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2,300,130 10/1942 McCurdy 181/67 X
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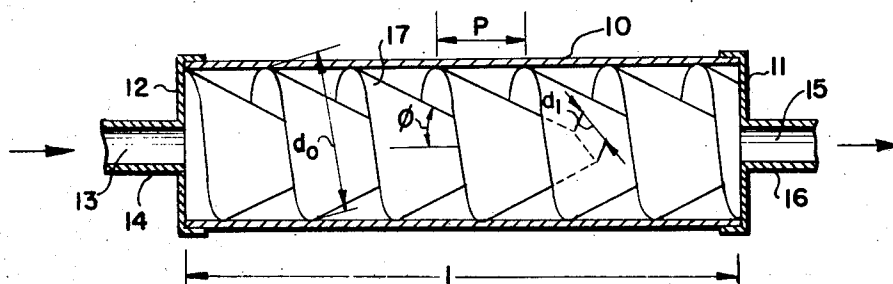
[54] **SOUND AND RESONANCE CONTROL DEVICE**
9 Claims, 3 Drawing Figs.

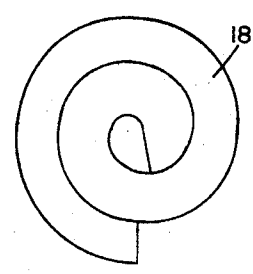
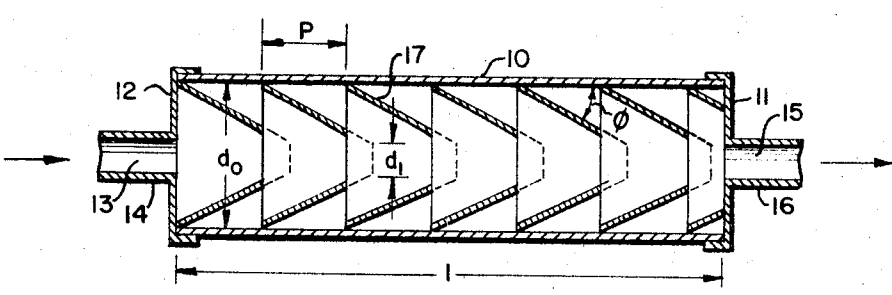
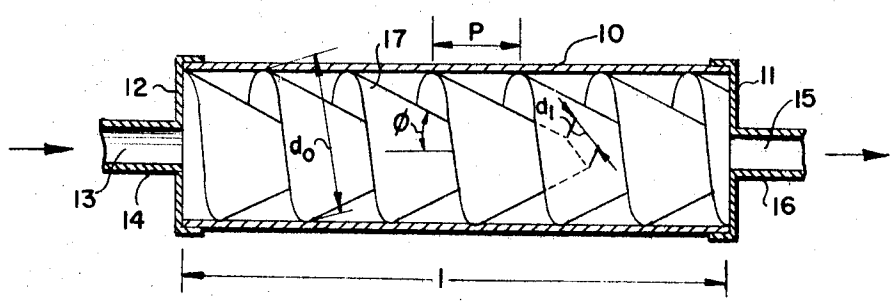
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[56] **References Cited**
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1,003,531 9/1911 Smoot et al. 181/70 X
1,127,892 2/1915 Hornquist 181/67 X
2,274,599 2/1942 Freeman 181/67 X

ABSTRACT: Sound and resonance apparatus for systems engaged in dissipating gases under varying temperature, pressure and velocity conditions.

The present invention is directed to control systems adapted to muffle and/or silence the explosive sound of gas emulsion under elevated temperature, pressure and high velocities as in exhaust gases emitted from various engines such as combustion engines, industrial tubular structures, firearms and the like by directing said gas into a muffler device or system having a concave end of a helicoidally formed body by casting or provided by a strip wound into a number of helicoidal cones; namely, and helicoidal cones having their transverse surfaces inclined, pitched or sloped at an angle within controlled limits to the axis of the helicoid and distance between the base and apex of each of said helicoid cones; namely, the frustums, by which is meant a spatially formed helicoidal cone being within prescribed spaced limits in order to effect maximum efficient as to resonance and sound control and the beneficial utilization of the exhaust gases to do work.





