

- [54] **MUFFLER AND SPARK ARRESTOR FOR INTERNAL COMBUSTION ENGINE**
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- [73] Assignee: **Enviro-Acoustic R & D Inc.**, Duluth, Minn.
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- [52] U.S. Cl. **181/49, 181/57**
- [51] Int. Cl. **F01n**
- [58] Field of Search **181/47, 49, 47 B, 181/36 A, 63, 40, 46, 48, 56, 57**

References Cited

UNITED STATES PATENTS

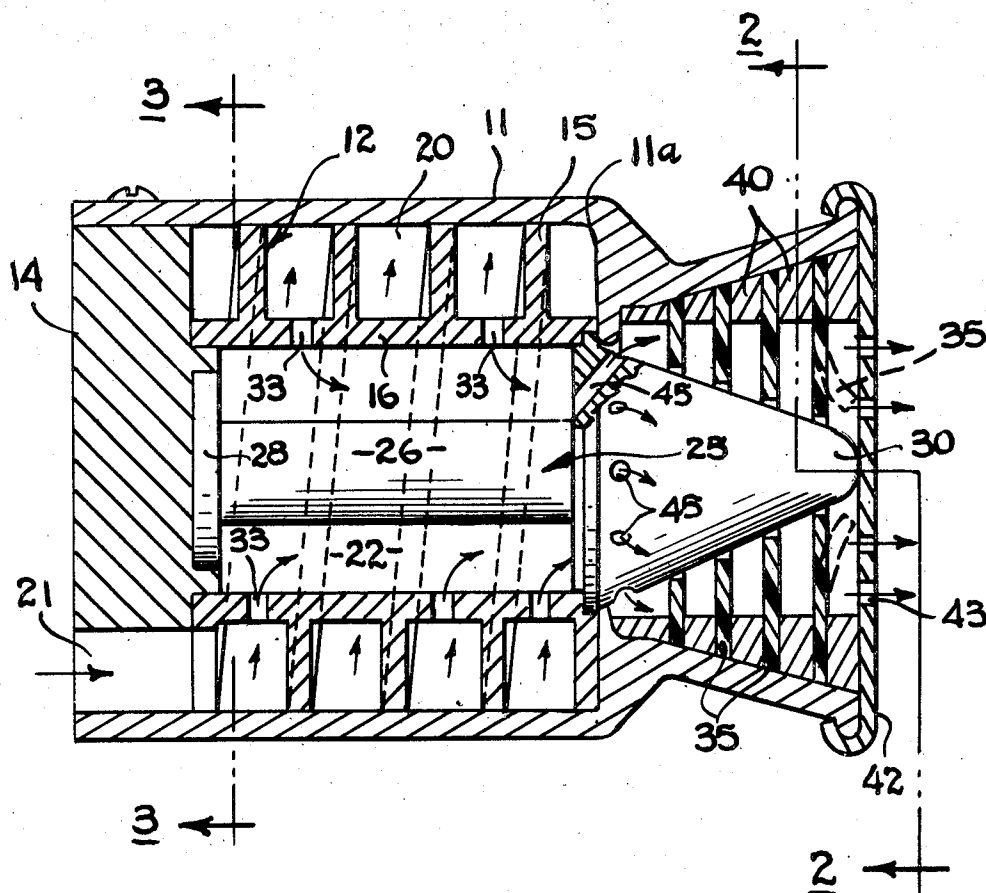
- 2,933,148 4/1960 Hendry 181/47 A

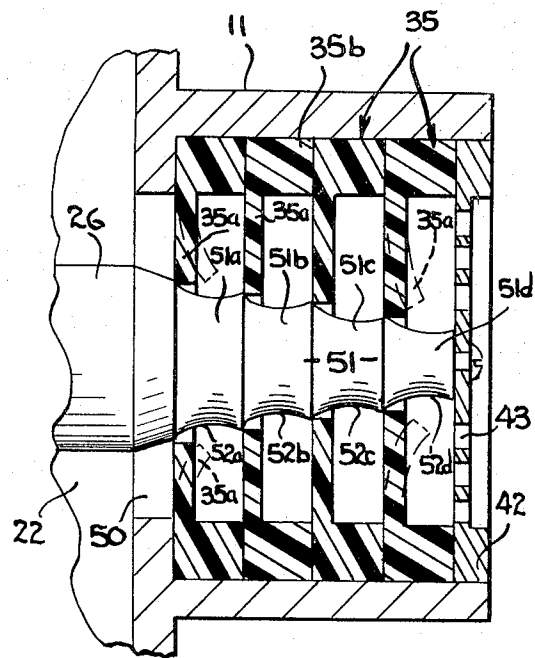
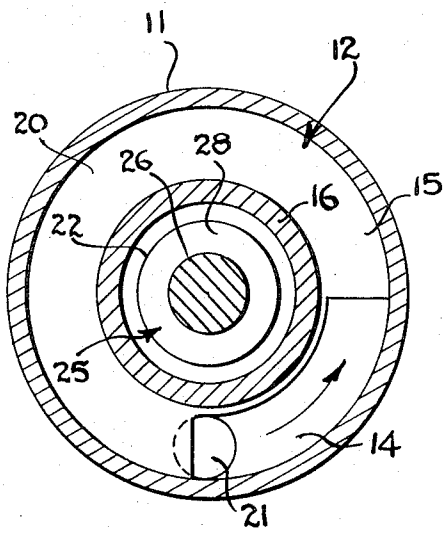
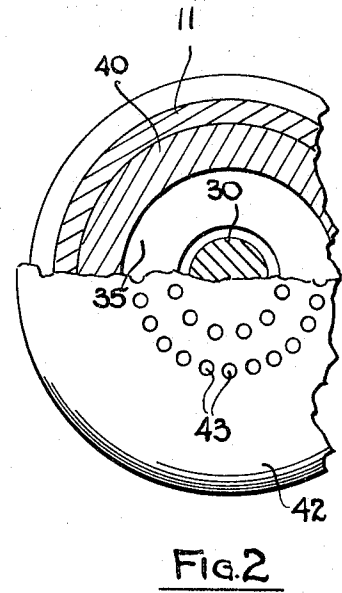
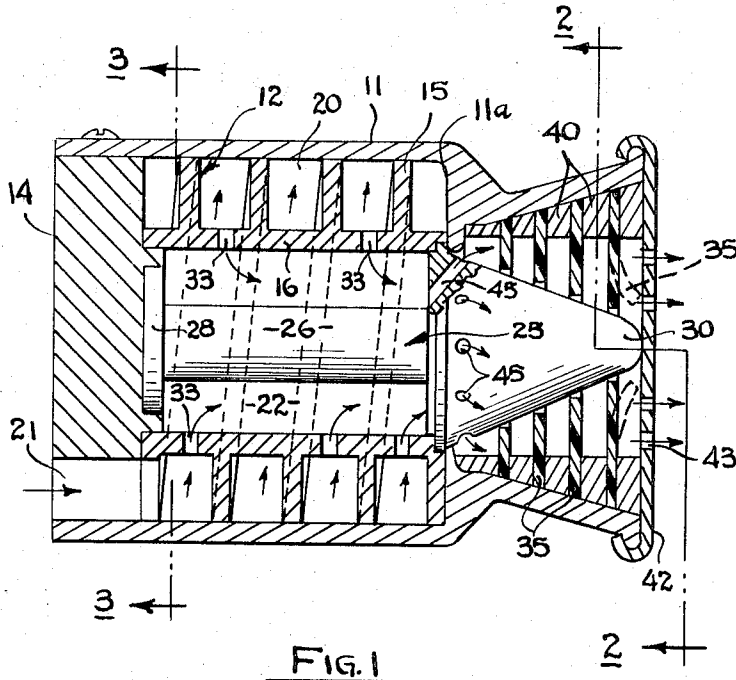
Primary Examiner—Richard B. Wilkinson
Assistant Examiner—Patrick Salce
Attorney—Edward A. Sokolski et al.

[57] ABSTRACT

A tuned cavity is provided to receive the exhaust gases from an internal combustion engine, the cavity being proportioned so that an acoustical standing wave is set up therein at the principal frequency of the noise output of the engine, pressure nodes of this wave appearing at the opposite ends of the cavity. The gas from the cavity is passed through a series of apertures spaced therealong into a chamber in a manner so as not to significantly affect the standing wave pattern. The gas is then passed from the chamber to a section comprising flexible diaphragm means which acts as an inertial damper and a flap valve, the gas being exhausted into the ambient atmosphere from the diaphragm section.

