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FLYWHEEL AIR PUMP

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Figure 1

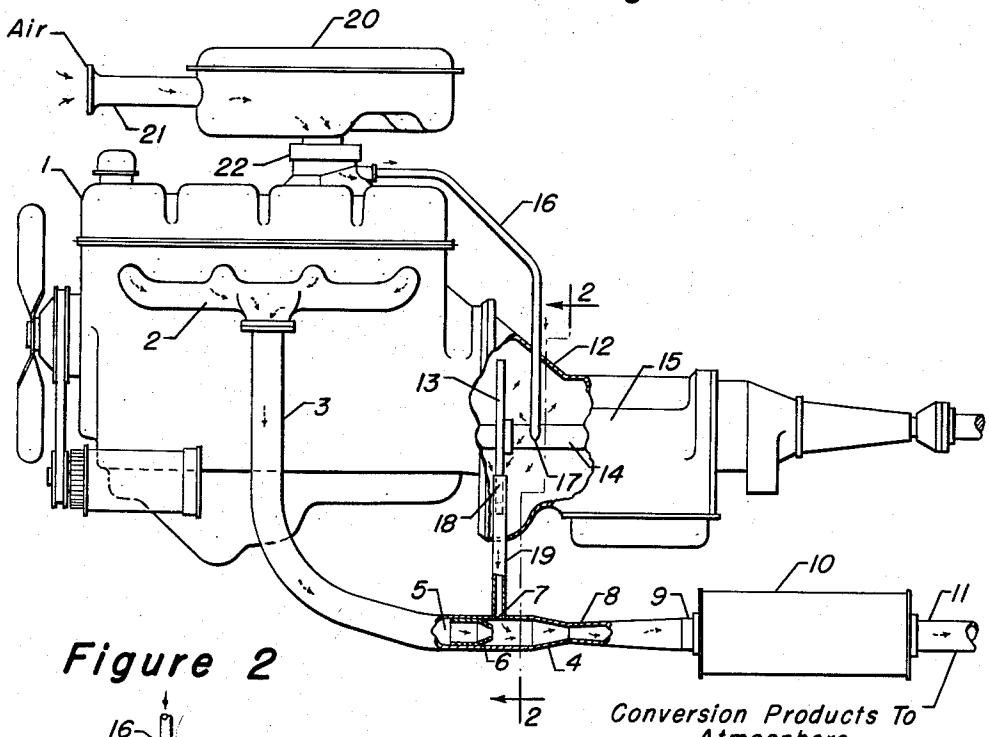


Figure 2

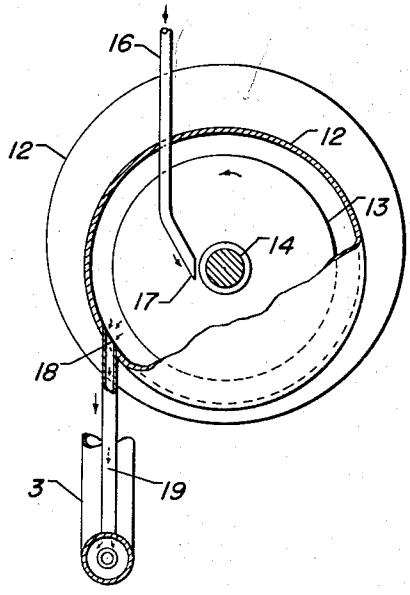
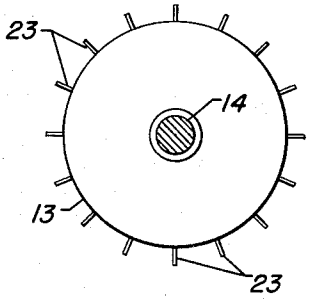


Figure 3



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FLYWHEEL AIR PUMP

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This invention relates to the conversion of engine exhaust gases and more particularly it concerns apparatus for introducing secondary air into the exhaust gases emanating from an internal combustion engine.

