Aug. 20, 1968 H. D. RIGGAN 3,397,682

APPARATUS FOR EXHAUST GAS SEPARATION

Filed Nov. 25, 1966 2 Sheets-Sheet 1

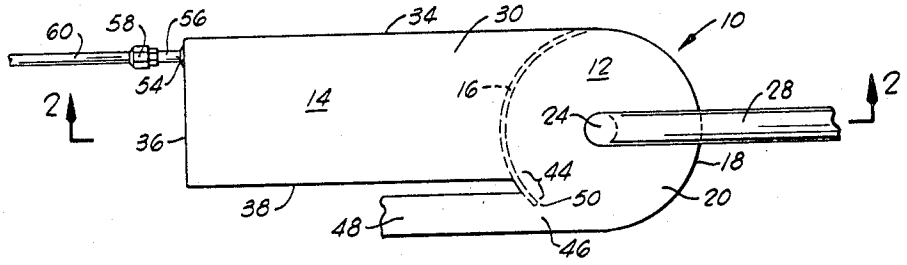

Fig. 1

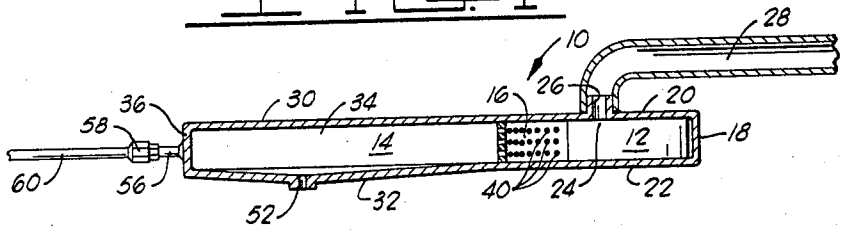

Fig. 2

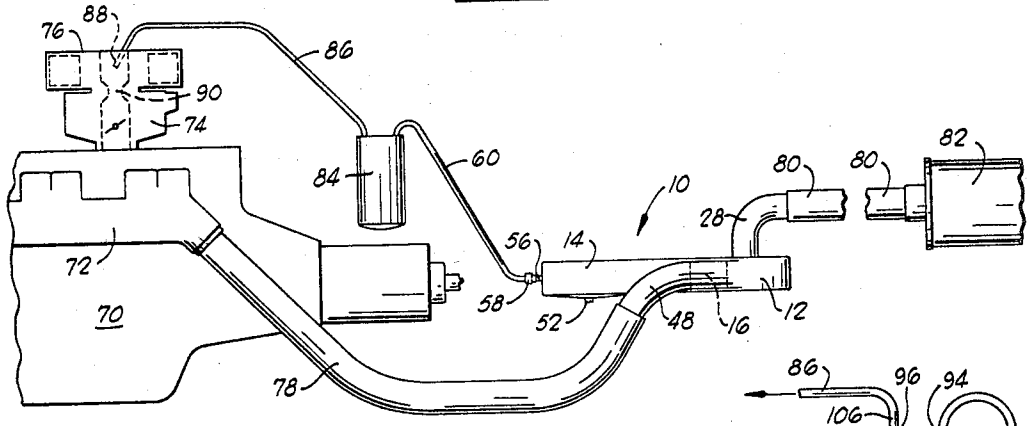

Fig. 4

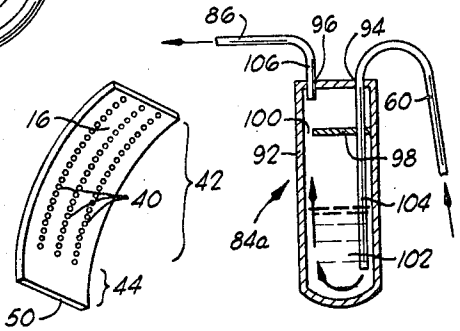

Fig. 3 Fig. 5

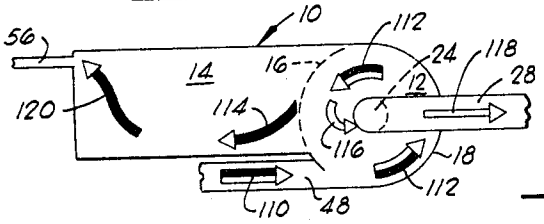

Fig. 6

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APPARATUS FOR EXHAUST GAS SEPARATION