19 Claims, 13 Drawing Figures





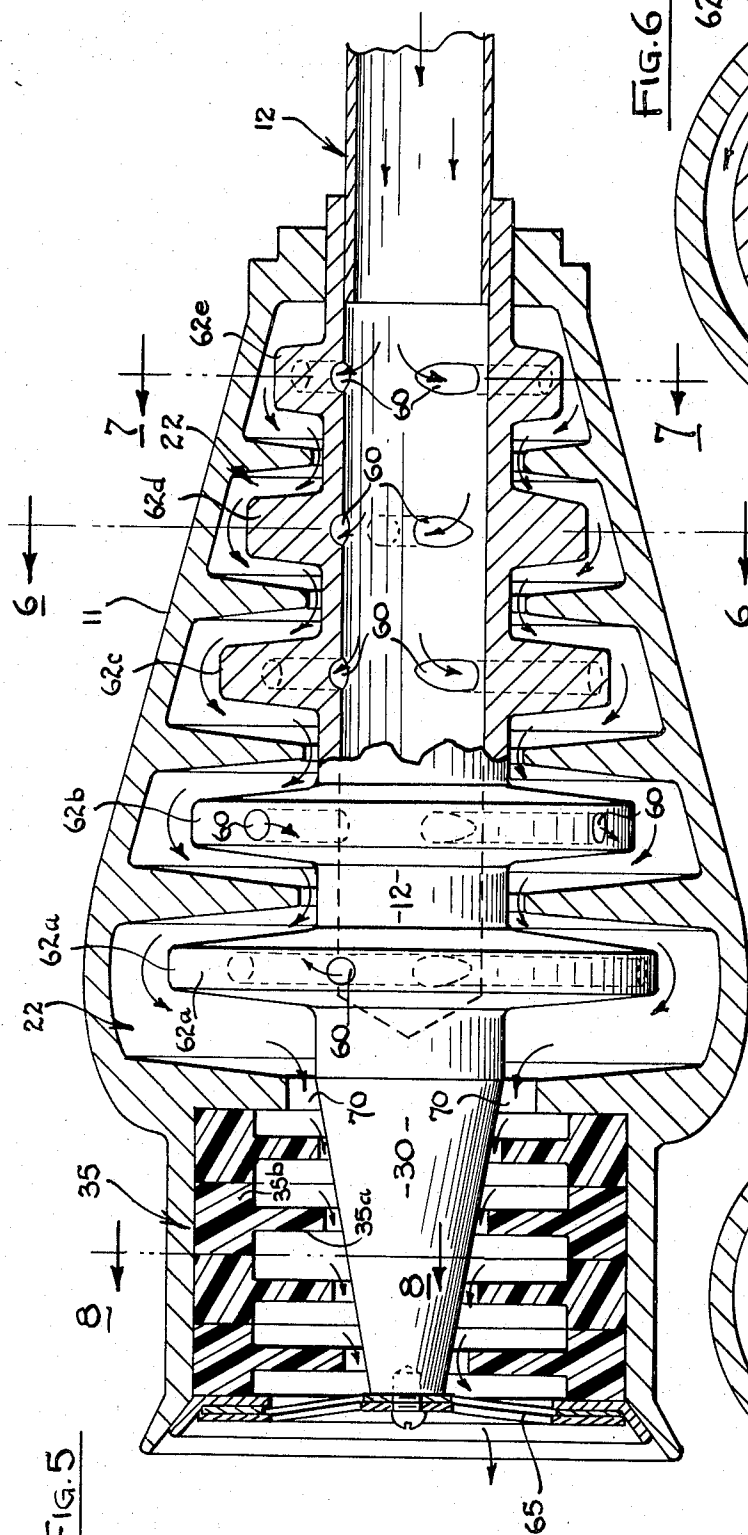


FIG. 5

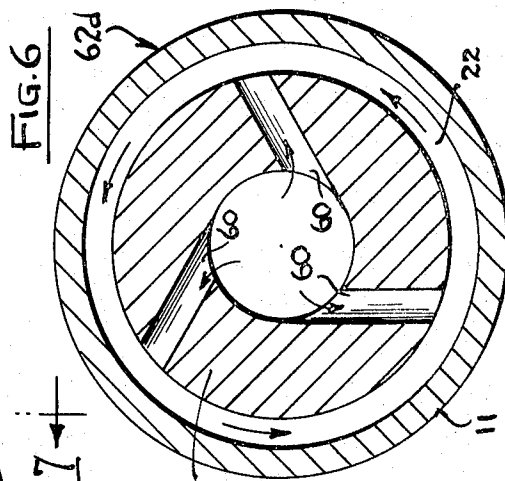


FIG. 6

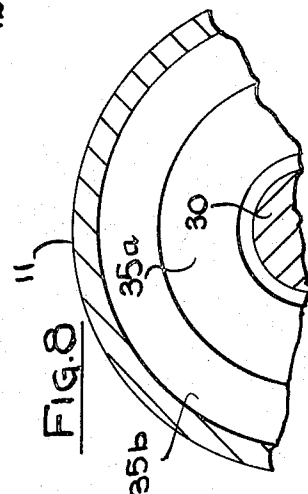


FIG. 8

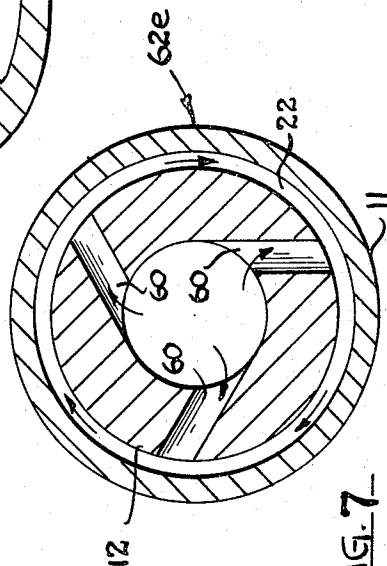


