June 30, 1936. W. E. SPICER 2,046,193

MUFFLER

Filed Jan. 3, 1931

Fig. 1.

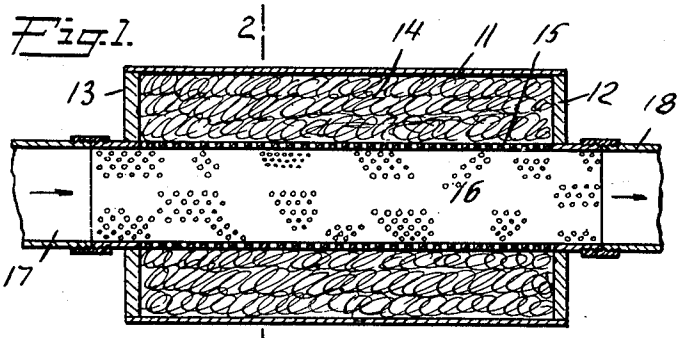


Fig. 2.

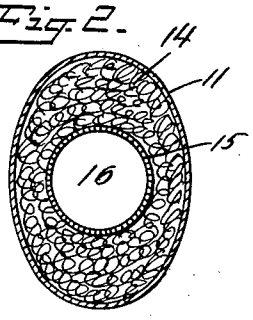


Fig. 3.

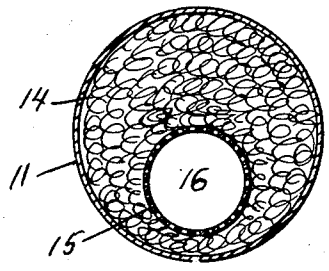


Fig. 4.

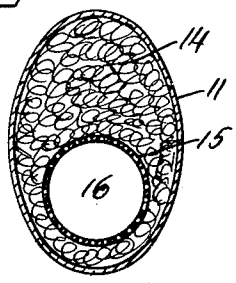


Fig. 5.

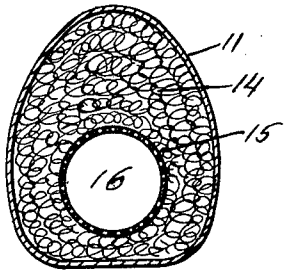


Fig. 6.

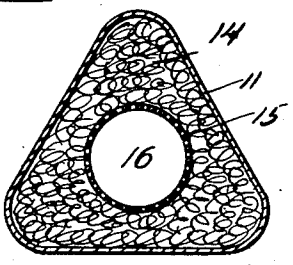


Fig. 7.

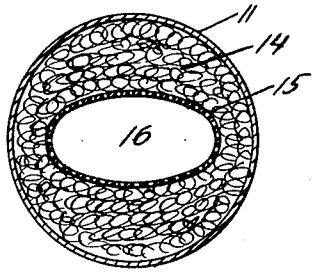


Fig. 9.

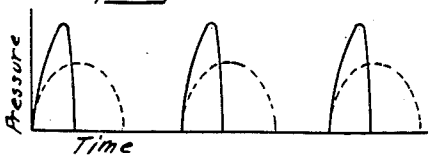


Fig. 10.

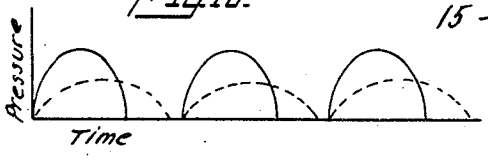
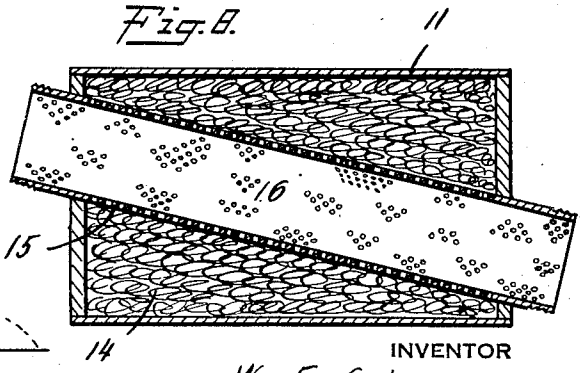


Fig. 8.