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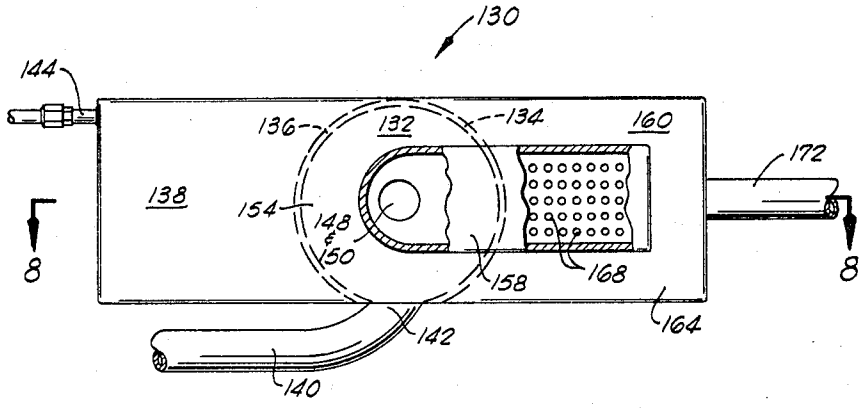

Fig. 7

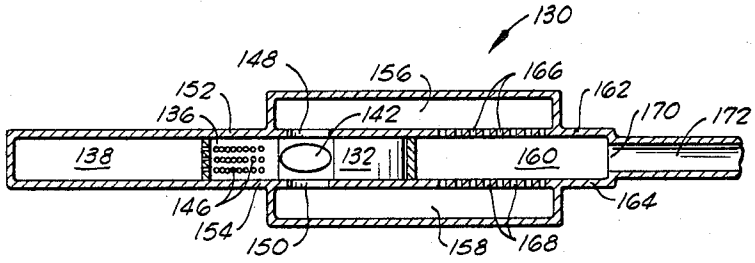

Fig. 8

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APPARATUS FOR EXHAUST GAS SEPARATION

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8 Claims. (Cl. 123—119)

This invention relates generally to improved apparatus for treating the exhaust gases emitted from internal combustion engines and, more particularly, but not by way of limitation, it relates to an improved gas separator device for use with an internal combustion engine to feed back the more combustible exhaust gases for recycle through the combustion processes.

The present invention contemplates improved apparatus for processing exhaust gases such that heavier, combustible gases are separated out for reapplication through the fuel input system of an internal combustion engine. The invention utilizes a cyclone unit which receives exhaust gases and centrifugally separates the heavier more combustible components of gas from the lighter components which may be expelled as exhaust into the surrounding air. The cyclone provides a condensation space wherein water and other solid impurities may be separated from the heavier gas components and suitably drained or eliminated, and the heavier gas components are then directed back to the fuel input system of the engine.

Therefore, it is an object of the invention to provide a fuel extraction system for use with internal combustion engines which greatly reduces the amount of irritating gases which are emanated from the engine combustion process into the surrounding air.

It is a further object of the present invention to provide a fuel extraction process for treatment of exhaust gases which enables more efficient fuel consumption in an internal combustion engine with the attendant advantage of reduction of irritating exhaust gases.

Finally, it is an object of the present invention to provide a cyclone unit which functions to recycle certain combustible exhaust gases and which has no moving parts and, further, which can be easily formed by conventional molding and/or sheet forming techniques with a minimum of machining required.

Other objects and advantages of the invention will be evident from the following detailed description when read in conjunction with the accompanying drawings which illustrate the invention.

In the drawings:

FIG. 1 is a front or broad side view of a cyclone unit.

FIG. 2 is a sectional side view of a cyclone unit as taken along lines 2—2 of FIG. 1.

FIG. 3 is a foraminous wall portion of the cyclone unit of FIGS. 1 and 2.

FIG. 4 is a diagram of an exhaust gas processing system utilizing the cyclone unit of FIG. 1.

FIG. 5 is a filter unit which is suitable for use in the system of FIG. 4.

FIG. 6 is a schematic illustration of gas flow during operation of the cyclone unit.

FIG. 7 is a partially cutaway side view of an alternate form of gas separating unit.

FIG. 8 is a section taken on lines 8—8 of FIG. 7.

As shown in FIG. 1, a cyclone unit **10** consists essentially of a first cylindrical chamber **12** and a second collecting chamber or condensation space **14** which are separated by a foraminous wall **16**. The foraminous wall **16** is arcuate and preferably of the same radius as a cylindrical wall **18** of cyclonic cylinder **12**.

