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METHOD AND APPARATUS FOR CONSUMING COMBUSTIBLE
GASES IN ENGINE EXHAUST GASES

3,468,124

Filed April 25, 1967

4 Sheets-Sheet 1

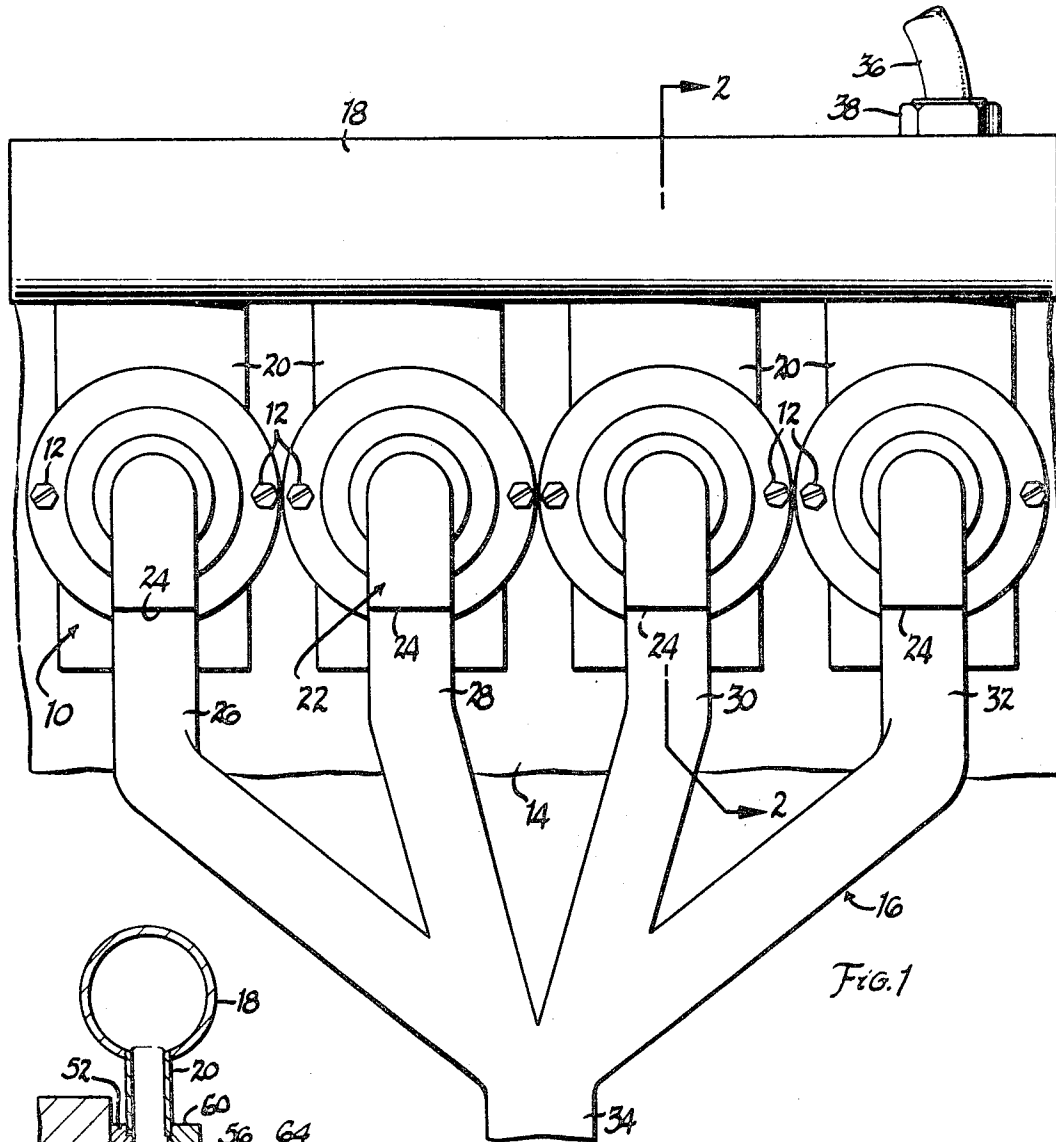


FIG. 1

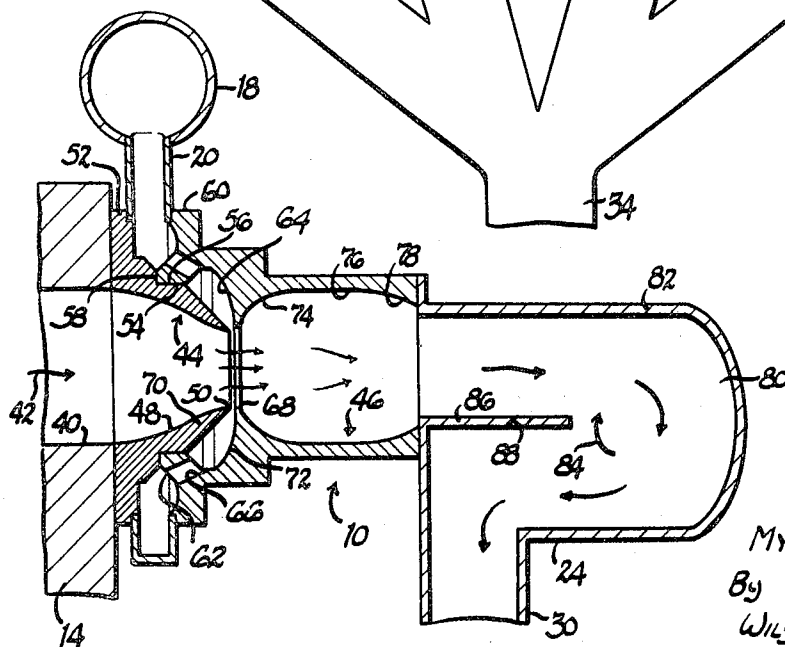


FIG. 2

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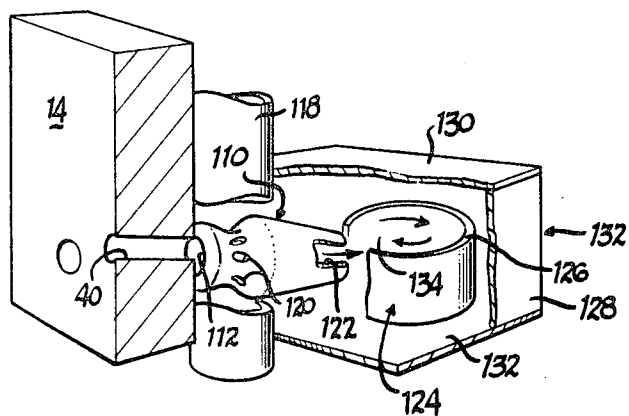