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SOUND AND RESONANCE CONTROL DEVICE

BACKGROUND OF THE INVENTION

The art on muffling sound as in exhaust silencers for exhaust systems of engines and the like is well known by reference to U.S. Pat. Nos. 3,354,986; 3,348,629; 3,306,393; 3,315,761; 3,329,237 and 2,274,599 or as described in "Handbook of Noise Control" by C. M. Harris, Sections 18-7, 18-8 and 31-16 to 20. Generally, the methods described in the references cited as well as in other art on the subject control or silence noise to some degree but are ineffective in controlling resonance at varying frequencies or improving power output of engine systems or the like.

It is an object of the present invention to provide a sound control apparatus having improved silencing, resonance and power improving control.

Another object of the present invention is to provide a new and improved muffler for combustion engines.

Another object of the present invention is to provide a new and improved muffler designed to attenuate or minimize the occurrence of resonance at certain frequencies.

Still another object of the present invention is to improve engine efficiency by providing a new and novel muffler capable of controlling sound of the exhaust and back pressure at a minimum.

Other objects of this invention will be apparent from the following description.

SUMMARY OF THE INVENTION

The present invention is directed to a new, novel helixlike improved sound control device, such as a muffler for internal combustion engines, said muffler having a novel construction which essentially eliminates noise, prevents the occurrence of resonance and improves engine efficiency by reducing to an optimum low back pressure and utilizes the exhaust gases to effect improved engine operation said desired multifunctional effects being accomplished by controlling the direction of the exhaust gases emitted from the engine or related devices at elevated temperature and pressure and high velocity through a novel muffler device by having within the casing of the muffler a number of helicoidally formed cones provided by a winding or casting having a helixlike form or spiral cone and having their transverse surface inclined within specific controlled angle limits, as well as having within specified limits the spacing of each generated frustum or each geometric or spatial unit of said cone and the diameter of the base of each cone and also having the ratio of the spacing of said generated frustum of said cones to the diameter of the base of the cone within specified limits, so as to obtain the benefits of the present invention. Specifically, in a muffler of the present invention which is illustrated by FIG. 1, wherein l is the length of the muffler, d_o is the outside diameter of the muffler, d_1 is the cone orifice envelope diameter, p is the spacing of the helicoids and Φ is the angle which the helicoid makes with the centerline of the muffler; and the proportions of the muffler can be defined in the following terms: d_o/l , d_o/d_1 , d_o/p and Φ empirically it has been determined that the following ranges to the above parameter apply:

d_o/l should be from about 0.015 to 0.70;

d_o/d_1 should be from ∞ to 2;

d_o/p should be from 5 to 0.5; and

Φ should be from 90° to 20° . However, these parameters are not to imply that the values of d_1 , p and Φ are constant and they may be varied within a given muffler. Thus, as the volume of gases to be muffled increases, considerations of laminar flow would affect the ratios as follows: d_o/l and d_o/d_1 approach the lower value indicated above; d_o/p will approach the higher value and Φ will tend to be reduced. However, these trends are not to imply that the values of p , Φ and d_1 cannot be varied within the same muffler. Preferred is when the angle Φ is between about 20° and about 65° with the axis of the helicoid, the spac-

ing between each helicoidal cone (frustum) indicated in the illustration by the symbol l being between about 6 inches and about 48 inches and more. Table 1 illustrates variations in the above ratios.

TABLE 1

d_o/l		l			d_o/d_1		
1	2	8	12	12	.083	.166	.666
1	2	8	24	24	.0415	.083	.333
1	2	8	36	36	0.0278	0.0555	0.222
1	2	8	48	48	0.0208	0.0415	0.1666
1	2	8	60	60	0.0166	0.0333	0.1333
1	2	8	72	72	0.01385	0.0278	0.1111

¹ d_o/d_1 can be even less than "0" hence ∞ . The larger d_1 can be more than half of d_o , hence equal 2. So these limits can vary over a wide range.

² The lower ratio can be as low as d_o/l equals 0.01385 and the higher ratio can be as high as d_o/l equals .666 or 0.70.