Referring also to FIG. 2, it can be seen that the cyclone **10** may be formed of relatively narrow construction. Thus, the cyclonic cylinder **12** is formed by a pair of opposing cylindrical end walls **20** and **22** and the cylindrical wall

is formed by the circular plate **18** and the foraminous plate **16** joined thereto. An opening **24** is formed at the center of circular end wall **20** to have a flange **26** for receiving an exhaust pipe **28** affixed thereon by conventional pipe joining techniques. The exhaust pipe **28** can then direct lighter exhaust gases for expulsion through a conventional muffler system, including a resonator, if desired. The condensation chamber **14**, shown as being a generally rectangular form, consists of parallel end walls **30** and **32** sealed off by three side walls **34**, **36** and **38**, the fourth side being closed off by the circular foraminous plate **16**.

The arcuate foraminous wall **16**, shown in greater detail in FIG. 3, is perforated with a plurality of small holes **40** therethrough. The size and number of holes **40** tend to vary with exhaust input pressure, etc., thus, when employed with an average sized eight cylinder engine, it has been found that foraminous plate **16** can be perforated with three rows of holes **40** totalling seventy to eighty holes in all and being uniformly aligned around an upper arcuate portion **42** of the foraminous plate **16**. The holes may be on the order of from 1/16 to 3/16 in diameter and in some cases it may be desirable to drill the holes tangentially and in parallel through the foraminous plate **16**; that is, generally tangential to the inner diameter surface of plate **16** and so aligned to direct heavier particles of cyclically flowing gas into the condensation space **14**.

A lower portion **44** of the foraminous plate **16** is maintained free of holes to function as an additional portion of the cylinder wall while at the same time it limits the size of input opening **46** (FIG. 1) between the exhaust input pipe **48** and the cylinder **12**. That is, as exhaust gas is applied through input pipe **48**, the lower portion **44** of plate **16** may be sized to provide the desired cross section of input orifice **46**. Further, the lower edge **50** of the plate **16** may be formed as a straight edge, a circular shape, or any other shape which may serve to further refine the input gas behavior about the input orifice **46** as it is injected into the cyclonic cylinder **12** at a desired input pressure.

The internal volume of condensation space or chamber **14** is not particularly critical and it merely needs to be sufficiently large relative to the cylinder **12** to store a portion of the heavier combustible gases. That is, since the gas feedback system from exhaust to input of the engine is effectively a closed system, the heavier combustible gases within space **14** should provide a suitable buffer in the circuit. Since any water present in the exhaust gases, as when initially starting the engine, are condensed in space **14**, it is desirable to provide a moisture drainage opening **52**, as shown in FIG. 2. It has been found that a hole of approximately 1/16 to 1/8 inch in a suitable, bottom disposed surface of condensation space **14** will provide sufficient water drainage without disturbing the pressure equilibrium through the cyclone unit **10**. The drainage hole **52** is shown situated in the bottom end wall **32** of FIG. 2, however, it should be understood that a vertically oriented operating attitude such as that shown in FIG. 1 would require replacement of the water drainage hole **52** in the bottom side wall **38**.

Combustible gases present in condensation space **14** can then be directed through exit opening **54** and exit tube **56** through a suitable sealing connector **58** to a tube **60** which leads back to the fuel input system of the internal combustion engine.

It should be understood that in some situations the water separation outlet for drain hole **52** would preferably be an orifice having a controlled opening rather than a continuous opening. Thus, it may be desirable to employ one of the well known types of valve which will be both reliable and inexpensive for accomplishing this function. A thermostatically controlled valve would perform to

good advantage, since moisture drainage is only required during the initial operation or heating up period of the internal combustion engine and the water drainage opening could be controlled by temperature change. Many other forms of such control valve are known in the art and may be employed to control the moisture relief function.

It should be understood that the particular shape of the cyclone unit **10** as depicted in FIGS. 1 and 2 is not a rigid requirement. The shape of cylinder **12** and tangential input of input pipe **48** through input orifice **46** are very desirable physical characteristics, however, the remainder of the cyclone unit may be formed in various shapes and spacings. It should be noted that such a cyclone unit **10** can be easily formed by conventional molding techniques and that the finished assembly will require a minimum of machining and/or further finishing. Thus, the cyclone unit **10** can be formed by molding the unit in two halves whereupon the respective halves can be joined together by conventional fastener devices, no moving parts being required. Also, the material from which cyclone units **10** may be constructed may be selected from any number of suitable metals or even selected ones of the high temperature plastics.