Fig. 3

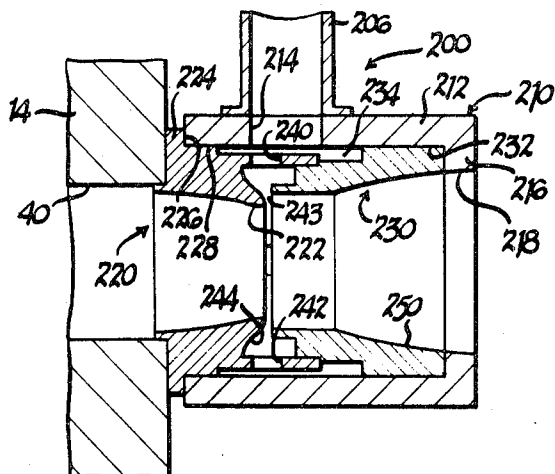


Fig. 4

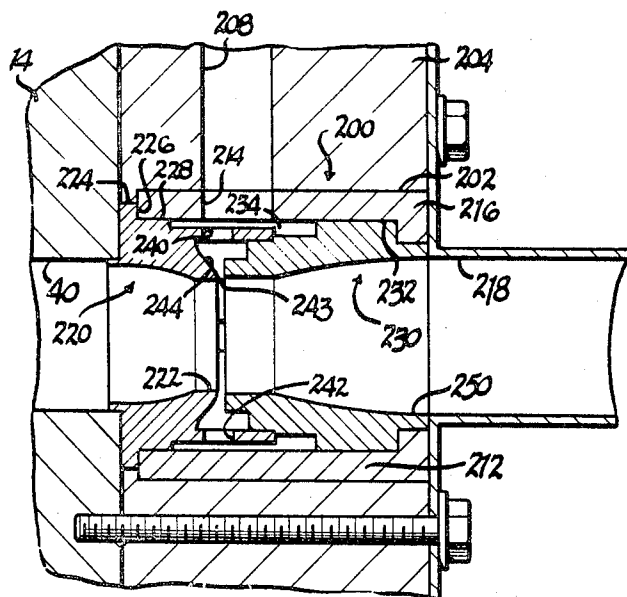


Fig. 5

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FIG. 6

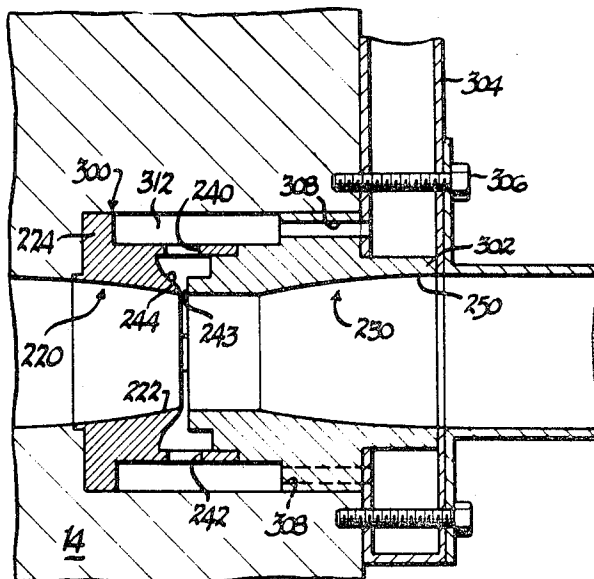


FIG. 7

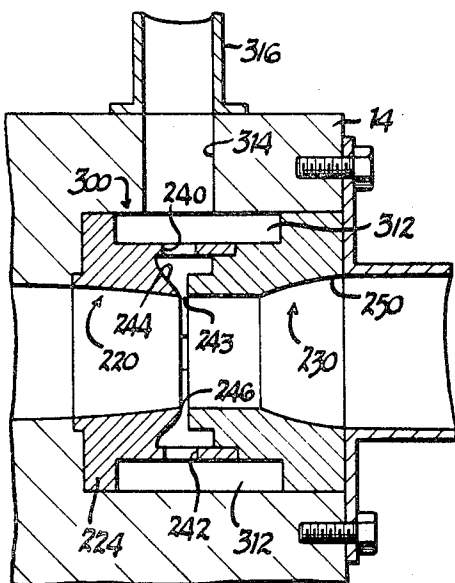
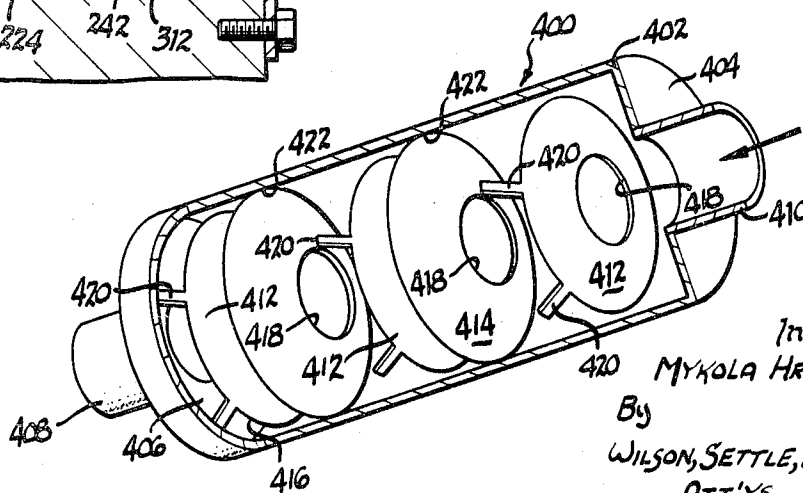