Generally, the spacing (p) may be varied along the length of the muffler to accomplish best the processing of the exhaust gases through this novel device, and to render acoustic tuning to effect maximum suppression of resonance. Not illustrated in the figure but which can be effectively accomplished is the change in same muffler the orifice diameters of individual or grouping of "helical-cones," the change in orifice diameter is to further facilitate acoustical tuning and to extract out objectional noise, and by changing the orifice diameter (d_1) within the "cones" further reduction in back pressure may be obtained.

To prevent the occurrence of resonance, or to provide for acoustical tuning and to minimize the back pressure following modifications should be also observed: (1) varying the cone angle Φ as in FIG. 1; (2) varying the orifice diameter (d_1) facilitates the reduction in back pressure as well; (3) varying the spacing distance (p); (4) varying diameter to the frustum spacing (p) and to the length ratio of the muffler d_o/l ; (5) perforating or sound proofing some of the helical cones towards the end.

FIG. 1 is a side view partially in section of a muffler of the present invention;

FIG. 1a is a sectional side view of an alternative embodiment utilizing helicoidal cones; and

FIG. 2 is a schematic view illustrating a rolled helicoidal sheet metal inside member.

In FIG. 1, which illustrates a muffler of the present invention, the muffler comprises of a casing 10, having end closure plates 11 and 12. The closure plate 12, is at the inlet end of the muffler, as indicated by the arrow, and is provided with an opening, 13, for the admission of gases under pressure and velocity conditions to the interior of the casing 10; the opening 13 is surrounded by a flange 14 for coupling to the exhaust from a motor. The inner structure just described can be accomplished by forming it from strip metal, or from appropriate stampings, or by casting. The helicoidal cone surfaces may also be lined with laminated material to house active chemicals or catalysts to modify the gases as they pass through the inner structure.

The end closure 11 is likewise provided with an exhaust opening, 15, also surrounded by a flange 16 for suitable coupling to an exhaust pipe if desired. While I have shown the flanges defining inlet and outlet openings as centered with respect to the casing, it will be understood that they may if desired, be placed eccentrically thereto.

Within the casing 10 is generally helicoidal baffle 17. This baffle is formed by twisting or coiling a strip of ribbon of suitable material such as metal in a generally helicoidal path so that the transverse surface of the ribbon or strip extends at controlled angle Φ of 20° — 65° to the axis of the helicoid and the "frustum" of each helicoid or cone is restrictively spaced as indicated by p .

The free inner edge of the baffle can be stabilized by folding it, doubling it, or otherwise reinforcing it.

The inclination of the transverse surfaces of the strip should preferably be such as to form an angle of between 20° and 65° with the axis of the helicoid, and this angle is indicated as Φ in FIGURE 1.

The spacing of adjacent helicoids or frustums convolutions (p) should be such, with relation to the inclination of the transverse surfaces thereto (Φ) that adjacent generally helicoidal surface overlap in planes perpendicular to the axis of the helicoid, as clearly indicated in FIG. 1. Also, the diameter of the cone (d_c) and the ratio of $\Phi:p$ should be within space predetermined limited to affect the sound and resonance control.

While the specific design of the helicoidal baffle depends upon the specific pressure and velocity conditions of the gas which it controls, it is preferable that the inclination of adjacent convolutions should vary from end to end of the baffle. When high-pressure conditions are encountered, it is preferable to provide the generally helicoidal baffle steeper initial angle (Φ) and with gradually or intermittently decreasing inclination. Thus, its first convolution should be arranged so that its transverse surface extends at a greater angle to the axis of the helicoid than do the succeeding convolutions. Under low-pressure conditions, it is preferable to provide the generally helicoidal surfaces at a less steep initial angle (Φ) of inclination, and with succeeding convolutions extending at still lesser angles. It should be noted that this device may be designed to follow an intermittent or a true helicoidal path, and mufflers embodying this when tested under practical conditions gave excellent results. Therefore, while the inclination, slope or pitch of the convolutions may be varied as desired, this device may be designed without such variations.

The construction of the mufflers of the present invention can be made by any suitable material and by any suitable means provided the helix conelike shapes within the casing of the muffler conform to the specification limits set forth. In order to have the helix conelike shapes corresponding in principle to the shape of an empirical logarithmic spiral and having the general mathematical formula, $\rho^x = Ae^{\alpha\theta}$ (I) wherein x is an integer of from 1 to 12, preferably 5 to 7; A and α is a unit measure and is a constant; ρ represents the vector radius, and e is the base of the natural logarithm.

