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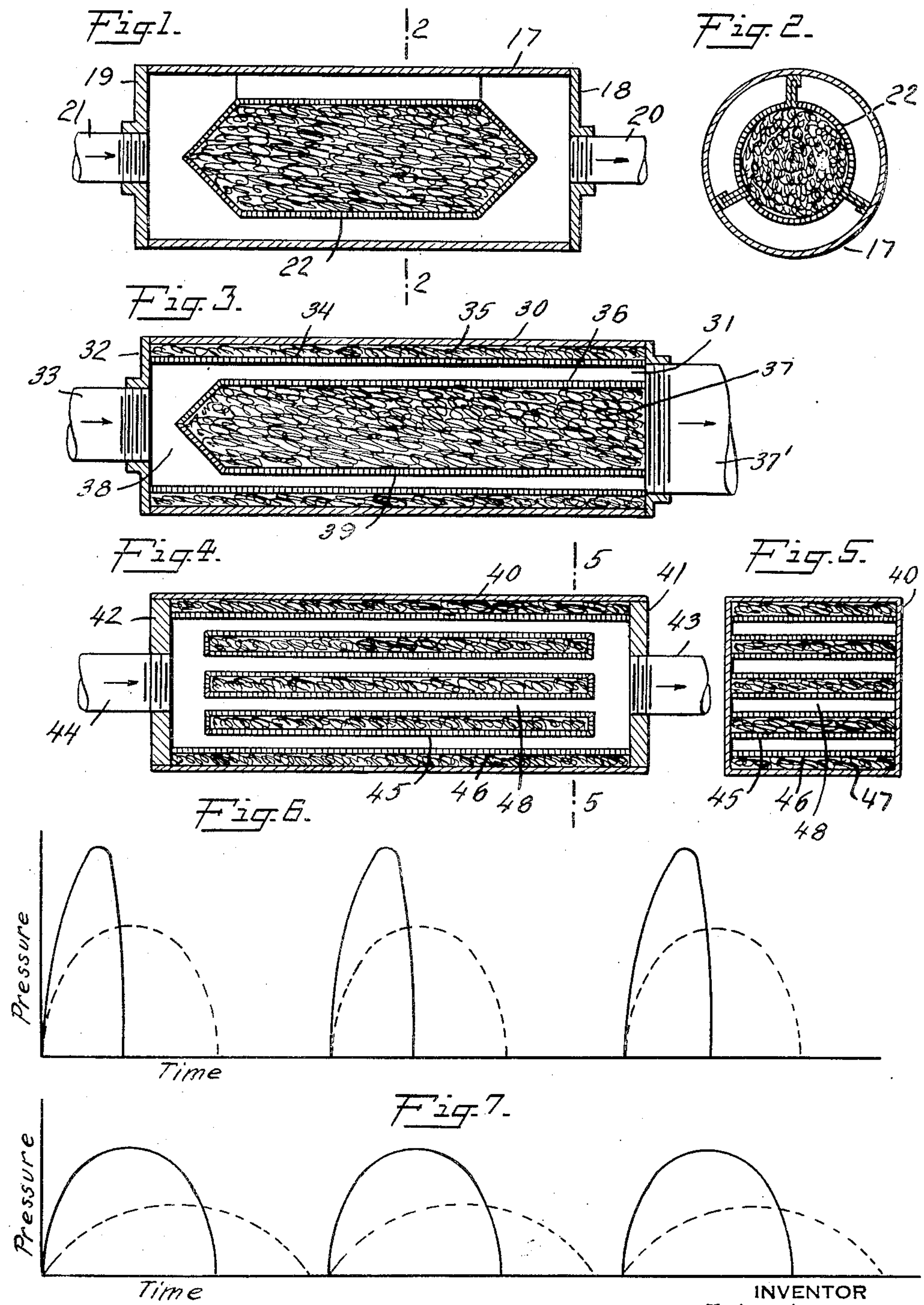
EXHAUST MUFFLER

Original Filed May 8, 1929



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UNITED STATES PATENT OFFICE

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EXHAUST MUFFLER

Original application filed May 8, 1929, Serial No. 361,376. Divided and this application filed May 29, 1929. Serial No. 366,890.