FIG. 8



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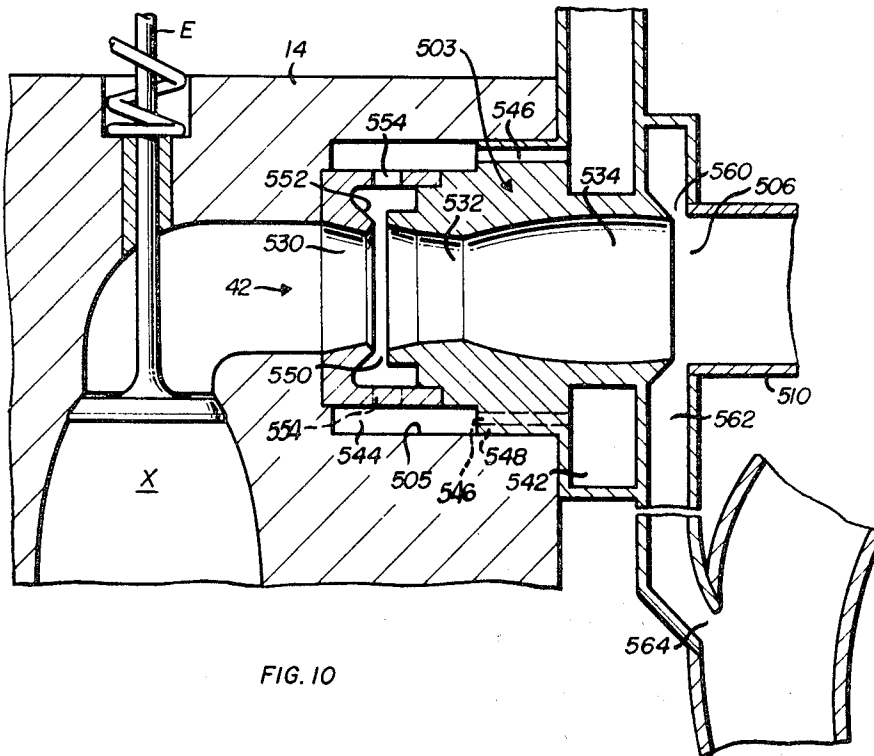


FIG. 10

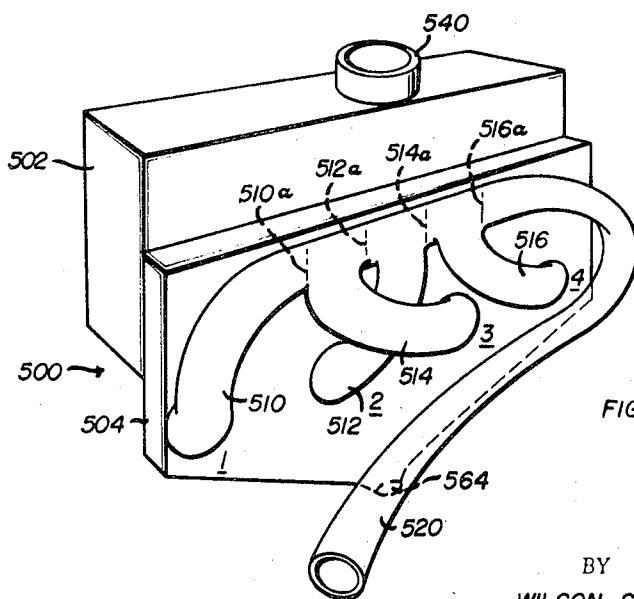


FIG. 9

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METHOD AND APPARATUS FOR CONSUMING COMBUSTIBLE GASES IN ENGINE EXHAUST GASES

3,468,124

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Continuation-in-part of application Ser. No. 473,351,
July 20, 1965. This application Apr. 25, 1967, Ser.
No. 642,990

Int. Cl. F01n 1/14, 3/10

U.S. Cl. 60—30

6 Claims

ABSTRACT OF THE DISCLOSURE

A system for burning the combustibles of exhaust gases by using the heat content of the gases and before releasing the exhaust gases to the atmosphere. The exhaust gases are ignited in a burner chamber at the exit of each cylinder of an internal combustion engine. The reburned exhaust gases are passed through individual circulating chambers and then isolated chambers having a volume approximately equal to the volume of the exhaust gases emanating from each cylinder during an exhaust stroke. The exhaust gases from each cylinder are merged according to the order of firing of the cylinders into an exhaust tube to prevent back-pressure in the isolated chamber.

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of my co-pending application Ser. No. 473,351 filed July 20, 1965, now abandoned.

BACKGROUND OF THE INVENTION

The present invention relates generally to a system for eliminating carbon monoxide from engine exhaust and more particularly to a novel method of and apparatus for essentially completely burning, by way of secondary combustion, residual carbon monoxide following discharge thereof as exhaust from the cylinder of an internal combustion engine and before the exhaust is emitted to the atmosphere.

This invention features: (1) utilization of air for secondary combustion which is drawn from the atmosphere by venturi action and which is uniquely mixed with the cylinder exhaust, (2) effectuation of secondary combustion solely by the heat of the cylinder exhaust at the venturi immediately adjacent the engine cylinder, (3) use of a unique recirculating chamber and (4) use of independent, substantially straight exhaust passages contained within a novel exhaust manifold.

While it is common in the combustion art to effect a secondary combustion of cylinder exhaust for the purpose of purifying the exhaust before it is released into the atmosphere (as taught by U.S. Patents 2,005,249, 2,649,685, 3,058,299, 3,091,078 and 3,124,930), certain disadvantages exist and important problems remain unsolved. Some objectionable characteristics found in the secondary combustion prior art are:

(1) The use of complex and costly prior art equipment has prohibited large scale commercial distribution;

(2) The inability of prior art developments to completely burn all residual carbon monoxide and the like due to, for example,

(a) the difficulty encountered in pro-rationing the quantity of air required for secondary combustion with the quantity of cylinder exhaust, or

(b) the existence of flow inhibiting backpressure and poor secondary explosion characteristics present in con-

ventional exhaust manifold, exhaust pipe and muffler systems which extinguishes secondary combustion before all the carbon monoxide is burned;

(3) Reliance upon both auxiliary ignition and auxiliary air supply equipment driven by electrical or mechanically operating devices; and

(4) Combustion interference encountered between the egress of exhaust from the several engine cylinders at spaced time intervals, e.g. flow of exhaust from one cylinder, by reason of the secondary combustion explosion may be caused to flow out of the secondary combustion air intake of another cylinder.

