregoing criteria have been achieved to general satisfaction, however, the latter of the three yet remains to be solved upon the basis of practicality for widespread applicability.

In addition to various irritants normally contained in combustion engine exhaust gases there is also contained a substantial amount of quite poisonous gases, mainly comprising carbon monoxide. In the combustion of petroleum or hydrocarbon fuels during normal engine cycles a relatively high percentage of carbon monoxide results because of the inefficiency of supporting the complete combustion necessary to the elimination of carbon monoxide. This particular gas is well known to be quite deadly and yet conventional engine exhaust systems allow same to pass relatively unhindered therethrough into the atmosphere with a consequent pollution of the air in a manner much more harmful to health than visible pollution.

Although various attempts have in the past been made to eliminate carbon monoxide from exhaust gases limitations in each proposed method have precluded widespread acceptance thereof. For example, a suitable purification system should not deleteriously affect operation of the engine to which it is attached nor should the complexity, size, or cost be overly large. To the contrary general acceptance of any system of this type requires that same be inexpensive both to manufacture and operate, have only a minimum size in order to fit onto already complex and crowded automotive assemblies, and provide a large order reduction in carbon monoxide in order to justify any use at all of same.

It is well known that carbon monoxide will react with oxygen to form the harmless gas carbon dioxide under suitable conditions and in fact within a combustion engine of the automotive type this reaction proceeds partially but not to completion, so that some of the carbon monoxide (CO) remains to be exhausted. One of the foregoing conditions is the presence of heat in substantial quantities and the reaction will only proceed at a temperature in excess of about 1400° F.

The present invention provides a system for carrying to completion the above noted reaction in an exhaust gas while at the same time maintaining a system simplicity consonant with widespread applicability thereof. In the present system size is minimized by the conservation of heat therein and this further serves to maintain small the cost of operating the system. Of further importance is the feature of system safety for reaction conditions therein are such that explosions would be possible without

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the inherent safety of the present system. Inasmuch as the reaction herein contemplated is necessarily carried out at an elevated temperature provision is made for the reduction in temperature of exiting gas to a nominal level so as to preclude hazards therefrom and herein this is accomplished in a minimum space so as to maintain a practical overall size of the apparatus. The foregoing is accomplished with substantially no measurable pressure drop through the system so that engine operation remains unaffected. Maximum importance in this or any purification process attaches to the resultant product purity and the present invention reduces the carbon monoxide content of exhaust gases from a conventional automobile engine to such a low level as to be undetectable with commercial exhaust gas analyzers, or even eliminate all of the carbon monoxide.

It is an object of the present invention to provide purification apparatus for completing combustion of exhaust gases from a combustion engine to the end of converting noxious portions thereof into innoxious gases.

It is another object of the present invention to provide apparatus for providing an elongated burning path for engine exhaust gases to complete combustion thereof.

It is a further object of the present invention to provide an exhaust gas purification system wherein such gas is subjected for a substantial time to such temperatures as to complete reactions removing carbon monoxide therefrom.

It is yet another object of this invention to provide an exhaust system establishing additional and substantially complete combustion and reducing the temperature of gas exiting therefrom to a safe level.

It is a still further object of the present invention to provide an exhaust gas combustion apparatus including heat exchange means conserving heat therein and materially reducing the temperature of gas leaving the apparatus.

The invention possesses other objects and features of advantage, some of which, with the foregoing, will be set forth in the following description of the preferred form of the invention which is illustrated in the drawing accompanying and forming part of the specification. It is to be understood, however, that variations in the showing made by the said drawing and description may be adopted within the scope of the invention as set forth in the claims.

The invention is illustrated in the accompanying drawing wherein:

Figure 1 illustrates in more or less diagrammatic form an exhaust system in accordance with the present invention in attachment with a motor, parts being shown in cross-section.

Figure 2 illustrates the reaction vessel and cooling unit of the system as shown in Figure 1.

Figure 3 is a view similar to Figure 2, but showing a modified construction of the reaction member.