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 is a division of my co-pending application Serial No. 361,376, filed May 8, 1929 (now Patent No. 1,811,762, granted June 23, 1931).

My improved exhaust muffler departs very decidedly in construction from the exhaust mufflers heretofore employed.

The explosion within the cylinder of an internal combustion engine creates tremendous pressure therein. The steam or vapor in the cylinder of 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 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 exhaust noises the muffler must suppress the pressure peaks and thus even the flow of the escaping gas pulses to the point where a sound is not created. In addition, I have found that sound communicated to or generated within the muffler should be silenced.

The mufflers of the present day accomplish the desired result by any or all of the following methods: cooling the exhaust gases and diminishing their volume; allowing the gases to expand and reducing their pressure while confined; creating eddy currents and internal friction within the gases; causing friction between the gases and the walls and passages within the muffler; and/or impeding the forward progress of the gases by the interposition of baffles in their path. The typical muffler of today is a metal shell connected in the exhaust system of an engine which may incorporate one or more of the following features: an expansion and mixing chamber followed by a small outlet; a tortuous passageway; a series of obstacles or baffles in the passageway; and/or a jacket in which a cooling medium is circulated.

Only a limited sphere of application can at best be found for a muffler with a cooling jacket. The expansion chamber alone is not successful since it approaches the condition of the atmosphere and sound is created therein. The types embodying tortuous paths, obstacles, and baffles, retard the flow of gas, and in so doing, build up a back pressure within the muffler and reduce the efficiency of the engine. There is a muffler being produced which actually assists in the scavenging of the cylinder but the scope of its application is limited to special types of engines of known, constant speed.

It is an object of my invention to provide an exhaust muffler whose scope of application extends to practically all of the common types of explosion and steam engines, to fire arms, and to air intakes and exhausts as in air compressors.

It is a further object of my invention to provide a muffler which will not build up sufficient back pressure to appreciably reduce the efficiency of the engine.

It is a further object of my invention to provide a muffler which will silence explosion noises more effectively than do the mufflers at present employed.

It is a still further object of my invention to provide a muffler which is more simple in construction than are the present mufflers of commerce.

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 drawings, 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;

Fig. 3 is a longitudinal, sectional view of another form of my invention;

Fig. 4 is a longitudinal, sectional view of another form of my invention;

Fig. 5 is a transverse, sectional view on lines 5—5 of Fig. 4; and

Figs. 6 and 7 are charts which illustrate the effect of my muffling device upon exhaust gases.

One form of my invention is shown in Figs. 1 and 2. Outer cylindrical shell 17 is connected, as by welding, to discs 18 and 19. These discs may in turn be threaded to receive outlet and inlet pipes 20 and 21, respectively. Inner perforated shell 22 may be made of ribbed sections with the sections crimped together at the ribs as shown in Fig. 2, the ribs resting upon the inner surface of outer shell 17 and holding shell 22 in place. Within shell 22 the non-flammable gas-pressure absorbing and sound absorbing material is packed. The gases pass unobstructed through the annular duct or channel. The shell is filled with a porous gas-pressure absorbing and sound-absorbing material which may be a mineral fibre, steel, copper or other metallic wool or mixtures thereof, or any other porous sound absorbing, non-flammable matreial such as sized crushed mineral matter, mica, exfoliated vermiculite such as zonolite, blown slag, coke, pumice or other porous aggregates and built-up units of such aggregates. For silencing blow-off gases, air compressor intake and exhaust noises, and noises produced by gases at room temperature, flammable sound-absorbing materials such as wool, cotton, or other cellulosic fibers 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 a material to that transmitted by an equal area of 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 assembled. In the mufflers of my 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, by 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. The absorbing material should be of appreciable thickness for best results. It should be at least one-quarter of an inch thick and preferably one-half inch or more. By mineral fibre I contemplate natural or artificial mineral wool, shredded asbestos, or any other mineral material of the same general nature.