SUMMARY OF THE INVENTION

It is a primary object of the present invention to overcome the aforementioned prior deficiencies by providing an efficient, inexpensive secondary combustion system, including both method and apparatus, for essentially completely eliminating carbon monoxide issuing from an internal combustion engine or the like before the exhaust is emitted to the atmosphere.

An additional important object of this invention is the provision of a novel method of and apparatus for using the heat of exhaust emerging from an internal combustion engine along with naturally drawn air intermingled with the hot exhaust to achieve substantially complete secondary combustion of residual carbon monoxide and unburned carbon particles.

Another important object of this invention is the provision of the unique manifold and muffler structure comprising separate exhaust passages leading from each of respective ones of cylinder exhaust burners such that the exhaust passages are generally parallel and slightly convergent with respect to each other to accommodate essentially complete secondary combustion without flow-inhibiting back-pressure and secondary explosion dissipation.

A further and no less important object of this invention is the provision of a novel system including method and apparatus for achieving complete secondary combustion of residual carbon monoxide emerging from an engine cylinder, which system embodies a unique venturi action induced adjacent the exhaust valve of the engine cylinder to draw air, by natural draft, into the region of the venturi throat in the form of an annular converging stream which air is thoroughly commingled with the hot exhaust issuing from the cylinder.

Another important object of this invention is the provision of a unique system including method and apparatus, which system includes a reburner circulation chamber which creates a novel circulation action of the reburned exhaust issuing from a residual carbon monoxide burner to insure substantially complete secondary combustion.

These and other objects and features of this invention will become more fully apparent from the appended claims as the ensuing detailed description proceeds in conjunction with the accompanying drawings in which:

FIGURE 1 is a side elevation of a presently preferred embodiment of this invention mounted upon an internal combustion engine;

FIGURE 2 is a cross-sectional view taken along line 2—2 of FIGURE 1 illustrating one presently preferred residual carbon monoxide burner as well as a "goose-neck" circulation chamber;

FIGURE 3 is a perspective representation of another presently preferred residual carbon monoxide burner equipped with a circulating reburner chamber adjacent the effluent end thereof;

FIGURE 4 is a cross-sectional view of still another

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presently preferred residual carbon monoxide burner assembly mounted external of an engine block;

FIGURE 5 is a cross-sectional view of the residual carbon monoxide burner assembly of FIGURE 4, but with the assembly mounted directly in a recess in the engine head adjacent the engine block;

FIGURE 6 is a cross-sectional view of still another presently preferred residual carbon monoxide burner with the burner mounted in a recess in the engine block and air for secondary combustion being supplied through an external conduit;

FIGURE 7 is a cross-sectional view of the burner of FIGURE 6 similarly placed in a recess in the engine block but in this instance supplied with secondary combustion air through a bore located directly in the engine block;

FIGURE 8 is a perspective representation of a muffler which may be utilized with the present invention to accommodate essentially complete secondary combustion by substantially eliminating exhaust manifold back-pressure normally caused by conventional mufflers;

FIGURE 9 is a further modified embodiment of a carbon monoxide eliminating system; and

FIGURE 10 is a vertical fragmentary sectional view of the system shown in FIGURE 9.

GENERAL

The basic purpose of the present invention is to provide an efficient and inexpensive device which will consume essentially all carbon monoxide gases immediately as they issue from the cylinder exhaust ports or openings at the engine block of an internal combustion engine. Carbon monoxide contained within the crankcase may similarly be fully burned to form carbon dioxide.

Reference is now made to the drawings wherein like numerals are used to designate like parts throughout. FIGURE 1 depicts, in side elevation, a plurality of carbon monoxide burners 10 fastened, for example, by bolts 12 to an engine block 14, each carbon monoxide burner 10 being in fluid communication with both the exhaust port of an engine cylinder and a unique exhaust manifold, generally designated 16 (FIGURE 1). Air is supplied from the atmosphere by a venturi action to the respective carbon monoxide burners 10 by means of a main air conduit 18 and respective feeder branch conduits 20, the feeder conduits 20 respectively communicating with individual ones of the burners or chambers 10 to induce secondary combustion in a manner to be more fully described subsequently.

Exhaust gases issuing from each burner 10 pass through an exhaust circulating chamber, generally designated 22, located immediately downstream of the outlet to the associated burner 10.

Each exhaust circulating chamber 22 communicates at its effluent end 24 with an essentially isolated passage comprising a portion of the exhaust manifold 16. Each passage is designed to have a volume or capacity substantially equal and preferably slightly less than the volume of gases exhausted from each cylinder after the exhaust valve opens, for a purpose to be described later. This volume of gases is determined by among other things the size of the combustion chamber and the pressure developed within the chamber. The manifold passages which are respectively designated 26, 28, 30 and 32, also merge with each other at modest acute angles and in the firing order of the cylinders to thereby function both to (1) restrict the erupting of explosionary gases being combusted at the burners 10 along essentially a single path which does not extend in communication with any other cylinder and (2) to accommodate rapid evacuation from the burners of carbon dioxide formed by combustion at the burners 10. The single exhaust manifold passage 34 communicates with the muffler of desired construction,

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for example that depicted in FIGURE 8, as will subsequently be explained.

Carbon monoxide contained within the crankcase area of the internal combustion engine of which the engine block 14 forms a part may be circulated through the breather tube of the engine (not shown) or the like and deposited in the air conduit 18 by use of the hose 36. A fitting 38 secures the hose effluent end to the air intake conduit 18 in any suitable manner, as by threaded connection.