Considering now the invention in some detail and referring first to Figure 1 of the drawing, there is shown a conventional automotive engine **11** including a carburetor **12** with an input gasoline line **13** and an exhaust manifold **14** with a manifold pipe **16** attached thereto and leading exhaust gas therefrom. It is contemplated by the present invention that gases exhausted from the engine **11** shall be further burned to a state of complete combustion and to this end there is provided an air pump or blower **17** which may be driven by the engine through a belt drive **18** from the engine crank shaft **19**. Air delivered by the blower is directed through a pipe **21** and T-connection **22** to a primary air control valve **23** that in turn connects to a mixing chamber **24**. This chamber **24**, which may be defined by a cylindrical member, also has a connection through a metering valve **26** and line 27 to the carburetor fuel line 13 with fuel being thereby drawn into the chamber by the ejector effect of air passing over the fuel connection in traversing the chamber. Attached to the output end of the mixing chamber, wherein air and fuel are combined to form a combustible mixture, is a burner nozzle 28 disposed in a housing 29 and adapted to form a fine spray of intermixed air and fuel. A spark plug 31 extending into the nozzle housing 29 and adapted for continuous pulsed operation from the automotive engine electrical system serves to repeatedly supply an arc or spark adjacent the nozzle 28 for igniting the mixture of primary air and fuel spraying therethrough. The nozzle housing 29 axially communicates with one leg 32 of a Y-connection 33 wherein there may be mounted a ceramic tube 34 through which the burning gas from the nozzle passes to enhance and promote combustion. To another leg 36 of the connection 33 there is attached the engine manifold pipe 16.

There is thus mixed in the connection 33 burning gas from the nozzle and exhaust gas from the engine, and in order to promote complete burning of the exhaust gas a secondary air circuit is provided. To this end a conduit 39 connects the air inlet of chamber 24 and the manifold pipe 16, and a secondary air control valve 38 is operatively positioned in the conduit so that secondary air is supplied from the blower in controlled amounts to the manifold pipe for mixing with exhaust gases. In order to prevent possible accidents from overpressure in the air system just described there is attached such as to the T-connection 22, a safety valve 41 which operates to open the system to the atmosphere at internal air pressures greater than the safety valve settting.

Attached to the above described Y-connection 33 in flow communication therewith is a reaction vessel 42 or burner-muffler as it may also be termed. The engine exhaust gas with entrained secondary air mixes with the burning gas and primary air from the nozzle at the confluence of the Y-connection legs and passes into the vessel 42. An exhaust line 43 extends from the vessel 42 to conduct away completely processed exhaust gases and there may be connected in this line an additional muffler or muffler-burner conveniently of a construction like the vessel 42 for the purpose of reducing the temperature and noise of the ultimate exhaust.

As regards the structure and function of the reaction vessel or burner-muffler 42, same will be seen in Figure 2 to define a central axial reaction chamber 46 aligned with the entering flow of gas. The reaction chamber 46 is considerably elongated to the end of maintaining exhaust gases at a predetermined minimum elevated temperature for sufficient time for the desired reaction thereof to proceed to completion. There is disposed about the reaction chamber 46 a mass of refractory material 47 capable of form or dimensional stability at high temperatures and providing very low resistance to the passage of gas therethrough. Although the reaction chamber 46 may actually be defined by a solid tube 40 of refractory material such as shown in Figure 3 it is advantageous to employ the material in a particle form rather than as a single solid mass in the interests of free gas flow through interstices between the particles, and also by reason of minimized production costs. Where the tube is of solid form, it will be provided with perforations 45. The refractory material herein employed may advantageously comprise lava rock, slag or ceramic and same as shown in Figures 1 and 2, is enclosed between an inner tube 48 and an outer tube 49. These tubes are mounted by rigid joinder to an inlet end plate 51 of the vessel 42 which is apertured to receive the Y-connection 33 in axial alignment so that the inner tube appears as an axial extension of same. The entry end of the tube 49 is closed by end plate 51, and the other end of the tube extends axially beyond an end wall 50 of tube 48 to terminate in an end wall 55. There is thus formed

a generally annular enclosure around the tube 48 completely filled with and confining the refractory material 47. The inner and outer tubes are formed of a material which retains structural rigidity at high temperatures such as stainless steel and the tubes 48 and 49 as well as end wall 55 of the latter are perforated by a multiplicity of closely spaced apertures 52 and 53 respectively providing a substantially unobstructed gas flow path therethrough. An outer shell 54 spaced radially outward of the outer tube 49 is connected between the aforementioned input end plate 51 and an output end plate 56 to entirely seal the vessel except for the input through end plate 51 and the exhaust line 43 extending through the output end plate 56. Within the shell 54 and about the outer tube 49 there is defined an expansion chamber 57 receiving gas passing through the refractory mass and, as the outer tube does not extend to the output end plate 56 of the vessel, this chamber communicates with the exhaust pipe 43 so that gas may readily flow into the latter for exhaust from the vessel.