PREFERRED EMBODIMENT

In order to illustrate the invention an engine muffler was constructed the inside functional members being formed by endless cones of helicoidal shape having the restrictions imposed as defined and corresponded to the shape of an empirical logarithmic spiral as defined within the limits of the above formula (I).

The inside functional members of the muffler were formed of endless cones of helicoidal shape. In order to form these cones at different pitches inclination or slopes and heights, strips were cut out of 24-gauge or 26-gauge metal corresponding to the shape of an empirical logarithmic spiral and having the general mathematical formula (I). In one muffler x represented 5; in another, $5\frac{1}{2}$; in $5\frac{1}{2}6$; in another $6\frac{1}{2}$. Theta (θ) was used from 0° to 900° . Alpha was used as unit of inches. In the formula A and α were used as constants and e in the formula was the base of the natural logarithm. Rho (ρ) represented the vector radius. This illustrated in FIG. 2 showing the sheet metal member 18 formed in accordance with the foregoing.

Each spiral strip was rolled to form a multiple continuous layer truncated cone. In some cases the cone was rolled from the inside; that is, with theta equaling zero; in other cases the cone was formed starting from the point where theta equals 900° . In each case, the sequence of cones was different as to pitches. The former method produced cones in which the sequence commenced with short cones and steep pitch. Such a muffler constructed by these cones offered greater resistance to exhaust gases and produced somewhat higher values in back pressure. The latter method produced cones in which the sequence commenced with cones of greater height and lesser slope, the range of slope of which varied between 15° and 35° . In this case the unrestricted central opening amounted to about $1/64$ — $1/8$ of the overall diameter of the baf-

fle. A muffler constructed of these cones offered less resistance to exhaust gases and the back pressure was at a minimum, for example, at 60 m.p.h. the back pressure was found to be about $\frac{1}{2}$ pound per square inch; at 84 m.p.h. it was found to be about $1\frac{1}{4}$ pound per square inch, which is substantially better than the performance of conventional mufflers. A spider constructed for each muffler of about $\frac{1}{2} \times \frac{1}{2}$ inch strip metal can be made to fit into the previously formed 5-inch cylinder or direct into the tailpipe. The truncated cone can be pulled apart so as to form a series of endless generated cone-shaped portions so shaped that the apex of one cone fell within the base of the succeeding cone and the "frustum" of each cone is spaced within prescribed limits. This series of cones can be inserted into the spider and each cone can be welded, screwed, slotted, etc., to the sides of the spider.

The completed spider, with the cones welded thereto, can then be inserted into the respective cylinders. The sidewalls of the spider in each instance can be welded to the sides of its respective cylinder.

Both ends of the respective cylinders can be sealed by welding or otherwise fastening caps thereto with adapter tubes of each end having a diameter of 2 inches at the inside at the exhaust end, and a diameter of $1\frac{1}{4}$ inches on the inside at the inlet end.

These mufflers which differ as pointed out above in the selection of different values of x in the formula, were installed in turn and the performance checked under actual operating conditions over a period of time. Under the conditions tested it was found that the muffler constructed where x was equal to $5\frac{1}{2}$ performed most satisfactorily, although all of the mufflers performed in a satisfactory manner and in a manner superior to the performance of conventional mufflers. While for the particular engine, this value of x was found to be desirable, it will be appreciated that this is merely a specific example. Engines vary materially both in design and function and in each case, it will be desirable to design a muffler adapted to suit the conditions encountered. Variation in design for different conditions will effect not only the design of a stamping from sheet metal, as described above, but also structural design of the muffler, including design consideration, such as slope of the baffle, spacing of its convolutions, and the relative opening, if any, as their apexes. While not one specific muffler can be designed to take care of all eventualities, nevertheless, mufflers designed in accordance with the present invention are suitable for a wider range of conditions than are conventional mufflers. Accordingly, then, the value of x and its constants A and α might have any positive values of greater variation, as for example, x was tried when equal from 1 to 12.