As hereinbefore explained, a series of gas pressure peaks emerges at high velocity from pipe 21. Each peak tends to expand in all directions. The gas and pressure waves freely pass through perforated shell 22 and enter the core. 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 low manufacturing costs I prefer circular openings. Holes suitable may vary from approximately 0.070 to 0.125 inches 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 from 2½ percent up to 35 percent 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. The shape, size and distribution of the perforations all have an influence on the ease with which gases and sound pass through the sheet of 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. 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 2½ 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.

The fibrous gas-pressure absorbing and sound absorbing material comprises non-flammable fibers distributed in heterogeneous arrangement to form tiny interstices, pores or cells of more or less uniform size and distribution. It is packed in such a manner that usually only from 1 to 20 percent of annular space 2 is occupied by the actual fibres of the material and therefore 80 to 99 percent is free space. The packed fibers, depending on their physical properties, weigh after packing in the muffler, from 4 to 100 pounds per cubic foot. The packed mineral wool weighs from 9 to 36 pounds per cubic foot, the fibers occupying from 5 to 20 percent of the space. Steel wool weighs from 4 to 100 pounds per cubic foot, the fibers occupying from 1 to 20 percent of the space. Especially good results are obtained with steel wool packed to occupy 2 to 5 percent of the space. If the fibers are packed too loosely they jar down into a more compact mass after the muffler is put into use, and if they are packed too tightly the gas-pressure obsorption and acoustic absorption are cut down, thereby decreasing the muffler efficiency. The absorbing material is subjected to violent pounding and vibration by the oscillating influence of the exhaust gases and must not disintegrate readily under those conditions. Certain types of mineral wool resist this disintegrating action much better than others. However, a metallic wool like steel wool is highly resistant to this action. The sound-absorbing portion of the muffler, therefore, provides an expansion space for gas-pressure peaks and the maximum pressure of the pulse of gas is decreased as a result of the expansion, the pressure wave being longer and lower in intensity. Fig. 6 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 the core to further flatten the wave characteristic. Relatively speaking, the rapidly moving gas enters the core in the form of a succession of rapid compressions and rarefactions. The compressions are suppressed and merged together by the choking effect of the walls of the tiny pores or cells with a resulting reduction of the intervening rarefactions. Fig. 7 shows in solid lines the pressure wave characteristic corresponding to the dotted curve of Fig. 6. The dotted lines of Fig. 7 show the pressure wave characteristic after the gas has undergone 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, and especially if shell 22 is made of smooth perforated, sheet metal, 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. I believe this to be entirely new in the muffler art.

I believe that some noise is generated at the end of pipe 21 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 since sound does not project itself in single directions to form rays. It emanates equally in all directions unless it encounters reflecting surfaces. Foraminous shell 22 allows this sound to pass freely therethrough and it is thereafter absorbed by the material in the core.

Fig. 3 illustrates a further modification of my invention embodying a combination of the features illustrated in Figs. 1 and 2. Outer metallic cylindrical shell 30 has opening 31 at one end and is connected, at its other end to end closure disc 32 which may have a threaded opening to receive inlet pipe 33. Within outer cylinder 30 and spaced therefrom is inner coaxial cylinder 34 of perforated sheet metal. The annular expansion space 35 is filled with loosely packed gas-pressure absorbing and sound absorbing material. Centrally located within inner cylinder 34 is cylindrical core 36 of perforated metal which may have a conical end as shown and which is also filled with absorbing material 37. The gas enters and is allowed to expand in space 38 and thereafter follows annular channel 39, lined on both sides with absorbing material, to the exit opening 31 which may open directly to the atmosphere, or communicate with an exhaust pipe 37′. This muffler shows a high muffling efficiency for the space occupied by it and is well adapted to be used where a high efficiency muffler occupying a small space is needed as on outboard motors.