The desirability of removing certain components from vehicular exhaust gases is of importance at the present time. The unavoidably incomplete combustion of hydrocarbon fuels by the gasoline or diesel engine results in the generation of substantial amounts of unburned hydrocarbons and other undesirable waste products which are released to the atmosphere through the exhaust line. With the ever-increasing concentration of automobiles, particularly in urban areas, the resultant discharge of these undesirable products into the atmosphere may reach high proportions. These combustion products are known to react with atmospheric oxygen under the influence of sunlight to produce smog. Such waste products include, for example, saturated and unsaturated hydrocarbons, carbon monoxide aromatics, partially oxygenated hydrocarbons such as aldehydes, ketones, alcohols, and acids, as well as oxides of nitrogen and sulfur. Methods for converting vehicular exhaust gases to harmless materials such as, for example, carbon dioxide and water, may be classified into two broad areas: (1) catalytic conversion and (2) non-catalytic or thermal conversion. In the catalytic method, the exhaust gases leaving the engine are passed, with or without heating or cooling, into contact with a suitable conversion catalyst and the conversion products of the resulting reactions are then discharged into the atmosphere. In general, the preferred conversion reactions involve more or less complete oxidation of combustibles, and to achieve this end it is necessary to provide sufficient oxygen, obtained from air or other oxygen-containing gas, in the exhaust gases prior to contact with the catalyst. In the thermal method, the exhaust gases are simply heated to, or maintained at, a sufficiently high temperature, in the presence of oxygen, so as to burn without utilization of a catalyst. With either method it is necessary to provide at least a stoichiometric amount, and preferably an excess amount, of oxygen or air in the exhaust gases. It is not feasible to manipulate the carburetor in order to provide such excess air since this would seriously reduce the efficiency and power output of the engine; therefore, it is usually desirable to separately add the required amount of air to the exhaust gases at a point between the exhaust valve ports of the engine and the catalytic or thermal conversion zone located downstream therefrom. Such excess air is often referred to as "secondary air," as distinguished from the primary air injected by the carburetor and employed to support combustion of the fuel within the engine cylinders proper.

There are two means most generally employed to provide the secondary air: the engine-driven air compressor, and the jet pump or aspirator, the latter being perhaps more widely favored because of its lower cost and absence of moving parts. Both types of air movers have certain advantages and disadvantages. The air compressor is usually a simple single-stage device driven by the fan belt or otherwise operatively connected to the crankshaft; it is generally capable of delivering larger quantities of air at higher pressures than an aspirator. Like other engine accessories, it requires periodic maintenance and eventual replacement and, during operation, consumes a portion

of the power output of the engine otherwise available for driving the vehicle. A further drawback of the air compressor is that, since its output is roughly proportional to the speed of the engine, it tends to deliver too much air during deceleration when the engine speed is momentarily high and the corresponding exhaust gas throughput is low: the resulting disproportionate concentration of air in the combined gas feed to the oxidation zone tends to quench the reactions and in some cases will cause the converter to flame out." Although such behavior may be corrected by a suitable control system such as an automatic throttle valve located in the compressor discharge line and actuated in response to intake manifold vacuum or throttle position, this again entails additional equipment, expense and maintenance problems.