FIG. 4 shows an internal combustion engine and exhaust system utilizing the fuel extraction scheme of the present invention. An internal combustion engine **70** of the gasoline type is shown generally to include an exhaust manifold **72**, carburetor **74** and the associated air cleaner **76**. The exhaust manifold **72** is joined to an exhaust pipe **78** which is led rearward into connection with the input pipe **48** to the cyclone unit **10**. The exhaust pipe **28**, carrying lighter, non-combustible gas components, is connected to an exhaust pipe **80** which is then led back for connection to a muffler **82** in conventional manner. Also, as commonly employed in the art, it may be desirable to include a resonator (not shown) in the exhaust circuit.

The cyclone unit **10** is shown horizontally oriented with a water drain **52** on a lower broad side of condensation chamber **14**, however, it should be understood that certain designs may require a different orientation in which case a water drain hole can be appropriately located at a lowermost point. Combustible gases collected in the condensation chamber **14**, can be directed through exit **56** and connector **58** to the tube **60** which can be applied through a suitable filter **84** and further delivery tube **86** for input to the engine carburetor **74**. The recovered combustible gases may be injected into the fuel input system in any of several ways but it has been found preferable to terminate the tube **86** in a suitable nozzle end **88** which may be placed directly into the throat **90** of carburetor **74**. It should be understood, of course, that the type of fuel reinjection is variable with the particular application of the fuel feedback system. For example, in the event that an internal combustion engine of the diesel type is employed, the input of recovered fuel must be carried out by suitable application through the associated fuel injection system.

The filter **84** is not an absolute necessity, however, it has been found that improved and more reliable functioning of the system is obtained when such filter is included. There are various types of vapor filters which may be employed and FIG. 5 shows one type of filter which has been used to good advantage in the system of FIG. 4. The filter **84*a*** consists of a closed canister **92** which is formed to have an input opening **94** and an output opening **96** through an upper end, and a baffle plate **98** is suitably secured across the canister **92** at its upper extremity, leaving only a small vapor passage **100**. The canister **92** is then filled approximately half full with a selected oil **102** having desired viscosity and density characteristics. The fuel tubing **60** is then either applied to or shaped into a tubing extension **104** which is extended downward through the input opening **94** and terminated near the bottom of canister **92**. Similarly, the fuel tubing **86** is either formed into or connected to a tubing section **106** which is extended downwardly through the output hole **96** in sealing engagement to terminate just beneath the upper end of canister **92**. Thus, the filter **84*a*** serves to allow the dissoluble gas components to pass from the tubing **60** to the delivery tube **86** while soluble gas components, water and particulate matter is removed from the flow.

OPERATION

The operation of the system is explained hereafter with particular reference to the system of FIG. 4 as it is employed with an internal combustion engine of the gasoline type. Gaseous end products remaining after combustion are collected within the exhaust manifold **72** and dispelled through the exhaust pipe **78** to the cyclone unit **10**. The gases are injected into the cyclone unit **10** through its input pipe **48** into the cyclone cylinder **12**; whereupon the gases are rotated about the inner confines of cylindrical wall **18** (FIG. 1), centrifugal separation of the gas substances taking place. The rapid rotation of the gases within cylinder **12** results in the separating out of the heavier, combustible gas products within the condensation chamber **14** while the lighter, and generally non-combustible gaseous products are exhausted from the center of cylinder **12** through the output tube **28** to succeeding muffler **82** and other gas disposal equipment.

Referring now to FIG. 6, the operation of the cyclone unit **10** is shown in schematic form. The exhaust gases consisting of a mixture of heavier and lighter components, shown by the black-white arrow **110**, are applied through input tube **48** tangentially into the cylinder **12**; whereupon the mixed gases proceed in a cyclical flow, represented by black-white arrows **112**. The centrifugal force exerted upon individual particles of gas and other substances will tend to force the heavier components toward the outer confines of cylinder **12** while the lighter components are concentrated toward the center of cylinder **12** adjacent the outlet opening **24**. The heavier gas components then pass through the plurality of holes **40** in the arcuate plate **16**, shown generally by black arrow **114**, such that the combustible gas components are collected in the condensation space **14**. The lighter gas components, shown by white arrow **116** will pass out through exhaust tube **28** as shown by white arrow **118**. Also, the collected heavier gas components are maintained within the condensation space **14** to proceed as via black arrow **120** and outlet tube **56** for reapplication through the fuel input system of the engine.