As noted above the engine exhaust gas with secondary air added, mixes with the burning gas from the nozzle 28 and as a consequence the exhaust gas is raised to sufficient temperature to itself burn. The burning gases enter the reactor vessel and pass therealong to establish burning throughout the reaction chamber. Considering a particular reaction of importance herein, it is desired to prevent CO from exiting through the exhaust pipe and in order to do so the reaction $CO+O \rightarrow CO_2$ is carried out to completion, i.e., the carbon monoxide is oxidized. This reaction proceeds at a temperature of 1400° F. or more and thus in the reaction vessel a temperature in excess of 1400° F. is maintained. The burning gas from the nozzle supplies heat to the exhaust gas at a temperature in the neighborhood of 2000° F. and further the incompletely burned fuel in the exhaust gas is ignited thereby and burns to add further heat within the reaction chamber.

The refractory material mass 47 surrounding the reaction chamber 46 serves in part as a heat exchanger in that it removes heat from escaping gas to lower the temperature thereof and also serves as a heat reservoir so as to maintain a desired temperature in the reaction chamber whereby the oxidation of carbon monoxide proceeds therein. The refractory material preferably has a high specific heat so as to store a large amount of heat derived from hot gases passing thereover and to return same to the chamber as required to maintain the reaction temperature therein. It may be noted that due to the use of the particles, a maximum area of contact is afforded between the refractory material and the hot gases passing through the interstices between the particles, and at the same time the unimpeded free flow permitted the gas traversing between the particles, avoids any danger of any substantial back pressure.

Although the refractory material 47 removes heat from the hot gases flowing therethrough to reduce the gas temperature yet the gases exiting from the reaction vessel may have a temperature that is higher than desired and in order to further lower the temperature the muffler or muffler-burner 44 may be formed like the reaction vessel although preferably on a reduced scale so that gases flow through a second layer of refractory material therein to give up additional heat and emerge with only a nominal temperature. Of additional interest relative to the reaction vessel is the noise damping properties thereof for although the mass of refractory material through which the purified gases flow produces only a very minimum resistance to gas flow it does provide an effective noise muffler owing to the lack of direct paths therethrough for sound wave passage and of course the second unit or muffler 44 serves further to reduce the noise level of exhausting gas.

Considering now a summary of operation of the above described system, the motor 11 in operation drives the blower 17 to supply both primary and secondary air, the latter passing amounts controlled by the valve 38 into the engine manifold pipe 16 leading exhaust gases from the engine. The primary air is directed in amounts controlled by the valve 23 into the mixing chamber 24 in a stream wherein it entrains gasoline drawn, for example, from the engine fuel system. The mixed air and gasoline forming a highly combustible vapor is directed through a nozzle 28 into a housing 29 wherein a continuously pulsed spark plug or the like ignites same to produce a blast of burning gas or vapor directed through the ceramic tube into the Y-connection 33. Within the latter member 33 the burning vapor mixes with and ignites the air-exhaust gas mixture from the manifold line 16 and all is directed into the reaction chamber 46 whereat burning of the exhaust gas continues to completion. The burning vapor from the nozzle may have a temperature in the vicinity of 2000° F. and serves not only to ignite the exhaust gas but also to supply heat thereto for raising the gas temperature to that required for reaction of carbon monoxide, the gas within the reaction chamber being maintained at a temperature in the range of 1450° F. to 1750° F. Various other undesirable constituents of engine exhaust gases are also operated upon in the reaction chamber for unburned gasoline vapor is therein burnt and same in this manner gives out heat to help maintain reaction in the chamber. This complete combustion in the reaction chamber serves to remove visible vapor from the exhaust whereby smoke is substantially eliminated from the exhaust. Solid constituents normally found in engine exhaust are also broken down and generally consumed within the reaction vessel by the high temperatures therein. With a substantial reaction length in the chamber sufficient time is present during transit of exhaust gases therethrough for substantially complete combustion to occur and further for the carbon monoxide to be in fact completely eliminated. In flowing out of the reaction chamber and through the refractory material the very hot gases give up heat to the material for lowering the exit gas temperature and for providing a heat source available itself to apply heat at reaction temperature for furthering the reactions desired.

Numerous exhaust purification systems may be constructed in accordance with the present invention and, as an example to follow, conditions and results obtained in one instance were measured as follows:

Engine—1955 "Mercury" V8 internal combustion engine operating on pump gasoline.

Reactor—26 inches long by 6 inches square defining the outer shell, 24 inches long by 5 inches square for the outer tube, and 22 inches long by 2 inches square defining the reaction chamber.