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MUFFLER

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Application January 3, 1931, Serial No. 506,361

4 Claims. (Cl. 181—42)

My invention relates to mufflers for noise producing gases and more particularly to exhaust mufflers for expanding and noise producing pulsating gases such as are discharged from internal combustion engines.

This application covers an improved construction over that shown in the F. H. Schnell application, Serial No. 361,376, filed May 8, 1929 (now Patent No. 1,811,762, granted June 23, 1931).

It is the object of this construction to secure better muffling than has heretofore been obtained throughout the entire range of frequencies of sound generated by the explosion of and the expansion of gases.

The explosion within the cylinder of an internal combustion engine creates tremendous pressure therein. The steam or vapor in the cylinder in a steam engine is also under very high pressure. Upon the opening of the exhaust port the gas emerges at high velocity, very quickly reducing the pressure in the cylinder. By the word gas I mean to embrace both gas and vapor. The result is a succession of pulses or slugs of gas at high pressure traveling through the exhaust manifold or pipe, or any other type of exhaust system, at a high velocity. Upon the emergence of the gas pulse into the atmosphere an additional spurt in velocity is probably acquired by reason of expansion, and a sharp sound results. The greater the pressure gradient between the pulse of gas and the atmosphere the greater the velocity and the sharper the sound. In order to successfully silence pulsating exhaust noises the mufflers must suppress the pressure peaks and thus even the flow of the escaping gas pulses to the point where the volume of sound generated is below the desired minimum. In addition the sound communicated to or generated within the muffler should be silenced.

The muffler disclosed in the Schnell patent does not employ the principles employed in other present day mufflers. Those mufflers rely on the use of tortuous paths, obstacles and baffles which retard the flow of the gas, but in so doing, they build up a back pressure within the muffler which reduces the efficiency of the engine. In the Schnell invention the noise producing gas passes along the surface of gas-pressure absorbing and sound absorbing material, the passageway being free of baffles and being straight or of such shape that it does not substantially increase the back pressure of the flowing gas.

The muffler of this application may be applied to practically all the common types of explosion and steam engines, to firearms and to air intakes and to exhausts, as in air compressors.

Other and further objects of my invention will become apparent as the following description progresses, which is to be taken in conjunction with the accompanying drawing wherein:

Fig. 1 is a longitudinal, sectional view of one form of my invention;

Fig. 2 is a transverse, sectional view on line 2—2 of Fig. 1;

Figs. 3 to 7 are transverse, sectional views of other forms of my invention;

Fig. 8 is a longitudinal, sectional view of another embodiment of my invention; and

Figs. 9 and 10 are charts which illustrate the effects of my muffling device upon exhaust gases.

In one form of muffler for internal combustion engines shown in Figs. 1 and 2 of the drawing, an outer sheet metal oval shaped cylinder 11 is welded or otherwise fastened at its ends to sheet metal end closure discs 12 and 13. Cylinder 11 encloses an intermediate space 14 packed with a porous, gas-prssure absorbing and sound absorbing material which may be a mineral fiber, steel, copper, or other metallic wool or mixtures thereof, or any other porous gas-pressure absorbing and sound absorbing, non-flammable material such as sized crushed mineral matter, mica, exfoliated vermiculite such as Zonolite, ground slag, coke, pumice, or other porous aggregate such as Haydite and built up units of such aggregate that may be made by cementing the particles together at their points of contact. Porous burned clay products may be used. For silencing blow-off gases, air compressor intakes and exhaust noises, and noises produced by gases at room temperature, flammable gas-pressure absorbing and sound absorbing material such as wool, cotton, or other cellulosic fibers may be used. In some instances the muffler may be used under circumstances which would tend to cause the deterioration of steel wool and in such instances a metallic wool formed of stainless steel or other steel, or rust resisting alloys may be used.