The efficiency of fuel extraction of the cyclone unit **10** is dependent upon maintaining a proper pressure balance through the system. Thus, the exhaust pressure which appears as the input pressure at input tube **48** must be substantially maintained through cylinder **12**, exhaust tube **28** and the muffler system, while a suitable pressure buffer for the recovered combustible gas circuit is formed by the condensation chamber **14**. Thus, the total area of gas passage space through arcuate plate **16** (holes **40**) as well as the radius of the cylinder **12** may be varied to obtain maximum efficiency for a given average exhaust pressure as applied through input pipe **48**.

The size of the condensation space **14** is not critical, however, it should be large enough such that an adequate reserve of combustible gas can be maintained therein, and it should be of sufficient size that a degree of cooling of the combustible gas is effected to increase the condensation of water vapors. It should be noted too that the initial exhaust gas, as applied through input pipe **48** for rotation within the cyclone cylinder **12**, receives appreciable cooling effect therein. As the mixed gases are rotated, and during their separation phase, an increase in the velocity of the gases results in a corresponding decrease in pressure which tends to extract heat from the gaseous matter. The lower portion **44** of the arcuate plate **16** is extended to define an input orifice **46** (FIG. 1) of predetermined size which will provide the desired gas input velocity to the cylinder **12**. The size of the input opening **46** and therefore the input velocity of the gases can be varied depending upon the particular application of the cyclone unit;

that is, internal combustion engines of varying horsepower and exhaust pressure will require different characteristics of the attendant cyclone unit **10**.

It should be understood that the system can be applied with equally good results to an internal combustion engine of the diesel type. In this case a larger cyclone unit and associated components will generally be required and fuel re-injection must be carried out by adding the recovered or secondary fuel through the primary diesel air induction assembly.

ALTERNATIVE EMBODIMENT

FIGS. 7 and 8 disclose an alternative form of cyclone unit **130** which is constructed as an integral part of an exhaust muffler system. The cyclone-muffler unit **130** consists of a cyclonic cylinder **132** which is formed by a solid cylindrical wall **134** and a foraminous or perforated cylindrical wall **136** which may be similar to that shown in FIG. 3. A generally rectangular space **138** is sealingly connected to include the foraminous cylindrical wall **136** as one wall thereof. Thus, in a manner similar to the construction of cyclone **10** (FIG. 1), internal combustion engine exhaust flowing through exhaust pipe **140** is injected through inlet **142** and provides tangential flow of exhaust gases into the cyclonic cylinder **132**. Heavier gas components which migrate through foraminous wall **136** for collection within the space **138** are available through output tube **144** for reapplication to the fuel input system of the internal combustion engine.

The foraminous cylindrical wall **136** is perforated as by a plurality of holes **146**, e.g., 75 to 80 holes of about one-eighth inch diameter arranged uniformly about the wall, the area of perforation being variable with engine power and the attendant exhaust pressure. A pair of openings **148** and **150** are formed on each side of the cyclonic cylinder **132**. The openings **148** and **150** are placed axially symmetrically in opposite cylinder end walls **152** and **154** respectively. The axial holes **148** and **150** communicate in turn with generally rectangular side chambers **156** and **158**, respectively, which are affixed in vapor sealed relationship on opposite sides of the cyclone-muffler unit **130** as will be further described.

Another generally rectangular chamber **160** is also joined to the opposite or rearward cyclone wall, solid cylindrical wall **134**, of the cylinder **132**. Respective side walls **162** and **164** of chamber **160** are each formed to have a plurality of holes **166** and **168** therethrough. The respective groups of holes **166** and **168** may be on the order of 3/16-inch holes and arranged relatively uniformly and in a central region of respective side walls **162** and **164** so that they are enclosed by the respective side chambers **156** and **158**. Thus, the side chambers **156** and **158** (shown partially cut away in FIG. 7) are secured in symmetrical fashion on each side of the cyclone-muffler unit **130** to enclose a passage between the respective axial openings **148** and **150** out of cyclonic cylinder **132** and through the respective plurality of holes **166** and **168** leading into the rearward chamber **160**. The rearward chamber **160** then communicates through opening **170** to the tail pipe **172** whereupon the final exhaust gases are dispensed into the surrounds.

