April 22, 1958 J. WILLSEA 2,831,547

METHOD OF AND APPARATUS FOR SILENCING THE EXHAUST OF INTERNAL COMBUSTION ENGINES

Filed Jan. 11, 1954

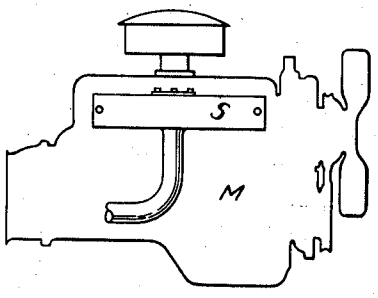


Fig. 1

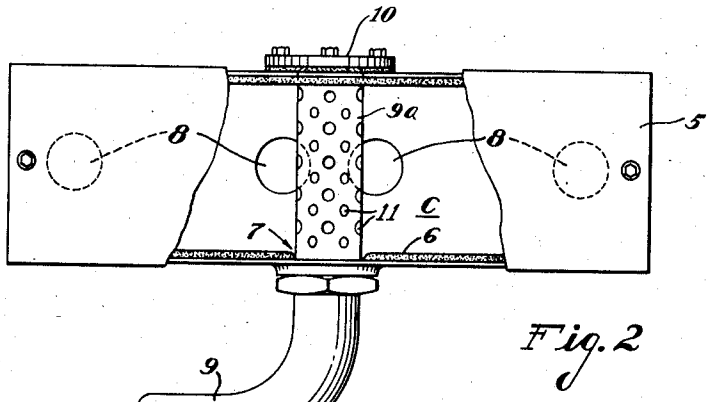


Fig. 2

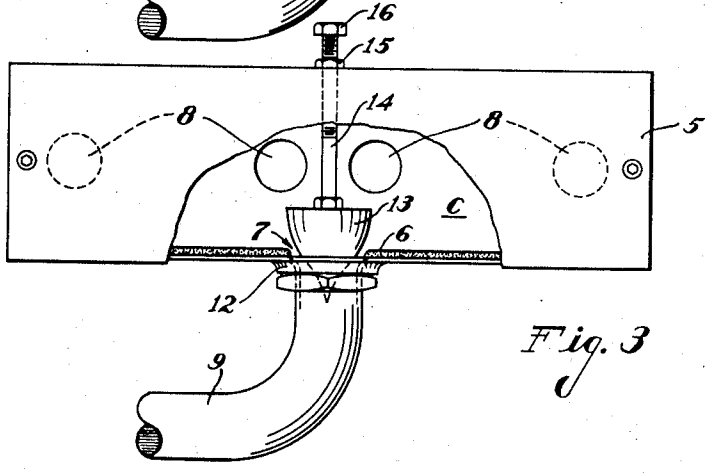


Fig. 3

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United States Patent Office 2,831,547 Patented Apr. 22, 1958

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METHOD OF AND APPARATUS FOR SILENCING THE EXHAUST OF INTERNAL COMBUSTION ENGINES

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Application January 11, 1954, Serial No. 403,162

5 Claims. (Cl. 181—40)

This invention relates to the method of and to apparatus for silencing sharp reports of explosions and especially to reducing the noise caused by the varying pressure in the exhaust gases resulting from explosions in the several cylinders of internal combustion engines employed in automobiles and the like.

It is well known that the rotational inertia of such an engine is the power that enables an automobile to accelerate. Any force working against the rotational inertia of the engine will tend to retard acceleration thereof. When, however, the exhaust valves of the respective engine cylinders are opened, any resistance to the outflow of the exhaust gases therethrough until they reach free air at the rear of the car, will react as back pressure against the pistons in the several cylinders all during the time that the exhaust ports in these cylinders are open. The effect of this back-pressure is proportionately greatest at the beginning of acceleration of the engine when the rotational inertia thereof is the least, although when the engine is accelerated to full speed for delivering maximum horsepower, the back pressure forces against the pistons while substantial, have the least proportionate effect on the engine efficiency. Thus any reduction in the resistance to the outflow of exhaust gases from the several cylinders will increase the efficiency of the engine, the increased efficiency being most pronounced at the beginning of acceleration. Consequently the silencing of an internal combustion motor should be effected with minimum back pressure so that there will be the least reduction of engine efficiency.