In view of the fact that every material which is not a perfect reflector of sound is, to a degree, an absorber of sound, it would probably be well to draw some sort of a specification for the term "sound absorbing material" as that term is used in the present case. In all acoustic data the sound transmitted by an open window is used as the standard of comparison. The ratio of the sound absorbed by an area of material to that transmitted by an equal area of an open window is called the absorption factor or value of that

material. If a material one square foot in area absorbs one-fourth the sound transmitted by one square foot of open window that material is said to have an absorption factor or value of 25 percent. In this specification whenever the term "sound absorption factor" or "value" is used in conjunction with an absorbing material or construction in a muffler, it is to be understood that this factor or value is obtained by measuring the absorption of such material or construction in the usual way by means of flat pads and the like of identical material and construction. This is necessary, since it is very difficult or impossible to obtain the factor after the muffler is constructed. In the mufflers of this invention, as the sound absorption factor of the sound absorbing material decreases, the size of the muffler must increase and a material with a factor of 10 percent or less would probably necessitate an unwieldly size. Hence, in the present consideration for sound absorbing material I do not contemplate a material having an absorption factor of less than 10 percent at 1024 double vibrations per second. Throughout this specification all absorption values are based on 1024 double vibrations per second. For most situations an excellent muffler may be constructed with a material having an absorption factor of 25 percent or more. For exceptional results I prefer to use a material having a factor greater than 45 percent. Because of the present state of the art it is impossible to express the gas-pressure absorbing qualities of the filler similarly. Since the sound absorbing and gas-pressure absorbing properties apparently are closely related numerical data are confined to the former and are usually assumed to apply to the latter. The combined absorbing effect may be expressed in terms of muffler efficiency as is explained hereinafter. By mineral fiber I contemplate natural or artificial mineral wool, shredded asbestos, or any other mineral material of the same general nature.

An inner cylinder 15 of foraminous rigid material such as perforated sheet metal provides a straight open unobstructed central duct 16 extending from end to end of the muffler. Because of the high temperature of internal combustion engine exhaust gases, cylinder 15 expands and therefore it preferably is not fastened to either metal discs 12 or 13 or both, thereby forming a slip joint to prevent buckling since cylinder 11 which is also fastened to discs 12 and 13 does not expand appreciably. Disc 13 may be provided with a threaded central opening to receive pipe 17 which conducts the exhaust gases into the muffler. It is usual in automobile mufflers to provide a slip joint so that pipe 17 is free to move in disc 13 and such construction may be employed in place of the threaded connection shown. The arrows in the drawings illustrate the direction of gas flow. The gases are finally exhausted through pipe 18. It is preferred to have the internal diameter of cylinder 15 of at least the same size as exhaust pipe 17. If it is smaller it increases the back pressure. If cylinder 15 is larger than pipe 17 the acoustic absorption usually decreases, the exceptions occurring under certain special conditions. The contributing factors which cause these conditions are not fully recognized or understood.

As hereinbefore explained, a series of gas-pressure peaks emerges at high velocity from pipe 17. Each peak tends to expand in all directions. The gas and pressure waves freely pass through perforated cylinder 15 and enter annular space 14. The property of the perforated sheet metal of permitting the free transmission of gas and sound therethrough, together with its other advantages makes it the preferred foraminous material for a device of this character. The perforations may vary in size and shape. Because of lower manufacturing costs I prefer circular openings. Holes suitable may vary from approximately 0.070 to 0.125 inch in diameter but I do not wish to be limited to these dimensions. For most purposes the holes are evenly distributed throughout the area of the sheet metal although such even distribution is not necessary. The holes are present in sufficient number so that their total area represents 2.5% to 35% of the area of the sheet metal though fair results may be obtained with holes having an area as low as 1 percent of the area of the sheet. A greater area may be perforated. The size, shape and distribution of the perforations all have an influence on the ease with which gases and sound pass through the sheet metal. The holes should be small enough so that the absorbing material will not work its way out through them when the muffler is in service but not too small to be plugged by dirt and especially the carbon present in the exhaust gases of internal combustion engines. Excellent results are obtained when the ratio of the unperforated portion of the metal forming such facing to the openings therein is such that a substantially continuous surface is exposed to the sound waves and gas-pressure waves. In such cases the average dimensions of the individual openings are usually less than the distance between the edges thereof. Tests show that a muffler containing absorbing material faced with a stiff perforated sheet, the perforated area of which is as low as 2.5 percent of the area of the sheet with holes about .075 inch in diameter absorbs as much sound as and has a muffling efficiency equal to a similar muffler in which the perforated facing is omitted. It is possible to omit the perforated metal facing or other foraminous facing by constructing a moulded annular or other suitably shaped absorbing material as by bonding sized crushed mineral particles together at their points of contact to form a porous mass. Such a moulded gas-pressure absorbing and sound absorbing material has an opening therethrough corresponding to the foraminous tube 15. In another construction metallic fibers like steel wool are formed into a mattress by stitching the fibers together with a metallic thread such as steel wire. The mattress is used to line the inside of the muffler shell 1. Under certain conditions the foraminous duct may be omitted when such a mattress is used.