The jet pump or aspirator avoids some of these problems but creates others. In its simplest form, the aspirator is serially connected in, or forms a part of, the exhaust gas conduit and is disposed upstream from the conversion zone. Aspirators are well known in the art of fluid transport and only a brief description of the principal elements thereof is necessary here. In essence, an aspirator consists of an inlet nozzle arranged to discharge into a venturi-shaped diffuser section. The diffuser generally consists of an inlet throat section having a cross-sectional area smaller than the aspirator outlet and a gradually expanding section downstream therefrom to increase the area up to that of the aspirator outlet. A conduit, port, or piezometer duct for admitting the aspirated fluid connects with the interior of the aspirator at a point downstream from but adjacent to the nozzle opening. A stream of motive fluid is passed through the nozzle and is thereby formed into a high velocity jet which passes into the diffuser and creates a region of low pressure in the throat section thereof, into which the aspirated fluid is drawn. The diffuser functions to mix the motive fluid and the aspirated fluid and to convert the residual velocity of the mixture into pressure. When an aspirator is employed to introduce air into an exhaust gas stream, the exhaust gas itself serves as the motive fluid, the secondary air being the aspirated fluid. Where the source of the exhaust gas is an internal combustion engine, particularly a spark ignition engine operated under widely varying conditions of speed and load as in the case of a motor vehicle, peculiar difficulties are thereby encountered. The ordinary operation of a motor vehicle may be divided into four modes, namely, the modes of idle, acceleration, cruise and deceleration. At idle and deceleration, most spark ignition engines operate with a richer fuel: air ratio than during the open throttle operation of acceleration and cruise. The secondary air requirements for satisfactory oxidation of the exhaust gas are hence larger, relative to exhaust gas flow, at such rich mixture, low engine speed operation; in other words, the mass ratio of secondary air aspirated to exhaust gas must be greater at low engine speed and consequently at low exhaust gas flow, than at high engine speed, corresponding to high exhaust gas flow. If the aspirator is designed to inject the proper amount of secondary air required at idle and at deceleration, the nozzle size must be made relatively small, and consequently the back pressure in the spark ignition engine is high and causes poor engine performance at cruise or acceleration, to say nothing of burning up the exhaust valves under these conditions. On the other hand, if the aspirator is designed within the limits of back pressure at maximum exhaust gas flow whereby the nozzle size becomes somewhat larger, insufficient secondary air is injected at idle and deceleration. It may thus be seen that a jet pump or aspirator does not have a sufficiently wide range to meet the flexible demands of automotive applications. A further drawback of the aspirator is the high noise level caused by the rushing in

of secondary air, which is particularly noticeable and bothersome at low engine speeds.

We have discovered that such undesirable effects can be largely overcome by utilizing the fly-wheel of the internal combustion engine itself as an air mover, either alone or in combination with a conventional aspirator. The flywheel is typically connected to the crankshaft ahead of the transmission and is disposed within a confining shroud or chamber sometimes referred to as a "bell housing." Although the chief purpose of the flywheel is to increase the rotational moment of inertia of the crankshaft in order to dampen out pulsations, we have found that with suitable modifications the flywheel in combination with its housing can also be made to function as a radial flow fan or booster capable of moving a surprisingly large volume of air.

In a broad embodiment, this invention is directed to apparatus for introducing air into the exhaust gas of an internal combustion engine which comprises means for introducing air from the atmosphere into the flywheel housing of the engine at a point radially inward of the periphery of the flywheel, means for withdrawing a stream of air tangentially from said housing at a point which is a greater radial distance from the axis of rotation of said flywheel than the point of air introduction, and means for conducting said stream of air into the exhaust system of the internal combustion engine.

A more specific embodiment of this invention is directed to apparatus for introducing air into the exhaust gas emanating from an internal combustion engine which comprises an air inlet port in the flywheel housing of said engine communicating with the interior thereof at a point between the periphery of the flywheel and its axis of rotation, an air discharge port in said housing communicating with the interior thereof at a point adjacent the peripheral surface of said flywheel, and conduit means extending tangentially from said housing and connecting said air discharge port with the exhaust system of said engine.

A more limited embodiment of this invention relates to a flywheel fan-aspirator combination apparatus for commingling air with the exhaust gas emanating from an internal combustion engine which comprises an air inlet port in the flywheel housing of the engine located radially inward of the periphery of said flywheel; an air discharge port in said flywheel housing contiguous to the peripheral surface of said flywheel; an aspirator having a motive fluid inlet port, an aspirated fluid inlet port, and a combined fluid outlet port; conduit means connecting the exhaust manifold of said engine with said motive fluid inlet port; and an air discharge conduit connecting said air discharge port with said aspirated fluid inlet port, the upstream portion of said air discharge conduit lying on a line forming a tangential extension of the direction of rotation of said flywheel.