FIG. 7

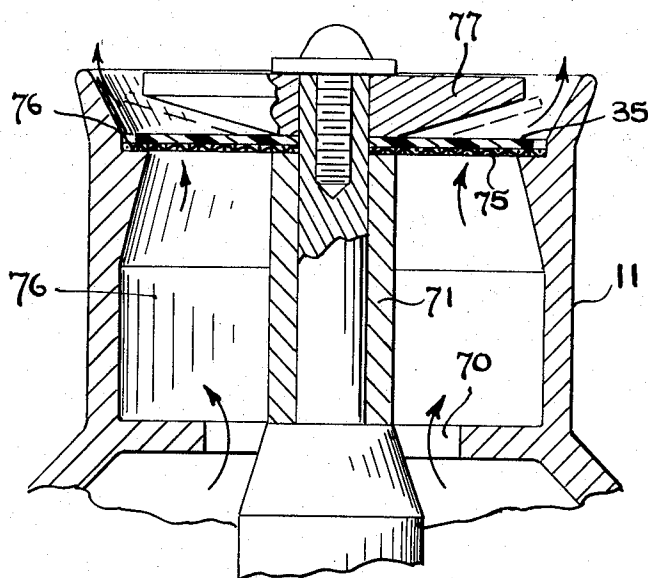


FIG. 9

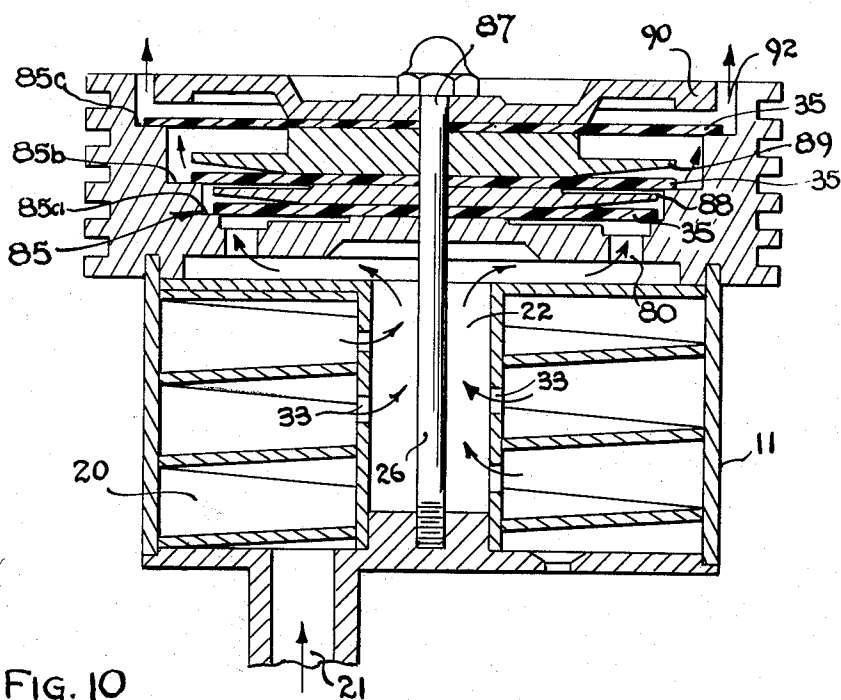
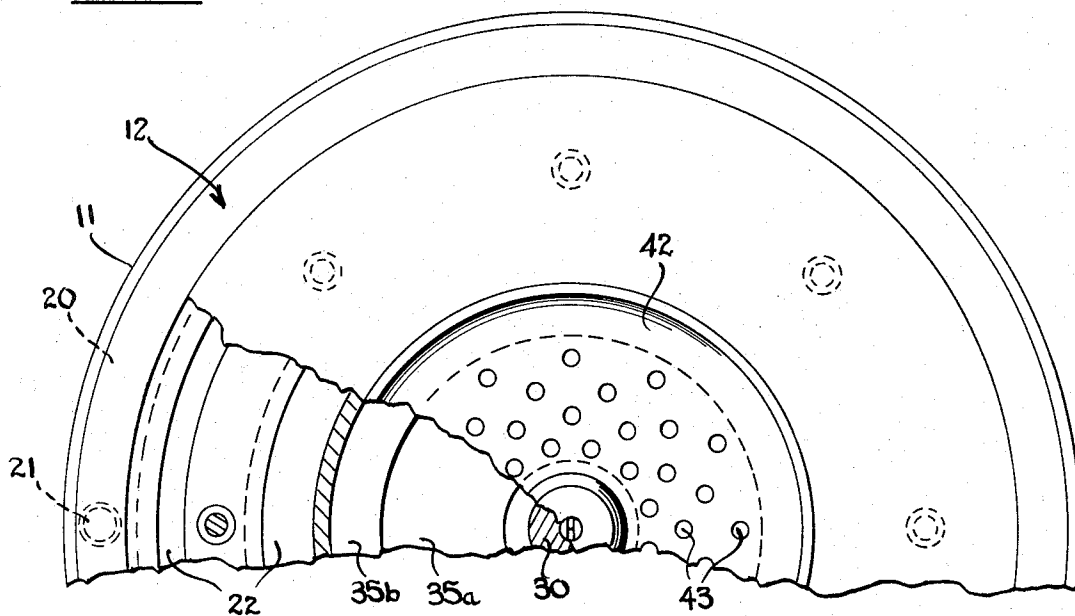
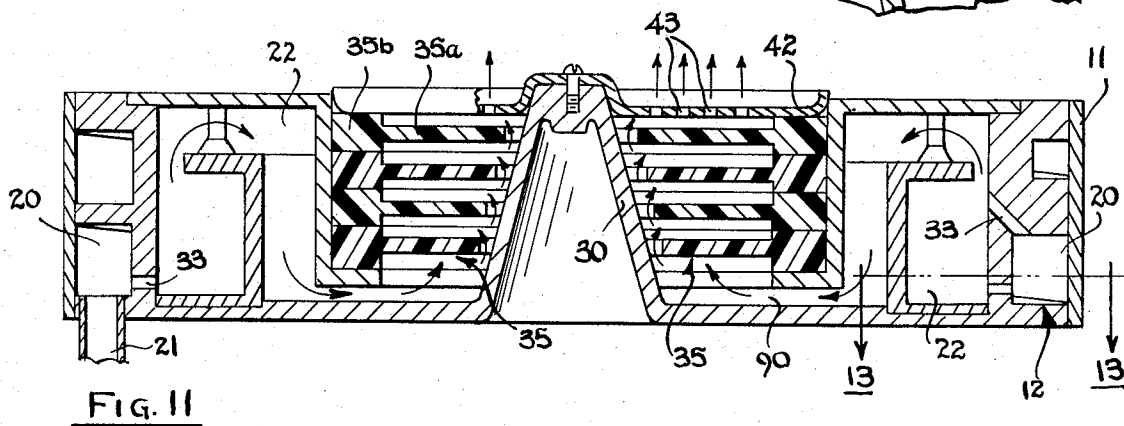
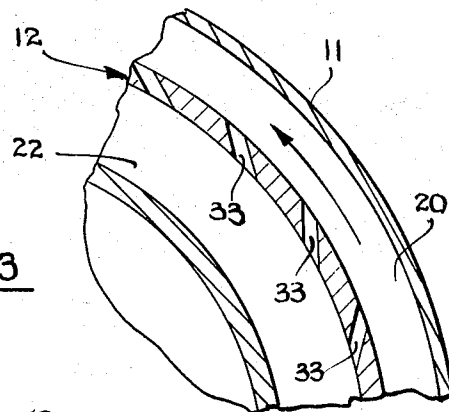