It is important to note that in accordance with the above and as indicated in the drawings, the length of the reaction chamber is approximately ten times the maximum cross-sectional extent thereof. With this ratio, all of the gases will be maintained in intimate thermal relationship with the hot wall surfaces defining the chamber, and due to the considerable length of the chamber and the consequent long exposure of the gases to the heat of such surfaces, thorough and complete combustion of large volumes of the gas will be effected at the temperatures aforesaid.

Exhaust gas analysis of the above engine without the reactor being utilized, showed a 7.9% carbon dioxide and 3.8% carbon monoxide content. However, with the purification apparatus as above set forth, the analysis showed a 9.2% carbon dioxide, and 0.00% carbon monoxide.

The foregoing gas analysis was obtained by an Orsatt Test with the reaction chamber at about 1450° F. and was made with a conventional gas analyzer. Further, the foregoing test was made at engine idling speed and was repeated at increased speeds up to high speed engine operation without the tests indicating any carbon monoxide in the ultimate exhaust while in all tests no smoke or odor was noted in the exhaust.

What is claimed is:

1. An exhaust gas purifier comprising means defining an elongated reaction chamber adapted to receive exhaust gas and having a substantially closed end, a nozzle supplied with a combustible vapor, means igniting said vapor passing through said nozzle, means directing said ignited vapor into intimate mixture with exhaust gas at said reaction chamber for heating and burning the exhaust gas in said chamber, a mass of a refractory material having a high specific heat and high-temperature dimensional stability and defining a large plurality of gas passages disposed about said chamber in communication therewith whereby gas flows out of said chamber through said mass, and an outer casing radially spaced from said mass and extending axially beyond the same defining with the latter an expansion chamber having an opening therein for discharge of gas.

2. An engine exhaust purification system comprising means defining an elongated high temperature reaction chamber adapted to receive exhaust gas, means directing into said chamber a high temperature flame of sufficient heat content to raise exhaust gas to a temperature of 1400 degrees Fahrenheit, a heat exchanger formed of a large mass of refractory material disposed about said reaction chamber in heat exchange relation thereto and defining a large plurality of minute gas flow passages from said chamber for removing heat from gas passing therethrough, and means defining an expansion chamber having a discharge opening substantially encompassing said material and in communication with the passages therein.

3. An exhaust gas purification system as claimed in claim 2 including a pair of coaxial perforated tubes defining therebetween an enclosure filled with said refractory material in particulated form admitting of gas flow therethrough with said inner tube defining said reaction chamber, said inner tube providing the sole inlet for said gas, and all of said gas being required to pass through said refractory material prior to discharge thereof.

4. An exhaust gas purification system comprising a vessel including a closed shell having end plates with an aperture in each, an outer perforated tube secured to one of said end plates coaxially within said shell and having a perforated end wall spaced from the other end plate for defining with said shell an expansion chamber communicating with an aperture of the other end plate, an inner perforated tube secured coaxially within the outer tube to the same end plate as the latter in communication with the aperture in the attached end plate for defining within itself a reaction chamber and with an end of said inner tube spaced from said end of the outer tube, and particulated refractory material disposed in packed relation between said inner and outer tubes for admitting gas flow therethrough; piping means communicating with said reaction chamber and adapted for connection to an engine exhaust; means establishing a flow of air, means directing a controlled amount of said air flow into said piping means for mixture with exhaust gas therein; means mixing a controlled amount of said air flow with a combustible fuel and igniting same to produce a burning gas flow; and means directing said burning gas flow into said piping means adjacent the confluence thereof with said reaction chamber for heating and burning exhaust gas in said reaction chamber to purify same.

5. An exhaust purification system as claimed in claim 4 further defined by a second vessel like the described vessel and connected by piping from the reaction chamber thereof to the end plate aperture of the described vessel communicating with the expansion chamber thereof for cooling gases exhausted from the latter.

6. An exhaust gas purification system for an internal combustion engine, comprising a tubular unit of refrac-

tory material defining an elongated passage for said gas, means adjacent the inlet of said passage for igniting the gas entering the passage, means for introducing secondary air into said passage adjacent said igniting means and directing all of said gas and air into said passage, said refractory unit having provided therein a plurality of passages extending through said material, an expansion chamber in communication with said last passages, and a product discharge outlet communicating only with said expansion chamber and spaced from said passage by said material.

7. A system as set forth in claim 6 in which the length of said elongated passage is substantially approximately ten times the maximum cross-sectional extent thereof.

8. A system as set forth in claim 6 in which the length

of said elongated passage is approximately 22 inches and the cross-sectional area thereof is approximately 4 square inches, and the temperature in said passage adjacent said igniting means is approximately 2000° F., and the temperature throughout substantially the entire length of said passage is maintained between approximately 1400° F. and 1700° F.

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