Fig. 9 shows in solid lines a hypothetical diagrammatic representation of several gas pulses as they enter the muffler and in dotted lines is a similar representation of the same pulses after expansion has taken place. The pressure wave characteristic has become flattened. I also believe that a second phenomenon takes place within annular space 14 to further flatten the wave characteristic. Relatively speaking the rapid moving gas enters the annular space 14 in the form of a succession of rapid compressions and rarefactions. The compressions are suppressed and merged together by the choking effects of the walls of the tiny pores or cells with a resulting reduction of the intervening rarefactions. Fig. 10 shows in solid lines the pressure wave characteristics corresponding to the dotted curve of Fig. 9. The dotted lines of Fig. 10 show the pressure wave characteristic after the gas has un-

dergone the choking action of the porous sound absorbing material. The porous material offers practically no resistance to the fairly steady flow of the gas stream through the straight and unobstructed duct 15 and especially if duct 15 is made of smooth perforated sheet it facilitates the flow with the net result that there is practically no resistance to the gas flow and little or no back pressure is built up aside from that due to the surface friction. The absorption of the gas-pressure peaks by the absorbing material to smooth out the gas flow and eliminate the noise made by the gas slugs when emerging into the atmosphere is an important feature of my invention. I use the sound absorbing material for this double function without appreciably increasing the back pressure. The exact relation between these various factors, in so far as it affects the intensity of sound emitted from the muffler is not known.

I believe that some noise is generated at the end of pipe 17 as explained heretofore in connection with expansion chambers. This noise is silenced by the gas-pressure absorbing and sound absorbing material. It is not projected longitudinally of the duct 16 since sound does not project itself in a single direction to form rays. It emanates equally in all directions unless it encounters reflecting surfaces. Foraminous cylinder 15 allows this sound to pass freely therethrough and it is thereafter absorbed by the material in space 14.

Although a muffler of the Schnell construction, in which the absorbing material thickness does not vary appreciably throughout the annular space 14, is efficient, it apparently absorbs selectively at certain frequencies, its efficiency seemingly being lowest at the low frequencies. These frequencies may be gas-pressure frequencies induced by sounds, explosions or mechanical means. Since the sound absorption and gas-pressure absorption are effected more or less simultaneously it has been impossible to determine whether this selective absorption is caused by an effect either on the sounds reaching or generated in the muffler or on the gas-pressure waves or both. I believe also that the gas-pressure peak absorption varies with the absorber thickness for varying exhaust gas speeds. For this reason the noise produced by the individual pressure slugs from any one internal combustion engine exhaust varies with the thickness of absorber, speed and power output of the engine. By providing a gas-pressure absorbing and sound absorbing lining which varies substantially in thickness in any transverse plane along the greater part or all of the duct 16 it is possible to obtain a better absorption since all frequencies seem to absorb more uniformly, and if my hypothesis is correct, it absorbs gas-pressure peaks more uniformly at all exhaust gas speeds. There is also less chance for any one frequency or pressure effect due to a certain gas speed to build up with such a varying thickness. It is desirable that the maximum thickness of the lining in some of the transverse planes should be at least twice the minimum thickness in the same transverse plane.

There are many constructions which allow the thickness of the lining to vary substantially in any transverse plane along the duct length. Some of these are illustrated in the accompanying drawing. Fig. 2 shows the use of a circular duct in an oval shaped container. Fig. 3 shows a circular duct off center in a circular container. Fig. 4 shows a circular duct off center in an oval container. Fig. 5 shows a circular duct in an odd shaped container. Fig. 6 shows a circular duct in a substantially triangular shaped container. Fig. 7 shows an oval duct in a circular container. Fig. 8 illustrates another construction whereby the thickness of the lining varies substantially along transverse planes. In this construction a circular container is used but the duct enters off center at one end and leaves off center at the other end at the side opposite from the first end.

