The present invention relates to mufflers and exhaust systems and has for its primary object the provision of a new and improved construction and arrangement increasing the operating efficiency of motor cars with which they may be used.

Exhaust systems and mufflers have become an important factor of cost to car owners. One reason is the relative short life because of corrosion. Another is the higher price brought about by the considerable variety of constructions which increase the cost of storage, etc. A reason for the variety of constructions required resides primarily in the fact that mufflers as built to date are comparatively large and bulky and have to be designed in accordance with the available space in which they are to be used. Cars have been recently constructed with lower and lower ground clearance with the result that greater difficulties have been encountered. Thus, as a great variety of constructions and dimensional requirements of components of exhaust systems, together with the rapidly increasing number of cars in use and the short life of the components, the matter of cost is becoming increasingly important.

It has been believed quite widely that the influence of the muffler on the performance of a four-stroke engine is, as a practical matter, very small and that an effective muffler should have a volume approximately 3 to 5 times the total cylinder displacement of the engine. On the other hand, it has been verified, especially as a result of studies of racing cars, that the construction and dimensions of the exhaust system is an important factor in the performance of the engine. It can be shown by tests that faulty construction or dimensioning can cause losses as high as 10% in engine performance, which losses can be avoided, in accordance with the present invention, by the construction and arrangement of an exhaust system with a muffler so as to utilize the kinetic energy of the exhaust gases for improving engine suction and, thus, the cylinder filling or intake.

Tests have shown that utilization of the kinetic energy of the exhaust gases can produce an increase in operating efficiency. By and large, a primary consideration in the design of exhaust systems has been the so-called back pressure, which is the average pressure in the manifold. Much of the existing literature indicates that it is essential for the effective working of the engine that the back pressure be as low as possible. However, this is not the entire answer. The average back pressure in the exhaust system depends on the load-rate of the engine and it increases almost linearly when the load increases. Back pressure itself is not the determining factor, the latter actually being the amount of residual gases left in the cylinder as a result of the back pressure. The present invention contemplates changes in the exhaust system equipped with a muffler so as to utilize the kinetic energy of the exhaust gases to improve suction and cylinder filling, thereby to improve performance of the engine, even though the average back pressure may be increased.

Tests made by others have shown that the maximum power output bears a certain relation to the length of the exhaust pipe, which relationship is believed to depend on the kinetic energy of the gases flowing in the exhaust system, although it has not been accurately explained in the literature. The results of tests, indicating the foregoing, are set forth and will be described later herein in connection with Figs. 1 to 3. These tests indicate that utilization of a proper length of exhaust pipe produces pressure minima in the manifold at the required moments to increase the engine suction and thereby increase the operating efficiency of the motor.

In accordance with the present invention the exhaust system with a muffler is constructed so that it includes no substantial expansion chambers and the total length of the exhaust system or pipes is a whole number times the distance between the pressure peaks travelling in the pipes under normal loading conditions, which distance is referred to as the "wave length," whereby it is possible to produce in the manifold pressure minima at the correct moments to increase the suction and cylinder intake. Further, in accordance with the present invention, the exhaust system additionally includes a muffler or silencer. The latter can be included in the system under the following conditions: (1) that there be included no chamber or enlargements in the system (including the silencer or silencers or other chambers filled with absorption materials), which could act as substantial expansion chambers; (2) that the gas flow velocity remain substantially constant throughout the system; (3) that the distance from the exhaust manifold to the first silencer be some whole number (preferably 2 times the wave length, i.e., the distance between the pressure peaks travelling in the pipes under normal loading conditions); (4) that the distance from the first silencer to the second silencer, if there is one, or to the end of the exhaust pipe follow the same rule; and, (5) that the muffler have a length corresponding to the above mentioned whole number times the wave length.

Accordingly, it is an object of the present invention to provide a new and improved exhaust system including one or more mufflers constructed and arranged to produce pressure minima at correct times to increase engine suction and cylinder filling and to provide adequate muffling or sound attenuation.