The structural modifications which are required to convert the integrally mounted flywheel into an air pump are very simple and inexpensive to install. In the simplest form of the invention, a duct, port or other air inlet means is provided in the flywheel housing and is arranged to permit the inflow of air into the interior of the housing at one or more points which are radially inward of the periphery of the flywheel. One or more air discharge ports are provided in the flywheel housing at a greater radial distance from the axis of rotation of the flywheel than the air inlet port, preferably at one or more points in the casing of the housing adjacent the periphery of the flywheel. An air discharge conduit is connected to the housing in such manner that it extends tangentially therefrom and connects the air discharge port with the exhaust line leaving the engine exhaust manifold. The term "extending tangentially" as employed in the specification and appended claims means that the air discharge conduit, or at least the upstream end portion thereof, lies on a line which is substantially parallel to, or coextensive with, the plane of rotation of the flywheel and forms a linear tangential extension of its direction of rotation. The flywheel, acting as a radial flow impeller, forces the indrawn air at greatly increased rotational velocity to the periphery of the flywheel where the air impacts against the confining wall of the housing and some of its kinetic energy is thereby converted to static pressure. A stream of air is withdrawn tangentially at increased velocity and pressure through the discharge conduit and is directed thereby into the engine exhaust line.

Although the scope of the present invention contemplates that the flywheel air pump may constitute the sole means of injecting secondary air into the exhaust gas, it is especially advantageous to utilize the flywheel air pump in conjunction with an aspirator, so that the advantages of both types of air movers may be realized. In this embodiment, the aspirator is serially connected in the engine exhaust line and the air discharge conduit from the flywheel air pump is connected to the aspirated fluid inlet port of the aspirator. The nozzle of the aspirator may then be made somewhat larger than normal, that is, it is sized to accommodate exhaust gas flows in the higher range and to provide the proper secondary air:exhaust gas ratio under medium-to-high speed driving conditions without creating excessive back pressure in the engine exhaust manifold. Were it not for the flywheel air pump, an aspirator sized in this manner would provide insufficient secondary air at engine speeds extending from idle up to low speed cruise, e.g., 20–35 miles per hour vehicle speed. However, the flywheel air pump makes up the deficit at low engine speeds, in effect acting as a booster fan. Since a flywheel is not conventionally designed as a radial flow impeller, that is, it is not provided with vanes, it reaches its peak air output at a rather low engine speed and does not provide excessive air or otherwise interfere with the aspirator at the higher engine speeds. Thus, the secondary air rate is determined by the aspirator design and is substantially controlled by the aspirator over the greater portion of the engine operating range, and it is only at the lower engine speeds that the flywheel air pump comes into play. Connecting the flywheel pump in series with the secondary air inlet to the aspirator has the further advantage that it effectively silences the "snoring drone" noise characteristic of aspirators which is especially disconcerting to automobile passengers at low speeds.

The structure and operation of the invention may best be described in conjunction with the drawings which are presented as illustrative of the best mode of practicing the invention, but are not intended to be limiting upon its generally broad scope. FIGURE 1 is a sectional elevation view of a typical automotive type internal combustion engine showing the flywheel pump in combination with an exhaust line aspirator. FIGURE 2 is a cross sectional end view of the flywheel housing taken along line 2—2 of FIGURE 1. FIGURE 3 illustrates a modified form of flywheel having radially extending vane members.

Referring to FIGURE 1, there is shown an automotive type internal combustion engine 1 having an exhaust manifold 2 which discharges into exhaust pipe 3. An aspirator is indicated generally at 4 and is comprised of the following elements: motive fluid inlet port 5, convergent nozzle 6, aspirated fluid inlet port 7, diffuser 8, and combined fluid outlet port 9. Outlet port 9 is connected to an appropriate exhaust gas reactor or converter 10 which may be a non-catalytic or thermal type afterburner, or a catalytic muffler containing a suitable oxidation catalyst such as platinum-alumina, copper chromite, vanadium pentoxide, and the like. Gaseous effluent from converter 10 is discharged to the atmosphere through tailpipe 11. Immediately to the rear of engine 1 is flywheel housing 12; a flywheel 13 is disposed within housing 12 and is rotatably mounted on shaft 14 which extends into transmission housing 15.