THE CARBON MONOXIDE BURNER OF FIGURES 1 AND 2

As can be seen by reference FIGURE 2, the engine block 14 is provided with an exhaust port 40 immediately adjacent to an engine cylinder at the exhaust valve (not shown), the exhaust flowing as indicated by arrow 42 during the exhaust stroke of the piston contained within the cylinder in question. For ease of fabrication and assembling, the carbon monoxide burner chamber 10 comprises two parts generally designated 44 and 46, respectively. Of course, the burner chamber 10, if desired, could be formed as a single piece. The burner part 44 comprises an exhaust influent opening at 48 and is internally configured in the form of a venturi thereby providing a venturi throat at 50. The burner part 44 also has a transversely extending flange 52 through which the previously described bolts 12 pass in order to secure the burner 10 to the engine block 14 as previously described.

The burner part 46 is received in concentric relation to the burner part 44 by slip fitting the cylindrical surface 54 of the part 46 over top of the cylindrical surface 56 of the part 44. Thus, the parts 46 and 44 abut each other at 58, when assembled. The part 46 also provides a flange 60 through which the bolts 12 pass, as previously described. The left face of the flange 60 is inwardly grooved at 62. Near the apex of the groove 62, there is provided a plurality of air influent cylindrical passages 64. The inlet air passages 64 are supplied with air from the atmosphere by natural draft or venturi action through the air inlet conduit 18 and the branch conduits 20. The downstream end of each inlet aperture 64 communicates with a divergent conical passage 66. The passage 66 terminates in a generally arcuate or annular opening 68, immediately downstream of the venturi throat 50. Thus, the edge 70 of the part 44 cooperates with the edge 72, which is of larger diameter when compared with the circular edge 70, to form the annular opening 68.

Hence, the air flowing from the opening 68 is a diverging stream annular in cross section which commingles with the exhaust passing through the exhaust port 40 and the venturi throat 50 at an acute angle. This thoroughly mixes the exhaust and air causing an eruption or explosion which is in fact secondary combustion of unburned or partly burned carbon particles, the explosive combustion being evidenced by the existence of a jet flame or blaze disposed slightly downstream of the venturi throat 50. This system by actual test has proved to be surprisingly beneficial and efficient.

Atmospheric air is drawn through the conduit 18, the branch line 20 and ultimately through the annular opening 68 into the venturi section by reason of a simultaneous reduction of pressure head and an increase of velocity head in the stream of exhaust passing through the venturi. In this way the amount of air necessary to achieve essentially complete secondary combustion is self-regulating. By appropriately sizing the internal configuration of the burner 10, the precise amount of air necessary for secondary combustion is drawn through the annular opening 68 cyclically with each exhaust stroke of the associated engine cylinder.

As can be seen by inspection of FIGURE 2 the internal configuration of the burner part 46 downstream of the throat 50 is generally divergent at 74, essentially straight at 76 and convergent at 78.

THE EXHAUST CIRCULATING CHAMBER OF FIGURE 2

The exhaust circulating chamber 22, previously generally described in conjunction with FIGURE 1, is generally configured in the form of a "goose-neck" wherein the gaseous products of a secondary combustion issuing from the venturi outlet 78 flow generally in the manner depicted by the arrows in the exhaust circulating chamber 22. The exhaust circulating chamber 22 thus comprises a set apart goose-neck reservoir 80 enclosed within an external housing 82. The reservoir 80 accommodates a certain amount of recirculation as depicted by the arrow 84 and also changes the direction of flow of the gaseous products of secondary combustion through approximately 180 arcuate degrees at the wall 85 and thereafter through approximately 90 degrees at the effluent opening 24 of the chamber 22. A baffle plate 86, provided with an angularly disposed aperture 88, extends into the goose-neck reservoir 80 to inhibit passage of exhaust issuing from one engine cylinder and out the annular opening 68 in one burner 10 mounted at an adjacent engine cylinder. The plate 86 also accommodates a beneficial muffling action which tends to silence both the noise of influent air and of secondary combustion occurring in the region of the venturi throat during operation. The angular aperture 88 further aids in causing recirculation of gases in the reservoir 80 when the pressure in the inlet to the reservoir is greater than the outlet, at 30.

THE CARBON MONOXIDE BURNER OF FIGURE 3

A carbon monoxide burner 110 is utilized in the embodiment of FIGURE 3, which burner 110 has the general configuration of a nozzle. Thus, the exhaust issuing from an engine cylinder through the exhaust port 40 of the engine block 14 passes through the influent opening 112 of the burner 110. Air drawn by venturi action, passes from an air intake conduit 118 through a plurality of radially disposed intake apertures 120 in the burner 110. The air intake thus flows into the burner nozzle 110 as substantially an annular stream of flow. The apertures 120 may be disposed with respect to the longitudinal axis of the burner 110 at any desired angle. It is to be noted that the air intake apertures 120 are disposed approximately at the throat or constriction of the nozzle burner 110. The effluent opening 122 of the burner 110 is also of somewhat reduced cross sectional area.

THE EXHAUST CIRCULATING CHAMBER OF FIGURE 3

The hot air exiting through the effluent opening 122 from the burner 110 is vortically circulated through an exhaust circulating chamber, generally designated 124, one or more times. The chamber 124 is essentially disc shaped and thus comprises a circular band of metal 126 forming the main gas deflecting portion of the chamber. The walls 128 and 130 of the exhaust manifold 132 fit tightly against the side edges of the metal band 126 to form the enclosed exhaust circulating chamber 124. Thus, the flow of gas into and out of chamber 124 is occasioned solely at the upper opening 134.

The advantage of utilizing the exhaust circulating chamber 124 is that, as depicted by the arrows of that figure, the hot gases which have been exhausted through the outlet port 122 of the burner 110 are circulated generally vortically one or more times past the hot outlet port 122 to further oxidize any residual carbon monoxide not fully burned during the secondary combustion occurring in the burner 110. Thereafter, exhaust gases are expelled from the chamber 124 and displaced along the exhaust manifold 132, through a muffler (not shown) and out into the atmosphere.