In the operation of the FIG. 7 and 8 embodiment exhaust gases input through pipe **140** are cyclically moved about the inner cylindrical confines of cylinder **132**. The heavier gases tending to move to the outer extremities and lighter gases being forced to the inner positions, heavier gases migrate through the foraminated cylinder wall **136** into the condensation chamber **138** and, thereafter, heavier combustible gases are available for passage through the tube **144** for return to the fuel input system of the engine. Simultaneously, as heavier gas components are forced outward within the cylindrical chamber **132**, the lighter gases, generally non-combustible in nature, become concentrated in the central region along the axis of the cylindrical space **132** to flow outward through the respective axial holes **148** and **150** through the side walls **156** and **158** and communicating holes **166** and **168**, respectively, into the rear chamber **160** for collection and continuous expulsion through tail pipe **172**.

The foregoing discloses novel apparatus for installation with any of various types of internal combustion engines, diesel, gasoline, or whatever, for the purpose of removing and recovering unburned fuel components from the exhaust gases. The invention serves not only to remove certain harmful by-products of the combustion process from the exhaust gases, thereby alleviating at the source certain irritating components which contribute to the build up of the substance known as "smog," but also to remove and recycle unburned gases, thereby improving the work vs. fuel consumption ratio of the engine. It should be understood that the invention is not limited to the physical configuration and size of components as specificially stated herein since variations in the exigencies attendant a particular engine application may require certain known variations as to condensation chamber volume, cyclone radius, etc.

Changes may be made in the combination and arrangement of elements as heretofore set forth in this specification and shown in the drawings; it being understood, that changes may be made in the embodiments disclosed without departing from the spirit and scope of the invention as defined in the following claims.

What is claimed is:

1. In an exhaust system for internal combustion engines which includes a fuel input system, an exhaust manifold, a first exhaust pipe connected thereto, cyclone, means connected to said first exhaust pipe, a muffler system, second exhaust pipe means connecting said cyclone means and said muffler system, and an input conduit connected from the cyclone means to the fuel input system of the internal combustion engine, said cyclone means comprising:

a cylinder having an opening tangential to the cylinder inner wall and connected to receive exhaust gases therein from said first exhaust pipe, said cylinder having an outlet opening along its central axis which is connected to said second exhaust pipe, and a portion of the cylinder wall being foraminous to allow the passage of heavier components of exhaust gas therethrough;

a generally box-like chamber sealingly connected to said cylinder such that said foraminous cylinder wall portion forms a part of said enclosure, said chamber having an exit opening from an upper extremity thereof which communicates with said input conduit.

2. Apparatus as defined in claim **1** which is further characterized to include:

filter means connected between said exit opening and said input conduit to receive all of the heavier combustible gases therethrough.

3. Apparatus as defined in claim **2** wherein said filter means comprises:

canister means partially filled with oil and closed with respect to surrounding air;

means for receiving said heavier combustible gases from said exit opening and introducing said gases to the interior of said canister means below the surface of said oil container therein; and

an outlet conduit directing said gases from the upper space of said canister means to the input conduit and fuel input system of said engine.

4. Apparatus as set forth in claim **1** wherein said engine is a gasoline engine, said fuel input system includes a carburetor having a throat portion, and said input conduit directs recovered combustible gases into the throat of said carburetor.

5. Apparatus as set forth in claim **3** wherein said engine is a gasoline engine, said fuel input system includes a carburetor having a throat portion, and said in-

put conduit directs recovered combustible gases into the throat of said carburetor.

6. Apparatus for extraction and recirculation of combustible gases from the exhaust gases of internal combustion engines, comprising:

a cylinder having an exhaust outlet opening through each circular end in alignment with the cylindrical axis;

a gas inlet port directed through and tangentially to the cylinder wall for receiving exhaust gases therethrough;

a foraminous wall forming one portion of said cylinder wall;

a first chamber connected to said cylinder about said foraminous wall portion of said cylinder wall such that its volume communicates with the cylinder volume through the foraminous wall;

outlet means connected to the wall of said first chamber to receive exhaust gas from an internal combustion engine;

a second chamber connected to the opposite side of said cylinder about said closed cylinder wall, said second chamber side walls each having a plurality of openings situated generally parallel to said respective exhaust outlet openings;

a pair of side chambers sealingly connected on each

side of said cylinder and second chamber to enclose said respective exhaust outlet openings and plurality of holes to direct exhaust gases from said cylinder into said second chamber; and

exhaust pipe means leading from said second chamber to the surrounds for expulsion of exhaust gases.

7. Apparatus as set forth in claim 6 which is further characterized to include:

second outlet means formed through a lowermost wall of said first chamber to allow the escape of any collected liquids.

8. Apparatus as set forth in claim 6 wherein said cylinder is formed to have a height which is less than its radius.

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