An object of the invention is to develop a muffler, which can be made of small size and which, because of its small size, both eliminates the large number of types hereeto required and reduces corrosion and at the same time effectively dampens the sound and increases the efficiency of the engine.

A further object of the present invention is the provision of a muffler in which silencing is effected by dividing the flow pass through several streams having different length flow paths and then recombining them to effect muffling and in which the muffler is made of relatively small size by arranging the flow paths in what may be defined as concentric relation. Due to the small cross section, the use of the muffler can be increased, because a small muffler can be mounted under nearly every car. Also, the small size of the muffler reduces the corrosion because small size means a smaller amount of gas at each unit of surface of the outer casing. The amount of acid solution formed by condensed exhaust gases at each unit of surface is substantially smaller than in mufflers commonly used and, thus, the corrosion is reduced.

Another object of the invention is the provision of a muffler comprising a casing, an inlet for said casing and an outlet from said casing in which said inlet, casing and outlet are generally longitudinally aligned, and also having passage defining means in the casing providing communication between the inlet and outlet and dividing the gas entering through said inlet into two generally longitudinally disposed streams and then reuniting the streams for discharge through said outlet, and wherein said passage means maintains the sum or difference and the direc-
tion of the kinetic energy of the gas contained in the two streams substantially identical with the kinetic energy of the gas flow at the inlet and outlet.

As earlier indicated herein, it is seen that with open exhaust pipes of a particular length, the pressure minima are considerably lower than with open pipes of other lengths. As heretofore explained, it is the kinetic energy of the exhaust gases and the properly timed minima in the manifold or back pressure and thereby improve the suction and cylinder filling to provide the improved results. Based on studies on Mr. Smith's work, it appears that the wave length in his experiments was about 2.2"±1".

In order to provide a system usable in modern automobiles, the exhaust system of the present invention utilizes the kinetic energy to improve operation and at the same time it provides a muffling, silencing or attenuation of the exhaust. The system utilizes a muffler indicated as a whole by reference character 10, referring now to Figs. 4, 5 and 6. The muffler has an outer casing 12 which, in the illustrated embodiment, is cylindrical. The casing has a tapered reduced inlet end 14 providing an entrance for an inlet pipe 16 having an outwardly projecting portion 16A by means of which the muffler may be connected by a pipe 17 to the manifold 20 of an automobile engine, not shown. Similarly, the muffler has a tapered reduced outlet end 22 provided with a discharge pipe 18, the outwardly projecting portion 18A of which is connected as by pipe 24 to atmosphere, or a second muffler, or, as shown, to a resonator 26. This is connected to the atmosphere by tailpipe 28, see Fig. 6.

The resonator is not required but is advantageous in its presence. The interior of the muffler casing 12 is divided into sequential chambers or compartments 30, 32 and 34 by the transverse partitions 36 and 38 in casing 12, and through which the inner portion 18B of the outlet pipe 18 extends. The compartment 30 provides muffling in accordance with the present invention while compartments 32 and 34 dampen intermediate and high frequencies in known manner.

The inlet pipe 16 has an inner portion 16B having an exit end 16C open into the first chamber 30, which is constructed in accordance with the present invention, through an intermediate cylinder 40 provided with an internal central imperforate portion 42 which reflects or reverses the exhaust gases striking it and with a plurality of indentations 40A at one end whereby it is attached to the end 16C of pipe 16. The circumferential spaces between the indentations 40A provide a plurality of channels 44 extending from the region 46 inside of the intermediate cylinder to a forward region 30A of the compartment or chamber 30. The chamber 30 is connected by an annular passageway 30B to a rear portion 30C of the chamber 30 surrounding the inner portion 18B of the outlet pipe 18. The chamber portion 30C is connected through a second series of passageways 44B defined by a second series of indentations 40A to a region 48 within the inner cylinder 40 at the inner end 18C of the outlet pipe 18. The intermediate cylinder is thus conveniently supported by the opposite ends of the pipes 16 and 18.