FIG. 10



MUFFLER AND SPARK ARRESTOR FOR INTERNAL COMBUSTION ENGINE

This invention relates to mufflers for internal combustion engines and more particularly to such a device utilizing a tuned cavity in conjunction with chamber and diaphragm sections into which the exhaust gas is successively passed.

With greater consciousness of noise pollution, there has been an increasing demand in recent years for greater suppression of the noise produced by internal combustion engines. This problem has become particularly brought to light with regard to two-cycle engines, such as used in motorcycles, chain saws, lawn mowers and the like. A particular situation where the need for muffler devices which more effectively decrease engine noise is in the case of equipment such as chain saws and cycles used in forest land where the disturbance of the quietude by these devices has come under particular scrutiny. An additional problem presented in the use of internal combustion engines in this type of environment is the fire hazard presented by sparks emitted from the engine exhaust.

While many various types of mufflers have been developed over the years, most of these either do not provide the desired noise suppression or, if they do, so drastically decrease engine efficiency as to be unusable. Further, many of these prior art devices do not effectively eliminate the possibility of sparks escaping from the engine exhaust and thus cause undesirable fire hazards.

The device of this invention overcomes the aforementioned shortcomings of the prior art in providing a muffler which affords a significant improvement in noise suppression over prior art devices and at the same time does not detract from engine efficiency. Further, the device of the invention is designed so that it is impossible for sparks to pass therethrough and appear in the engine exhaust.

It is therefore an object of this invention to provide an improved internal combustion engine muffler which provides greater noise suppression without impairing engine efficiency.

It is another object of this invention to provide a highly efficient muffler which effectively arrests engine spark emission.

Other objects of this invention will become apparent as the description proceeds in connection with the accompanying drawings, of which:

FIG. 1 is a cross-sectional view of one embodiment of the invention;

FIG. 2 is a partial cross-sectional view taken along the plane indicated by 2—2 in FIG. 1;

FIG. 3 is a cross-sectional view taken along the plane indicated by 3—3 in FIG. 1;

FIG. 4 is a cross-sectional view of an alternative diaphragm assembly configuration which may be utilized in the embodiment of FIG. 1;

FIG. 5 is a cross-sectional view of another embodiment of the invention;

FIG. 6 is a cross-sectional view taken along the plane indicated by 6—6 in FIG. 5;

FIG. 7 is a cross-sectional view taken along the plane indicated by 7—7 in FIG. 5;

FIG. 8 is a cross-sectional view taken along the plane indicated by 8—8 in FIG. 5;

FIG. 9 is a cross-sectional view of an alternative diaphragm assembly which may be utilized in the embodiment of FIG. 5;

FIG. 10 is a cross-sectional view of still another embodiment of the invention;

FIG. 11 is a cross-sectional view of still a further embodiment of the invention;

FIG. 12 is a partial top plan view of the embodiment of FIG. 11; and

FIG. 13 is a cross-sectional view taken along the plane indicated by 13—13 in FIG. 11.

Briefly described, the device of the invention comprises a tuned chamber which has a cavity length such as to be acoustically resonant at the principal frequency of the noise output of the engine with which the device is to be utilized. The acoustical standing wave pattern set up by the gas output of the engine in the tuned chamber has pressure nodes at both ends of the cavity, one of such ends being dead-ended while the other provides an inlet for the gas output of the engine. Gas from the tuned chamber is bled off through apertures spaced there-along into a manifold chamber. The total cross-sectional area of the apertures through which gas is fed from the tuned chamber into the manifold chamber is preferably made equal to or greater than the cross-sectional area of the inlet to the tuned chamber so as to avoid restriction of the gas flow. The gas is fed from the manifold chamber to a diaphragm assembly which acts as an inertial damper, this diaphragm assembly including flexible diaphragm means which is actuated in response to the gas pressure to allow flow therethrough in accordance with such pressure. The gas is exited from the diaphragm assembly to the ambient atmosphere. The diaphragm assembly responds to back pressure so as to restrict the muffler outlet, thus attenuating noise caused by back pressure effects.

Referring now to FIGS. 1—3, a first embodiment of the invention is illustrated. Mounted in housing 11, which has a circular cross-section, is tuned cavity unit 12 which comprises a cylindrical end plate portion 14 and a helical blade portion 15 which extends upwardly from hollow cylinder 16. Formed between blade portions 15 is a helical chamber 20. End plate 14 has an aperture 21 formed in the end thereof which provides fluid communication to one end of helical chamber 20. The other end of helical chamber 20 is dead-ended against wall portion 11a of casing 11. Aperture 21 provides an inlet to the muffler device from an engine exhaust (not shown) with which the device is utilized.