Figs. 4 and 5 illustrate a still further modification of my invention. Outer sheet metal shell 40 is welded or riveted or otherwise fastened to metallic end pieces 41 and 42 which may be rectangular and which are threaded to receive outlet and inlet pipes 43 and 44 respectively. Within shell 40 there is a plurality of parallel spaced perforated metal shells

45 which are filled with loosely packed absorbing material. This muffler also shows a high efficiency for the space occupied by it and is well adapted for use with outboard and similar motors.

Perforated metal sheets 46 may be spaced about the thickness of one of the shells 45 from the sides of outer shell 40 and the space 47 between them may be filled with absorbing material. Channels 48 form passageways for the gases to pass through the muffler.

Tests conducted with my invention gave surprising results. Keeping constant the muffler length and the thickness of the layer of gas-pressure and sound absorbing material adjacent the interior of the outer shell it was found that varying the diameter of the muffler within reasonable limits produced no appreciable change in ultimate quantity of sound, measured by means of an acoustimeter, which emerged from the muffler when the latter was connected in the ordinary manner in the exhaust system of an internal combustion engine. However, when the unmuffled exhaust noises were acoustically separated from the gases and conducted to the muffler through an intake pipe similar to that used in the prior tests, it was found that the quantity of sound emerging from the muffler varied with the diameter of the muffler. From such data it appears that a muffler of small diameter, while it does not permit much expansion and does not act as efficiently upon the gas pulses, acts more efficiently upon the noise created therein with ultimate muffling equal to or better than that of the larger device which allows the gas to expand more and thus acts more efficiently upon it but acts less efficiently upon the noises created therein. The muffler absorption for any one absorber may be increased by increasing the thickness of the absorber within limits, or by increasing the outside diameter of the muffler within limits, or by increasing the length of the absorber without changing its thickness, or by decreasing the gas duct diameter within limits.

While I have illustrated and described but a very few simple forms of my invention, it is understood that I may employ a great many forms since I believe that I have invented the broad principle of providing a muffler with gas-pressure absorbing and sound absorbing material adjacent the path of the exhaust gases and do not wish to be confined to structural details. For instance, the inner shells may be of wire screen, or other suitable foraminous material, or may be entirely omitted as hereinbefore explained, and the general shape of the device need not be cylindrical. Its cross section may be circular, rectangular, elliptical or of any other form and the manner of assembling the parts may vary considerably from that described hereinbefore. The rectangular section is more effective than the circular section because of the greater area of absorber exposed to the gases in proportion to the cross-sectional area of the duct. My muffler consists essentially of a duct lined with gas-pressure absorbing and sound absorbing construction which may be a duct lined with absorbing material without a foraminous lining. It may be a fibrous sound-absorbing lining combined with a foraminous or perforated section of engine exhaust pipe or any duct conducting noise-producing gases. For non-pulsating noisy gases such as are encountered in intakes of air compressors, the cutting down of the gas pressure peaks is not a factor.

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 relative to 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 or 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 change therein which causes them to emerge almost, if not quite, noiseless.

Mufflers which are considered satisfactory and used by automobile manufacturers, show by acoustimeter measurement, a total muffling efficiency of at least 55 per cent 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 power due to 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 percent 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 occupy a small space, are light in weight, and may be built at a considerable saving in cost over the present-day muffler.

I claim:

1. A muffler for noise-producing gas comprising an open-ended shell and a core of gas-pressure absorbing and sound absorbing construction with an annular space between said shell and said core forming a substantially unobstructed passage for the gases from the inlet of said muffler to the outlet thereof.