With reference to FIGURES 1 and 2, an air inlet conduit 16 extends through a wall of housing 12 and its

lower open end **17** is disposed substantially adjacent the axis of rotation of flywheel **13** (the center line of shaft **14**). An air discharge port **18** is cut through housing **12** at a point adjacent the periphery of flywheel **13**. An air discharge conduit **19** connects port **18** with aspirated fluid inlet port **7** of aspirator **4**. As may be seen in FIGURE 2, the upstream end portion of conduit **19** extends tangentially from housing **12**, lying on a line which represents a tangential extension of the direction of rotation of flywheel **13**. It is desirable that conduit **19** be as short and free from bends as possible in order to minimize pressure loss therethrough.

For the purpose of eliminating possible entrainment of dust, water and other impurities into the the flywheel housing and subsequently into the exhaust system, it is desirable, but not necessary, that air filtering means be provided on the air inlet line. One suitable scheme is shown in FIGURE 1 wherein the carburetor air filter is so utilized. Combustion air enters carburetor air filter **20** via air scoop **21**, and the filtered air is then drawn into carburetor **22**. Air inlet line **16** is connected to the carburetor at a point upstream from the fuel addition zone so that a slipstream of filtered air is sucked into flywheel housing **12** through line **16**. Alternatively, a separate air filter of the replaceable cartridge type may be installed at the air inlet line, if desired.

The foregoing discussion has assumed that the flywheel itself will be employed in unmodified form, that is, in the shape in which it is fabricated by the engine manufacturer. This construction is highly satisfactory where an aspirator is utilized in combination with the flywheel pump, since the latter will complement the aspirator at low engine speeds but does not have the power to overcharge secondary air at high engine speeds where the aspirator itself limits and controls the air flow rate. However, in those cases where it is desired to omit the aspirator and utilize only the flywheel pump as the sole means of supplying secondary air, the factory-installed flywheel generally cannot furnish sufficient air at the relatively high discharge pressures required during high speed operation since the flywheel was not designed in the first instance as a radial flow impeller. In order to make the flywheel pump more efficient in this respect, it may therefore be desirable to modify the flywheel through the addition of radial vanes. Such arrangement is illustrated in FIGURE 3, wherein a number of short, radially extending vanes **23** are connected, as by welding, to the rim of flywheel **13**, being circumferentially spaced therearound. The scope of the present invention also includes more sophisticated forms of a flywheel-impeller such as a semi-open impeller, or an enclosed impeller which may have vanes which are set at a backward angle to the tangent line of the impeller rim, or other special impeller designs which are well known to the fan and blower arts.

Various modifications to the above-described apparatus will suggest themselves to those skilled in the art. For example, if the flywheel pump is used alone, without an aspirator, the delivery rate of secondary air will be approximately proportional to the engine speed and, as previously pointed out, excessive air may temporarily be delivered to the conversion zone during periods of rapid deceleration; such characteristic may be corrected by installing a bellows-operated throttle valve in air inlet line **16** or air discharge line **19**, and connecting the bellows operator of the valve to the engine intake manifold. The high intake manifold vacuum produced by deceleration causes the throttle valve to assume a more closed position, and the flow rate of secondary air will accordingly be reduced.

In one embodiment of the invention, air inlet line **16** may be dispensed with altogether, and one or more air inlet ports are then provided in the wall of flywheel housing **12** at points inward of the periphery of the flywheel and preferably close to its axis of rotation. In another embodiment, the air inlet conduit may simply be a short length of tubing directed upwardly away from the underside of the engine, or extending into the engine compartment proper, so as to avoid entrainment of road dirt and water into the exhaust gas oxidation zone.