THE CARBON MONOXIDE BURNER OF FIGURES 4 AND 5

FIGURES 4 and 5 depict another presently preferred

carbon monoxide eliminator or burner 200 which may be mounted either directly against the engine block 14 by any suitable means in the manner depicted in FIGURE 4 or may be mounted in a recess 202 of an engine head 204 adjacent the engine block 114, as shown in FIGURE 5. In the first instance, air is supplied by venturi action through an air conduit 206, while in the latter case, air is supplied through a bore 208 located in the engine head 204.

The construction of the burner 200 is the same in both FIGURES 4 and 5. The burner 200 comprises an external casing, generally designated 210, which comprises a cylindrical body 212 having an air influent opening 214 therein and an inwardly directed flange 216 at one end forming an opening 218 at the downstream side of the burner 200.

Two additional components of the burner 200, i.e. those generally designated 220 and 230, are inwardly configured to form a venturi section having a throat 222. A flange 224 of the part 220 abuts the forward end of the cylindrical casing 212 at 226 in sealed relation. Bolts (not shown) are used to secure the flange 24 to the engine block in a suitable known manner. The forward interior end of the cylindrical casing 212 rests on the cylindrical surface 228 and may threadedly engage the same, while the rearward end rests on cylindrical surface 232 of the part 230 and may threadably engage the same to unite the parts 210, 220 and 231. An annular chamber 234 is provided in between the casing 212 and the burner components 220 and 230 as depicted in FIGURES 4 and 5. Moreover, the burner component 220 has a plurality of air influent apertures 240 through which influent air passes, ultimately merging in a chamber 242 and passing as a divergent stream of air annular in cross section through the annular opening 243 into the venturi immediately downstream of the throat 222. An air deflecting surface 244 deflects the air being displaced through the chamber 242 so that the divergent stream of air contacts the engine exhaust flow at an acute angle to maximize the mixing action between the air and the exhaust and thereby accommodate substantially complete secondary combustion just downstream of the venturi throat. The internal configuration of the burner component 230 comprises a slightly divergent surface 250, forming part of the overall venturi section.

THE CARBON MONOXIDE BURNER OF FIGURES 6 AND 7

The burner depicted in both FIGURES 6 and 7 and generally designated 300 is essentially the same burner as the burner 200 absent the external casing 210. In FIGURE 6 the burner component 230 is provided with an annular extension 302 to appropriately channel draft air drawn through an external air intake conduit 304 (which conduit is secured by bolts 306 to the engine block 14), and through a plurality of elongated openings 308 disposed in the flange 310 of the burner component 230. Air emerging from the openings 308 thereafter passes through an annular chamber 312, through the apertures 240 and into the chamber 242, against the deflecting surface 244 and subsequently out the essentially annular opening 243 at the venturi throat 222.

The embodiment of FIGURE 7 differs from that of FIGURE 6 only in that no external conduit for air intake is provided. Here, air passes through a bore 314 in the engine block 14, the air being supplied through an exterior air intake conduit 316.

THE MUFFLER OF FIGURE 8

As depicted in perspective in FIGURE 8, one preferred type of muffler which may be utilized with any carbon monoxide elimination system of the previously described embodiments, comprises a muffler which is constructed to prohibit the exertion of back-pressure upon the car-

bon monoxide elimination apparatus and thus accommodate rapid evacuation of the products of combustion issuing from the carbon monoxide elimination system, including carbon dioxide, to prevent extinguishment of secondary combustion action.

Structurally, the muffler 400 of FIGURE 8 comprises an external cylindrical casing 402 having end walls 404 and 406 as well as an influent pipe 410 and an effluent pipe 408. Internally secured to the inside surface of the cylindrical casing 402, for example by welding, are a plurality of conically-shaped baffle plates 412 and 414, respectively, the apex of which projects upstream. The baffle plates 412 and 414 are alternately situated in the casing 402, each plate 412 having exhaust openings 416 at the periphery adjacent the muffler casing 402 and each plate 414 having a central exhaust opening 418. The plates 412 are, for example, welded to the casing 402 at radial struts 420 to the inside of the muffler casing 402, while the plates 414 are welded to the casing 402 at their external peripheral edges 422. Thus, the flow of exhaust through the muffler 400 is generally sinusoidal and practically no back-pressure is exerted by the muffler upon the exhaust manifold of an internal combustion engine equipped with any one of the foregoing carbon elimination systems. Thus, more complete secondary combustion is accommodated.

OPERATION

Inasmuch as each of the previously described carbon monoxide elimination systems operate in essentially the same way, for purposes of brevity and clarity only the elimination system depicted in FIGURES 1 and 2 will be operatively described.

The present invention utilizes a principle of inducing secondary combustion between hot exhaust and air, drawn by venturi action, solely by means of the high temperature of the exhaust. Thus, it is important that any carbon monoxide burner of this invention be situated in very close proximity to the exhaust valve or the exhaust port of a cylinder of an internal combustion engine.

During operation the temperature of the exhaust valve, at the head thereof, will run sometimes as high as 1400° and occasionally slightly in excess of that temperature. Thus, the exhaust passing adjacent the valve head, which heats the valve head, will also exceed 1400° F. By locating the carbon monoxide burner, as for example burner 10 of FIGURES 1 and 2, as close as practicable to the valve head self-combustion between the exhaust and the air is induced. This is because the ignition temperature of carbon monoxide, in the presence of sufficient oxygen, is approximately 1225° F. It is only necessary that the ratio of carbon monoxide to air fall into the range of 12 to 74% for self-ignition when the exhaust temperature exceeds 1225° F.

In operation, the apparatus of FIGURES 1 and 2 being assembled as depicted in those figures, the cylinders of the internal combustion engine of which the entire block 14 is a part is operated to cyclically deliver exhaust gases to the respective carbon monoxide burners 10, four of which are shown in FIGURE 1. Flow of exhaust gases from an engine cylinder to any one of the burners 10 forces the exhaust to pass through the venturi throat 50 (FIGURE 2) causing a substantial reduction in the exhaust pressure head and a substantial increase in the exhaust velocity head. This phenomenon sucks or draws atmospheric air through the conduit 18, the branch conduit 20 and the annular influent opening 68, just downstream of the venturi throat 50. The influent air being directed along the converging passage 66 impinges as a converging conical stream upon the flow of exhaust passing through the venturi throat 50 at an acute angle. This results in thorough mixing of the air and the exhaust followed instantaneously by an eruption or explosion evidenced by a visible jet flame, thus essentially all unburned or partially burned carbon is converted to carbon dioxide through secondary combustion.