The inlet pipe 16 is provided with a plurality of aper-
tures 50 through which some of the exhaust gases flow to chamber portion 30A. Some of the exhaust gases flow through the exit end 16C into the region 46 of the inner cylinder 49 from whence they flow forward through passage 44 to combine with the gas flowing through the apertures 50. The reunited streams flow through the annular passageway 30B. In flowing through this passageway a small portion of gas in the inner cylinder region 46 flows outwardly through the apertures 53 to combine with the major portion of the gas flow.

The gas then flows into chamber portion 30C where some of the gas flows 44B through the passageway 44B to region 48 of the inner cylinder where it combines with a small amount of gas to that region 48 through the apertures 54 in the inner cylinder. The gas from region 48 then enters the inlet pipe 18 at inlet end 18C where it is combined with gas flowing into the pipe through apertures 56 in the pipe head of the partition 36. All the exhaust gas then flows through the pipe 18 where the chamber 32 dampens intermediate frequencies of the gas by virtue of the apertures 58 in the pipe between partitions 36 and 38. The gas then flows through the length of pipe associated with compartment 34 which is filled with glass wool or the like 34A and where the pipe is provided with apertures 60 to dampen high frequency sounds.

It will be noted that the total of the exhaust gases indicated by III flows into the inlet pipe 16 at entrance 16A. This total flow is divided into two streams indicated by the reference characters I and II. The portion I enters the chamber 30 at region 30A, flows through the apertures 50 and from region 30A it flows through annular passageway 30B to the region 30C. A second portion of the gases indicated by reference character II flows out through the discharge end 16C of the inlet pipe into the region 46. From this region the greater portion, indicated by IIA, returns through passageway 44 to be united with stream I for flow through the annular passageway 30B. A small portion IIB of stream II flows through the passageway 52 into the annular passageway 30B. From the annular passageway 30B the total flow goes into the chamber portion toward 30C. A small part IIB of the flow enters region 48 through the apertures 54. The major flow goes to region 30C where part of it enters the outlet pipe through apertures 56 and part returns to intermediate cylinder region 48 and then returns through the inlet end 18C of the output pipe to be united with stream I. The total flow then goes through the pipe at compartment 32 where the noise of the middle frequency are damped and past chamber 34A where highest frequency noise are damped. It should be understood that the chambers 32 and 34 need not be utilized.

The cross section areas of the flow passages are so dimensioned that the velocity of the gas at the different cross sections is nearly identical and cross section of the muffler corresponds to that of the inlet pipe so that the kinetic energy remains constant. Also, the amount of gases which are flowing along the two paths I and II are substantially equal. The difference between the longer path I-IIA and the shorter path I is substantially equal to the distance between the pressure peaks at the inlet whereby effective muffling or silencing of the noise is effected in both halves of the muffler.

The apertures 52 and 54 need not be used and the pipe ends 16C and 18C can have another diameter than the pipe itself. Also, the holes 59 can be located quite near the front end of the casing 12.

In FIGS. 7 and 8 there is illustrated a modification of the muffler enabling it more readily to be installed under the car to the exhaust system at the point where it works most effectively. This advantage is obtained by constructing the muffler in a substantially flat form and without the high and intermediate frequency muffling compartment 32 and 34 of the first described embodiment.

The muffler, indicated as a whole by reference character 109, comprises a substantially flattened outer casing 102 having tapered inlet and outlet ends 104 and 106 adapted to receive inlet and outlet pipes 110 and 112, respectively. The casing 102 includes a pair of longitudinally extending and spaced apart interior partitions 110 secured to the sides of the casing and centrally of which is disposed an imperforate baffle 114. The inlet pipe 110 has a portion 110A projecting outside of the casing, an intermediate portion 110B with a series of apertures 111 therein and an exit portion 110C that is spaced from the partition 114 and opens into an inner chamber 118. Similarly, the outlet pipe has an external projecting portion 112A, an intermediate portion 112B with a series of apertures 113 and an inlet portion 112C spaced from the partition 114 and opening into an inner region 118.