Mounted in the chamber 22 formed by cylinder 16, is a core member 25. Core member 25 has a central shaft 26 with a disc shaped portion 28 at one end thereof. Attached to the other end of shaft member 26 is a conical portion 30. A plurality of apertures 33 formed in conical portion 30 provide fluid communication between helical chamber 20 and central chamber 22. The sum total of the cross-sectional areas of apertures 33 is preferably made at least equal to that of inlet aperture 21 so that there is no restriction to the gas flow.

A plurality of flexible diaphragm members 35, which may be of silicone rubber or thin metal alloy diaphragms single or laminated as a suitable material, are mounted between washer members 40 in one end of casing 11. Diaphragm members 35 are washer shaped and have increasingly smaller central apertures in going

towards the end of the casing so as to provide an approximate match with the conical surface of member 30. The edges of diaphragms 35, as already noted, are held in position between washers 40 which may be of a suitable metal, such as steel. Covering the end of housing 11 is a circular cover plate 42 having a plurality of exhaust apertures 43 formed therein. Fluid communication is provided between chamber 22 and the diaphragm assembly by means of passageways 45 formed in the end portions of conical portion 30.

Helical chamber 20 is dimensioned so that its total length provides acoustical resonance at the principal frequency (fundamental) of the noise output of the engine with which the muffler device is to be utilized. Thus, an acoustical standing wave pattern is set up in the gas in chamber 20 with a pressure vibration node appearing at wall 11a and at inlet 21. The pressure node (vacuum condition) appearing at inlet 21 provides good intake to the muffler to contribute to engine efficiency.

The exhaust gas which enters helical chamber 20 is fed to central chamber 22 through apertures 33, but with these apertures spaced along the extent of the helical chamber such gas transfer does not interfere with the standing wave pattern set up in the helical chamber. As already noted, the sum of the cross-sectional areas of apertures 33 is preferably made at least equal to that of inlet 21 so that no restriction is provided to the flow of gas. Chamber 22 acts as a manifold to collect gas flowing from the helical chamber and distribute such gas to the diaphragm assembly, as now to be described. The gas is fed from chamber 22 through passageways 45 against diaphragm elements 35. Diaphragm elements 35 are driven by the gas pressure away from conical member 30 to permit a flow of gas through exhaust apertures 43 in accordance with the magnitude of the gas pressure. Thus, automatic adjustment of the exhaust is provided in response to the engine exhaust gas pressure. It is to be noted that diaphragm elements 35 tend, in conjunction with conical portion 30, to close the exhaust passageway in response to back pressure, thus tending to avoid such back pressure effects from contributing to engine noise. It is also to be noted that the construction of the muffler is such that it is virtually impossible for sparks from the engine to pass therethrough. The diaphragm assembly thus acts as an efficient inertial damper to effectively suppress noise.

Referring now to FIG. 4, an alternative configuration of the diaphragm assembly which may be utilized in the embodiment just described is illustrated. It is to be noted that the utilization of this diaphragm assembly involves the use of a different core member 25 than that shown in the embodiment of FIG. 1 but that the remainder of the device, except for the diaphragm assembly now to be described, can have the same configuration as that shown and described in connection with FIG. 1.

Central shaft 26 has a tapering end portion 51 with a series of sections 51a-51d having circular cross-sections. Sections 51a-51d each have scalloped surfaces 52a-52d which facilitate the gas flow through the diaphragm assembly in response to the gas pressure.

Diaphragm elements 35 have base portions 35b formed integrally therewith and washer shaped portions 35a which extend inwardly from the base portions. Base portions 35b are mounted in abutment one against the other in the end portion of housing 11 by

suitable means such as cementing. The washer-shaped portions 35a have increasingly smaller inner diameters in going towards cover plate 42 to match the edges of corresponding scalloped portions 52a-52d. In the absence of any significant gas pressure, the inner edges of portions 35a of the diaphragm elements rest in abutment against the edges of the scalloped portions as shown in FIG. 4, effectively sealing the diaphragm member to the flow of gas particularly in the presence of back pressure. With a flow of gas from the manifold chamber 22 through a ring-shaped channel 50, diaphragm elements 35a are driven away from the edges of the scalloped portions as indicated by the dotted lines, in the nature of flap valves, to permit the flow of gas therethrough. By virtue of the scalloped portions 52a-52d, a greater flow of gas is permitted through the diaphragm elements for a given movement thereof, thus effectively providing higher speed of response of the diaphragms in permitting flow therethrough in response to a given gas pressure. As for the previous embodiment, the gas is exhausted into the ambient atmosphere through apertures 42 in cover plate 42.

Referring now to FIGS. 5-8, another embodiment of the invention is illustrated. Tuned cavity 12 may be linear in form rather than helical, as for the first embodiment. Only the very end portion of this cavity is illustrated in FIG. 5. The cavity is dimensioned as for the helical cavity of the first embodiment to provide acoustical standing wave resonance at the principal noise frequencies of the engine. As for the first embodiment, the cavity is designed to provide standing wave pressure nodes at the opposite ends thereof so as to afford a vacuum condition at the intake thereto.