Much of the back pressure in the conventional exhaust silencing systems of internal combustion engines arises from the fact that the exhaust valves of the several cylinders discharge into an exhaust manifold, which includes pipes having relatively small internal diameters approximately the size of the exhaust valve ports. Since the exhaust gases are discharged through the exhaust valve of each cylinder in the form of nodes of pressure or pulse masses of exhaust gases, they tend, if unrestrained, to expand in all directions but the small piping of a conventional manifold is the same size as the exhaust port. Hence the pressure nodes can expand only by crowding their way at high velocity through the small and crooked manifold pipes with resulting back pressure. But the higher the velocity of gas flow through small pipes, depending on their lengths, the greater the resistance there is to such flow and consequently the greater the back pressure on the pistons in the respective cylinders. The volume of exhaust gases is four or more times greater than the displacement of the cylinder hence the velocity of the gases discharged therefrom is higher than the critical velocity at which the resistance changes from its directly proportional relation to the velocity and begins to vary as the square of the velocity.

Another large resistance to the discharge of exhaust gases, is the immediate bending of the manifold piping which gathers these gases from the respective cylinders into one pipe such as a tail pipe. Conventionally this

piping has one bend downward, a second bend toward the main pipe, and a third bend downward into the main pipe. The three bends in the small piping are right angle bends and the energy needed for bending the stream of exhaust gases in a small pipe becomes back-pressure equivalent to about three times the energy of back-pressure resulting from forcing the exhaust gases through a straight pipe of corresponding size, that is, one increase for each bend.

Furthermore, conventional manifold piping is in the form of an unfinished iron casting with the result that the internal wall surfaces are exceedingly rough and friction is the largest single source of resistance. Consequently friction between the flow of exhaust gases and these rough surfaces is very large, thereby developing very large additional back pressure on the motor.

The extremely high temperature of these gases is a further cause for back pressure in the flow of exhaust gases through small pipes, because of the greater expansive activity in the gases at higher temperatures.

A main feature of the present invention relates to a method of silencing the explosions of an internal combustion engine while reducing the back pressure on the engine to an extremely low value, which comprises expanding said pulses in a confined space at least twice as large as the expanded volume of the gases from each pulse whereby the pressure of each intermediate pulse in succession is reduced to a lower more nearly uniform common pressure, and passing the gas at the reduced pressure through a passageway to the atmosphere at a point remote with respect to said cylinders.

A further main feature of the present invention relates to a method of silencing the explosions of an internal combustion engine while reducing the back pressure on the engine to an extremely low value, which comprises discharging the pulses or pressure nodes of exhaust gases in succession from the several cylinders of the motor into a confined space of a volume at least four times greater than the volume of each cylinder, expanding the pulses in the confined space to reduce the pressure thereof to substantially low and uniform pressure, then discharging the gas efficiently at the lower resulting pressure through vena contracta or a Venturi orifice, and guiding the discharged gases at the resulting lowered pressure to a remote point through a tail pipe.

Another important feature of the invention relates to novel apparatus whereby the present method can be practised to the end that the shortcomings of prior silencing arrangements are eliminated.

Other features and advantages of the invention will appear from the detailed description and claims when taken with the drawings in which:

Fig. 1 is a side elevation of an internal combustion engine, having the silencer of the present invention attached to one side thereof and cooperating therewith;

Fig. 2 is an enlarged view, partially broken away, of one form of the silencer, with the motor omitted; and

Fig. 3 is a similar view of a modified form of the invention.

In the drawings, M designates a multi-cylinder internal combustion engine or motor, to one side of which there is bolted with interposed cushioning gaskets (not shown), the silencer S of the present invention in communication with the exhaust valves of the several cylinders. While the motor M is herein illustrated as a four cylinder engine, it may comprise various numbers of cylinders in accordance with conventional practice. The silencer S is preferably in the form of a closed chamber C defined by a box 5 made of cast aluminum to give rigidity to its walls and to dissipate some of the heat from the exhaust gases introduced therein. This box is conveniently lined with a layer or coating 6 of asbestos or

other sound cushioning heat-proof material. The box 5 is imperforate except for an exhaust outlet 7 and except for lateral openings 8 to register in gas-tight relation with exhaust ports of the several cylinders. The chamber which approximates the length of the motor block, has a depth and width to fit under the hood of an automobile (not shown). Ideally the chamber should be of a size such that the expansion of each explosion or node of pressure issuing from an exhaust port of the motor, as well as the continuous effect of all explosions, is lost in the general chamber volume such as results when the space is filled with gas under average or uniform pressure greater than atmospheric pressure. Practically the volume of the chamber is at least four times the volume of each cylinder discharging into it so that the individual explosions or nodes of pressure from the exhaust ports are almost completely expanded and at least partially transformed from velocity pressure into lower static pressure.

The most important dimension of the chamber C is its horizontal width which ideally should be wide enough to permit the pulses of exhaust gases from the successive explosions, which issue from the exhaust valves as high pressure, high velocity jets, to expand and be dissipated in the chamber, into static pressure, without substantial impact against the opposite chamber wall. Practically this horizontal dimension may be reduced with some sacrifice in the desired results, in the event that space becomes a factor as in the space under an automobile hood.