It will be noted that the construction provides the spaced passageways 124 between the end 110C of the inlet pipe and the adjacent longitudinal partition 108 and corresponding passageways 126 between the partitions 108 and the partition 112C of the outlet pipe. Likewise, the longitudinally extending passageways 128 are provided between the outer sides of partitions 108 and the semi-circular portions 102A of the casing.

As in the previously described embodiment, the incoming gases enter the muffler through the pipe 110. A first portion 110A enters the interior of the muffler. A second portion 110B enters the region 118 through the exit 110C of the inlet pipe. From region 118 the gases 118B flow back through the passageway 124 and are reunited with the gas stream 1 and the entire flow is then through the passageway 128 to the chamber portion 132. Here gas stream 1 enters the outlet pipe 112 through the apertures 126 and gas stream 112B flows chamber 122 through the passageway 126 and there into pipe 112 where the two streams are reunited and flow out through the outlet portion of the pipe.

In this embodiment the cross sections again are such that the gas flows into substantially two streams of equal size and velocity. The flow paths of streams I and II are of lengths differing in magnitude by the wave length, i.e., the pressure peaks, so as to provide effective dampening.

As heretofore indicated, the mufflers should be located properly in the exhaust system. Referring to FIG. 6, the distance from the exhaust manifold to the exhaust valves should be about two wave lengths, the muffler should be of a length equal to a wave length, and the distance from the muffler to the end of the tailpipe 28 should be a whole number multiple of the wave length.

A muffler like that of FIGS. 7 and 8 adapted for use on about 30 European cars with exhaust piping of a diameter of 45 mm, has a length of 450 mm, a thickness of 46 mm. and a width of 105 mm. It has been used with a glass wool filled resonator having a length of 450 mm., a thickness of 55 mm. and a width of 105 mm. Accordingly, it appears that the wave length for normal loading ranges can be considered to be 450 mm. As a result, the central partitions 42 and 114 in the two mufflers are located one-half wave length from each end—which location has been found to provide effective sound dampening.

Also, and speaking generally, the ratio of the combined volume of the manifold 28, pipe 17, the muffler 10 and pipe 24 relative to the total volume of the exhaust system is such that cooling of the exhaust gases in the exhaust system by the ambient air, when the engine is turned off, does not cause the air to flow in through the tailpipe faster than pipe 24.

In both the embodiments of the invention described above the kinetic energy of the exhaust gases remains fundamentally unaltered. The flow with the muffler in the system is comparable to the corresponding flow through an open pipe type exhaust without a muffler and, thus, differs sharply from corresponding properties of mufflers used thus far and adapts open pipe principles to exhaust systems equipped with mufflers. Also, the capability of the
muffler of the present invention with respect to sound damping is at least as good and generally better than the damping provided by traditional car mufflers. In addition, one muffler can be used on many cars with improved gas efficiency, gas consumption, power output and acceleration and a reduction in exhaust fumes and carbon.

Also, use of the mufflers of the present invention has indicated that the wave length, i.e., the distance between pressure peaks within reasonable normal loading ranges does not vary greatly, so that the mufflers can be applied to many cars and operate satisfactorily over relatively wide loading ranges.

An important advantage of the present invention is the more effective utilization of the fuel with a consequent reduction in carbon monoxide and partly burned fuel in the exhaust gases, as well as reduction in the presence of propane, butane, etc.

Another advantage is that the choke need be opened but about half of the time.

Mufflers in use indicate very little inside corrosion and it is expected that they will have a life of at least three years. It is expected also that galvanizing the exterior adds to the life.

The small size of a muffler made in accordance with the present invention can be noted from Fig. 9 where such a muffler 10 has been shown alongside a muffler 140 of a conventional type 85 it can replace.

While the present invention has been described in connection with details of illustrative embodiments thereof, it should be understood that these details are not intended to be limiting of the invention except insofar as set forth in the accompanying claims.