Other methods for obtaining the desired effect will suggest themselves to those skilled in the art. In any form of device I may choose to construct the cross sectional area of the outlet should be large enough not to build up any appreciable back pressure. Many present mufflers assist the silencing action by constricting greatly the cross sectional area of the gas outlet but this cannot be done without building up back pressure.

Although published data available on the mechanics of noise production by internal combustion engine exhausts are meagre I believe the hypotheses and explanations hereinbefore advanced to explain the manner in which my device accomplishes the muffling of exhaust explosion noises are true. Whatever the theories and explanations may be, the fact remains that although a substantially straight and unobstructed path is offered the exhaust gases and noises, they do not traverse that path unchanged but undergo a decided change therein which causes the gases to emerge quieted in proportion to the amount of effective absorbing material used.

Mufflers which are considered satisfactory and used by automobile manufacturers, show by acoustimeter measurement, a total muffling efficiency of at least 55 percent when the internal combustion engines, for which the mufflers were designed, are run at full load. A muffler for an automobile engine which has a muffling efficiency at full load of 75 percent is exceptional. Although the muffling efficiency of satisfactory mufflers for automobiles is only 55 percent at full load, it must be recognized that in cities where this efficiency should be high, automobile engines practically are never run at full load. Under light loads, characteristic of city driving, the efficiency may be well over 95 percent. Even on country roads where high speeds may be attained, automobile engines are seldom subjected to full load. On the other hand, motor boat engines and especially outboard motors, are very often run at full load, so that unless the muffler efficiency is high, that is, above 95 percent, the exhaust noise is excessive. This noise is heard for a long distance over the water and therefore is objectionable. The ordinary outboard motor muffler, although seemingly inefficient, has an efficiency of from 75 to 90 percent at the sacrifice of some back pressure. Stationary internal combustion engines and others which are run so that they are well loaded, usually must be equipped with high efficiency mufflers.

The efficiency of the muffler is determined by measuring the noise generated by the gases escaping into the atmosphere with and without muffling. The percent efficiency is the ratio of the decrease in measured sound to that measured without muffling. The muffler efficiency should be determined when the muffler is used with the engine for which it is designed. This is essential since the size, shape, amount of absorbing material, and other variables of the muffler are determined for each of the various sizes and types of engines.

Using my invention, as hereinbefore described, it is possible to construct mufflers of varying efficiencies, from 55 per cent to well over 95 percent by varying the quantity and type of absorbing material and by varying the construction as hereinbefore described. Such mufflers may be constructed so as to cause practically no increase in the back pressure on the engine at full load aside from that due to the surface friction of the duct walls. Furthermore, such mufflers may be made to occupy a small space, may be made light in weight, and may be built at a considerable saving in cost over the present-day muffler.

I claim:

1. A muffler comprising a substantially imperforate, oval outer casing having an opening in each end, a filling of sound-absorbing material in said casing, a cylindrical foraminous duct through said filling connecting said openings, the distance between said duct and said casing being at least twice as great along the major transverse axis of said casing as it is along the minor transverse axis of said casing, whereby the maximum thickness of said absorbing material in any transverse plane along said duct is at least twice the minimum thickness in the same plane.

2. A muffler comprising a substantially imperforate casing having an opening in each end, a lining of sound absorbing material in said casing having a duct therein connecting said openings whereby all of the gases passing through said casing flow through said duct, said duct being displaced substantially from the central axis of said casing so that the thickness of said absorbing material varies substantially in any transverse plane along the duct, the maximum thickness of said absorbing material in a given one of said transverse planes being at least twice the minimum thickness in the same transverse plane.

3. A muffler comprising a substantially imperforate casing having an opening in each end, a filling of sound absorbing material within said casing, a cylindrical passageway through said filling connecting said openings and communicating with said filling, whereby all of the gases passing through said casing flow through said passageway, said passageway being displaced substantially from the central axis of said casing, whereby the thickness of said lining varies substantially in any transverse plane along the greater part of its length.

4. A muffler comprising a substantially imperforate casing having an opening in each end, a foraminous tube within said casing connecting said openings whereby all of the gases passing through said casing flow through said tube, sound absorbing material in the space surrounding said tube, said tube being displaced substantially from the central axis of said shell whereby the thickness of said lining varies substantially in any transverse plane along the greater part of its length.

WALTER E. SPICER.