It is preferred, but not necessary, that air discharge conduit **19** be oriented to receive air from the periphery of the flywheel. Thus, if desired, air discharge conduit **19** may connect with the flywheel housing at a point intermediate the periphery of the flywheel and its axis of rotation, provided only that the point of air withdrawal is a greater radial distance from the axis of rotation than the point of air introduction. The present invention also contemplates the use of two or more air discharge conduits tangentially connected to and circumferentially spaced around the flywheel housing and arranged to discharge into a common air collection header which communicates with an exhaust line aspirator, or with the exhaust gas line or exhaust manifold directly if an aspirator is not employed in the exhaust gas conversion system.

Although the present invention relates primarily to the injection of air into the exhaust gas stream of an internal combustion engine, the utility of the invention is not so limited. Certain exhaust gas oxidation catalysts exhibit improved activity and/or stability, with respect to the oxidation of hydrocarbons and carbon monoxide generated by the incomplete combustion of leaded gasolines, when various chemical additives are injected into the exhaust gas stream ahead of the conversion zone. For example, it has been found that the stability of a platinum-alumina catalyst is substantially increased by the addition to the exhaust gas of a minor proportion of hydrogen halide or halogenated hydrocarbon such as ethylene dibromide or t-butyl chloride. Accordingly, the instant invention may be employed for this purpose. A storage tank containing the desired additive may be connected to inlet line **16** and the additive permitted to pressure out or vaporize at a controlled rate into the suction air stream; alternatively, a slipstream of air may be taken from a discharge port from the flywheel housing and bubbled through a vaporizing chamber containing a bath of liquid additive, the resulting effluent comprising a mixture of air and additive then being charged to the exhaust system.

It is within the scope of this invention to employ the flywheel air pump not only in automobiles, trucks, buses and other vehicles but also in conjunction with stationary internal combustion engines including gasoline, diesel, and natural gas engines found in pumping and compressing units, electrical power generation peaking stations, prime movers for oil refinery service, etc.

It will be appreciated that the present invention provides a very simple and inexpensive means of injecting air or other extraneous fluid into the exhaust gas stream from an internal combustion engine. A standard internal combustion engine is easily adapted to serve as an air pump by cutting suction and discharge ports in the flywheel housing and welding or bolting a discharge conduit to the housing in the manner aforesaid. The serial combination of air pump and aspirator may be installed at a fraction of the cost of an auxiliary air compressor alone and, once installed, is virtually maintenance-free. As compared to the auxiliary air compressor, operating cost is also lower since much less power is required and fuel consumption is reduced. Furthermore, the combination of flywheel air pump and aspirator is capable of providing optimum concentration of air in the exhaust gas stream over the full range of engine operating conditions, a most desirable feature which neither the auxiliary air compressor nor aspirator alone can achieve.

We claim as our invention:

1. In an internal combustion engine having an exhaust line, an exhaust gas converter in the exhaust line, a flywheel housing and a vaneless flywheel within the housing and driven by the engine; the combination of an aspirator in said exhaust line between the engine and said converter, said aspirator having an air inlet port and an

oversized exhaust gas nozzle whereby at engine idling speed, if said inlet port communicated directly with the atmosphere, the amount of air aspirated into the exhaust gas emanating from the engine would be insufficient for maximum exhaust gas conversion by said converter; a radial flow fan comprising said vaneless flywheel and housing; means for introducing atmospheric air into said housing at a point between the periphery and the axis of rotation of said flywheel; a discharge port in the housing at a point adjacent the periphery of the flywheel for withdrawing a stream of air from the housing; and a discharge conduit connecting between said discharge port and the air inlet port of the aspirator for introducing said stream of air into the exhaust gas issuing from said nozzle.

2. Apparatus as defined by claim 1 further characterized in that the point of air introduction into said housing is positioned substantially adjacent the axis of rotation of said flywheel.

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