The vertical height of the chamber ideally should be such that it will accommodate the expansion of the explosive jet of gases from each exhaust valve while the jet is expanding radially with respect to its axis of travel so that the jet cannot strike a chamber wall until it has become an expanded body of gas. The distance between valve ports will allow enough space for lateral expansion between explosion jets other than where two exhaust ports are adjacent each other but this last situation will not be harmful since the purpose is to avoid having the jets hit a metal wall and an adjacent exhaust port does not have an immediately consecutive explosive jet in the course of the normal order of firing the cylinders. Furthermore, the two adjacent ports will not be discharging simultaneously, or even without considerable sequential spacing in the consecutive order of firing. In this manner, the noise from the walls of the box arising from the impacts thereagainst of the individual explosion jets or nodes of pressure, will be greatly reduced since these nodes are largely dissipated or disintegrated in the great volume of the chamber. While the size and shape of the chamber is such that the explosion jets or nodes of pressure are reduced therein to a low level of force, the common exhaust port 7 from the chamber should be of such a size that it will carry the steady flow of the expanded jets of gas to the tail pipe. Although at low engine speeds, there is sufficient volume in the chamber C for the complete expansion of each successive pressure node which eliminates the variation in pressure in the exhaust gases and consequently the noise therefrom, however, the rapid succession of pressure nodes at high engine speeds does not allow sufficient time between nodes for complete expansion. But it is not convenient to make the confined space of the chamber large enough to completely expand the pressure nodes generated at high engine speed and further means is therefore provided in accordance with this invention for an efficient reduction of the pressure in the nodes as they leave the confined space.

The chamber C discharges into the atmosphere at a remote point, through a tail pipe 9 of suitable length. This pipe which is open at its remote end, extends into the chamber in sealed relation with the wall of box 5, through the exhaust outlet 7, preferably located in the bottom of the box. The end portion 9*a* of the tail pipe 9, which is located within the chamber, can be made integral therewith but it is preferably made of a separate removable piece as shown. Thus a variety of different end portions 9*a* can be used as desired. The upper end of pipe portion 9*a* is closed by a gasket carried on the underside of a removable cap 10 which seals an opening in the top of the box 5. This cap permits the substitution of various pipe portions 9*a* and serves to hold a selected pipe portion in registry with tail pipe 9 at the discharge outlet of the chamber. Portion 9*a* of the tail pipe is provided with a plurality of lateral openings 11 conveniently arranged according to a symmetrical pattern. These openings constitute a series of vena contracta or small jets discharging from the chamber into the tail pipe. The more openings 11 that are provided in the tail pipe portion, the more the pressure nodes of the explosions are broken up or disintegrated before they are carried to the discharge end of the tail pipe where exhaust noises can be heard. The large number of small openings 11 in the tail pipe 9 constitute orifices from the expansion chamber to the passage through this pipe, thereby filling the passage with exhaust gas more efficiently than if this were effected through a small number of large openings.

In the operation of the system, when an exhaust valve in a cylinder opens, the exhaust gases in the form of a jet explode outward horizontally as far as convenient into a confined space of such a vertical dimension that the exhaust jet does not slide against the top or bottom of the chamber while expanding sidewise from the jet axes. The convenient rectangular shape of the chamber provides a volume somewhat larger than the expanded exhaust gases, so that noise is minimized and the only back pressure on the piston is for pushing the expanded gases through the tail pipe which is a minimum requirement. This equipment would be entirely satisfactory for low engine speeds. But it would be inconvenient to enlarge the confined space for high engine speeds.

At high engine speeds before the exhaust gases of one cylinder can expand fully, the exhaust gases of another cylinder begin to expand in the confined space. Here again the elasticity of exhaust gases gives tremendous advantages by applying the laws of aerodynamics in the present invention. If the tail pipe is extended into the confined space of the chamber, the tail pipe can be filled efficiently by having round holes in the side thereof. A particular number of small round holes fill the tail pipe exactly and efficiently without substantial turbulence. The greater the pressure in the confined space, the faster the tail pipe will be filled, thus relieving pressure by almost completely converting the energy of pressure into velocity so efficiently that any remaining back pressure, will apply the least back pressure against the pistons. The flow through these holes naturally assumes the vena contracta shape and size and this flow determines the particular number of holes. The provision of pipe portions 9*a* having openings 11 of different size and arrangement, permits the selection of a pipe portion best adapted for use with a given type of motor.