Gas is fed from standing wave cavity 12 to manifold chamber 22 through a series of channels 60 spaced along cavity 12. A series of three apertures 60 are formed in each of pancake shaped portions 62a-62e which extend outwardly from cavity 12 in concentric relationship therewith. The passageways 60 of alternate members 62a, 62c, and 62e are canted in one direction to cause a swirling of the gas in the proximate portions of chamber 22 in a first corresponding direction, while the passageway 60 of pancake members 62b and 62d are canted in an opposite direction to cause opposite swirling of the gas in their associated portions of chamber 22. The diaphragm assembly of the device is formed by a conical central member 30 and a plurality of diaphragm elements 35 having base portions 35b and washer shaped portions 35a which operate in conjunction with conical portion 30 to provide the flap valve action, as described in connection with the first embodiment. The diaphragm elements 35 are fixed in position in casing 11 by suitable means such as cementing. An exhaust aperture 65 is provided for exiting the gas from the diaphragm assembly.

In operation, this embodiment functions as follows: Gas in tuned cavity 12 is fed from this cavity through passageways 60 into chamber 22. By virtue of the opposite canting of passageway 60 in successive pancake members 62a-62e, the gas is caused to swirl in opposite directions in adjacent portions of chamber 22. Such opposite swirling of the gas tends to cause phase cancellation of the acoustical energy, further contributing to noise reduction. The gas is exited from chamber 22 into the diaphragm assembly through circular aperture 70. The diaphragm assembly operates as in the first embodiment to provide a passageway for the gas which is

in accordance with the flow pressure. It is to be noted that while this embodiment has a somewhat different configuration than the first embodiment, it still contains the same basic elements, namely, a tuned cavity from which the gas is bled off along its extent into a manifold chamber and finally passed through a diaphragm assembly for exhaust.

Referring now to FIG. 9, an alternative configuration for the diaphragm assembly which may be utilized in conjunction with the tuned cavity and manifold chambers of the prior embodiments is illustrated. This embodiment utilizes a single diaphragm element 35. This diaphragm, which is for those of the other embodiments is washer-shaped, is supported on central post portion 71 and is positioned between filter screen 75 and limit stop member 77, which restricts the outward excursion of the diaphragm. Screen 75 is supported on shoulder 76 as is the diaphragm. Gas enters the diaphragm assembly through circular aperture 70. The pressure of the gas entering the cavity 76 of the diaphragm assembly drives the diaphragm 35 upwardly to permit the exhaust of the gases. The maximum excursion of the diaphragm is limited by limit stop member 77, as indicated by the dotted lines. As for the previous embodiments, the amount of such excursion up to the maximum permitted by member 77 is responsive to the gas pressure. Back pressure drives the diaphragm to the substantially closed position as shown in drawing.

Referring now to FIG. 10, still another embodiment of the invention is illustrated. In this embodiment, the gas is passed from inlet 21 into a spiral resonant cavity 20 where a standing wave pattern is set up in the same fashion as described in connection with the embodiment of FIGS. 1-3. The gas is passed from resonant cavity 20 through apertures 33 into central manifold chamber 22, again in the same manner as in the first described embodiment. The gas is then passed from chamber 22 through circular aperture 80 into the diaphragm assembly which includes a plurality of circular diaphragm elements 35, having successively greater outside diameters. The central portions of the diaphragm elements 35 are held fast between limit stop members 88-90 in retainer 85 which is affixed to housing 11 by means of bolt 87. The edges of each of diaphragm elements 35 rest against stepped portions 85a-85c respectively of retainer portion 85. The upward excursions of diaphragm elements 35 are limited by stop members 88-90 respectively. Gas is exited from the diaphragm assembly through circular aperture 92. Thus, the diaphragm elements permit passage of gas in response to gas pressure but are limited in their opening by means of the stop members. Further, in response to back pressure, the diaphragm elements effectively close the gas channel formed by the diaphragm assembly.

Referring now to FIGS. 11-13, a final embodiment of the invention is illustrated. This embodiment utilizes a concentric construction with the basic elements thereof in internal-external concentric relationship to each other, thereby affording a relatively flat compact configuration. The tuned cavity 12 is formed by helical chamber 20 which receives the exhaust gas from the engine through inlet 21. As for the previous embodiments, an acoustical standing wave pattern is set up in tuned cavity 20 with pressure nodes being located at the opposite ends thereof.

It is to be noted that in this embodiment as in certain previous embodiments, the cavity also acts to separate carbon particles from the gas by virtue of the centrifugal force developed with the rotation of the gas. The gas is drained off from helical cavity 20 into manifold chamber 22 by means of apertures 33. The diaphragm assembly is centrally located and includes a conical member 30 which operates in conjunction with diaphragm elements 35 having base portions 35b and washer-shaped portions 35a which form flap valves in conjunction with conical member 30. The construction of this diaphragm assembly is generally similar to that of the embodiment of FIG. 5. The gas is exited from the diaphragm assembly through apertures 43 formed in cover plate 42.

The gas feeds into the diaphragm assembly through channel 90 and operates to open the flap valves formed by the diaphragm elements 35 in accordance with the gas pressure in the same manner as described in connection with previous embodiments.

The device of this invention thus operates to effectively suppress noise generated by an engine without impairing the efficiency of the operation thereof and further effectively prevents engine sparks from feeding therethrough into the exhaust.