2. A muffler for the exhaust gas of an internal combustion engine comprising an open-ended shell and a core of gas-pressure absorbing and sound absorbing construction in said shell, said core comprising porous-packed non-flammable fibers, with a channel for said gas between said shell and said core forming a substantially unobstructed passage for the gases from the inlet of said muffler to the outlet thereof.

3. A muffler for noise-producing gas comprising an outer open-ended metallic shell, and an inner foraminated shell spaced from said outer shell, said inner shell containing gas-pressure absorbing and sound absorbing material, and a channel between said shells, said channel forming a substantially unobstructed passage for the gases from the inlet of said muffler to the outlet thereof and offering no appreciable resistance to the flow of said gas therethrough.

4. An exhaust muffler for internal combustion engines comprising an outer, open-ended metallic shell, an intermediate, coaxial, open-ended perforated metal shell forming a space between said shells, the space between said shells being filled with porous-packed non-flammable gas-pressure absorbing and sound absorbing material, and an inner, coaxial, perforated metal shell, said inner shell enclosing porous-packed, non-flammable, gas-pressure and sound absorbing material and forming a space between said intermediate shell and said inner shell, the space between said intermediate and inner shells forming an open channel for the exhaust gas.

5. A muffler for noise-producing gas comprising an open-ended outer shell, an intermediate coaxial open-ended foraminated shell forming a space between said outer shell and said intermediate shell, a filling of porous-packed gas-pressure absorbing and sound absorbing material arranged in the space between said shells, an inner coaxial foraminated shell forming a space between said intermediate shell and said inner shell, and a filling of porous-packed gas-pressure absorbing and sound absorbing material arranged in said inner shell, the space between said intermediate and inner shells being an open channel offering practically no resistance to the flow of said gas therethrough, the absorbing material between said outer shell and said intermediate shell and within said inner shell presenting surfaces to said gas and being of such thickness and efficiency that its average sound-absorption value is at least 25 percent.

6. A muffler for the exhaust gas of an internal combustion engine comprising in combination with an open-ended shell, a core of gas-pressure absorbing and sound absorbing construction comprising porous-packed non-flammable fibers weighing from 4 to 100 pounds per cubic foot, with a channel for said gas between said shell and said core, said channel forming a substantially unobstructed passage for the gases from the inlet of said muffler to the outlet thereof, said muffler having a muffling efficiency of at least 55 percent when used with a fully-loaded engine.

7. A muffler for the exhaust gas of an internal combustion engine comprising in combination with an open-ended shell, a core of gas-pressure absorbing and sound absorbing construction, with a channel for said gas between said shell and said core, said channel forming a substantially unobstructed passage for the gases from the inlet of said muffler to the outlet thereof, said muffler having a muffling efficiency of at least 55 percent when used with a fully-loaded engine.

8. An inner core for an exhaust muffler for an internal combustion engine comprising a cylindrical perforated metal shell enclosing porous-packed, non-flammable gas-pressure absorbing and sound absorbing material, at least one end of said shell being conically

shaped, said shell having longitudinal, exteriorly projecting ribs.

9. As a new article of manufacture, a perforated sheet metal shell enclosing porous-packed gas-pressure absorbing and sound absorbing material, said shell having exteriorly projecting ribs.

10. As a new article of manufacture, a cylindrical perforated metal shell enclosing porous-packed metallic fibers, at least one end of said shell being conically shaped, said shell having longitudinal, exteriorly projecting ribs.

11. A muffler for the exhaust gas of an internal combustion engine comprising in combination, a duct for said gas extending substantially unobstructed from the inlet of said muffler to the outlet thereof and an expansion space contiguous and inside of said duct, said space containing gas-pressure absorbing and sound absorbing material exposed to said gas when passing through said duct.

12. A muffler for the exhaust gas of an internal combustion engine comprising in combination, a duct for said gas and expansion spaces contiguous both inside and outside of said duct, said spaces containing gas-pressure and sound absorbing material exposed to said gas when passing through said duct.

In testimony whereof I affix my signature.

FREDERICK H. SCHNELL.