The modified form of the invention shown in Fig. 3, differs from that already described in that the tail pipe 9 does not project into the chamber C. Instead this tail pipe, at its junction 12 with the bottom of the box at exhaust port 7, is formed into a flared funnel-like shape similar to a Venturi tube throat. A tapering pointed plug 13 of the contour shown in Fig. 3, is adjustably mounted with its point directed toward the center of the opening in the tail pipe thereby defining an annular discharge orifice. The plug 13 is carried on a threaded stem 14 which is threaded in an opening in the top of the box and is locked by the nut 15. The stem 14 terminates in a wrench head 16, whereby the tapered plug 13 can be adjusted toward and away from the opening in pipe 9, to vary the size of the discharge orifice. The

discharge orifice construction functions as an adjustable Venturi nozzle which smooths the successive explosive pulses of exhaust gases from the several cylinders into a continuous swift emission of gases through the tail pipe.

The operation of the modified form of the invention illustrated in Fig. 3 is similar to that disclosed in Fig. 2 except that the thin walled orifices in the tail pipe extension which develop a plurality of jets in the form of vena contracta flow, are replaced by a single Venturi nozzle which transforms the pressure energy in the chamber into velocity energy for rapid discharge through the tail pipe.

What I claim is:

1. Sound-muffling apparatus for an internal combustion engine having a plurality of cylinders, each provided with an exhaust port, said apparatus comprising a box defining a single, confined chamber, said box being secured to said engine so that said chamber is in immediate sealed communication with all said exhaust ports so that all said ports discharge into said chamber, said chamber having a volume several times greater than that of any one of said cylinders, and a tail pipe communicating in sealed relation with said chamber and extending to a point remote with respect to said cylinders, a perforated conduit enclosed within the chamber and extending a substantial distance therein, said conduit connecting with said pipe and having its end distal from said pipe closed, and said pipe being open to atmosphere at its end distal from said box.

2. Sound-muffling apparatus for an internal combustion engine having a plurality of cylinders, each provided with an exhaust port, said apparatus comprising a box defining a confined chamber in immediate sealed communication with said exhaust ports so that all said ports discharge into said chamber, said chamber having a volume at least four times greater than that of each cylinder, said box having opposed openings in its opposite walls, a tail pipe having one of its ends sealed in one of said openings in communication with said chamber and having its other end extending to a point remote with respect to said cylinders and open to atmosphere, a removable pipe extension with perforated side walls held in the chamber with one end in substantially gas-tight relation with the sealed end of the tail pipe, and means sealing the other box opening and the opposite end of the pipe extension.

3. Sound-muffling apparatus for an internal combustion engine having at least one cylinder provided with an exhaust port, said apparatus comprising a box defining a confined chamber in immediate sealed communication with said exhaust port, said chamber having a volume several times greater than that of said cylinder, said box having an opening in its side, a tail pipe having one of its ends sealed in said opening and having said end flared to provide a Venturi throat, the other end of the tail pipe extending to a point remote with respect to said

cylinder, a tapered plug with its smaller end directed toward the flared end of the tail pipe to define therewith an annular orifice, and means adjustably mounting the plug for axial movement toward and away from the flared end of the tail pipe.

4. Sound-muffling apparatus for an internal combustion engine which has a plurality of cylinders, each provided with an exhaust port, said apparatus comprising a box defining a single, confined chamber, said box being secured to said engine so that said chamber is in immediate, direct, sealed communication with all said exhaust ports so that all said ports discharge into said chamber, said chamber having a volume several times greater than that of each cylinder, said box having top and bottom walls, end walls, and a side wall opposite said engine, and said box being wide enough and high enough that the jets of gases exhausting from said engine can expand without substantial impact against the opposite side wall and the top and bottom walls of said box, a tail pipe connected to said box and extending to a point distal from said box, said tail pipe being open at its distal end for communication to atmosphere, and said tail pipe communicating at its other end with said chamber through a thin-walled orifice which is smaller than the internal diameter of said pipe.

5. Sound-muffling apparatus for an internal combustion engine which has a plurality of cylinders, each provided with an exhaust port, said apparatus comprising a box defining a single, confined chamber in immediate, direct, sealed communication with all said exhaust ports so that all said ports discharge into said chamber, said chamber having a volume at least four times greater than that of each cylinder, said box having top and bottom walls and end walls, and said box having two side walls, one of which abuts against a side of said engine and is provided with lateral openings to register in gas-tight relation with the exhaust ports of the several cylinders of the engine, and said box being wide enough and high enough that the jets of gases exhausting from said engine can expand without substantial impact against the other side wall of the box and against the top and bottom walls of the box, a tail pipe connected to said box and extending to a point distal from said box, said tail pipe being open at its distal end for communication to atmosphere, and said tail pipe communicating at its other end with said chamber through a thin-walled orifice which is smaller than the internal diameter of said pipe.

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