While the invention has been described and illustrated in detail, it is to be clearly understood that this is intended by way of illustration and example only and is not to be taken by way of limitation, the spirit and scope of this invention being limited only by the terms of the following claims.

We claim:

1. A muffler for operation with an engine comprising: a tuned cavity for receiving exhaust gases of the engine, said cavity having a length such as to set up an acoustical standing wave pattern at the principal noise frequency of the engine combustion, with a pressure node of said standing wave being located at the inlet of said cavity; a manifold chamber for receiving gas from said tuned cavity; aperture means distributed over the extent of said tuned cavity for feeding gas therefrom into the manifold chamber without significantly affecting the standing wave pattern in the tuned cavity; and diaphragm means for receiving gas from said manifold chamber and passing said gas into the ambient atmosphere in accordance with the pressure of the gas received thereby, said diaphragm means operating as an inertial damper and a valve which opens in response to the pressure of the gas received from said manifold chamber and closes in response to back pressure from the ambient atmosphere.
2. The device of claim 1 wherein the sum of the cross-sectional areas of the aperture means for feeding gas from the tuned cavity to the manifold chamber is at least equal to the cross-sectional area of the inlet to the tuned cavity so that there is substantially no restriction to the gas flow.
3. The device of claim 1 wherein said tuned cavity is in the form of a helical chamber.
4. The device of claim 1 wherein said diaphragm means comprises a plurality of serially arranged washer-shaped flexible diaphragm elements having successively greater central apertures formed therein going from the inlet of the diaphragm assembly to the outlet thereof, and central post means having a tapered con-

figuration to match such increasing hole diameters, the diaphragm elements being mounted over said central post means whereby said diaphragm elements form flap valves in conjunction with the central post means.

5 5. The device of claim 4 wherein the central post means is conically shaped.

6. The device of claim 4 wherein the central post means comprises a series of sections having scalloped surfaces.

7. The device of claim 1 wherein said cavity, said manifold chamber and said diaphragm means are arranged in external-internal concentric relationship with each other to form a flat configuration.

8. The device of claim 7 wherein the manifold chamber is encircled by said tuned cavity and in turn encircles the diaphragm means.

9. The device of claim 1 wherein there are a plurality of pancake shaped members extending outwardly from said tuned cavity in concentric relationship therewith, the aperture means for feeding gas from the tuned cavity to the manifold chamber being formed radially in said pancake members, the apertures in adjacent pancake members being canted in opposite directions so as to cause opposite directional swirling of the gas in adjoining sections of the manifold chamber.

10. The device of claim 1 wherein said diaphragm means comprises a single diaphragm element and further including means for fixedly retaining the central portion of said diaphragm element and shoulder means against which the edge portions of said element rest, whereby gas pressure lifts the edge portions of said diaphragm element away from said shoulder means to permit the passage of exhaust gas through the diaphragm element.

11. The device of claim 10 and further including stop means for restricting the movement of the edges of said diaphragm element away from said shoulder means.

12. The device of claim 1 wherein said diaphragm means comprises a plurality of diaphragm elements and further including means for fixedly retaining the central portions of said diaphragm elements and shoulder means against which the outer edge portions of said diaphragm elements rest in the absence of exhaust gas pressure thereagainst, the edge portions of said diaphragm elements being lifted away from said shoulder means in response to the exhaust gas pressure to allow the passage of gas past the diaphragm elements in accordance with the magnitude of the gas pressure.

13. The device of claim 12 and further including limit stop means for restricting the excursions of said diaphragm elements away from said shoulder means.

14. The device of claim 1 wherein said tuned cavity is in the form of a linear chamber.

15. In an engine muffler a diaphragm assembly for

providing inertial dampening and affording valve action comprising:

a plurality of flexible diaphragm elements, means for feeding the exhaust gas received by the muffler from the engine to said diaphragm elements,

central post means, and

means for supporting said diaphragm elements over the central post means in serial arrangement and in concentricity with each other, with a portion of said elements being free to move in response to gas pressure to operate as a valve which opens in response to the pressure of said exhaust gas and closes in response to back pressure from the ambient atmosphere.

16. In an engine muffler a diaphragm assembly for providing inertial dampening and affording valve action comprising:

a plurality of flexible washer shaped diaphragm elements having successively greater control apertures formed therein going from the inlet of the diaphragm assembly to the outlet thereof,

means for feeding the exhaust gas received by the muffler from the engine to said diaphragm elements,

central post means having a tapered configuration to match the successively greater control apertures of the diaphragm elements, the diaphragm elements being mounted over the central post means whereby said diaphragm elements form flap valves in conjunction with the central post means, and means for supporting said diaphragm elements in serial arrangement with a portion of said elements being free to move in response to gas pressure to operate as a valve which opens in response to the pressure of said exhaust gas and closes in response to back pressure from the ambient atmosphere.

17. The device of claim 16 wherein the central post means is conically shaped.

18. The device of claim 16 wherein the central post means comprises a series of sections having scalloped sections.

19. The device of claim 16 wherein said means for supporting said diaphragm elements includes means for fixedly retaining the central portions of said diaphragm elements and shoulder means against which the outer edge portions of the diaphragm elements rest in the absence of exhaust gas pressure thereagainst, the edge portions of the diaphragm elements being lifted away from the shoulder means in response to the exhaust gas pressure to allow the passage of gas past the diaphragm elements in accordance with the magnitude of the gas pressure.

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