The exhaust gases, issuing from the burner 10 through the effluent, slightly converging opening 78, are circulated within the exhaust circulating chamber 22 as previously described and thereafter the exhaust gases pass through the exhaust manifold 16 (FIGURE 1) and the muffler 400 (FIGURE 8).

Of course, the exhaust issuing from each engine cylinder contains a substantial quantity of carbon dioxide and the very process of burning residual carbon monoxide at the burner 10 creates additional carbon dioxide. In order to prevent carbon dioxide from prematurely extinguishing the explosive secondary combustion flame, an absence of back-pressure downstream and an isolated exhaust passage downstream of each burner, through which the products of secondary combustion pass, have been found to be surprisingly beneficial.

Utilization of standard mufflers and exhaust manifolds in conjunction with carbon monoxide burners of the type herein disclosed have been found to allow carbon dioxide to prematurely extinguish secondary combustion and, furthermore, possess a further disadvantage of accommodating exhaust communication directly between cylinder exhaust ports so that the explosion incident to secondary combustion at any one burner will spread in several directions including out the air intake of another burner. Use of the standard exhaust manifolds also accentuates exhaust noise.

The previously described exhaust manifold 16 (FIGURE 1) provides individual passages 26, 28, 30 and 32 connected with the respective four illustrated cylinders which passages confine the gases issuing from the burners 10 and thereby direct the explosion incident to secondary combustion along each said passage, the passages merging into the somewhat larger passage 34. Thus, providing a recirculating chamber adjacent each burner will substantially eliminate any back-pressure or reverse flow of exhaust gases back to the burner chambers. Furthermore, by restricting the volume of each passage, 26, 28, 30 and 32 to approximately the volume of gases emanating from each cylinder during one cycle of operation and connecting the passages to the single outlet manifold passage according to the firing order of the cylinders and at acute angles, the pressure and flow produced by exhausting a subsequent cylinder will force the exhaust products of the previous cylinder along the manifold passage 34. This feature is of extreme importance since it will further reduce any back-pressure or reverse flow of carbon dioxide containing gases back to the burner chambers. This eliminates any carbon dioxide from being forced back to the burner chambers 10 which would tend to extinguish the secondary combustion. In this way, all carbon dioxide is readily drawn away from the burner 10 as secondary combustion is simultaneously occurring and, moreover, no back-pressure is exerted upon the burners. Hence, buildup of excess carbon dioxide is not permitted and premature extinguishment of secondary combustion is avoided.

It should be noted that, apart from the flow area restrictions internal of the burner, no flow restrictions are present in the remainder of the exhaust system. This further facilitates ready downstream movement of the gases issuing from each burner 10.

THE CARBON MONOXIDE ELIMINATING SYSTEM OF FIGURES 9 AND 10

The slightly modified system shown in FIGURES 9 and 10 is particularly adapted for use in conjunction with a conventional muffler system by utilizing an exhaust manifold system which is readily capable of compensating for any back-pressures caused by the standard mufflers of a conventional muffler system.

The system shown in FIGURES 9 and 10 includes a box like structure generally designated as 500 divided into an air intake compartment 502 and a decompression compartment 504. The engine block 14 which has a conventional exhaust valve E is counterbored at 505 to

receive a burner 503. The burner 503 is in open communication with the discharge port of each cylinder chamber X through which exhaust gases, indicated by arrow 42, flow during the exhaust stroke of the piston E. The outlets of the burners 503 are in open communication through opening 506 with conduits 510, 512, 514 and 516. The conduits or isolated exhaust passages again are of a size to have a volumetric capacity equal to the volume of the exhaust gases received from each cylinder during an exhaust stroke of a piston therein. Thus, the volumes of the respective passages between the inlet opening 506 and the dotted lines, indicated by the reference numerals 510a, 512a, 614a and 516a, are equal in volume and the respective passages terminate into a common conduit at a relatively small acute angle and in the order determined by the firing order of the respective cylinders.

Thus, assuming that the firing order of the cylinders is 1, 3, 2 and 4, the passages are connected to a common exhaust manifold 520 in the manner shown in FIGURE 9. Therefore, as the pressure of the exhaust gases in the passage defined by conduit 510 is reduced substantially to the manifold pressure, the forces or flow of exhaust gases from the subsequently exhausted cylinder (No. 3) will cause a flow of gases at an acute angle adjacent the end of the passage 510, generally designated by the dotted line 510a, to thereby draw the gases from the first cylinder passage and prevent any back-pressure into the burner chamber 503.

The carbon monoxide burner 503, shown in FIGURE 10, includes an inlet port or venturi throat 530 immediately adjacent the engine cylinder at the exhaust valve E to receive the flow of gases indicated by the arrow 42. The exhaust gases flowing from the valve through the venturi throat 530 will be directed into a venturi orifice 532 defining the carbon monoxide burner. The outlet opening 534 of the venturi orifice is slightly smaller in diameter than the opening 506 defined in the surface wall forming the decompression chamber, for a purpose to be described later.

The air compartment 502 is in open communication with the atmosphere through an intake opening 540 and with each of the inlets of the venturi orifices 532. For this purpose, the air compartment defines main chambers 542 which are in communication through openings 546 with annular chambers 544 defined by the counterbored openings 505, the burners 503 and flanges 548 integral with the burner. A restricted annular opening 550 communicates with the inlet of the venturi orifice 532 immediately downstream of the venturi throat 530 and with the chambers 542 through openings 554 to provide a divergent annular stream of air into the inlet of the venturi orifice 532.

An air deflecting surface 552 deflects the air being displaced through the openings 554 so that a divergent stream of air contacts the engine exhaust flow at an acute angle at the venturi orifice inlet to maximize the mixing action between the air and the exhaust thereby accommodating substantially complete secondary combustion just downstream of the inlet to the venturi orifice or section 532.