What is claimed is new and desired to be secured by Letters Patent of the United States 16:

1. A muffler comprising an elongated flattened casing of generally rectangular cross section, a pair of longitudinally extending interior partitions of lengths shorter than the casing mounted in said casing in spaced relation to each other, said partitions being equally spaced from the adjacent sides of the casing and also equally spaced from the ends of the casing, a transverse imperforate baffle located centrally of and extending between the partitions, and opposed inlet and outlet pipes having ends disposed between the interior partitions and spaced from the transverse baffle, said inlet and outlet pipes having a plurality of apertures intermediate their ends and opening into the outer casing between the ends of the casing and adjacent ends of the interior longitudinal partitions, said inlet and outlet pipes being of a diameter corresponding substantially to the narrow dimension of the flattened casing.

2. A muffler for an exhaust system comprising an elongated flattened casing of generally rectangular cross section of which the opposite shorter sides are rounded, a pair of longitudinally extending interior partitions of lengths shorter than the casing mounted in said casing in spaced relation to each other and from the adjacent sides of the casing to provide end chamber regions and a first pair of passageways from one end chamber region to the other of the casing, a transverse imperforate baffle located centrally of and between the partitions, and opposed inlet and outlet pipes having outer ends outside of the casing and inner ends disposed between the interior partitions and spaced from the transverse baffle to provide inner chambers at opposite sides of the baffle, said inlet and outlet pipes being of a diameter corresponding substantially to the narrow dimensions of the casing and providing a second pair of passageways at opposite sides of the pipes and between the pipes and the partitions to provide communication between the inner and end chambers, and said inlet and outlet pipes having a plurality of apertures intermediate their ends and opening into said end chambers between the ends of the casing and the adjacent ends of the interior partitions.

References Cited

UNITED STATES PATENTS

<table>
<thead>
<tr>
<th>Patent Number</th>
<th>Date</th>
<th>Inventor</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,338,520</td>
<td>4/1920</td>
<td>Moore</td>
<td>181—53 XR</td>
</tr>
<tr>
<td>2,018,084</td>
<td>10/1935</td>
<td>Oldberg</td>
<td></td>
</tr>
<tr>
<td>2,099,887</td>
<td>11/1937</td>
<td>Health</td>
<td></td>
</tr>
<tr>
<td>2,109,220</td>
<td>2/1938</td>
<td>Noblit et al.</td>
<td>181—54</td>
</tr>
<tr>
<td>2,111,537</td>
<td>3/1938</td>
<td>Noblit et al.</td>
<td>181—54</td>
</tr>
<tr>
<td>2,182,204</td>
<td>12/1939</td>
<td>Hector</td>
<td>181—54</td>
</tr>
<tr>
<td>2,193,791</td>
<td>3/1940</td>
<td>Hollerith et al.</td>
<td></td>
</tr>
<tr>
<td>2,205,946</td>
<td>12/1942</td>
<td>Wilson et al.</td>
<td></td>
</tr>
<tr>
<td>2,567,668</td>
<td>9/1951</td>
<td>Lieverse et al.</td>
<td></td>
</tr>
<tr>
<td>2,640,557</td>
<td>6/1953</td>
<td>Gaffney</td>
<td>181—56 XR</td>
</tr>
<tr>
<td>2,675,088</td>
<td>4/1954</td>
<td>McLeod</td>
<td></td>
</tr>
<tr>
<td>2,872,998</td>
<td>2/1959</td>
<td>Tinker</td>
<td>181—53</td>
</tr>
<tr>
<td>3,194,341</td>
<td>7/1965</td>
<td>Haag</td>
<td>181—54 XR</td>
</tr>
<tr>
<td>3,512,603</td>
<td>10/1965</td>
<td>Walker</td>
<td></td>
</tr>
</tbody>
</table>

FOREIGN PATENTS

<table>
<thead>
<tr>
<th>Patent Number</th>
<th>Date</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,060,344</td>
<td>11/1953</td>
<td>France</td>
</tr>
</tbody>
</table>

ROBERT S. WARD, Jr., Primary Examiner.

RICHARD B. WILKINSON, Examiner.