The effectiveness of the present device as an acoustic muffler is contingent upon varying the spacing so that the frequency spectrum of sound tuned out approaches the optimum range. Also, varying within a given muffler the outside diameter of the helicoidal cones, that is, constructing the muffler as the "frustum" of a cone rather than a cylinder, and that in combination with the spacing of the helicoidal cones, creates an uninterrupted continuous series of acoustical chambers within the muffler of varying dimensions and volume so that each chamber is tuned to extract a given frequency segment of sound, and in total, most objectional sound. The propositions of the acoustical chambers would be determined through empirical test and might be peculiar to each specific engine design, or condition of the engine performance.

Resonance at corresponding frequency is common in mufflers and in the present device can be effectively eliminated by several means. In the first place, the portion of the muffler at which the resonance originates may be located readily by listening devices such as for example as the use of an ordinary stethoscope. Alternately, the resonance may be located by placing a stick against the muffler, moving the stick throughout its length and observing the location at which the resonant effect is most audible.

Avoidance of resonance, can be accomplished providing some means for breaking up the pattern of the exhaust gas

flow at or adjacent the source of the resonance. A simple means is to cut the muffler at the point of resonance and to thereafter rotate one portion of the muffler with respect to the other and thereafter coupling the two parts together. Other means of eliminating resonance is to form separations in the muffler construction, insertion of foraminous screens at point of resonance, deforming the helical-conical baffle rotating the helical-conical baffle out of phase, providing openings such as by drilling holes in the cylindrical wall or casing at point of resonance, or providing means to prevent vibration and to deaden the baffle.

The muffler device of the present invention is actively doing work in removing the exhaust gases. The work done by this system corresponds in some fashion to the Bernoulli theorem, except in this case the exhaust gases under pressure and velocity are the sources of energy to produce this work. Since this variable can be optimized, the back pressure and resonance can be controlled by a prescribed design.

Mufflers of the type disclosed herein have been thoroughly tested in operated and its found that they are superior to conventional-type mufflers, both in reducing the sound of the motor exhaust and also in overall efficiency of the motor. The back pressure produced by these mufflers is relatively smaller. Moreover, mufflers according to this invention may be produced in continuous lengths at relatively small cost. their installation in motor vehicles is greatly simplified since they may be applied in the same manner as conventional exhaust pipes or insert into the exhaust-tailpipe. The mufflers may be flexible and may accordingly be bent to the necessary shape for fitting in the desired vehicle.

The drawings and the foregoing specification constitute a description of the improved muffler in such full, clear, concise, and exact terms as to enable any person skilled in the art to practice the invention, the scope of which is indicated by the appended claims.

I claim as my invention:

1. A new and improved silencing device comprising an elongated tubular casing having an inlet and outlet opening for exhaust gases and having in said casing a helicoidal conelike structure through which the exhaust gases flow at elevated temperature and pressure and at a high velocity in a spiral movement the slope angle of the helical cone structure being between about 20° and 90° , the spacing for each of the helical cones being within specified limits, the ratio diameter of the cone to the length of the muffler being from about 0.015 to 0.7, the ratio of the diameter of the cone to the orifice ranging from infinite to 2 and the ratio of the diameter of the cone to the spacing of the helicoils ranging from 5 to 0.5.

2. The device of claim 1 being a muffler wherein the ratio of the diameter of the cone to the spacing of the helicoils ranges from 2 to 0.5 said muffler being capable of inhibiting resonance and utilizing the exhaust gases to produce useful work.

3. The muffler of claim 2 designed for combustion engines, said muffler having a plurality of helicoidal cones, the slope angle of each cone increasing progressively from the inlet to the outlet opening.

4. The muffler of claim 2 designed for combustion engines, said muffler having a plurality of helicoidal cones, the slope angle of each cone decreasing progressively from the inlet to the outlet opening.

5. The muffler of claim 3 having holes in said helicoidal cone structure.

6. The muffler of claim 4 having holes in said helicoidal cone structure.

7. The muffler of claim 3 wherein the helicoidal cones are out of phase with each other.

8. The muffler of claim 4 wherein the helicoidal cones are out of phase with each other.

9. The muffler of claim 1 having curved deflectors.