As was indicated hereinabove, the outlet opening 534 of the venturi section 532 is slightly smaller than the opening 506 connecting each of the passages 510, 512, 514 and 516 to the decompression compartment. This results in an annular opening 560 surrounding the outlet opening of each venturi section 532 to thereby place the conduit or passages such as passage 510, in direct communication with a chamber 562 defined by the decompression compartment 504. The lower end of the compartment 562 communicates with the single exhaust manifold passage 520 at a restricted area along the passage to thereby define a venturi 564. Thus, the decompression chamber, the respective individual isolated passages 510, 512, 514 and 516, along with the common

exhaust tube 520 define individual recirculating chambers for each of the burners 503.

In operation of the apparatus of FIGURES 9 and 10, the cylinders of the internal combustion engine are operated to cyclically deliver exhaust gases through the respective openings or inlets 530. The flow of the exhaust gases from the engine cylinders through the outlets 530 forces the exhaust gases to pass through the venturi orifice 532 causing a substantial reduction in exhaust pressure head and a substantial increase in the exhaust velocity head at the reduced throat portion of the venturi orifice 532. This will cause a reduction in pressure at the annular opening 550 to thus draw atmospheric air from the compartment 542, through the openings 548, the chambers 544 and the openings 554. The angle of entry of the air into the venturi section resulting from the deflection surface 552 will cause a thorough mixing of the air and the exhaust gases and, due to the temperature of the mixture, there will be an instantaneous explosion or burning to thus ignite all of the unburned or partially burned carbon converting this carbon to carbon dioxide through the secondary combustion.

The velocity of the exhaust gases through the outlet 534 of the venturi orifice will force the exhaust gases through the passages such as 510, and into the single exhaust manifold 520. By proper orientation and sizing of the respective passages 510 through 516 and by arranging the outlets thereof in serial order determined by the firing order of the respective cylinders, the exhaust gas flow of the second cylinder to be fired (No. 3) will help draw the gases from the passage connected to cylinder No. 1 to thereby eliminate any back-pressure which would cause a mixture of carbon dioxide with the original carbon monoxide emanating from the cylinder.

Also the unique arrangement of the decompression compartment 504 defining recirculating chambers 562 will eliminate any back-pressure in the burning chamber defined by the venturi section 532 since any pressure head or back-pressure developed in the main exhaust manifold 520 will be drawn into the decompression compartment 562 through the respective annular openings 560 thereby further eliminating any possibility of the exhaust gases containing carbon dioxide from entering the burning chamber. The unique arrangement of the manifold 500 along with the associated parts will prevent any carbon dioxide from prematurely entering the burning chamber to extinguish the secondary combustion flame therein. Furthermore, by placing the entire compartment 500 directly adjacent the engine block, the heat from the operation of the internal combustion engine will further increase the temperature of the air being drawn in as well as maintaining the exhaust gases at a higher temperature to insure secondary combustion of the combustible exhaust gases.

What is claimed and desired to be secured by United States Letters Patent is:

1. In a method of reducing the combustible content of exhaust gases from an internal combustion engine having a plurality of cylinders and wherein an air stream is mixed with the exhaust gases from each cylinder, the amount of air being sufficient to initiate secondary combustion in burner chambers of the combustible gases leaving the cylinders but being insufficient to cool the exhaust gases below the auto-ignition temperature of the exhaust gases and the exhaust gases from each burner chamber are directed into isolated exhaust passages and from each exhaust passage at an acute angle into a single exhaust tube, the improvement of directing the flow of gases along a continuous flow direction change at least 180 arcuate degrees between each burner chamber and exhaust tube to prevent reverse flow of gases into the burner chambers.

2. In a method of reducing the combustible content of exhaust gases from an internal combustion engine having a plurality of cylinders and wherein an air stream

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is mixed with the exhaust gases from each cylinder in burner chambers connected to the outlet of each cylinder, the improvement of directing the exhaust gases from each burner chamber into outlets of isolated exhaust passages, directing the gases from the outlets of each exhaust passage at an acute angle into a single exhaust tube, and establishing communication between the inlets of each exhaust passage and the exhaust tube at a point downstream of the connection of all of the exhaust passages with the exhaust tube.

3. In an internal combustion engine having a plurality of working cylinders, an exhaust valve in each cylinder operable periodically to vent exhaust gases from said cylinders through exhaust ports and a burner chamber connected to each port in which the combustibles in said exhaust gases are ignited before venting the exhaust gases to the atmosphere, the improvement of directing means communicating with the ambient atmosphere and each burner chamber to supply an amount of air sufficient to support combustion of the combustibles in said exhaust gases in each burner chamber, an isolated exhaust passage communicating with the outlet of each burner chamber, a single exhaust tube receiving the gases from each of said isolated passages, and means defining a circulating chamber between each burner chamber and associated isolated passage which inhibits flow of gases from the passage to the burner chamber.

4. In an internal combustion engine having a plurality of working cylinders, an exhaust valve in each cylinder operable periodically to vent exhaust gases from said cylinders through exhaust ports and a burner chamber connected to each port in which the combustibles in said exhaust gases are ignited before venting the exhaust gases to the atmosphere, the improvement of directing means communicating with the ambient atmosphere and each burner chamber to supply an amount of air sufficient to support combustion of the combustibles in said

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exhaust gases in each burner chamber, an isolated exhaust passage communicating with the outlet of each burner chamber, a single exhaust tube receiving the gases from each of said isolated passages, and a recirculating chamber communicating adjacent one end with each exhaust passage and at the opposite end with said exhaust tube to accommodate reverse flow of gases in said isolated passages.

5. The structure as defined in claim 3, in which each of said circulating chambers define a reverse bend having a central member which (1) muffles exhaust noise and (2) inhibits the flow of exhaust gases from the passages to the burner chambers.

6. The structure as defined in claim 4, the further improvement of means for connecting each isolated passage to the exhaust tube along a portion of its length in the order of firing of said cylinders whereby the exhaust gases received by said tube from one of said passages are forced along said tube by the exhaust gases of a subsequent passage.

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